INVESTIGATION OF ROAD ASSET MANAGEMENT PRACTICES IN ETHIOPIA (A CASE STUDY: ADDIS ABABA CITY ROADS AUTHORITY)

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This is to certify that the thesis prepared by Yetnayet Bihon, entitled: *Investigation of Road Asset Management Practices In Ethiopia (A case Study: The Addis Ababa City Roads Authority)* and submitted in partial fulfillment of the requirements for the degree of Master of Sciences (Construction Technology and Management) compiles with the regulations of the university and meets the acceptance standard with respect to originality and quality.

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DECLARATION

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university. All sources of materials used for the thesis have been duly acknowledged.

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ABSTRACT

Currently, the construction industry is one of the biggest industries in Ethiopia contributing 10% to the Gross Domestic Product(GDP).It needs to be emphasized that road construction in Ethiopia is the means through which development are achieved.The economic growth of the country depends on availability and utilization of physical infrastructures.Road construction and utilization in Ethiopia are the means through which development strategies are achieved. The development of road construction projects can be enhanced through well established Asset Management system that will improve tactical and operational decisions by applying the required knowledge to gain wisdom for provision of strategic infrastructures. However, most of the road construction in Ethiopia encounters problems due to lack of proper Asset Management practices. In this respect, this study‘s objective was to investigate Roads Asset Management practices in Ethiopia the case of AACRA.In order to find answers to the research questions and to achieve the objectives of the study, quantitative and qualitative ways of research adapted. Interviews and questionnaires analyzed quantitatively whereas the desk study analyzed qualitatively explanatorily to assess alternatives, diagnose a situation, and discover new ideas. Accordingly, interpretation and discussion were made on the basis of results.

The findings of the study revealed that there is lack of: Asset management system components implementation rated as low with a result of 54.5%, 63.6%,64%,82% and 73% respectively except condition assessment rated as medium with a result 45.5%,technologies like individual management system implementation in AACRA is in the planning phase as the response of the (7) professional in aggregate revealed, Integration of those management systems also is not there yet, Decision making levels are not explicitly defined in AACRA except programming and budgeting level rated as 54.5%. 91% of respondents revealed that there is lack of professional associations, conferences, short courses and 73% of the respondents disclosed that there is lack of organized asset management department. Some of the specific recommendations forwarded are decision making levels should be explicitly defined, applying different individual management systems and integration of those management systems is necessary and etc. Finally framework and organizational structure were developed for effective and efficient Road Asset Management.

Key Words: Asset management, Individual management systems, Data, Decision making , Project selection and AACRA

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ACCRONYMS

AACRA Addis Ababa City Roads Authority

AASHTO America Association of State Highway and Transport Official

AIT Albert infrastructure and Transportation

AM Asset Management

ARAN Automated Road Analyzer

APCC Australian Procurement and Construction Council

APWA American Public Works Association

BMS Bridge Management System

BIS Bridge Information System

CBA Cost Benefit Analysis

CEA Cost Effectiveness Analysis

CMS Congestion Management System

CPI Capital Planning Initiative

dTIMS Deighton Total Infrastructure Management System

EIA Economic Impact Analysis

ERA Ethiopian Roads Authority

FA Financial Analysis

FHWA Federal Highway Administration

FIIDCA Federal Integrated Infrastructure Development Coordinating Agency

GPR Ground Penetrating Radar

GPS Global Positioning System

HAPMS Highways Agency pavement Management System

HATRIS Highway Traffic Information Systems

HDM4 Highway Design and Management Model

HWD Heavy Weight Deflectometer

IRR Internal Rate of Return

IRI International Roughness Index

JICA Japan international Cooperation Agency

LCCA Life Cycle Cost Analysis

LTAMP Long Term Asset Management Plan

MMS Maintenance Management System

MDSHA Maryland State Highway Administration

MAC Managing Agent Contractor

MA Managing Agent

NCHRP National-Cooperative highway Research program

NPV Net Present Value

OECD Organization of Economic Cooperation and Development

PMS Pavement management System

PST Project Selection tool

PCI Pavement Condition Index

RSDP Road Sector Development Program

RAM Road Asset Management

SMS Safety Management System

SIMS Structure Management System

TAC Transport Association of Canada

TAM Transport Asset Management

TIMS Transportation Infrastructure Management System

US United States

UKPMS United Kingdom Pavement Management Systems

VOC Vehicle Operating Cost

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Currently, the construction industry is one of the biggest industries in Ethiopia contributing 10% to Gross domestic product (GDP). This industry is an enormously important part of economic growth of the country. The economic growth of the country depends on availability and utilization of physical infrastructures. Reports indicate that about fifty-eight percent(58%) of the federal capital budget of Ethiopia is consumed by the construction industry mainly by the road subsector that generates significant employment opportunities. It needs to be emphasized that road construction in Ethiopia is the means through which development are achieved. Growth in agricultural output, which will constitute the primary basis for growth in the economy of Ethiopia is dependent on transport availability, mainly road transport-, which needs to be efficiently integrated with the rural communities as well as with the urban centers.

The ERA-, seventeen years RSDP (2014) Assessment Report states Ethiopia has more than 99,522 km in 2014(an increase of 275 percent). As a result, the road density per 1000 sq. km has increased to 90.5 km.

Considering the impacts of road transport on the growth of the economy of the country, the Ethiopian urban and rural road networks needs an effective way of management practice to enhance cost efficiency, serviceability and performance quality.

Road construction and utilization in Ethiopia are the means through which development strategies are achieved. In this regard , Road Asset management is essential to sustainably grow , for developing countries like Ethiopia. As Ethiopia is economically growing significantly during globalized age, it needs the entire construction infrastructure to be well integrated to bring a fast and outstanding economic development. It is therefore justifiable to investigate the existing Asset Management practices in the Ethiopian road sub-sector, mainly in the Addis Ababa City Roads Authority.

The development of road construction projects can be enhanced through well established Asset Management system that will improve tactical and operational decisions by applying the required knowledge to gain wisdom for provision of strategic infrastructures. However, most of the road construction in Ethiopia encounters problems due to lack of proper Asset Management practices. This adversely affects the sustainable development of the road construction sub-sector as well as the economic development of the country. With this understanding Asset Management should increasingly be used to characterize a business-like approach to road network management. (PIARC, 2005).

Generally Transportation facilities constitute one of the valuable public assets and accounts for a major share of public sector investment worldwide. As being one of the critical facilities it demands better investment decisions for system preservation, expansion and operation based on comprehensive information in a holistic and proactive way (FHWA, 1999).

The approach to public works asset management must change, and asset management tools can facilitate this change. It's time to go beyond the current pavement management approach to improve the effectiveness of management practice through the development and implementation of more comprehensive tools, especially those that can be used to better communication with funding authorities. The pavement management system is currently used to help provide mangers with information needed to make management decisions for pavements. The knowledge and information in pavement management can be used directly in asset management. (Dewan ,2004)

The Ethiopian Roads Authority(ERA) was restructured to sustain and accelerate quality improvement of the federal road network. A new Road Asset Management Department, headed by Deputy Director General has been set up recently with responsibility for road asset management coordination. Ten Road Asset Management Coordination Directorates have been set up located in different parts of the country and administer roads under their respective jurisdiction. The Road Asset Management Department will be responsible for short and long term road network maintenance plan to ensure mobilization of adequate resource for the maintenance of the network and the provision of roads with acceptable operating condition for vehicles. The department is responsible to produce effective network maintenance plan using standard road asset management tools such as Pavement Management System (PMS) and Highway Development and management Model (HDM 4). The Department is also responsible for functional classification and numbering of the road network and for data base of the network using PMS and HDM 4 and other appropriate tools.(ERA,2013). Where as in Addis Ababa City Roads Authority there is a Road Asset Management Directorate on Vice president level.

The failure to maintain roads is tantamount to an act of disinvestment, for it implies the sacrifice of past investments in roads. According to the study carried out by The World Bank in the eighty-five developing countries an estimated $45 billion worth of road infrastructure has been lost over the past two decades owing to inadequate maintenance. This loss could have been averted with preventive maintenance costing less than $12 billion Harral and Faiz, (cited byRegassa,2015). So it is very necessary to develop Road Asset Management practices in the pertinent organizations in Ethiopia.

1.2. STATEMENT OF THE PROBLEM

A well-functioning transport system is crucial for the economic growth of Ethiopia. Road transport is the dominant mode of transportation in the country and accounts for more than 95% of freight and passenger movements. By the end of 2013, Ethiopia had 99522 km road network of roads. The road density was 90.5 km of road per 1000 square km of area (RSDP, 2014). As stated by world Bank(Campbell, 2009), Road density in Ethiopia was low when compared with other developing countries, such as Latin America and Asia with 120 km and 180 km respectively per 1000 km square area. Not only the above indicators in the case of Ethiopia are low but even those available road infrastructures are not well utilized because of low traffic operating on them and also low vehicle-kilometer coverage.

Governments of both developing and developed countries are placing greater emphasis on road administrations to improve the efficiency of, and accountability for, the management of the road network. Indeed in many countries , the national road administration and some smaller- local highway authorities face formal accountability and reporting requirements on how they manage their assets. It is for these reasons that many governments are considering how they can introduce the concept of asset management within the roads sub - sector. (OECD, 2001)

As stated by Robinson (2000), lack of information and political awareness on the importance of sufficient investment for the maintenance of the road infrastructure lead to its chronic under- financing and deterioration. This chronic underfunding and lack of maintenance can very quickly jeopardize this huge asset which has been built at great expense and effort in the last decades. As a consequence it can no more serve the required level of service. As a matter of fact shortfall in investment for maintenance of the road infrastructure and its dramatic consequences huge deterioration of the network results in, higher risks of accidents, problems of congestion, increased noise and a reduced service to society. The asset management system provides preventive, periodic and routine maintenance activities in addition to an emergency maintenance, which requires urgent need of maintenance.

One of the problems of the Ethiopian road - infrastructure development is - lack of coordination with pertinent government agencies. After construction of multi- million Birr worth of roads, different government agencies - like the Ethiopian Telecommunication Corporation (ETC), the Ethiopian Electric light and power Authority (EELPA), etc excavate the road for their purposes , and leave it without restoring - because of poor Asset Management awareness and absence of prior plan of the undertakings. If there is no separate institution like asset management office that manage and coordinate the works of different governments agencies with newly constructed roads then it will not serve the intended purpose resulting in poor drainage or deformation defects on the road. Fortunately Ethiopia has established a new office Federal Integrated Infrastructure development coordinating Agency(FIIDCA). As stated in proclamation number 857/2014 withthe objective of coordinating the execution of integrated infrastructure development works in accordance with roads master plan and to develop formula for the assessment of compensation for properties to be removed and landholdings to be expropriated due to integrated infrastructure development works.The problem can only be avoided through an effective asset management system which can apply in a holistic road management approach.Therefore, we need a well defined government asset management policies, regulation and strategies.

Some road administrations are approaching the issue or road management by treating roads as a capital asset. The aim under this approach is the conservation of the inherent asset value of the network expressed in monetary terms. The concept is readily understandable by wide range of decision-makers at all levels in the administrative hierarchy. The basic concept assumes that the current asset value of any road network can be estimated in monetary terms with reasonable accuracy at a particular point in time (Robinson ,2000).

The RSDP phases I, II and III from 1997 to 2010 were focused on expansion of the trunk road network and is estimated to have resulted in cost of USD 5.5 billion (2009, USD 1.0 = ETB 10.995).The Government was the highest contributor with 71%. The new RSDP IV (2011-15), which includes a major contribution to universal rural access, is a 5 year USD 7 billion program, and the government plans to construct, amongst others, over 15,000 km of trunk roads plus 70,000 km of rural access / feeder roads(Modjo - Hawassa Road appraisal Report, 2013).

Addis Ababais currently Ethiopia's largest metropolis, an officialdiplomatic capital of Africa, and the fourth largest diplomatic center in the world. The city risesfrom 1800 to 3200 meters above sea level. As the national economic center, Addis Ababareceives approximately 54% of Ethiopian investment(Peng Mo etal,2008). Addis Ababa is growing at high rate and a significant length of roads have been constructed and are under construction as well significant amount of budget were financed currently a billion birr worth of roads has been contracted.So, its justifiable to identify the application of the concept of asset valuation and Asset management inroad construction activities and its problems.

This study will try to come up with rational solution by investigating the current road asset management system on the AACRA road network management and then recommend a better way of road ownership and management for sustainable social and economic development of Ethiopia.

1.3 RESEARCH QUESTIONS

The research questions that this study will attempt to clarify and answer are ;

- What is the best practice of road asset management?
- What is the current practice of asset management at AACRA?
- What are the factors that affect asset management practice at AACRA?
- How is the pavement management system applied at AACRA Asset Management Directorate and how is the software applied for road maintenance purposes?

- Is the current asset management practice at AACRA effective and competent compared to worldwide asset management practices? If not, what ways of improvement can be suggested to make it effective and competent?

1.4 OBJECTIVES

1.4.1. General objective

The main objective of this thesisis toinvestigate Road Asset Management practices by takingAddis Ababa City Roads Authority as a case studythen find the possible way to improve the situation. Finally Framework and organizational structure proposed.

1.4.2. Specific Objectives

- To investigate the effect of asset management practice on the road network maintenance in Addis Ababa.

- To study and identify the factors affecting asset management practices at the AACRA.

- To observe and scrutinize the pavement management system application for the purposes of asset management at the AACRA.

- To investigate the asset valuation practice at the AACRA; and-.

- To recommend state of the art practices of asset management for the AACRA and to pertinent government organizations.

1.5. SIGNIFICANCE OF THE STUDY

Roads are one of the major assets in Ethiopia that provide significant social and economic benefits to communities. However, the road assets are in danger due to poor Asset Management practices. As road construction and maintenance activities consumes a huge amount of the nation's budget, it must be administered in a systematic manner through proper asset management practices. In this regard, this study will investigate the asset management practices and the factors affecting at the AACRA and to suggest a better way of administering the road network including its maintenance.

1.6. SCOPE AND LIMITATION OF THE STUDY

The scope of the research is to investigate the asset management practices in Ethiopia. The study is limited to flexible road pavement under the jurisdiction of the Addis Ababa City Roads Authority.

1.7. MOTIVATION OF THE RESEARCH

The research was initiated based on own observation that roads are deteriorated and pertinent government organizations excavate new roads for their own proposes possibly with less consideration of asset management. This results in failures of both regional and federal road networks. This practice should not continue and so the appropriate office should take the responsibility to protect the network from further deterioration and deformation since they were built with great effort and substantial budget .

1.8 METHODOLOGY OF THE STUDY

The research strategy adapted for this research are quantitative research of descriptive statistics method and qualitative research of exploratory type which diagnoses a situation, assess alternatives, and discover new ideas. The methodology followed for the research has four main parts which are described hereunder. Establishing the basis of the research aimed at defining the theoretical basis, and formulating the research questions through the following steps.

(i). Literatures were reviewed to obtain a theoretical basis for the Research, formulate the research questions and define the scope. To this effect, the main authors of textbooks in Asset Management system practice reviewed. The books were then reviewed in order to get a general understanding of the research area. Thereafter, relevant articles from journals and other publications were searched to conceptualize the Road Asset Management practices . Apart from searching in libraries, internet sources were used to obtain recent articles and research papers in the area.Therefore, the following were the procedures of the research:-

- Questionnaire were developed based on the literature reviews
- Interview schedule was prepared based on the literature reviews

(ii). Conducting the study: aimed at finding out The Asset management practices in Ethiopia

- A desk study to get a picture of Ethiopian Road Asset Management
- Questionnaire distributed and collected for asset management professionals in AACRA
- Interviewing key respondents to get in-depth understanding of Asset management practices in ACCRA

(iii). Analyzing the data; of desk study qualitatively using theoretical preposition whereasinterview and questionnaire quantitatively using descriptive statistics method of analysis.

(iv). Based on the research findings conclusion were drawn, recommendations forwarded and framework is developed.

1.9. ORGANIZATION OF THE THESIS

Chapter One:- provides an introduction to the research project. It provides a general background and provides the scope, research questions and objectives of the work.

Chapter Two:- provides a literature review of the issues surrounding Asset Management Practices, its importance, and how Asset management can assist in improving pavement maintenance and rehabilitation strategy

Chapter Three:- describes the research methodology and provide insight into the data sources.

Chapter Four:- presents the data analysis and discussion part of the research

Chapter Five:- presents the research conclusions ,recommendations, frameworks, organizational structure and future research areas.

CHAPTER TWO

LITERATURE REVIEW

2.1 HISTORICAL BACKGROUND OF ASSET MANAGENET

The concept of infrastructure management and more particularly of transportationinfrastructure management is not new to the world.In the second half of the 20th century, efforts and approaches focused on managingindividual transportation infrastructure asset types. Pavement, bridge, tunnel, trafficequipment, congestion, public transportation and various other types of individualmanagement systems have emerged during the last decades. Research in these areas isstill ongoing with important findings and continuous progress. Pavement managementsystems are the oldest and most abundant of these engineering management systems.This is due to the fact that pavements constitute almost sixty percent of the total infrastructureassets managed by transportation agencies (Haas et al. 1994).

Even though Asset Management (AM) science and practice is not new—agencies in Europe, New Zealand and Australia, and Canada startedin the late 1980s and early 1990s. When the transportation agencies in the United States were focusing on the management ofpavements and bridges as individual assets rather than on acomprehensive, integrated, and long-term approach to managingall assets under their jurisdiction. (NCHRP,2013)

Interest in transportation asset management (TAM) began to grow as agencies struggled with growing needs and limitedresources. The 2000s brought a greater use of bridge and pavement management systems and greater use of TAM principles in everyday agency activities. Some states established policies that linked decisions to performance measures and good data; others implemented enterprise TAM software systems. In 2011, AASHTO published its TCAM - Guide: A Focus on Implementation, and in 2012, the Moving Ahead for Progress in the 21st Century Act (MAP-21) passed with requirements that state DOTs develop risk-based

TAM plans for pavements and bridges in the National Highway System (NHS) (Transportation Research Board, 2015).

During the last decade of the 20th century, there has been a slow but consistent movementtowards a more holistic approach to the management of these assets. Transportationagencies in the united states (US) and around the world have begun to acknowledge the merits of a morecomprehensive methodology for managing their infrastructure. This holistic way of dealing with the management of transportation assets, coupled with more ―business-like"objectives has led to what is today commonly known as Asset Management(Flinch and Briyant,2006).

2.2GENERAL AND SPECIFIC DEFINITIONS OF ROAD ASSET MANAGEMENT

Asset Management is a still-emerging conceptin the highway industry. But at its heart, it providesa solid foundation from which to monitorthe transportation system and optimize the preservation,upgrading, and timely replacement of highwayassets through cost-effective management, programming,and resource allocation decisions (FHWA,1999).

As stated by the Federal Highway Administration of the United States (1999) Asset "Asset Management is a systematic approach of maintaining, upgrading, andoperating physical assets cost effectively. It combines engineering principles withsound business practices and economic theory, and it provides tools to facilitate amore organized, logical approach to decision-making. Thus, asset managementprovides a framework for handling both short- and long-range planning "

Asset management is an emerging effort to integrate finance, planning, engineering,personnel, and information management to assist agencies in managing assets cost-effectively(AASHTO, 1997).

However, there have been many other definitions that consider different aspects of the business strategies pertaining to Asset Management and that also widen its scope beyond solely physical assets (McNeil, 2000). These are from Transport Association of

Canada(TAC), And America Public works Association(APWA) and the National -Cooperative Highway Research Program(NCHRP).

Generally, the following are definitions regarding TAM as provided by indicated sources:-

- Asset Management is a comprehensive business strategy employing people, information and technology to effectively and efficiently allocate available funds amongst valued and competing asset needs (TAC, 1999).

- Asset Management is a methodology to efficiently and equitably allocate resources amongst valid and competing goals and objectives (Danylo,1998).

- Asset management is a business process that incorporates the economic assessment of tradeoffs among alternative investment options to help make cost-effective investment decisions. (NCHRP,2013)

Finally, the Organization of Economic Cooperation and Development (OECD) emphasizes the service to the public, which is the end customer of the road agencies and administrations: AM as applied to the roads sector represents a systematic process of maintaining, upgrading and operating assets, combining engineering principles with sound business practice and economic rationale, and providing tools to facilitate a more organized and flexible approach to making the decisions necessary to achieve the public's expectations (OECD,2001).

OECDWG (1999) stated as follows: "Asset Management…goes beyond the traditional management practice of examining singular systems within the road networks, i.e., pavements, bridges, etc., and looks at the universal system of a network of roads and all of its components to allow comprehensive management of limited resources. Through proper asset management, governments can improve program and infrastructure quality, increase information accessibility and use, enhance and sharpen decision-making, make more effective investments and decrease overall costs, including the social and economic impacts of road crashes."

Definition derived in terms of asset management processes. In this regard, AASHTO (2005) stated as follows:"Asset Management process is , the set of processes aligning the development, operation and maintenance of assets, so as to meet the desired requirements and objectives shareholders in the organization".

Another definitions in terms of Asset Management processwas provided by Ma, Sun, and Mathew (2007) was provided as follows: "An Asset Management process is a set of linked (often interrelated) activities and the sequence of these activities that are necessary for collectively realizing Asset Management goals, normally within the context of organizational structure and resource constraints". This was presented in their report entitled "Asset Management Process: Modeling, Evaluation and Integration".

From the joint committee of AASHTO - AGC - ARTBA , Asset Management isdefined as the strategic approach to the optimal allocation of resources for the management , operation, preservation, and maintenance of infrastructure. The concept of AM combines engineering, economic principles, and sound business practices to support decision making at the network and project level (Ramakrishna, Amal, Prasanna,2004).

A simple working definition of AM would be: first, assess what you have; then, assess what condition it is in; and lastly, assess the financial burden to maintain it at a targetedcondition (Cagle. 2003). Asset management comprises the entire process from programming andplanning to preservation of the system and is characterized by a solid policy frame work,measurable objectives, and continuous performance monitoring. Thus, AM providesa framework for handling both short- and long-range planning." (Norwell et al.1997). In addition AM applies the principles of engineering, business management, and economicsthrough computer aided technology (Dewan,2004).

Asset management system is a strategic resource allocation framework that allows transportationorganizations to manage the condition and performance of transportation infrastructure costeffectively (Meyer et al, 2009). As stated by theOrganization of Economic Cooperation and Development (2001) asset management system generally:

- include inventory information for the asset and condition measures;
- include values of condition of the asset;

- include a performance prediction capability;
- ensure data integrity, enhance data accessibility and provide data compatibility;
- include all relevant components in life-cycle cost analyses;
- enable the removal of outdated systems and unproductive assets;
- consider both system and project optimization;
- report useful information on a periodic basis, ideally in real time; and
- facilitate iterative analysis processes that can be performed on a regular basis.

The asset management concepts of data supported decision making management systems havestrong relationship between condition and performance and an emphasis on trade off and investment analysis; which are integral components of daily business that support a certain roadagencies mission to provide a safe transportation system that ensures the mobility of people andgoods, enhances economic prosperity and preserves the quality of a countries environment andcommunities (FHWA, 2005).

The genesis of the movement towards AM in the United States has beenan understanding of the need for it. Highway agencies in the United States have moved their primary focus many times during the last fifty years: there was a shift fromexpansion to preservation from the 1960s to the mid 1980s; then the focus changed toreinventing from the mid 1980s to the beginning of the 21st century. Fromthat point of time until now, the focus has been on employing good and sound businesspractices. This new focus has many implications, including embracing quality,emphasizing the need to address strategic rather than tactical issues, integratingeconomics and engineering and taking advantage of the progress made in informationtechnology (AASHTO,1999).

2.3 ASSET MANAGEMENT BENEFITS

The New Mexico Environmental Finance Center (2006) and AASHTO (2005)have put benefits of asset management to include the following:

- better operational decisions;
- improved emergency responses;
- greater ability to plan and pay for future repairs and replacements;

- increased knowledge of the location of the assets;
- increased knowledge of what assets are critical to the utility and which ones aren't;
- more efficient operation;
- better communication with customers;
- rates based on sound operational information;
- increased acceptance of rates;
- capital improvement projects that meet the true needs of the system;
- organizations waste money and slow down their businesses with inefficiencies that can be alleviated by effective asset management;
- through asset management, agencies can monitor, define, optimize and track their businesses' assets and processes by automating which was previously manual;
- enhanced objective information made available for better decision making;
- track all the costs associated with an asset including an initial price, depreciated value, service costs, add-on equipment and upgrades;
- etc.

The main benefits of AM are in terms of finance and time and also an effective asset management is critical for successful customer service, regulatory compliances and the business viability.

An effective AM can provide increased efficiency in terms of services from assetsand help managers to maintain their assets with minimum possible costs (Dewan,2004). Accordingto the TAC (1999),one of the key aspects of AM isintegration. Asset Management Systems provide an integrated approach to all administration costs,for the road users, works, administration, environment or social costs, and the use of existingadministration data sources.

2.4 ASSET MANAGEMNT CHARACTERISTICS

As stated by Danylo (1998) AM is a generic framework of tools and methodologies aiming atenhancing the way of managing infrastructure, which emphasizes good business practices and asserts the holistic approach. It incorporates elements of various diverse disciplinessuch as accounting, value engineering, life cycle cost analysis, economics, riskmanagement, and user satisfaction.

AM also differs from the traditionalmanagement practices in the following ways:

- by applying strategic rather than tactical measures, goals and policies;
- by addressing decisions usually in a network, system-wide rather than a project level;
- by integrating existing individual infrastructure systems and databases in a common interoperable environment;
- by introducing and incorporating financial and economic performance measures, ideas and theories and treating the infrastructure management process as a ―business”, which has to be done efficiently and effectively;
- by modeling the way the internal processes are undertaken after the private sector, , and
- by establishing ways for efficient documentation and communication of the decision making process with two significant benefits: (i) making management decisions transparent to all kinds of shareholders, and (ii) rendering decision makers accountable for their choices.

2.5 ASSET MANAGEMENT PRINCIPLES

In its most general sense, AM is a business approach designed to align the management of asset - related spending to corporate goals. Typically, utilities adopt an AMapproach to either reducing spending, more effectively manage risks, or drive corporate objectives throughout an organization (Alexandria, 2002). Simply, AM is a corporate strategy that seeks to balance performance, cost and risk in order to ensure the optimum utilization of asset. Achieving this balance requires the alignment of corporate goals, management decisions, and technical decisions(Brown and Humphrey, 2005).

It also requires the corporate culture, business processes and information systems capable of making decisions based on asset-level data. Asset management is ambitious in scope and requires supporting metrics, organizational design, processes, information systems and corporate culture. Successful implementation can be quite disruptive and requires the involvement and support of top management, sufficient resources and effective change-management skills(Brown and Humphrey, 2005).

International Data Corporation found that companies practicing AM lowered their annual costs by nearly twenty percent on average.With AM, they can track all the costs associated with an asset including initial price. depreciated values, service costs, add-on equipment etc (Peregrine systems, 2000).

A robust AMstructure is supported by three pillars of competency: management, engineering and information. Building these competencies is daunting when reviewed in isolation. Far more difficult is developing cross functional expertise so that management , engineering and information skills can be addressed in a mutually supporting manner(Brown and Humphrey, 2005). Management means strategy, organizational design, performance management, resources planning, decision analysis and financial risk. On the other hand, engineering covers the planning, operations, maintenance, reliability, protection and technical risk. The information entails system architecture, business intelligence, knowledge management, integration and asset registry. In this way three pillars of competency support asset management (Brown and Humphrey, 2005).

The World is constantly changing to have effective AM solutions. AM is based on a robust and accurate repository.For this there is need to automate and regular input of reliable physical data, as well as newly acquired asset data. There is also a need to regular input of change data coming from consolidated service desk. the integration of reliable discovery tools into the process is critical to reconcile the physical view and the logical view within the AM repository (peregrine systems, 2000).

According to TAC (1999) ,AM usually exist within entities in order to either directly or indirectly support program delivery and this underpins the following five broad principles:

- Asset acquisition, disposal and life cycle management decisions are integrated into an entities of strategic and organizational planning;

- Asset planning decisions are based on an evaluation of alternatives, which assesses risks and benefits, and applies the government's core procurement principle of value for moneyacross the assets life cycle;
- An effective cost control structure is established for asset management;
- Accountability is established for asset condition use and performance; and
- Disposal decisions are based on analysis of the methods which achieve the best available net return.

2.6 ASSET MANAGEMENT COMPONENTS

According to FHWA (1999), Asset management system should be customer focused, mission driven, system oriented, long-term in outlook, accessible, user friendly and flexible. In addition, it should be goal driven and include components for data collection andanalysis, strategy evaluation, decision-making, program development, implementation, monitoring,and feedback.Generally, an asset management system should include the following elements:

- Strategic goals and policies;
- Inventory of assets (physical and human resources);
- Valuation of assets;
- Quantitative condition and performance measures;
- Measures of how well strategic goals are being met;
- Usage information;
- Performance prediction capabilities;
- Database to integrate individual management systems;
- Consideration of qualitative issues;
- Links to the budget process;
- Engineering and economic tools;
- Useful outputs, effectively presented; and
- Continuous feedback procedures.

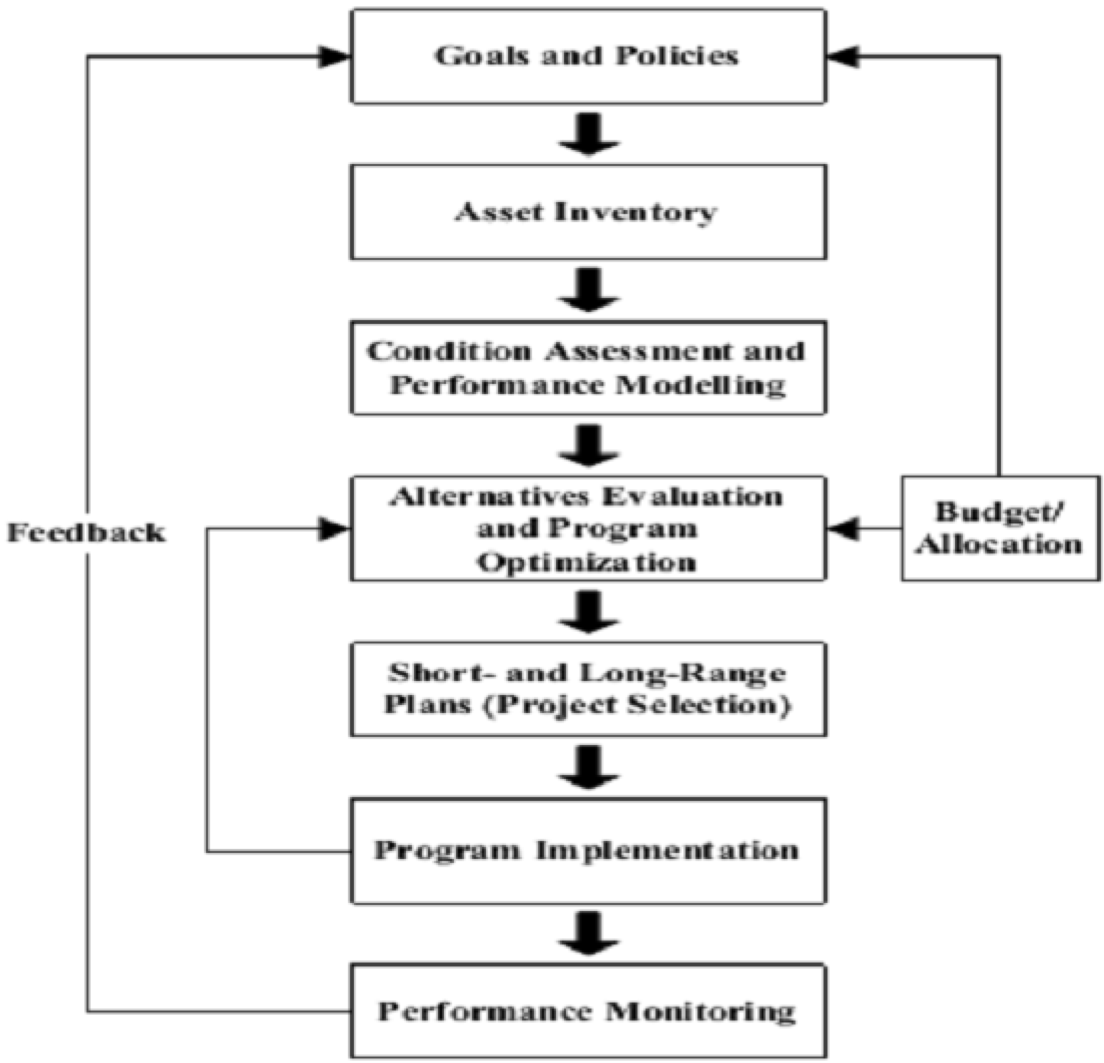
According to the same source FHWA (1999),the basic generic AM system components are the followings:

- Goals and policies;
- Asset inventory;

- Condition assessment;
- Performance monitoring;
- Alternatives analysis/program optimization;
- Short/long - range plans: and
- Program implementation.

Figure 2.0 below shows the generic asset management system components.

Figure 2.0: Generic asset management system components.



Source: FHWA,1999

Goals and policies: Goals, objectives and enabling policies frame an asset management process within an agency. An effective asset management approach will align anagency's vision, goals and objectives with performance measures and targets at various levels ofdecision making, and have enabling policies to ensure effective implementation (NCHRP, 2002). The sequence of AM begins with the goals and policies of a Road Administrationand the available budget goals, objectives and enabling policies frame an asset managementprocess within an agency (OECD, 2000). The asset management policy is a key element of an organizations plan. The policy providesa clear direction for AM and defines the key principles that underpinasset management for a council (Department for Victorian community, 2004).

The policies and objectives regarding AM and investment are intended to guide project selection and development (FHWA, 1999). The AM policy is a key element of the organization plan. The policy provides a clear direction for AM and defines the key principles that underpin asset management for an organization. As a minimum, organizations need to have an AM policy and strategy to provide direction and guidance for asset management planning. Furthermore the goal of asset management is to meet a required level of service in the most cost effective way through the creation, acquisition, operation and maintenance, renewal and disposal of assets to provide for present and future customers/communities. The life-cycle approach is central to asset management by taking account of the total cost of an asset throughout its life (State department of Victoria,2004).

Asset management is a goal-driven management process. To manage assets effectively,the decision-making process must be aligned with the agency‘s goals, objectives, and policies.Goals are expressed in terms of objectives to be met over the planning horizon. Policies aredeveloped to provide the necessary framework to support achieving target objectives. Policiesregarding engineering standards, economic development, community interaction, political issues,administration rules, and the agency‘s organizational structure influence asset managementcomponents (Texas department of transportation and FHWA,2007).

Most TAM programs have defined goals and/or objectives that guide maintenance, repair and rehabilitation decisions. Asset management best practice includes clearly defined goals and policies that can be translated into explicit performance measures and targets, and that are based on considerations of resources available to the agency (Meyer etal,2009).

Asset inventory*:* One of the critical elements of an asset management system is an up-to-date inventory of existing assets: data that identifies and accounts for the facilities that an agency owns. An inventory typically describes the attributes of existing assets that do not change with respect to time, including their respective locations in the overall asset base. For example, roadway inventory data includes information such as functional class, geometry, structure, material type and properties. Asset inventories are developed using location referencing systems often base on a Geographic Information System (GIS) platform, Global Positioning Systems (GPS), and imaging and related technologies. A good asset inventory will be updated regularly enough to provide current data on all assets (newer and older) at any time, to allow any asset to be identified as needed (Meyer .etal,2009).

The road assets usually contain roads, bridges and other engineering structures such as tunnels. Roads are usually divided into road substructure, running surface, equipment and accessories. These assets might contain also land areas (e.g. road areas, rest areas etc.). similarly, road assets contain unfinished road projects and road structures under constructions. real estate, buildings, machines, equipment etc. should be included in other fixed assets. (Jani, 2007)

The asset inventory contains information about physical location, characteristics, usage,work history, work planned, costs, resources, and any other information considered relevant bythe agency. Additional information provided by asset management systems may include financialreports about the agency‘s assets, showing both the current economic value and future asset
value estimates. Decisions regarding the type and amount of data to be collected are made basedon the agency‘s needs for decision support and available resources (Texas Department of Transportation and FHWA,2007).

Asset inventory can also be called an asset register. It needs to be an itemized list of all the assets and it must have some basic facts about each of those assets. As a very minimum, these basic facts should include the following as provided by (Opus, 2011)

- What type of asset is it ?
- Where is it located ?
- What size is it ?
- What is it made of?; and
- How old it is?

Haas-(1994) classifies inventory types into three as follows:

(i) **Geometry inventory**- which defines the physical characters or features of pavementselection which includes location reference, road way classification, and number of lanes,shoulder type and width, cross slope, curvature, presence and curve dimension. This datawill be used in planning for rehabilitation project to determine if reconstruction is required.

(ii) **Pavement structure inventory**- which is basically a record of the construction history of the project. It includes records of major maintenance or reconstruction projects including thetype of treatment used and the thickness of its respective layers.

(iii) **Cost data-**includes data on the cost of new construction, maintenance, and rehabilitation.Maintenance costs must be estimated based on the expected performance of the maintenancecrews and the condition of the pavements.

(iv) **Environmental (weather) and drainage data** includes a record of the local environmentalconditions where the assets is located.

(v) **Traffic inventory** is required to predict pavement performance and to prioritize theselection of rehabilitation options.

Condition assessment: Condition assessment is vital to an asset management process. It is useful to transportation organizations to not only maintain data on current asset condition but also past asset condition. Performance modeling is a valuable tool that allows transportation officials to predict the future condition and performance of assets. Many organizations strive to maintain their assets at a minimum defined level of service, i.e. maintain at least eighty percent of pavements in good condition on interstate roadways. The level of service of infrastructure assets is often directly related to available funding. Effective asset management practices can be used to predict the future condition of assets depending on available funds. (Meyeretal,2009).

Condition assessment is the process of continuous or periodic inspection, assessment, measurement andinterpretation of the resultant data to indicate the condition of a specific asset. The condition is usedto inform Depreciation and Remaining Useful Life calculations; and Capital Expenditure andMaintenance programs (Bundaberg Regional Council, 2011-2021). It is useful to transportationorganizations to not only maintain data on current asset condition but also past asset condition(Meyer et al. 2009). According to Flintsch and Bryant (2006) the data can be qualitative and generic(e.g., good, bad, etc.), or detailed and quantitative in accordance to established practices and standards(e.g., pavement condition index, bridge health indices, etc.).

Knowledge of current condition is needed to assess the asset network current scenario.Condition assessment is expressed in terms of performance measures selected by the agency.These performance measures should be the ones used by the agency to establish objectives.Condition indices, percentage of the network system rated in good condition, and remaining lifeof the asset network are some examples of performance measures used for physical assets (Texas Department of Transportation and FHWA,2007) .

Condition assessment is a tool to assistasset managers in managing road assets. Condition assessment assists in reporting changes in roadservice levels, identifying candidate assets for renewal treatment, selecting the optimum renewaltreatment and as an input into modeling of future condition and service levels and funding scenarios(Roorda, 2006).

Typical elements of the condition assessment are:

- Current asset stock;
- Condition of current assets;
- Operating and maintenance costs;
- Utilization of existing assets;
- User satisfaction with service provision; and
- Future renewal profile.

Performance monitoring: An important aspect of the use of asset management systems is the need to monitor performanceof the asset against defined required outcomes or targets of performance (OECD,2001). In order toensure that an asset management system is functioning optimally, performance monitoring needs tobe done constantly to ensure that a transportation organization is meeting its goals and following itspolicies (Meyer et al, 2009).The National Academy defines performance as follows: ―…performance is carrying out of atask or fulfillment of some promise or claim, and for infrastructure this means providing or enablingmovement of goods and people…that support other economic and social activities, a safe andhealthful environment, and a sustainably high quality of life." (National Academy,1995) Performance modeling is a valuable tool that allows transportation officials to predict the futurecondition and performance of assets (Meyer et al. 2009).

In order to ensure that an asset management system is functioning optimally, performance monitoring needs to be done constantly to ensure that a transportation organization is meeting its goals and following its policies. Determining the performance of transportation infrastructure requires the development of an effective performance measurement criteria. It was identified in the NCHRP Report No 551 that the core principles of TAM as: policy-driven, performance-based, analysis of options and tradeoffs, decisions based on quality information, and monitoring to provide clear accountability and feedback (Meyer .etal,2009).

Monitoring the asset performance over the planning horizon serves to assess whether the desired level of service is being accomplished or not. Performance monitoring requires trackingperformance over time, which allows the agency to detect changes in the asset condition and totake the necessary corrective actions if needed. The desired level of service targeted by the agencymay also be adjusted based on results from implementation (Texas Department of Transportation and FHWA,2007).

The following performance indicators were identified in the Report produced by the Organization for Economic Cooperation andDevelopment (OECD, 2001):

- Average road user costs;
- Level of satisfaction regarding travel time and its reliability and quality of road userinformation;
- Protected road user risk;
- Unprotected road user risk;
- Environmental policy/programs;
- Processes in place for market research and customer feedback;
- Long-term programs;
- Allocation of resources to road infrastructure;
- Quality management/audit programs;
- Forecast values of road costs vs. actual costs;
- Overhead costs (percentage);
- Value of assets;
- Roughness;
- State of road bridges: and
- Satisfaction with the road system.

Alternatives analysis/program optimization: TAM systems typically include alternative analysis and program optimization modules or routines that help agencies to specify a limited number of alternatives to meet the overall objectives of their asset management system cost effectively (Meyer .etal,2009).Aset of rehabilitation and maintenance alternatives may then be developed to meet this objective, andthe alternatives analyzed to determine the optimal set of alternatives (e.g., the set of alternatives thatcan be used to meet the specified objective at the lowest life cycle cost) (Hudson, et al. 1994).For example, an agency managing roadways may set as an objective a maximum percentage (say 10%) of the network mileage/kilometer that will be allowed to fall below a certain minimum desired level of service (also specified by the agency). A set of rehabilitation and maintenance alternatives may then be developed to meet this objective, and the alternatives analyzed to determine the optimal set of alternatives (e.g., the set of alternatives that can be used to meet the specified objective at the lowest life cycle cost) . TAM best practice will use methods and criteria that reflect stated policy objectives, performance measures and targets to prioritize projects. In addition, projects will be evaluated in terms of realistic estimates of life cycle costs, benefits and performance impacts(Meyer .etal,2009).

Program analysis implies studying different alternatives that may be feasible forimplementation. Analytical tools are developed to assist agencies in evaluating the implicationsof different investment scenarios and work plan strategies. ―What if" analyses are usuallyperformed to assess the impact of alternative management decisions. This type of analysis isdifficult, if not impossible, without the assistance of analytical tools. Analytical tools to assistevaluating alternative decisions may involve simulation, life-cycle costing, benefit/cost analysis,database query, optimization, risk analysis, and other methodologies. Decision-support tools toassist an agency‘s personnel in identifying needs and comparing investment alternatives areessential in the asset management processresources (Texas Department of Transportation and FHWA,2007).

Short/long range plans:TAM systems are a critical component of many transportation organizations‘ short and long term plans since past, present, and future infrastructure condition is an essential component of a short or long range plan. During planning, projects are prioritized and selected. Several transportation organizations with more advanced asset management systems are able to conduct scenario analysis to determine the effect of different funding levels on asset condition as part of their alternatives analysis processes.Asset management planning is a comprehensive process to ensure delivery of services when road infrastructure is provided in a financially sustainable manner. Asset management plan details information about road infrastructure assets including actions required to provide an agreed level ofservice in the most cost effective manner. The plan defines the services to be provided, how theservices are provided and what funds are required to provide the services. Road Asset Management(RAM) systems have a critical component used by many transportation organizations‘. These areshort and long term plans since past, present, and future infrastructure condition is an essentialcomponent of a short or long range plan (Meyer etal,2009). An AMP for each class ofmajor infrastructure can be developed. The asset management plan is to include data and information such as stated below (State Government of Victoria, Canada, 2004):

- physical identification – quantity, location, construction materials, year built [or estimate toclosest five_ (5)-year time block], condition, capacity, performance, estimate of remaining life;
- financial information – original cost (if known), renewal cost, written down current costreplacement cost; and
- links with service and performance levels.

An AMP is a strategic document that states how a group of assets is to bemanaged over a period of time. The plan describes the characteristics and condition of infrastructureassets, the levels of service expected from them, planned actions to ensure the assets are providingthe expected level of service, and financing strategies to implement the planned actions. A detailedasset management plan has the following sections :

- Executive summary;
- Introduction;
- State of local infrastructure;
- Expected levels of service;
- Asset management strategy; and
- Financing strategy;

Long Term Asset Management Plan (LTAMP) outlines the Goals and Strategies aimed at ensuring the sustainable management of community‘s infrastructure andfinancial capital. The LTAMP covers a period of ten (10) years and through these goals andstrategies aims to forecast the Whole of Life Costs (WoLC) of existing and planned assets (Bundaberg, 2011-2012). Acknowledging it will take several years to implement effective asset managementand sets a short term plan to focus its development.In line with the Long Term Asset Management Goal and Strategies,it need to identifyimprovement opportunities for the next 2 years. (Bundaberg 2011-2012).

Program implementation: Once planning and project selection are completed programs are implemented. These programs can relate to different types of actions (e.g., major rehabilitation or maintenance activities) as well as defining the different organizational units responsible for different actions. Program implementation often requires careful thought in terms of how an agency is going to provide the most cost effective and strategic management of transportation system assets (Meyer .etal,2009).

The implementation program must address every aspect of the management process. Procedures for goal review, policy review, data collection, data storage, data access, condition assessment, budget development, construction, maintenance, monitoring, and feedback should be considered in the implementation program. The implementation program should involve all management levels that participate in the decision-making process. The implementation of an asset management approach in the programming and budgeting cycle requires continuousencouragement from upper management as well as commitment from all personnel involved. Inpractice, an asset management approach can only succeed if it can support the agency management process efficiently. The effectiveness of an asset management approach should bereflected in savings to the agency. However, these benefits can only be achieved if the agency ensures that the asset management system is properly used at all management levels (Texas Department of Transportation and FHWA,2007).

These programs can relate to different types of actions (e.g., major rehabilitation or maintenanceactivities) as well has defining the different organizational units responsible for different actions (Meyer et al, 2009). The implementation process of asset management is influenced by organizationalculture, technology, staff skills, system usage, climate, demography, public opinion/value(including special interest groups), election cycle, fiscal situation, regional economics, andenvironmental regulations (AASHTO, 1997).

2.7 ASSET MANAGEMENT DECISION MAKING LEVELS

There are various decision making levels that represent different perspectives on the system, ranging from very specific, detailed, project orientedviews to generalized, comprehensive and strategic ones. According to (Haas et al. (1994); Hudson et al.(1997); andAASHTO (2001)the decision levels pertaining to AM as identified in literature are: the strategic level, network level, and project level.

The strategic decision-making level is the broadest and mostcomprehensive.It pertains to strategic decisions concerning all types of assets andsystems.The strategic level of decision making is concerned with generic andstrategic resource allocation and utilization decisions within the man-made environment.

Network level decision-making pertains to determining the overall agency-widemaintenance, rehabilitation and construction strategies and works programs. Thisdecision level considers system-wide decisions but the scope is narrower than thestrategic level. Overall budget allocation and transportation planning are the key focusareas. This decision level is often broken down into program and project selection levels(Haas et al. 1994).

The program decision-making level is concerned with the overall, network-wideprogramming of actions and allocations. It‘s a level involving policy decisions and theaim is the system-wide optimization of funds allocated to rehabilitation, maintenance ornew construction of infrastructure assets.

The project selection level is concerned with decisions on funding for projects or groupsof projects. This level generates decisions at a higher level of aggregation than the projectlevel but it requires more detailed information than the two previous ones. It serves as alink between the network level and the subsequent project level of analysis.The project level of decision making and analysis pertains to the specific, mode-wise,asset-wise and geographically determined projects. It addresses the overall work plan that needs to be developed at this level, for the specifically selected project in order to meet the agencies‘performance measures. It is also called field level or operational level andrefers to how the actual work is going to be done.

Although all the above hierarchical levels of decision making are clearly defined, thereexists significant overlapping among what the management needs to do at every level. The identification of the actual data needed at every decision making level is a verychallenging task. This is partly due to significant overlapping between the variousdecision levels. Another important reason is also the lack of relevant research initiativesin this field up to date. Decision processes can therefore be concerned with budget allocations, network optimization, works ' programming, and selection of alternative implementation methods.

2.8 ASSET MANAGEMENT DECISION PROCESS

Asset Management is an overall methodology and decision making framework that aims at the evidence-based justification and optimization of investments in infrastructure assets. Although it is mostly perceived as a strategic level tool, it nevertheless affects and can equally be successful at lower levels of decision making within a transportation agency.Asset management decision processes are the individual decisions that need to be made at every level of decision making, whether that is of a strategic, network, or project focus. Decision processes can therefore be concerned with budget allocations, network optimization, works ' programming, and selection of alternative implementation methods, among others. Decisions made at the different levels of Asset Management are heterogeneous and the supporting data needs are bound to be quite different(Flintsch and Bryant, 2006).

To systematically approach and identify the data needed to support Asset Management decision processes, it is necessary to first define the level of decision making these processes support. The analyst can then assess the level of aggregation of the data needed and identify the data needs for those specific decision making processes and problems (Flintsch and Bryant, 2006).

According to Haas et al. (1994), the data needed to support the various decisions at any of the various levels are different.Higher levels require more generalized information while lower ones tend to need moredetailed and specific data. The detail ofinformation required and its correlation with the considered network size and thecomplexity of the analytical models used have a specific relation with the different levelsof decision making. Furthermore, different levels of decision making have different focus on the network. Higher levels are mostly concerned with overall budget allocations and system utilization, while lower levels tend to focus more on the administration, funding and engineering of specific functions and processes. In addition, people who make decisions often have different backgrounds and interests. As a result, the decisions at each level are different in scope and data aggregation level and so should be the corresponding detail and quantity of the collected.

2.9 DATA COLLECTION METHODS

Data collection, data management, and data integration are essential parts of the Asset Management framework that are critical to its success. Timely and accurate data lead to information and form the basis for effective and efficient decision making(Nemmers, 1997). The pavement condition data is an important component in developing effective maintenance and rehabilitation strategies for many reasons. First, identifying appropriate maintenance and rehabilitation alternatives rely on pavement information such as thickness, current condition, traffic, climate conditions, etc. The pavement data includes many factors, for example, pavement current condition, pavement historical performance, pavement materials, pavement thicknesses, traffic information, pavement geometry, and environmental data (Al-Kathairi,2014).

Data collection is very much dependant on the intended use of the data. It is obvious that the level of detail and the depth needed for the collected data varies according to the hierarchical level of the decisions that need to be made. Although all decision-making levels are undisputedly part of the overall Asset Management process, data collection requirements have to specifically consider how the collected information is going to be used at the various management decision levels. Data needs for supporting strategic, network, or project level are significantly different in terms of degree of detail and required accuracy(Nemmers, 1997).

The methods used for the collection of asset management data include:

(i) manual;

(ii) automated;

(iii) semi-automated; and

(iv) remote collection.

Regardless of the methodused, the existence of an effective Quality Control and Quality Assurance (QC/QA)program is vital for the success and reliability of the collection. A brief description ofeach method is presented following (VDOT, 2004):

(I) Manual collection: This method employs two or more data collectors and a distance measuring device. The collected data are documented either with pen and paper or in most recent cases with hand-held computers equipped with GPS [Larson and Skrypczuk (a) 2004]. The data collectors walk from one site to the other and inspect and record the condition of the considered assets. A variation of this method, the windshield survey, uses a vehicle to perform the inspection while driving along the travel line; the recording is still done manually. Manual surveys allow for very detailed data collection but are very labor intensive and require more time per asset than automated or semi-automated methods.

(ii) Automated collection: The method involves the use of a multipurpose vehicle which is equipped with a distance measuring device, digital video cameras (downward and/or forward looking), a gyroscope, laser sensors, computer hardware and potentially GPS antennas in order to capture, store, and process the collected data. The gyroscope and GPS are used to capture location data. The laser sensors are used to acquire pavement surface properties and the downward looking cameras are used to assess pavement surface properties (usually distresses). The forward looking cameras are used to determine the location of roadside assets and assess performance measures. Specifically developed software is generally used in order to visualize in three dimensions the location of the transportation assets from the digital two-dimension frames. The newest data collection equipments have achieved high automation and accuracy and are capable of very fast and comprehensive data collection (Peggar et al. 2004; Rada et al. 2004). In most cases, however, even with the use of automated methods, some post-processing of the data is required.

(iii) Semi-automated collection: This method involves similar equipment as the completely automated method but with a lesser degree of automation. It is very popular within transportation agencies and yields comprehensive and accurate data collection when properly implemented.

(iv) Remote collection: This last method pertains to the use of satellite imagery and remote sensing applications. These methods involve high resolution images acquired through satellites or other types of images and scans obtained by remote sensing technologies (lasers, aerial photos, aerial GPR, etc). The images are used in conjunction with ground information in order to reference the location of the transportation assets and to assess asset condition or capture various asset attributes and characteristics (NASA 2000; NCRST 2001).

2.9.1 Automated Data collection Equipments

According to Al-Kathairi (2014) in Automated data collection some of state of the art equipment including Automated Road Analyzer (ARAN), Heavy Weight Deflectometer (HWD) and Weigh in Motion traffic equipment are used to assess the structural and functional conditions of the pavement. From the ARAN testing: roughness (ride), rut depth, surface macro texture and surface distress results were collected. From the HWD testing: layer modulus and remaining structural life were calculated and reported. From the Weigh in Motion study the current axle loading was determined for evaluating remaining life. A brief description of each of Automated equipments presented below:-

- **Automated Road Analyzer(ARAN)**

The ARAN car shown in Figure 2.0 was used to carry out the surface profiling and imaging. The ARAN car is designed to provide advanced, automated and high quality pavement profile measurements and imagery for use by engineers and construction managers. The ARAN is capable of capturing real time continuous highway-speed data acquisition of longitudinal profile parameters and International Roughness Index (IRI) with differential GPS Data and Digital Photo Logging. Figure 2.1below shows an Automated Road Analyzer (ARAN).

Figure 2.1: Automated Road Analyzer (ARAN)

Source: Fugro Roadware Inc, 2012 as quoted by Al-kathairi

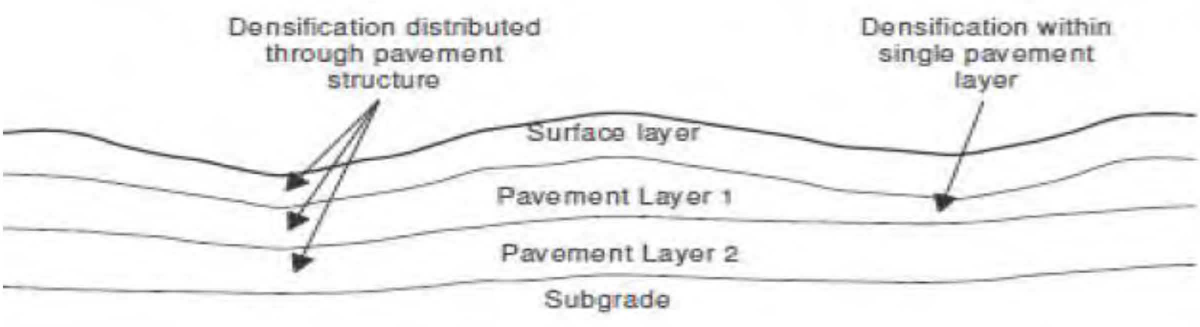
The Automated Road Analyzer can measure road conditions for example:

- Roughness;
- Rutting; and
- Surface Macro texture.

The roughness of pavement is generally defined as an expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle (and thus the user). Roughness is an important pavement characteristic because it affects not only ride quality but also vehicle delay costs, fuel consumption and maintenance costs. The World Bank found road roughness to be a primary factor in the analyses and trade-offs involving road quality vs. user cost (UMTRI, 1998). Roughness is also referred to as "smoothness" although both terms refer to the same pavement qualities. As per ASTM E1926 standard the roughness is reported in terms of International Roughness Index (IRI). The IRI is considered the most universal and recognized index by agencies to express the roughness of pavements. IRI is generally expressed in meters/kilometer (or millimeters/meter). As the roughness increases, the riding comfort and sense of safety decrease that implies the need of maintenance.

A rut is defined as the maximum vertical pavement displacement, in the transverse profile, either across the wheel path (wheel path rut) or across the lane width (lane rut) measured from a reference plane. Traffic-associated permanent deformation (rutting), in particular, result from a rather complex combination of densification and plastic flow mechanisms. Densification, according to Paterson (1987) is the change in the volume of material as a result of the tighter packing of the material particles and sometimes also the degradation of particles into smaller sizes. Rutting due to densification is usually fairly wide and uniform in the longitudinal direction with heaving on the surface seldom occurring, as illustrated in Figure 2.2.

Figure 2.2: Rut profile as a result of Plastic Flow (shoving)



Source: Kannemeyer, 2003 as quoted Al-Kathairi

The ARAN is configured with a laser based system that by the triangulation method measures the surface transverse profile to 0.1mm resolution at 1280 points across a 4.0m width behind the survey vehicle(Figure 2.3)

Figure 2.3:ARAN profile measurement systems

Source: Fugro Roadware Inc, 2012 as quoted by Al-Kathairi

The wire model algorithm with the ARAN connects the high points on the pavement transverse profile and establishes the rut depth under these points, as shown in Figure 2.1. The wire model expresses the rut depth based on a wire stretched over the high points. The distance to the pavement from the wire is calculated and the highest values constitute the rut depth. The rut depth is then determined in each wheel-path across that profile from the center of the lane using a reference level.

The pavement surface macro texture is measured using a 64kHz laser mounted in the right (outer) wheel-path of the ARAN vehicle. The ARAN system measures and reports surface macro texture in terms of Mean Profile Depth (MPD) in accordance with ASTM E1845 and ISO 13473-1. This is a measure of macro texture based on the height of the highest peaks above the mean depth, calculated over a 100mm line.

The pavement surface skid resistance is a function of the surface textures that include the wavelength ranges described by micro texture, consisting of wavelengths of 1μm to 0.5 mm, and macro texture, with wavelengths of 0.5 mm to 50 mm. Micro texture is a surface characteristic having wavelength components less than 0.5mm, formed by the irregularities on the surface particles exposed at surface level, and is normally measured with a friction measurement device such as the Side ways-force Coefficient Routine investigation Machine (SCRIM). The micro texture is affected primarily by aggregate characteristics (shape, angularity and texture). Macro texture is a surface characteristic related to potential channels for water drainage between the vehicle tire and road surface, which has a wavelength range of 0.5 mm to 50 mm. Macro texture is a function primarily of the mixture gradation and design.

- **Pavement Structural Assessment utilizing HWD**

Heavy Weight Deflectometer (HWD) testing employs a non-destructive device which includes nine geophones, as shown in Figure 2.4, designed for multi-purpose pavement applications, ranging from unpaved roads to airfields. HWD generated data, combined with layer thicknesses, can be confidently used to obtain the resilient elastic moduli of the structural layers within a pavement structure. This information was, in turn, used in the structural analysis to determine the bearing capacity, estimated expected life, and to develop a rehabilitation plan.

Figure 2.4: Heavy Weight Deflectometer (HWD)

Source: Abu Dhabi Municipality data collection reports, 2014 as quoted by Al-kathairi

The pavement structural evaluation was conducted using the Dynatest Heavy Weight Deflectometer. A minimum of three tests were carried out at each location in accordance with ASTM D4694. The drop loads were 60 kN, 90 kN and 130 kN. At each test point, the peak applied load and peak deflections were recorded from nine geophones at selected offsets ranging from under the center of the load to a distance of 1.8m from the load.

The Back-Calculation analysis of the HWD data was carried out using ELMOD 6.0 to report layer resilient elastic modulus. The remaining structural life was determined in terms of tolerable equivalent standard axles load repetitions (80kN) using the Austroads subgrade deformation and asphalt fatigue criterion.

The following were automatically recorded during the survey:

- Linear Reference (Station);

- GPS Location;
- Peak Load;
- Peak Deflection for each of the 9 Geophones;
- Surface Temperature;
- Air Temperature; and
- Date and Time of Test.

In addition, in some cases a Geocoded video logging vehicle equipped with three cameras was used in which two cameras mounted for collecting the road data related to road furniture within right of way at right and left side of the road while one camera was to capture the pavement condition Figure 2.6 shows a picture of the vehicle used for geocoded video logging.

Figure 2.5: Vehicle used for Geocoded video logging

Source: Abu Dhabi Municipality data collection reports, 2014 as quoted by Al-kathairi

The data collected through Geocoded video logging included a number of factors, For example:

- Road Identification and Classification;
- Street Name;
- Type of Pavement;
- Gullies and Catch Basins;
- Street Lights;
- Road Side Cameras;
- Control Cabinets;
- Traffic Signs;

- Gantry Signs;
- Road/Pavement Markings;
- Traffic Signals;
- Bus Stands;
- Fire Hydrants;
- Bollards;
- Location of Bridges;
- Kerb-stone;
- Fence;
- Parapets;
- Barriers;
- Guard Rails;
- Foot Path / Walkways;
- Median;
- Roundabouts conditions and Geometric Configuration;
- Layby;
- Cat Eyes and Studs;
- Condition and type of Island;
- Humps/Speed Breakers; and
- Location and Condition of Pedestrian Crossing.

2.10. DATA CHARACTERISTICS AND PROPERTIES

The research of various sources on how agencies worldwide deal with decision makinghas brought to light particular attributes and characteristics that the collected data shouldpossess in order to be useful for this purpose. Regardless of the particular type orcategory that the collected data fall into, it is of paramount importance that whenincorporated in a database they exhibit the following characteristics (Deighton,1991):

- Integrity: whenever two data elements represent the same piece of information, they should be equal;
- Accuracy: the data values represent as closely as possible the considered piece of information;
- Validity: the given data values are correct in terms of their possible and potential

ranges of values; and

- Security: sensitive, confidential and important data are protected by restricting access to them and by properly ensuring systematic and frequent ―backing-up" inother storage media.

As a fifth characteristic it is also recommended that the data elements be rigorouslydefined in a Data Dictionary and that – in the most ideal of all cases – these definitions becommon between all agencies and parties involved in this area of practice (Deighton,1991).In addition, the Western European Road Directors (WERD,2003) highlighted theimportance of the following criteria when selecting data required by anagency/organization:

- Relevance: every data item collected and stored should support an explicitly

defined decision need;

- Appropriateness: the amount of collected and stored data and the frequency of

their update should be based on the needs and resources of the agencyorganization;

- Reliability: the data should exhibit the required accuracy, spatial coverage,

completeness and currency; and

- Affordability: the collected data are in accordance with the agency's financial and

staff resources.

Agencies planning to engage in data collection according to (WERD 2003), should take in to account and determine the following parameters:

- The specification of the data to be collected;
- Their frequency of collection;
- The accuracy and quality that the data should exhibit; and
- Their completeness and currency.

As a general recommendation it is noted that the accuracy, quality and currency of thedata should be decided based on the cost of the data collection and the value and benefitassociated with the data in question. ―Data should only be collected if the benefits thatthey provide outweigh the cost of their collection and maintenance" (WERD,2003).Data collection costs can and should be minimized by collecting only the needed data andonly when needed. The data collection activities and methods used should be based on and produce results that match the levels of accuracy, precision and resolution requiredby the decision processes to be supported (Smith and Lytton,1992).

2.11. DATA MANAGEMENT

Once the data have been acquired by one or more of the above described methods and technologies they are stored in various formats and storage media. Data formats include: paper format, electronic databases, and geo-referenced database systems (such as Geographic Information Systems, GIS). The storage media employed can be paper forms (still in use in many agencies), hard disks, magnetic tapes, CDs, DVDs and combinations of thereafter.Electronic data are the easiest to share and can exist in various forms such as text, graphics, photos, and videos. They can be stored either in flat files or in structured database files (relational, object-oriented), which can be stand-alone or part of a database system (Flinch and Briyant,2006).

Organizational culture has traditionally prompted agencies to create database/information management systems that support specific applications such as pavement, bridge, sign, equipment, finance, and other management systems. These independent, legacy, stovepipe systems have to be linked in order to efficiently support Asset Management. The realization of this goal has proved to be extremely challenging as the aforementionedsystems often use different data management technologies and information system environments (e.g. database design, software, hardware, etc.) as provided by the (FHWA, 2001 (f)).

2.12. DATA INTEGRATION

As transportation asset data have been collected at different times, by different units, using different methods, and stored in varying formats and media, there is naturally a need for data integration. Data integration is essential to transform the data into useful information, able to support decision making at the various management levels. Transportation agencies must organize the available data into suitable forms for applications at the different organizational levels of decision making. This venture presents a big challenge, as data integration is nothing but easy to implement(Flinch and Briyant,2006) .

According to FHWA (2001 (b)) data integration alternatives include two main approaches: a fused database and many interoperable databases. In the first case the integration strategy leads to the creation of one database that contains all integrated data; in the second case existing or newly created databases are linked together and the integration of the data is achieved with the use of queries that provide a view of the linked data.The choice among the two integration strategies depends on many factors and is clearly a judgment call for the agency officials.

The factors to be considered include:

- intended use of the integrated data (by whom and for what purpose);
- characteristics of the already existing databases/information systems;
- type and volume of the data that need to be integrated;
- currently available information technology;
- level of staff and resource allocation that will be dedicated to the process; and
- structure of the agency/organization itself (business units and their roles, data needs, people and information systems).

As location is an important property of all transportation assets, it has served in many cases as the common platform used for data integration. For example, various state department of transportation (DOT) offices of the US have used GIS and other geospatial tools for data integration (Flinch et al,2004). GIS software and related functionalities can alternatively be incorporated in the databases as external software that enhances the analytical and reporting capabilities of the system [(FHWA, 2001 (f))].

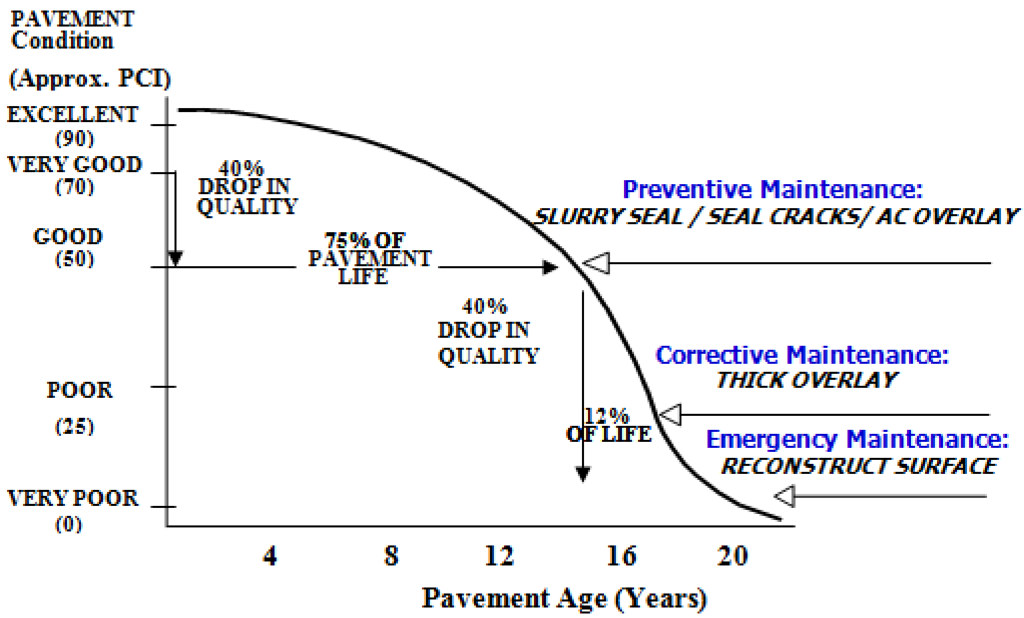
Another aid for the integration and interoperability of databases is the use of commonly accepted data definitions and consistent formats across systems. A standard data dictionary or global standard for data definition, representation, storage and communication could be of vital help to the effort of data integration, regardless of the integration strategy implemented. However, there have been many challenges identified by agencies that have tried to develop and implement data standards and that have attempted to convert existing, legacy data to these new standards. These challenges include agreeing on suitable data formats, models and protocols when the existingdatabases present extreme diversity; achieving support from the agency staff and getting people to conform to the new standards; and reducing as much as possible the effort and resources needed in order to develop and implement the standards [(FHWA, 2001 (f)].

2.13 PAVEMENT MAINTENANCE TYPES

Maintenance Management is an orderly and systematic approach to planning, organizing,monitoring and evaluating maintenance activities and their costs. A good maintenance managementsystem coupled with knowledgeable and capable maintenance staff can prevent health and safetyproblems and environmental damage; yield longer asset life with fewer breakdowns; and result inlower operating costs and a higher quality of life (Al-Kathairi,2014).

Maintenance activities impact all road stakeholders such as Financers, Agencies, and Users. As aresult the maintenance management systems should shoulder the benefit of these stake holders in apositive. In general, maintenance can be classified into the following categories (Al- Kathairi, 2014): Typically three types of pavement maintenance are applied. As show in Figure 2.6below, these three maintenance types are Preventive, Corrective, and Emergency.

Figure 2.6: Types of pavement maintenance as per time and pavement condition



Source: Quoted from Al-Kaithairi which is acquired from Hicks et al., 2000

Preventive maintenance: This is used to correct minor deterioration, retard progressive failures, and reduce the need for corrective maintenance. It is performed before the pavement shows significant distress to provide a more uniform performing pavement system. Preventive maintenance is normally applied under a planned strategy of cost-effective treatments to an existing pavement system and its accessories that preserves the system, retards futuredeterioration, and maintains or improves the functional condition of the system. Preventive maintenance prolongs the life of a particular depreciated asset, either by replacing it with a new one, or by some other intervention (such as Slurry seal, Cracks seal or Thin overlay).

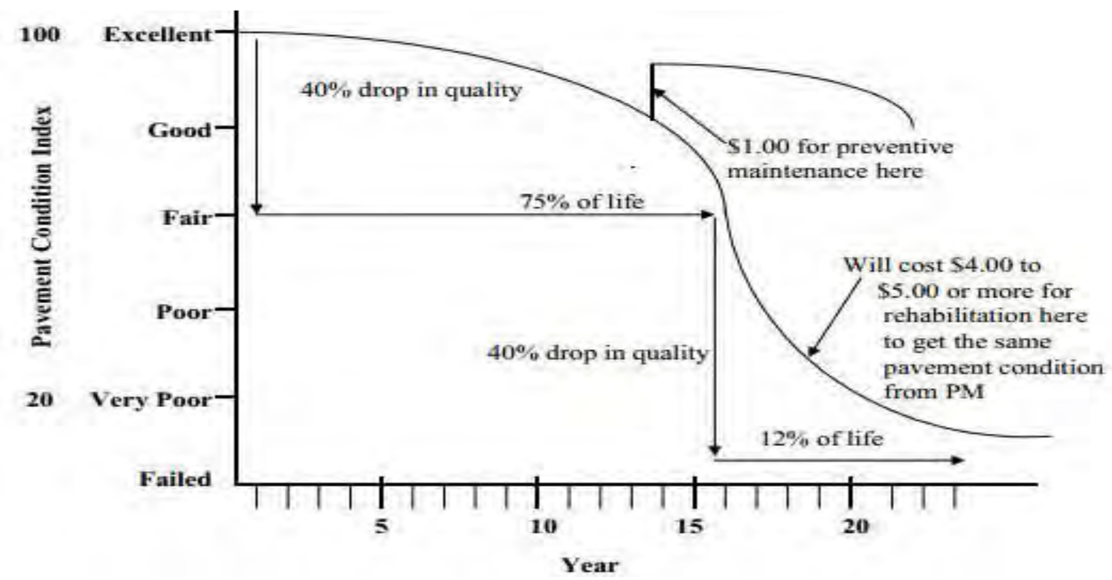
Corrective maintenance: This is performed after a deficiency occurs in the pavement; i.e., loss of friction, moderate to severe rutting, or extensive cracking. Corrective maintenance is generally performed after a deficiency occurs in the pavement system, such as moderate to severe heaving, raveling or extensive cracking. Corrective maintenance may also be referred to as reactive maintenance which is conducted in response to detection, through periodic safety and service inspections or as reported by members of the public, of flaws or defects that could adversely affect the safety of, or service offered by, the asset. Most reactive maintenance activities are performance-based, meaning that they occur when inspections reveal that the performance of an asset has fallen below the required level of safety or serviceability.

Emergency Maintenance: Performed during an emergency situation, such as flooding, sand storm or a severe pothole or trip hazard that needs repair immediately. This could also include temporary treatments that hold the surface together until a more permanent treatment can be performed. There are no clear boundaries between when a treatment is preventive versus corrective, or corrective versus emergency. All types of maintenance are needed in a complete pavement system preservation program. However, emphasizing preventive maintenance may prevent or prolong the need for corrective maintenance.

Although each type of maintenance is needed in a comprehensive pavement preservation program, the emphasis should be placed on preventing a pavement from reaching the condition where corrective maintenance is required, since the cost associated with this approach can be substantial (O'Brien ,1987).

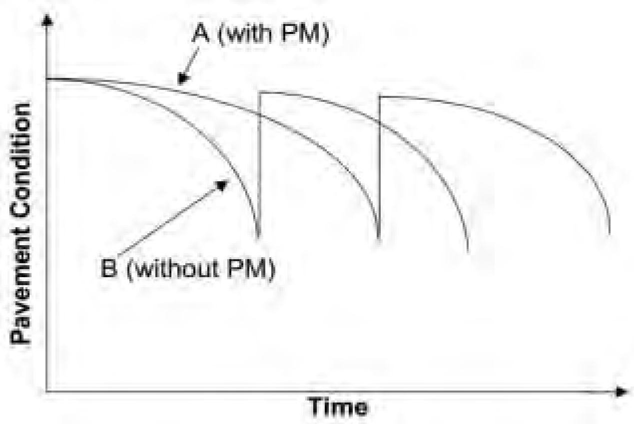
According to O'Brien (1987) the challenge is to determine the cost effectiveness of the preventive maintenance approach compared with standard practices of rehabilitation when the pavement wears out, such challenge is depicted in Figure 2.7which compares different treatments at different times.

Figure 2.7: Typical Variation in Pavement Conditions as function of Time



Source: O'Brien, 1987

Figure 2.8: Deterioration curves with and without preventive maintenance



Source: O'Brien, 1987

2.14. PROJECT SELECTION AND RELATED TOOLS

Project selection is a level of decision making that entails the evaluation of the attributes of different candidate projects for the purpose of funding and implementation. As a decision making level it addresses decisions pertaining to network level analysis and it functions as a ―bridge" between high-level network decisions and site-specific, detailed project level decision making. The project selection analysis is based on information that is aggregate enough to be able to see the ―big picture" of the competitive projects and therefore identify and assess their usefulness and overall impact but also detailed enough in order to capture the individuality of each project and be able to provide accurate cost estimates and identify implementation implications for the agencies and the users. The different types of work that may be encountered by an agency responsible for the management of roadway assets are rehabilitation, maintenance and new construction. Furthermore, typical roadway assets that are part of an agency's roadway transportation network are pavements, bridges, tunnels, signs, culverts, drainage systems, markings, medians etc (Virginia dot, 2004). Table 2 below shows Roadway Asset Types and Definitions.

Table 2.0: Roadway Asset Types and Definitions

Road way Assets	Definitions
Pavements	Flexible Pavements (HMA), PCC Pavements, Unpaved Roads; Paved Shoulders, and Unpaved Shoulders
Roadsides	Vegetation and Aesthetics, Trees, Shrubs and Brush, Historic Markers, and Right-of-way Fence
Drainage Structures	Cross Pipes and Box Culverts, Entrance Pipes, Curb and Gutter, Paved Ditches, Unpaved Ditches, Edge Drains and Under-drains, Storm Water Ponds and Drop Inlets
Traffic	Attenuators, Guardrail, Pavement Striping, Pavement Markings, Raised Pavement Markers, Delineators, Signs and Highway

Structures and Bridges	Overhead Sign Structures, Structural Culverts, Overall Bridge, Sound Barriers and Retaining Walls
Special Facilities	Movable Bridges, Rest Areas, River and Mountain Tunnels, Weigh Stations and Traffic Monitoring Systems

(Hudson et al,1997) stated that project selection follows the overall network programming decisions regarding the general funds that are going to be allocated in the different types of agency works. After the agency has decided on the amount of funds to be spent in maintenance, rehabilitation or new construction (or reconstruction) then the candidate projects that fall into each of these work programs need to be determined.

The selection of the different projects or different groups of projects to be included in a work program is heavily constrained by available budgets and usually resorts to some types of prioritization models. These models usually employ optimization, near optimization or other techniques in order to lead to results that can be used by theWorldwide practice in the area of project prioritization has shown that in order for the analysis to be comprehensive and as accurate as possible, the effects of economic and timing parameters should be considered. Recent research in this area has focused in proposing competent models that include economic analysis and multi-year prioritization in the optimization process. Some of these models take also into account the effects of certainty, risk and uncertainty in the outcome of the prioritization results (Li and Sinha, 2004).

2.14.1 Economic Evaluation

According to Cristina et al (2014) Pavement economic evaluation can be performed by means of the following types of analyses:-

Life-Cycle Cost Analysis (LCCA): Compares different investment alternatives based on their cost flows over the life-cycle (FHWA, 2003).(LCCA) uses economic principles to compare competing alternativeinvestment strategies . It incorporates initial and discounted future costs over the life cycle ofthe alternative investments and attempts to identify the best value or the lowest cost over time.LCCA has always been an important tool in supporting decisions on the most cost-effectivestructure (roads, utilities, buildings, etc.) or rehabilitation treatment (Haas etal,2003).

Many agencies use life-cycle cost analysis (LCCA) as a means of evaluating the long-term economic viability of pavement designs. As such, it is important for each agency to conduct a realistic assessment of pavement economics in order to provide objective input into the life-cycle cost analysis. LCCA has been highly recommended for finding optimal pavement designs in order to take account of a long-term pavement performance (AASHTO, 2002).

There is a difference between LCCA and financial analysis, as subsequently discussed. Basically, LCCA is used to compare the use (s) of funds while financial analysis is concernedwith cash flows (e.g., revenues, actual costs, and profits). LCCA uses today‘s costs for the futurecostestimates and then discounts them at the real cost of money. Conversely financial planningmust consider or program the actual cost outlays in the future (Haas etal,2003).

According to FHWA(2002) the differences between LCCA and BCA, and their appropriate applications, are discussed below because the distinction between LCCA and BCA can be confusing in day-to-day practice.

The agency that uses LCCA has already decided to undertake a project or improvement and is seekingto determine the most cost-effective means to accomplish the project‘s objectives. LCCA is appropriatelyapplied only to compare project implementation alternatives that would yield the same level of service andbenefits to the project user at any specific volume of traffic. LCCA, for instance, is an appropriate tool touse when comparing two alternatives to replace a bridge that has reached the end of its service life, whereeach design alternative will result in the same level of service to the user. Costs measured in LCCA typicallyinclude expenses to the State or local agency, such as construction, operation, and maintenance costs.As a matter of best practice, LCCA should also include costs accruing to the users of the project facility,especially costs associated with increased congestion and reduced safety experienced during project constructionand maintenance. Whereas BCA considers the benefits of an improvement as well as its costs. It can beused to compare design alternatives that do not yield identical benefits (e.g., bridge replacement alternativesthat vary in the level of traffic they can accommodate), as well as to compare projects that accomplishdifferent objectives (a road realignment versus a widening project). Moreover, BCA can be used to determinewhether or not a project should be undertaken at all (i.e., whether the project‘s life-cycle benefits willexceed its life-cycle costs).

Asset Management is a strategic approach to managingtransportation infrastructure. The goal of Asset Managementis to get the best results and performance from the preservation, improvement, and operation of infrastructureassets with the resources available. LCCA providesdecision-makers with the ability to determine the leastcost solution for a transportation investment requirementand is therefore a natural fit within the Asset Managementframework (FHWA,2002).

Cost-Benefit Analysis (CBA): Identifies the net benefit of an investment by comparing its present and future costs and benefits. The CBA considers that the selection of a project is justified if the value of the benefits exceeds that of the costs (FHWA, 2003). This method has been widely used in the infrastructure area, particularly for large projects such as dams and causeways. The Benefit/Cost ratio approach is not recommended for several infrastructure types, however, including pavements, because of the difficulty in quantifying benefits.

Cost-Effectiveness Analysis (CEA): Considers the costs with their present value and evaluates the benefits through an indicator measuring the investment‘s effectiveness. Thus, the CEA allows comparing alternatives which generate responses that are difficult to monetize(FHWA, 2003).

Economic Impact Analysis (EIA): Evaluates the effects on the local, regional or domestic economy by quantifying, among others, the effect on the economic activity, employment, immigration, tourism, etc (FHWA, 2003).

Financial Analysis (FA): Studies the financing needs of the project over its service life, considering the mismatch between expenditures and available resources(FHWA, 2003). Table 2below shows the types of economic analyses and applicable indicators.

Table 2.1: Types of economic analysis and applicable indicators.

Indicator	Types of Economic Analysis				
	LCC	CBA	CEA	EIA	FA
Net Present Value	X	X	X	X	X
Equivalent annual cost	X	X		X	X
Internal Rate of Return		X			X
Cost Benefit Ratio		X			
Cost effectiveness ratio			X		
Investment return period		X			X

Where, LCCA is Life-Cycle Cost Analysis; CBA is Cost-Benefit-Analysis; CEA is Cost Effectiveness Analysis; EIA is Economic Impact Analysis; FA is Financial Analysis.

In ACCRA no explicit way of utilizingAnalytical methods for maintenance and rehabilitation interventions. No Decisions made and implementations pertaining from analysis. So AACRA expected to develop economic analysis method for the road assets like life cycle cost analysis.

2.14.2 Costs and Benefits in the Economic Evaluation

According to Cristina et al (2014) the costs and benefits considered in the economic evaluation of pavements are classified in the following groups:

- **Agency costs:** Includes the costs that are necessary to put the infrastructure into service, as well as those associated to maintenance activities and mitigation.

- **Effect on users:** These effects are calculated by integrating three concepts: accidents, travel time (TT) and vehicle operating costs (VOC), the latter associated to fuel consumption, and wear of tires and other vehicle parts. A distinction is made between the effects generated during normal operation and those derived from work zones. The first correspond to the effects on users during periods when there are no operations that reduce the infrastructure's capacity. The second ones refer to the costs generated when circulating through a section where circulation has been modified due to maintenance or construction operations.
- **Externalities:** It refers to an action's direct impact on non-users (FHWA, 2003). They include effects such as air pollution, noises, adverse effects on the water quality, etc. The assessment of these externalities is difficult to monetize (FHWA, 2003; Khurshid et al., 2009). Although there are studies aimed at improving the quantification of these effects (Browne & Ryan, 2011; Cross et al., 2011), the usual practice is to exclude them from the economic evaluation, and to consider them in the decision making process through additional indicators.

2.14.3 Models for the Economic Evaluation of Pavement Preservation Activities

According to Cristina et al (2014) a number of existing economic evaluation models are described below:

- An international effort to develop improved road investment appraisal methods was undertaken by the British Overseas Development Administration, the Asian Development Bank, the Swedish National Road Administration, the Inter-American Federation of Cement Manufacturers and the World Bank. This study was built upon the widely-used Highway Design and Maintenance Standards model HDM-III. Emphasis in the study was on collating and applying existing knowledge, rather than undertaking major new empirical studies. However, the end product of the study was a completely new software package and associated documentation which will serve as the primary tool for the analysis, planning, management and appraisal of road maintenance, improvements and investment decisions that will supersede HDM-III HDM System (Gebremedihin,2015).

The HDM-4 (Highway Development and Management**)** is a system for pavement management in urban and interurban roads, which allows the economic evaluation of maintenance, construction of new roads and improvement of existing roads, among others (Odoki & Kerali, 2006).

HDM-4 is a very comprehensive software tool to appraise the technical and economic aspects of road investment projects. It introduces three application levels commonly used in decision making within the road subsector, are as follows:

- ❖ Strategic planning for estimating medium and long-term budget requirements for the development and preservation of a road network under various budgetary and economicscenarios.

- ❖ Program analysis for preparing single or multi-year work programmes under budget constraints.

- ❖ Project analysis for estimating the economic or engineering viability of different road investment projects and associated environmental effects. Typical projects include the maintenance and rehabilitation of existing roads, widening or geometric improvement schemes, pavement upgrading and new road construction (Haas, 2003). In Ethiopia HDM 4 is used for federal roads but it is not calibrated in Ethiopian case even if data were taken from Ethiopia during development of the model.

- The HERS-ST model (Highway Economic Requirements System-State Version), developed by the Federal Highway Administration, evaluates the improvements resulting from rehabilitation and reconstruction operations, excluding preservation treatments (FHWA, 2002).

- The Micro Paver management system**,** proposed by the US Defense Department for pavement preservation, uses the cost-effectiveness analysis with the PCI index (Pavement Condition Index) as condition indicator (Colorado State University, 2013).

- The Pavement View Plus system (Cartegraph, 2013**)** bases the economic evaluation on a cost-effectiveness analysis considering the OCI condition indicator (Overall Condition Index).
- The Real Cost Model, developed in the USA by the Federal Highway Administration, is based on the procedure taken from Walls and Smith (1998), which calculates the effect on users during normal operation and in work zones. However, the model is conceived only to evaluate pavement design alternatives, since it does not include preservation tasks.
- The MicroBENCOST model evaluates the users' cost and benefits, embracing seven types of projects: capacity increase, bypass construction, intersection improvements, pavement rehabilitation, bridge improvements, safety improvements, and improvements in railway crossings (Mcfarland et al., 1993). Therefore, it does not assess preservation operations.

All the above stated techniques and software tools constitute valid approaches for supporting project selection decision making, provided that they are used in full recognition of their capabilities and limitations.Since the way project selection is carried out by most agencies involves tools similar to the ones described above, it is reasonable to assume that the data needs of this particular level of decision making should include the type and amount of data that form the inputs of these models and techniques. In other words, project selection data needs should be focused on the particular inputs that the project evaluation models require. As different agencies employ different models and techniques the particular data needed for each agency are also bound to be different(Cristina et al,2014).

2.15. DETAIL REVIEW ONPAVEMENT MANAGEMENT SYSTEM

2.15.1 Features of a Pavement Management System

Effective and timely maintenance of roads and bridges under budgetary restriction is necessary to keep the network in good condition. This requires an efficient Pavement Management System (PMS) in Road and Highway Departments (Kahn, 2005). PMS have been defined as a set of tools or methods that assist decision-makers in finding optimum strategies for providing, evaluating, and maintaining pavements in a serviceable condition over a period of time (AASHTO, 1993). They also provide the information needed to support fund requests and justify maintenance and rehabilitation programs Huang(cited by Gebremedihin,2016).

This overall PMS is generally composed of two major sub-systems: information management system and decision support system. The information management system is the collection, storage and management of the required data; whereas, the decisions support system is the collection of algorithms that analyzes the data and provides recommendation to managers Huang(cited by Gebremedihin,2016).

Pavement management can be divided into two generalized levels: project and network. At the project level, consideration is given to alternative design, construction, maintenance, or rehabilitation activities for a particular project within the overall program (The U.S. Department of Transportation, 2000). The basic elements of a network-level PMS include an inventory, a condition assessment, determination of needs, prioritization of projects needing maintenance and rehabilitation, a method to determine the impact of funding decisions, and a feedback process Huang(cited by Gebremedihin,2016).

2.15.2 PMS Inputs

As the heart of the pavement management system is the database, which is the storehouse for all pavement-related information collected. This database possesses several features, including: a large capacity, user friendly access, flexibility for future expansion, security features, and compatibility with other databases that store related information (such as bridge, congestion, and traffic crash data). Every piece of information in the database is referenced to the particular section of pavement (i.e., the particular intersection or segment of road) which it describes (SEMCOG,2003).

According to SEMCOG,2003 the information collected and stored in the database can be divided into five categories:

- inventory data;
- construction data;
- traffic data;

- condition data (physical distress, roughness, structural capacity, friction); and
- treatment data.

Analytical Tools and Outputs

While the database is the ―heart" of a pavement management system, data are not useful unless they are presented in a meaningful way. It is the role of analysis procedures to transform the raw collected data into products — such as charts, graphs, and reports — that are helpful to decision-makers. A pavement management system can transform a spreadsheet containing pavement condition data into a map. A map can be quickly and easily used to examine the health of pavement in ways that are not readily apparent from columns of numbers. Analytic procedures are grouped into four categories:

- simple queries,
- pavement condition score calculations,
- remaining service life calculations, and
- strategy selection procedures.

2.16.STATE OF THE PRACTICE OF ASSET MANAGEMENT

UNITED STATES OF AMERICA

A number of states use and collect major PMS data types. In this investigation State DOTs were asked to report if their Pavement Management System (PMS) was using specifically identified data items, if these items were collected by the PMS's data collection activities, and the data collection methods (Flintsch et al,2004).

Concerning the various levels of U.S. government, there have been several reports coming from state DOTs and municipal departments that present and analyze their current state-of-the-practice. These reports refer to implementation efforts, general methodologies adopted and implemented, and breakthrough initiatives undertaken, among others. They indicate that many state and municipal transportation agencies have been moving towards an integration of individual management systems and databases to support Asset Management. For example, there have been efforts to integrate GIS in their information systems (Flintsch et al,2004).

Data Management

In Virginia Department of transportation the information is updated annually and stored in a corporate databasewith a GIS platform. The pavement and bridge data are kept in separate databasesthat feed the central database once a year which means they integrate the individual management systems with central data base. The accuracy needed for thevarious data items has not been addressed objectively. However, there aregood quality assurance procedures in place to check the information collected and input to the system. In Maryland state highway administration the data contained in the PST program are integrated with the MDSHA pavementmanagement database. Three sources of data are merged to create thePST roadway section data:Roadway inventory database: This database contains information on theroadway geometry, designation, and traffic. This data is referenced at0.1-mile intervals.Pavement performance database: This database contains ride quality, rutting,cracking, and friction condition data. This data also is segmented at 0.1-mileintervals.Construction history database: This database contains records that identifyevery layer in the pavement structure including construction, materialtype, and thickness data. The data is segmented in various lengths basedon consistent construction history and typically varies between 0.1 and 2miles in length.To create the roadway section data for the project selection program, the datafrom these three sources are merged and aggregated to provide summaryinformation at the intervals defined in the construction history database (Flinch and Briyant,2006).

Data Collection Equipments

The Maryland state highway transportation official annual network-level data collection includes ride quality,rutting, and friction for all directional miles under the responsibility ofMDSHA (100 percent coverage). These data are collected using automaticdata collection equipment: an automated roadway analyzer (ARAN) vehiclefrom Road ware, and a locked–wheel skid tester. The ARAN vehicle collectsride quality, rutting, right-of-way digital video, and downward digital video for automated cracking identification. At the project-level data collection includes pavement material structure andthickness determination, nondestructive deflection testing, and ride-qualitytesting. These data are collected using a high-speed profiler, a falling weightDeflectometer (FWD), ground-penetrating radar (GPR), drilling/coring rigs,and manual visual surveys (using the PAVER pavement condition index[PCI]) (Flinch and Briyant,2006).

Project Selection

Maryland state highway administration in the project selection process, the treatments applied to any of the pavementgroups are categorized into seven groups on the basis of their lifeexpectancy. The treatment groups are 15, 12, 8, 5, +4, and +2 years, as wellas –do nothing.” The first four treatment groups (5–15 years) are consideredmajor rehabilitation alternatives that effectively reset the pavement to anoriginal condition. The treatment groups of +4 and +2 years are consideredmaintenance treatments and are intended to reflect corrective or preventivemaintenance strategies that maintain existing conditions or correct onlya portion of the pavement and do not reset the pavement to an originalcondition. The treatment level group was created to reflect differences inperformance and cost of rehabilitation improvements and to allow settingconstraints that would force a minimum or maximum level of funding ineach treatment level group. In District of Colombia department of transportation most of the project selection is done within the individual stovepipe management systems. The PMS identifies appropriate treatment for each block based on distresstypes and severity. The system also includes a cost module that is used tocalculate costs for the candidate projects. The divisions then use cost–benefit analysis and project-to-project comparisons to determine the final list of prioritized candidate projects submitted for consideration by the director. In Virginia department of transportation project selection on various maintenance and rehabilitation (M&R) strategies considered for the main asset types have been defined by an expert panel composedof representatives from the Asset Management division and thedistricts. These panels have also defined the main selection criteria (and consequentdata needs) and best practices decision trees. The districts can adjustthe criteria on the basis of their knowledge and experience. The criteria aredocumented in the individual management systems (e.g., for pavement orbridges) and their respective guidelines and manuals (Flinch and Briyant,2006).

Decision Making Levels

In Maryland state transportation official they have formally identified decision making levels. Strategic Level Decisions regarding key program performance objectives, includingpercentage of roads with an acceptable ride quality, percentage ofMaryland‘s National Highway System mileage with acceptable ridequality, and average service life of State Highway Administrationpavements.Program Level Development of strategies for investment that meet a definedobjective such as maximizing condition or minimizing costs. Thestrategy provides direction in how to invest in the pavement network.Project-Selection Level Selection of individual roadway projects by district to match upagainst the strategy.Project-Design Level Detailed project-level design subject to the treatment level andproject costs defined in the previous level.In Virginia department of transportation they have formally identified and decision making levels. Strategic Level Decisions regarding cross-agency issues and funding allocation across the highway maintenance, mobility management, and operationprograms.Program Level Operation of the programs (i.e., highway maintenance) to achieveestablished State network performance targets.Project Level Works related to district maintenance engineers, such as identificationof funding for various projects (Flinch and Briyan,2006).

Finally, consulting firms and the private sector in general, have participated in several peer exchanging conferences and symposiums in order to bridge the gap between them and the public sector, regarding Asset Management implementation efforts and challenges (AASHTO, 1999).

ALBNERT, CANADA

The asset management function in AIT is evolving. A smallsection in headquarters, the highway asset management section,deals primarily with high-level performance measuredevelopment, target setting, and reporting, and provides datafor other areas. Program development is done by anothergroup, which coordinates input from regional infrastructuremanagers. The development of AIT‘s infrastructure managementinformation system is the responsibility of anothergroup. There are about seven staff members in the highwayasset management section, 12 in program development anddelivery, and nine regional infrastructure managers and engineers(in four regions)(FHWA,2005).

In the 1999 Capital Planning Initiative (CPI) was included governmentbusiness plan to ―ensure effective and innovativecapital planning and funding of government-owned and supportedinfrastructure. CPI also monitors trends on common (cross-assettypes) performance measures, uses infrastructure managementsystems to determine the status and predicted performanceof the province‘s infrastructure, reports on the ministries‘statements of intent as their actions relate to performancemeasures, and identifies cross-government capital needs andpriorities (FHWA,2005).

AIT began developing its transportation infrastructure management system (TIMS) in 1996. By 2006, TIMS will consist of a suite of 20 software applications that cover such highway assets as bridges, roads, culverts, signs, signals, and other associated structures and appurtenances. TIMS is expected to integrate the different databases, allowing AIT to optimize program delivery (FHWA,2005).

Data collected by AIT support the TIMS system andappurtenance inventory, are used in mapmaking, provideinput into highway surface and geometric design, identify crash characteristics, feed into performance measurement,and support truck routing and permitting. Transversepaved-surface characteristics, vertical and horizontalgeometry, line painting location and type, and locationof appurtenances are obtained from video log data(FHWA,2005).

AIT has embarked on a 3-year project (2002 to 2005) to collectbase data on the provincial highway system on all drivinglanes in each direction, which will be maintained overtime with a slightly reduced coverage (e.g., IRI/rut collectedin the driving lane in one direction, digital video logs made in only the driving lane in both directions, and newdata collected only on roads that have significantlychanged status). The various types of data have different schedules. For example,the IRI and rut data are collected annually on the entirenetwork. Surface distress data, collected by AIT staff, arecollected on a cyclical basis with 50 percent of the network collected each year(FHWA,2005).

AUSTRALIA

Australia and New Zealand have been among the pioneers of Asset Management. The first related efforts and reports date back to the late 1980's and since then a lot ofresearch has taken place in this subject area (Sheldon, 2004). One of the firstcomprehensive guides to Asset Management, ―Total Asset Management", was issued in 1996. A revised version has recently been published by the Australian Procurement and Construction Council, entitled ―Asset Management 2001" (APCC, 2001).

The Roads and Traffic Authority (RTA) ofNew South Wales is the agency responsible for the majorroads and bridges on this network. RTA's stated vision for itsstewardship of this network is to assure ―value for money" inits investment decisions, and to provide effective governanceand risk management in partnership with industry and thestate's communities (FHWA,2005).

RTA has information systems for inventory and condition data that can be used to assign project/work tasks as well as tomonitor systems performance. The physical assets monitored include road pavements, bridges, corridor assets, traffic facility(signs, lines and markings), and traffic signals (FHWA,2005).

RTA has purchased commercial software to manage its roadnetwork inventory data. The Road Asset Management System(RAMS) is the repository of road pavement and corridorinventory and condition data, including engineering history. ATraffic Asset Information Management System (TAIMS) keepstrack of the traffic facilities inventory (road signage, pavementmarkings, line marking, and safety barriers), including work task scheduling and management. RTA has separately developedin-house information systems to manage bridges (BIS) and slope stability, works ordering, contract management, and project management systems (FHWA,2005).

RTA uses a link/node location referencing system to locate itsinventory and condition data on the state road network. Thisis used in conjunction with global positioning systems (GPS) technologies for asset inventory updates. Given a commonreferencing system, inventory and condition items can be co-locatedand displayed with other spatial characteristics (FHWA,2005).

NEW ZEALAND

Similar efforts have taken place in New Zealand. Decisionmaking in the New Zealand transportation agenciesis guided by several tiers of planning activities conductedannually. At the strategic level, agencies must prepare astatement of intent that identifies proposed investment activitiesover 3 years, including how such investment will achieveperformance targets. Each agency also has a strategic plan,updated every year, that links adopted transportation goals tokey result areas and agency activities. A national state highwaystrategy defines the capital and preservation strategiesthat will be used to meet adopted goals and performance targets.A network statement is also prepared for each of 25contract areas that includes the following information on eachinfrastructure network: network description, overview of condition,issues/goals, performance measures and triple bottomlinereporting, asset management practices and strategies,current contractual commitments for maintenance, safetyimpacts, performance targets, a 10-year works program basedon modeling (including pavement deterioration), and adescription of any new initiatives(FHWA,2005).

The decision making process for determining priorities is based on life cycle costing procedures, which includes deterioration modelingto determine useful lives. Whole-of-life costing considers allcosts over the lifetime of an asset, discounted to the present.Given defined levels of service for each maintenance activity, agaps analysis is used to determine maintenance needs(FHWA,2005).

The Road Asset MaintenanceManagement (RAMM) system, begun in the 1980s, includesthe primary road inventory, condition data, and treatmentselections and interfaces with the pavement design system .The National Optimization of Maintenance Allocation by Decade (NOMAD), a module of RAMM, developsa 10-year program of investments by treatment type. Apavement modeling tool, dTIMS, uses deterioration modelingto predict future pavement condition. In this application, the road network is segmentedinto like-performing roads and appropriate treatments areidentified for different performance levels (FHWA,2005).

Data are collected both visually on 10 percent of theroad network each year and across the whole national networkwith a high-speed data-collection vehicle called a Sideways-Force

Coefficient Routine Investigation Machine(SCRIM). This vehicle collects data at 10-m intervals for skidresistance, rutting, roughness, and texture and videotapes thenetwork. These data are measured in both wheel paths toallow a comparison across the entire paved surface.Pavement strength data are collected with a falling weightdeflectometer at 200 m. These data are collected via privatecontractor on highways with over 2,000 average annual daily traffic (AADT), and cover about 10,000 lane-kilometers (10,900lane-miles) each year (or once every 3 years). Roughness isdefined at 100-m (109-yd) and 20-m (21.9-yd) sections, ruttingat 20 m (21.9 yd), skid resistance and rutting at 10 m(10.9 yd), and geometry at 10 m (10.9 yd). To calibrate thisdata-collection activity, Transit NZ uses 52 calibration sitesthroughout the country. A walking profilometer is used to validateIRI measurements (FHWA,2005).

ENGLAND

England is a world leader in transportation, known for having one of the lowest road fatality rates of any country in the world as well as for applying innovative technologies and methods for managing its infrastructure (FHWA, 2005). The British Highways Agency (HA) has reportedly been using individual management systems for pavements and maintenance and is currently moving forward in introducing new, more effective data management schemes in order to accommodate its new business functions (WERD, 2003).

Four key documents guide thedecisionmaking process in the Highways Agency:-theCorporate Strategic Plan, Business Plan, Balanced Scorecards,and Annual Report.10 Each has asset management elementsincorporated into it, although in some cases not in very prominentways. For example, one aim of the latest Business Plan(2005/2006) is maintaining of the road network at minimumwhole life cost, with pavement condition being a key performanceindicator. In addition to these corporate documents, theHighways Agency has a developed strategic plan for maintenance. Pavement asset data are the most used in supporting agencydecisionmaking. Uses of this data include calculating a roadcondition index, availability key performance indicator, andsafety key performance indicator; developing the investmentprogram; supporting a quieter surface program; definingbudget allocations; and linking to the agency‘s Web site forpublic information (FHWA,2005).

Individual management systems like historically, management information systems in the Highways Agency have been developed independently for all assets. TheHighways Agency Pavement Management System (HAPMS)has been under development since 1998.HAPMS receives data from avariety of sources and provides outputs to a public Web site,a program investment development tool, and budget analysis.Members of the Highways Agency and its transportationpartners can access HAPMS. And others individual management systems like United Kingdom PavementManagement System (UKPMS) ,the Highways Agency also has a Structures ManagementInformation System (SMIS), a repository of condition data forall structures on the national network. HATRIS, a traffic information system;Highways Agency Pavement Management System (HAPMS).HA-ES, an environmental management system; and NOMAD,a technology equipment database (FHWA, 2005).

In England according to FHWA (2005) the road network is divided into 14 operational areas with each area managed by a managing agent (MA), a private consultant usually operating under a5-year contract. There are two forms of MA. In the first form, the consultant is a separateorganization from the contractor carrying out the maintenance for the area. In the second form, thearea is managed and maintained by a company that combines the managing consultant with themaintenance contractor. The agent for the second form is known as a managing agent contractor(MAC). These managing agents are important implementing structure for the HighwaysAgency‘s asset management program. According to FHWA (U.S Department of Transportation 2005) the national government published a white paper in 1998 entitled A New Deal for Transport: Better for Everyone and a report called A New Deal for Trunk Roads in England. Three major investment areas were identified in these reports—maintenance, operations, and capital improvement—along with investment criteria on safety, environment, economy, accessibility, and network integration. They also identified new directions for the Highways Agency, one of which was to ―give priority to the maintenance of trunk roads and bridges with the broad objective of minimizing whole life costs."

OTHER COUNTRIES

In the Nordic countries (Norway, Sweden, Finland and Denmark) the use of individualmanagement systems has been abundant for many years. These countries are now beginning to investigate the merits resulting from the integration of these systems under an

Asset Management framework and research projects are being conducted in most of them (WERD 2003). In these countries there is also ongoing research in the area of data collection and its related topics (WERD 2003).

Germany has also been promoting the use of individual management systems for its road network . Significant work has taken place in the area of data collection and integration (WERD 2003), as well as in the creation of a common road data catalog for all German road administrations (WERD 2003).

2.17COST SAVINGS

Carrying out timely maintenance on a road in good condition will extend the life of a pavement. On the other hand, delays in executing maintenance generally leads to increased severity of deficiencies (i.e., to poor or very poor conditions) and can eventually lead to a need for complete pavement rehabilitation or reconstruction in later years. This can increase the life cycle costs associated with a particular pavement section Chairul (cited by regasaa,2015).

An area of major concern for most highway agencies today is the maintenance of deteriorating pavements. According to a World Bank report World Bank, 1988 (in Regasa,2015) the developing countries have lost precious infrastructure worth billions of dollars through the deterioration of roads. The cost of restoring these roads is going to be three to five times greater than the bill would have been for timely and effective maintenance. Vehicle operation costs rapidly outpace the costs of road repair as the condition of road passes from good to fair to poor'. In developing countries, the problem of highway pavement maintenance is of immense significance due to high traffic growth and inadequate funding. In India, (2003) it is estimated that an amount of $ 20 Billion was spent by road users on vehicle operation cost. The loss due to poor road condition is assessed to be around $ 4 Billion per annum.

Levik (cited by Regassa,2015), in his work Road Maintenance is Necessarydescribed the effect of neglecting road maintenance by raising different cases all over the world. In Sub-Saharan Africa 150 billion US dollars was spent in 3 decades building roads. Maintenance was neglected and a third of that investment has now been lost. The result is that 50 billion US dollars of key national assets are gone.

A recent analysis of how 85 countries allocated road maintenance funds showed that, spending 12 billion US dollars on preventive maintenance would have eliminated reconstruction costs of 40 billion US dollars. The result is that an average net cost of 330 million US dollars, are wasted on avoidable reconstruction in each country.

Based on the study made by World Bank (cited by Regasa,2015), most roads in Africa are poorly managed and badly maintained and almost without exception, the roads are managed by bureaucratic government road departments. The study further reveled that it would take nearly $43 billion to fully restore all roads classified as being in poor condition (i.e., requiring immediate rehabilitation or reconstruction). In other words, African countries have spent far too little on routine and periodic maintenance during the past twenty years. As a result, nearly a third of the $150 billion invested in roads has been eroded through lack of maintenance. Africa has been living off its assets. Restoring only those roads that are economically justified and preventing further deterioration will require additional annual expenditures over the next ten years of at least $1.5 billion. This amounts to nearly one percent of regional GDP and would increase current road spending from one percent to nearly two percent of regional GDP. The remaining roads in poor condition will have to receive minimal maintenance or be handed over to lower levels of government and local communities.

It is estimated that the extra costs of insufficient maintenance in Africa amount to about $1.2 billion per year, or 0.85 percent of regional GDP. About 75 percent of these costs must be paid with scarce foreign exchange. During preparation of the Integrated Roads Project in Tanzania, it was estimated that the annual economic costs of poor road maintenance were between $100 and $150 million. Likewise, during an RMI workshop in Kenya, it was estimated that the $40 million annual shortfall in road maintenance expenditure increased VOCs by about $150 million per year. In general, road maintenance and rehabilitation projects produce economic rates of return of over 35 percent.

Poor road maintenance also raises the long-term costs of maintaining the road network as maintaining a paved road for fifteen years costs about $ 60,000 per km. If the road is not maintained and allowed to deteriorate over the fifteen-year period, it will then cost about $ 200,000 per km to rehabilitate it. In other words, rehabilitating paved roads every ten to twenty years is more than three times as expensive, in cash terms, as maintaining them on a regular basis, and 35 percent more expensive in terms of NPVs discounted at 12 percent per year. Detail cost savings can be seen on a thesis done by Regassa (2015).

2.17.1 Benefit-Cost Analysis (BCA) of Road Asset Management System

It is generally expected that Asset Management (AM) improves agencies‘ performances in terms of their assets while simultaneously reducing their costs during maintenance and rehabilitation (M&R) activities.Afterimplementing AMS, appropriate M&R, will be identified using the decision making tools, including conditionprediction models and economic analysis tools. As stated by Mizusawe and Neil (2005) AMS, may improve performance and reduce costs simultaneously.

BCA analysis is usually used to prioritize alternatives including do-nothing for project evaluation. It is used to verify project‘s cost-effectiveness as well. If the cost-effectiveness isverified by the analysis, the project is eligible to be executed; otherwise, it should be terminated (Mizusawe and Neil,2005). Falls and Tighe (cited by Mizusawe and Neil,2005) verified pavement management system (PMS) implementation. They considered as benefits savings in agency and user costs before and after PMS implementation. Similarly they considered PMS development and expenditures as costs. They accounted for both costs and benefits to calculate abenefit-cost ratio. They found that the ratio was larger than 82, and then savings were about US$235million. Hudson et al (cited Mizusawe and Neil,2005) also calculated a benefit-cost ratio, using savings in agency costs for benefits, and PMS development, operation, and equipment costs from before and after the PMS implementation phase. The result showed that a benefit-cost ratio is 33 and there would be a saving of US$270 million using minimum confidence interval values.

According to a research conducted by Mizusawe and Mc Neil (2005) they pointed out that retrospective analysis for an agency which has already implemented PMS andprospective analysis for agencies where there is no PMS was done and depicted the concept of benefit-costanalysis. Benefits consist of savings in agency costs and savings in user costs. Agency costs and usercosts consider M&R costs and costs for travel time, vehicle operation, and safety, respectively. The savings in agency costs and user costs are expressed as follows:

Savings in Agency Cost = M&R Cost without PMS – M&R Cost with PMS
Savings in User Costs= User Cost without PMS – User Cost with PMS

The total for the two benefits is the benefits of PMS implementation. For the retrospective analysis, historical data used and M&R executed based on PMS' decision and user costs with PMS and simulateddata of M&R based on decision without PMS such as a worst first strategy and user costs without PMSover analysis period between after PMS implementation and present. On the other hand, in theprospective analysis, we will use data simulated by PMS for M&R and user costs with PMS and datasimulated by the current M&R strategy (e.g., worst first) for M&R and user costs without PMS over analysis period.

Costs include PMS development, operation, training costs, and survey equipment costsand are common to both the retrospective analysis and prospective analysis. However, the prospectiveanalysis should refer to other agencies' costs since there is no actual record. Retrospective analysis will answer whether benefits of implementing PMS exceed PMS costswhile taking into account the effect of PMS and the degree of conformity of agency's business to M&Rprogram made by PMS. If needed todivide impacts into the effect of PMS and the degree of conformity, we should have data on the originalM&R program recommended by PMS and compare with M&R and user costs without PMS. Thedifference between the M&R and user costs without PMS and those with PMS derived from the originalM&R represents the effect of PMS. Prospective analysis will address the effect of PMS only since there is no issue of conformity.

Finally the study concluded that the results of the analyses show us when benefits of PMS pay off the costs for PMS implementation, and current net benefit and benefit-cost ratio. If analysis period in the retrospective analysis is insufficient to pay off the PMS implementation costs, then the analysis has to shift to the prospective analysis in order to predict future benefit of PMS. Unfortunately AACRA has no historical data of M&R cost of executed projects with PMS and without PMS and user costs as well. The costs and benefits emanate from the implementation of AMS tabulated below in Appendix C.

CHAPTER THREE
MATERIALS,RESEARCH DESIGN AND METHODOLOGY

3.1 GENERAL

As road construction and maintenance activities consumes a huge amount the nation's budget and so, it must be administered in a systematic manner through proper asset management practices. In this regard, the main objective this research is to investigate asset management practices within the context of Ethiopia. The investigation started with a comprehensive and thorough review of literatures in order to gain related experiences. The literature reviews summarize the state-of-the-art and correspondingstate-of-the-practice implementation efforts in Asset Management.Tocomprehend the current practice of road Asset Management practices in Ethiopiathe following methodology has been adopted in the study.

3.2 RESEARCH DESIGN

In order to find answers to the research questions and to achieve the objectives of the study, quantitative and qualitative ways of research adapted. Qualitative research of explanatory type will be adopted in order to diagnose a situation, assess alternatives, and discover new ideas.Mixed-method research seems to be appropriate and is helpful in gaining a better understanding through an in-depth study of the new phenomenon based on its qualitative and quantitative aspects of the study. The overall approach to be followed are; having established the basis of the research, necessary data will be collected, analyzed, and conclusions and recommendations will be made based on the findings. The methods of data collections employed for the research are:-desk study, questionnaire, and interview.

3.3 DATA COLLECTION

3.3.1 DESK STUDY

Desk study was chosen as one of the tools to find out the answer for the second research question, What is the current practice of asset management in AACRA? "followed by the third question "How is the pavement management system software applied in AACCRA Asset Management Department? and how is the software applied for road maintenance purposes?" and the fourth research question " Is the current asset management practice inAACRA effective and competent compared to worldwide asset management practices? If not, what ways of improvement can be suggested to make it effective and competent?"

Desk study was chosen as one of the instruments to assess and obtain actual data about the Asset management practices from relevant studies, reports, documents like asset components implementation, decision making, data collection, data management and project selection and relevant tools during asset management practice in AACRA as used. The specific documents studied were manually collected data, Data collection equipment used, Excel sheet stored data, manually evaluated condition data and project selection and decision made on the collected data and currently executed maintenance works, Observation on the organization individual management usage and integration of those management systems and inventoried documents in excel sheet.

3.3.2 QUESTIONNAIRE DESIGN

The research is envisaged toinvestigate, Road Asset management practices in AACRA in depth by addressing questions focused on Road Asset management system and practice, road operation and maintenance, data collection ,management and integration, decision making, asset management components implementation, project selection, related tools and problems and challenges in Asset management practice and causes of the identified problems. The questionnaire design was based on a combination of an extensive review of literatures dealing with Road Asset Management. Questions were developed from the information gathered from literature and on best practices of Asset Management supplemented to achieve the research objectives. The questionnaire form, was accompanied by a cover letter**.**The questionnaire survey mainly contains close-ended questions because close ended questions are often easier and quicker for to record and code the responses obtained from the respondents, and also easier and quicker for the respondents to fill (circle) the responses. The questionnaire categorized in to four section the first section is the respondents position, section two is about general agency information on asset management , decision levels, and decision processes, section three of the questionnaire asked about information regarding data collection, management and integration and their relation to the project selection decision level of Roadway Assets and the last section of the questionnaire focused on factors affecting the implementation of asset management. The whole section of the questionnaire is depicted on Appendix A.

Limited numbers of open ended questions were also included in the questionnaire because open ended questions allow respondents to include additional information including feelings, attitudes and understanding of the subject and enable them to raise new issues. This allows the researcher to better access the Respondents' true feelings on an issue under study and to access extra information from them.

3.3.3 INTERVIEW

Information on research questions and objectives was requested from key informants in order to deepen the findings of the desk study and questionnaire. The purpose of the interview was to assess the practices and perceptions of key informants on Asset Management system practices.More efforts were done to identify additional problems which are were not identified through the questionnaires and the desk studies ; and to increase the accuracy and reliability of the challenges obtained through questionnaire. The interview schedule is depicted on Appendix B.

3.4 STUDY POPULATION AND SAMPLING TECHNIQUES

The target population were pertinent Government organization on the road sectorin Ethiopia such as Ethiopian roads Authority(ERA) and Addis Ababa city Roads Authority(AACRA). The Research focused on Addis Ababa City Roads Authority due to its accessibility and Vulnerability to Asset deterioration and damage as well as Addis Ababa is the home of Africa Union, United Economic Commission for Africa (ECA), etc.The sampling techniques was used to select representatives of the population and were purposive sampling andsnowball sampling.

Snowball samplingfocuses onasking people who have participated in a survey to nominate other people they believe would be willing to take part. This technique is often used when the population is difficult for the researchers to identify (Kitchenham, 2002).

Purposive sampling, is a useful sampling method consisting of getting information from a sample of the population that one thinks that she/he knows most about the subject matter.Non probability sampling is also known by different names such as deliberatesampling, purposive sampling and judgment sampling. In this type of sampling, items for the sampleare selected deliberately by the researcher; his choice concerning the items remains supreme. Inother words, under non-probability sampling the organizers of the inquiry purposively choose theparticular units of the universe for constituting a sample on the basis that the small mass that they soselect out of a huge one will be typical or representative of the whole(Kothari, 1990).

Accordingly the questionnaire is distributed to all asset management professionals and data collectors working in Road Asset management directorate in AACRA purposively. Whereas the interview is made using snow ball sampling method to team leaders and data base directorate director onlyso this will make it free from biased since the population is very small.

3.5. DATA ANALYSIS

Data collected through the desk study were analyzed in relation to the theoretical propositions and the method used to analyze the interviews and questionnairesdata was descriptive statistics method. This method of analysis helps to analyze the responses in actual numbers.

Rating scale is one of the most common formats for questioning respondents on their views or opinions of an event or attribute. In this regard, participants were asked to indicate the level of the implementation components of Asset Management and causes of problems on road asset management implementation by rating them on five point scale, (1 = very low, 2 = low, and 3 = medium, 4 = high, and 5 = very high).

The knowledge gained from these activities wasused to develop a framework for effective and efficientdata collection, particularly for project selectionand the identification of major criteria and dataattributes to this decision-making level. This research can help road authorities tailor their asset management activities according to their real decisionmakingneeds. In this way the research contributesboth to the reduction of costs and amore effective and efficient implementation of AssetManagement.

All the data that were collected and analyzed and the results generated were organized and summarized in order to reach at meaningful conclusions and forwarding of the required recommendations. Secondary data were used as supplementary source of information.

3.6 LIMITATION OF THE PAPER

The study is limited to flexible road pavement under the jurisdiction of the Addis Ababa city Roads Authority and there is a budget limitation .

CHAPTER FOUR

DATA COLLECTION, ANALYSIS OF FINDINGS AND DISCUSSIONS

4.1 GENERAL

This chapter deals with the analysis of the information's gathered from questionnaire, desk study and interview, it is structured according to the research objectives and questions and presents the findings andresults of the survey, which focuses on Road asset management system practices in Ethiopia the case study being Addis Ababa city Roads Authority. The documents referred during desk study included:- data collection, asset inventory, condition assessment , data management, data integration, project management system and project selection.Interviews were also conducted with key informants involved in road Asset Management in order to deepen the findings of desk study and questionnaire.Accordingly, interpretation and discussions would be presented on thebasis of the findings and limitations observed. The complete survey questions are provided inAppendix A and B.

4.2 DESK STUDY

Desk study was chosen as one of the instruments to assess and obtain actual data about the practices of road Asset management system from relevant studies, data's and documents.

4.2.1ROAD MANAGEMENT IN ETHIOPIA

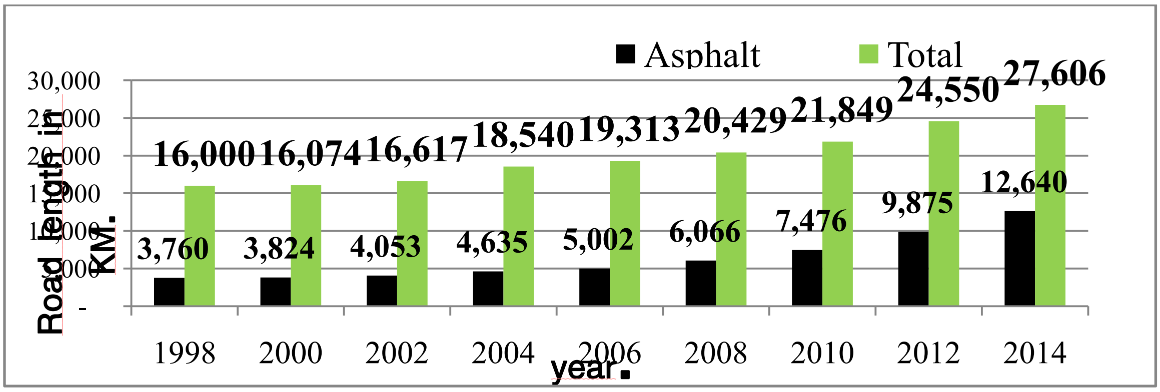
4.2.1.1 Ethiopian Roads Authority

In 1951, when the Ethiopian Roads Authority was established, the total road network amounted to 6,400 km. This network was built mainly during Italian invasion. By 1997 the road network had grown to 26,550 km, of which 3,708 km were paved. As a result of investments under Road sector development programs(RSDP) of I ,II, III and IV. The country‗s road network has increased from 26550 km in 1997 to 99,522 km in 2014 (an increase of 275 percent). As result, the road density per 1000 sq. km has increased from 24 km in 1997 to 90.5 km in 2014. Also substantial improvement has been registered in the condition of the country‘s road network. The proportion of road network in good condition increased from 22% in 1997 to 70% in 2014(RSDP report,2014).

ERA is responsible for the planning, construction, maintenance and administration of Federal Roads. For the last 17 years (1997-2014) with RSDP I ,RSDP II, RSDP III and RSDP IV programs, the Ethiopian Roads Authority invested more than ETB 160 billion for the construction and maintenance of Federal Roads(RSDP report,2014).

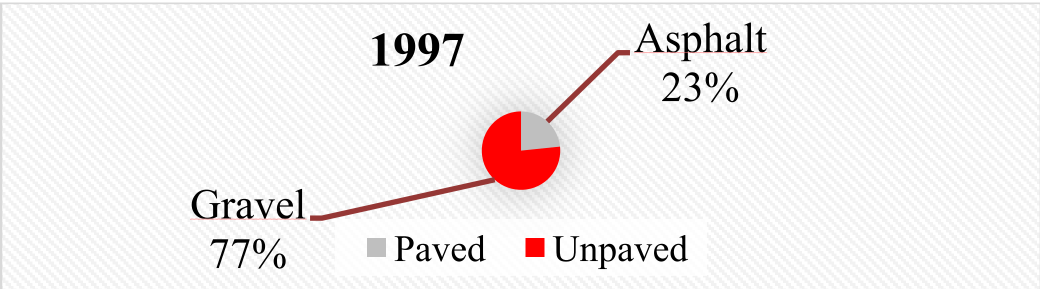
Figure 4 below shows the ERA road network between 1998 and 2014. Subsequently, Figures 4.1 (a) and (b) show roads by surface types in 1997 and 2015 respectively.

Figure 4.0: Ethiopian Road Authority Road network under its Asset Management



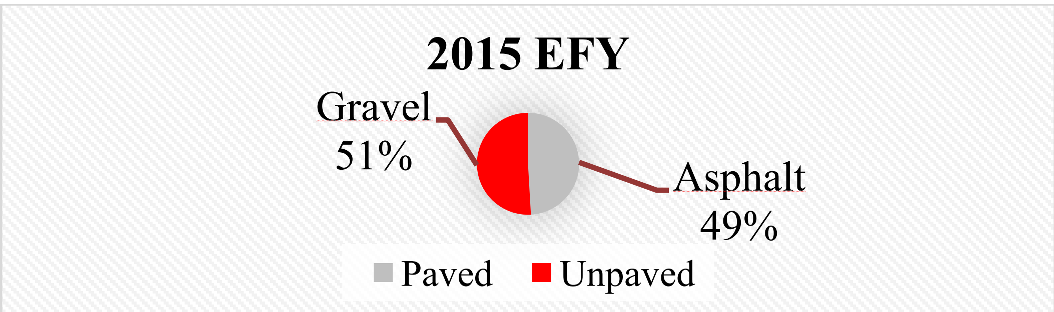
Source: ERA Road Asset management Directorate

Figure 4.1 (a): Surface Compositions of Roads under ERA in 1997



Source: ERA Road Asset Management Directorate

Figure 4.1 (b): Surface Compositions of Roads under ERA in 2015



Source: ERA Road Asset Management Directorate

It can be calculated from Figures 4.1 (a) and (b) above that the percentage share of asphalt roads has increased by about 113% from 1997 to 2015 and correspondingly, the percentage share of gravel roads has reduced by about 34% between the two periods.

4.2.1.2Road Maintenance in Ethiopia

Past failure to undertake adequately funded, planned and managed maintenance programs have led to the situation where the massive capital investments of the Road Sector Development Program (RSDP), have become necessary. However, the lessons of the past have been well learned by the Government and the Ethiopian Roads Authority (ERA), and much attention is now being focused on maintenance tasks (ERA, 2014). The total federal road network of which is being administered by ERA has reached to 26,857 km as of July 2014. Overall road network in Ethiopia has been increasing on the average by 3.2% yearly (Regassa,2015).

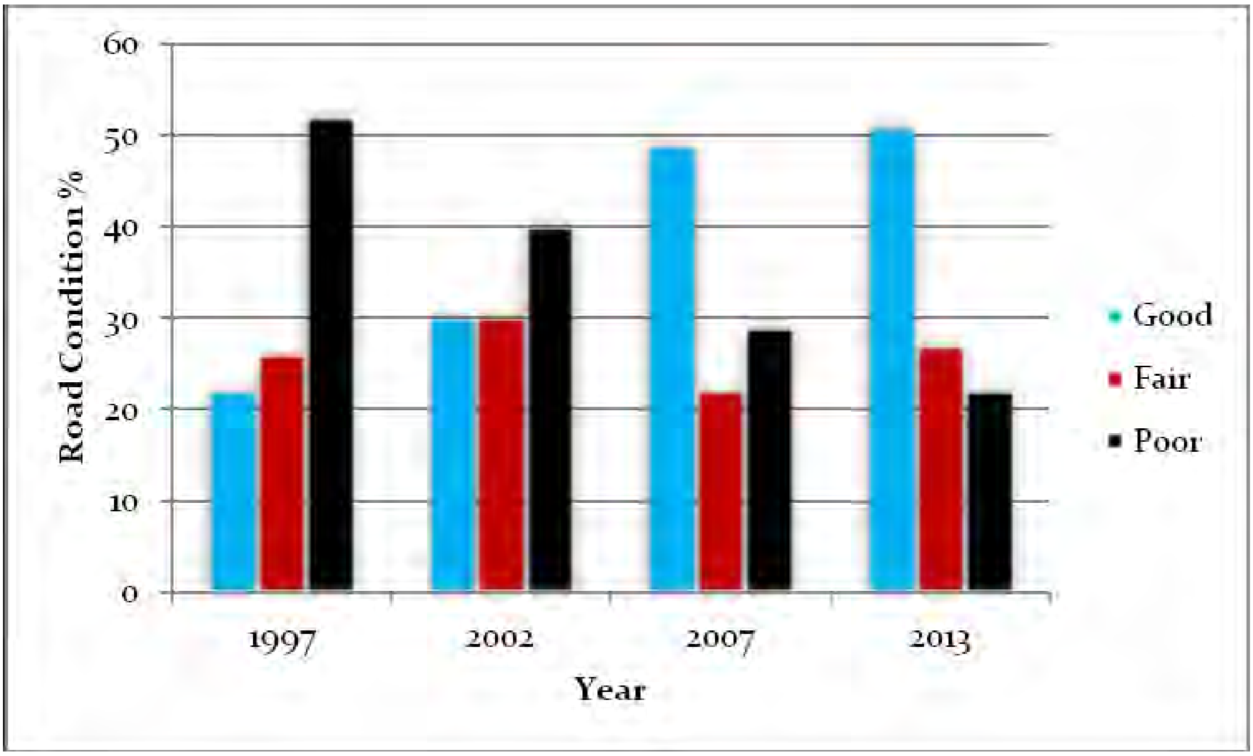
Improving the condition of the road network is still a challenge. The improvement of the road network in the country is only changing the condition of the network slowly. In the first year of RSDP, 52% of the road network was found to be in poor condition and only 22% was in reasonably in good condition. Owing to on-going rehabilitation, upgrading and maintenance intervention under the program, the proportion of the road network in good condition has increased to 50 percent and the road in poor condition has declined to 22%. The proportion of roads in good condition has overtaken the proportion of roads in poor condition from 2004 onwards and particularly the last two years owing to a massive intervention in terms of rehabilitation, upgrading and maintenance on major roads. The proportion of road network in good condition increased from 22% in 1997 to 70% in 2013. Another observation is that the roads in fair and poor condition are consistently declining shifting to good condition since the year 2002. The road condition from year 1997 to 2013 is presented below (ERA, 2014).presented in Table 4 below (ERA, 2014) and subsequently, Figure 4.0 shows the trend of the road condition improvement between 1997 and 2013 and subsequently Figure 4.2 show the road condition improvement.

Table 4.0: Road Condition Improvement from year 1997 to 2013

Year	Road Condition		
	Good	**Fair**	**Poor**
1997	22	26	52
2002	30	30	40
2007	49	22	29
2013	51	27	22

Source: The Ethiopian Roads Authority

Figure 4.2: Road condition improvement

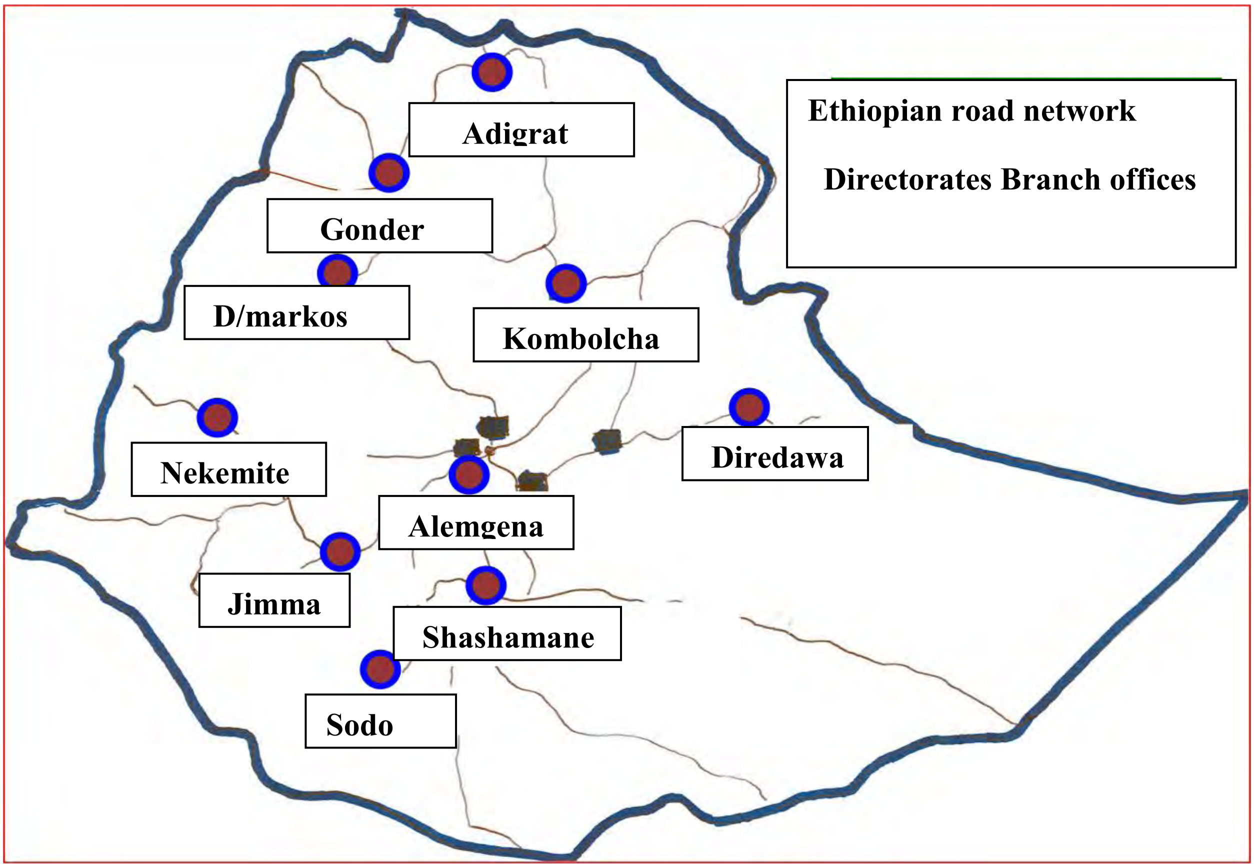


Source: Quoted from Binyam Regassa which was acquired from ERA(2014).

4.2.2Road Asset Management in the Ethiopian Roads Authority (ERA)

The Ethiopian Roads Authority(ERA) was restructured to sustain and accelerate quality improvement of the federal road network. A new Road Asset Management Department, headed by Deputy Director General has been set up recently with responsibility for road asset management coordination. Ten Road Asset Management Coordination Directorates have been set up located in different parts of the country and administer roads under their respective jurisdiction. The Road Asset Management Department will be responsible for short and long term road network maintenance plan to ensure mobilization of adequate resource for the maintenance of the network and the provision of roads with acceptable operating condition for vehicles. The department is responsible to produce effective network maintenance plan using standard road asset management tools such as Pavement Management System (PMS) and Highway Development and management Model (HDM 4). The Department is also responsible for functional classification and numbering of the road network and for data base of the network using PMS and HDM 4 and other appropriate tools.(ERA- ,2013). Figure 4.2 below illustrates the ERA Road Asset Management Network Directorates Branch Offices located in different parts of the Country.

Figure 4.3: Road Asset management Network Directorates Branch Offices



Source: ERA Road Asset Management Directorate

4.2.2.1 Asset management Implementation in the Ethiopian Roads authority

The Ethiopian Roads Authority have already implemented an Asset Management system. They have been utilizing individual management systems, the most predominant among them being pavement, bridgemanagement systems and Highway development and management tool (HDM4). Other systems include safety management system. ERA has established Pavement Management System to systematically manage the roadnetwork; the PMS system has incorporate road condition data collection equipment andsoftware for both paved and unpaved roads.In addition ERA has established a Bridge management systemencompasses all engineering and management functions that are necessary to efficientlycarry out bridge operations. These include data collection and its management, inspection,planning and programming, construction and maintenance.

Integration of road asset management system is an application of suitable asset management software which will integrate all individual road management systems. The system processed data obtained from different individual road asset management systems and generates a report fordecision making. Along with the integration of the individual system a central database for thewholly integrated asset management system should be developed. The level of integration of these individual systems within an overall Asset Management framework is still in the planning phase in ERA.

4.2.2.2 Data Collectionin Ethiopian Roads Authority (ERA)

ERA collects data both automated and manually. Automated equipments that ERA currently using are Hawkeye 1000, Hawkeye 2000 is not fully operational and Falling weight Deflecto meter (FWDM). In Automated data collection some of state of the art equipment including Automated Road Analyzer (ARAN), Heavy Weight Deflectometer (HWD) and Weigh in Motion traffic equipment are used to assess the structural and functional conditions of the pavement. From the ARAN testing: roughness (ride), rut depth, surface macro texture and surface distress results were collected. From the HWD testing: layer modulus and remaining structural life were calculated and reported. From the Weigh in Motion study the current axle loading was determined for evaluating remaining life(Al-Kathairi,2014).

Figure 4.4 - 4.8 below show**:** Hawkeye 2000 Road Data Collection Equipment; Falling Weight Deflectomter (FWD); Experts Road Condition Survey; Experts Road Condition Survey; and Hawkeye processing toolkit processing the collected data respectively.Check the above figure numbers with corresponding explanations.

Figure 4.4: Hawkeye 2000 Road data collection equipment

Source: ERA Road Asset Management Directorate

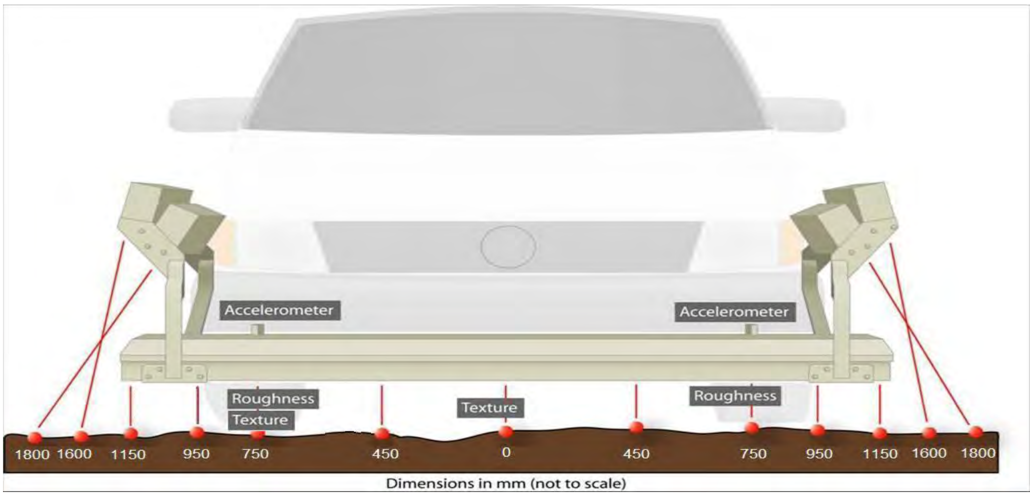
Figure 4.5: Hawkeye 2000 Road data collection equipment

source: ERA Road Asset Management Directorate

Figure 4.6: Falling Weight Deflectomter(FWD)

Source: ERA Road Asset Management Directorate

Figure 4.7: Falling Weight Deflectomter(FWD)

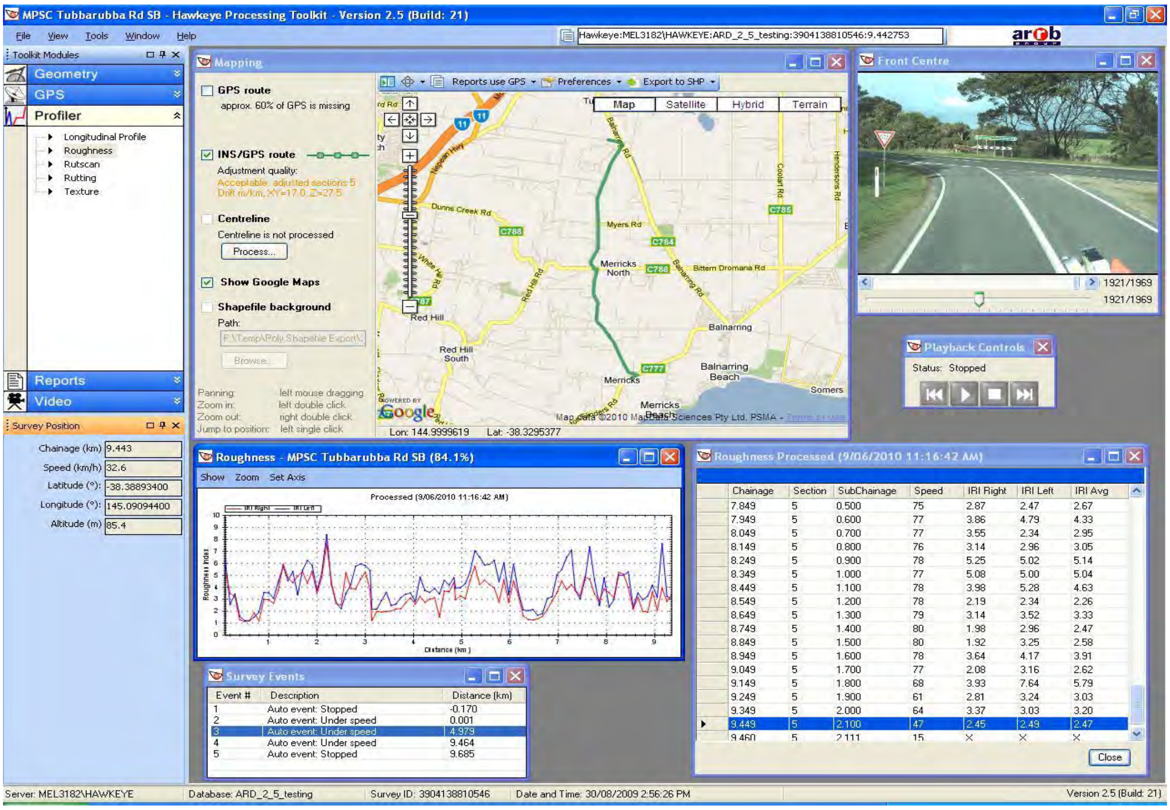


Source: ERA Road Asset Management directorate

Figure 4.8: Experts Road Condition survey

Source: ERA Road Asset management Directorate

Figure 4.9: Hawkeye processing toolkit processing the collected data



Source: ERA Road Asset Management Directorate

- The collected data will be encoded to the tool kit
- GIS will help to identify the exact place
- dTIMS^{TM}software used to manage the data base
- HDM4 is used to establish maintenance strategy including the economic impact

Decisions on what data to collect are based on staff experience, widely accepted data collection standards and specific needs of individual management systems The pavement and bridge data are kept in separate databases. The basic PMS has Data Base, Retrieval Methods, Analysis Methods, Updating Procedures.But ERA is planning to have asset management data base or inventory.

4.2.2.3 Project selection and decision making levels in ERA

The road way asset data is utilized for selection between two competitive projects. The most important data used to select projects in ERA are location, structural and functional conditions. The PMS gives an opportunity for ERA to identify appropriate treatment for each block based on distresstypes and severity. The system also includes a cost module that is used tocalculate costs for the candidate projects. The appropriate offices at ERA use cost–benefitanalysis and project-to-project comparisons to determine the final list of prioritized candidate projects.

Decision making levels that have been explicitly defined in ERA are:-

- at strategic level concerning policy of decisions for overall network;
- at project level of design concerning specific treatments or actions for selected projects;
- at programming and budgeting levels concerning the overall resource allocations for design, maintenance and rehabilitation throughout the entire network; and
- at project selection level which is selection of individual projects or groups of projects for funding or implementation.

4.2.2.4 Asset Management components implementation in ERA

The basic generic Asset Management components are Goals and policies, condition assessment performance monitoring, Alternative assessment and program optimization, short and long range plan and program implementation this components are implemented in ERA in moderate way.

Goals and policies regarding asset management has been practice as it is reported in ERA modernization report they have planned toformulate policy, to create an asset management integrated system, asset management data base, asset inventory, asset valuation and standardize reporting data exchange and short term and long term goals has been set.

4.2.3 ADDIS ABABA CITY ROADS AUTHORITY

In Addis Ababa current state, road networks are the main bloodlines of everyday activities. The history of the city‘s road development begins from the inception of the city. Minellik II constructed the first ever two roads in the city as well as in the country that stretch from Addis Ababa to Addis Alem and from his palace to English Embassy in 1902. In 1904, the first roller was imported by the emperor and was being pulled by many people for its operation. The Addis Ababa‘s modern road construction is highly interlinked with Emperor

Haile Sellase's ruling period. During the regime of Haile Sellase I, and several contractors were organized to carry out road construction(Jemal, 2015:5).

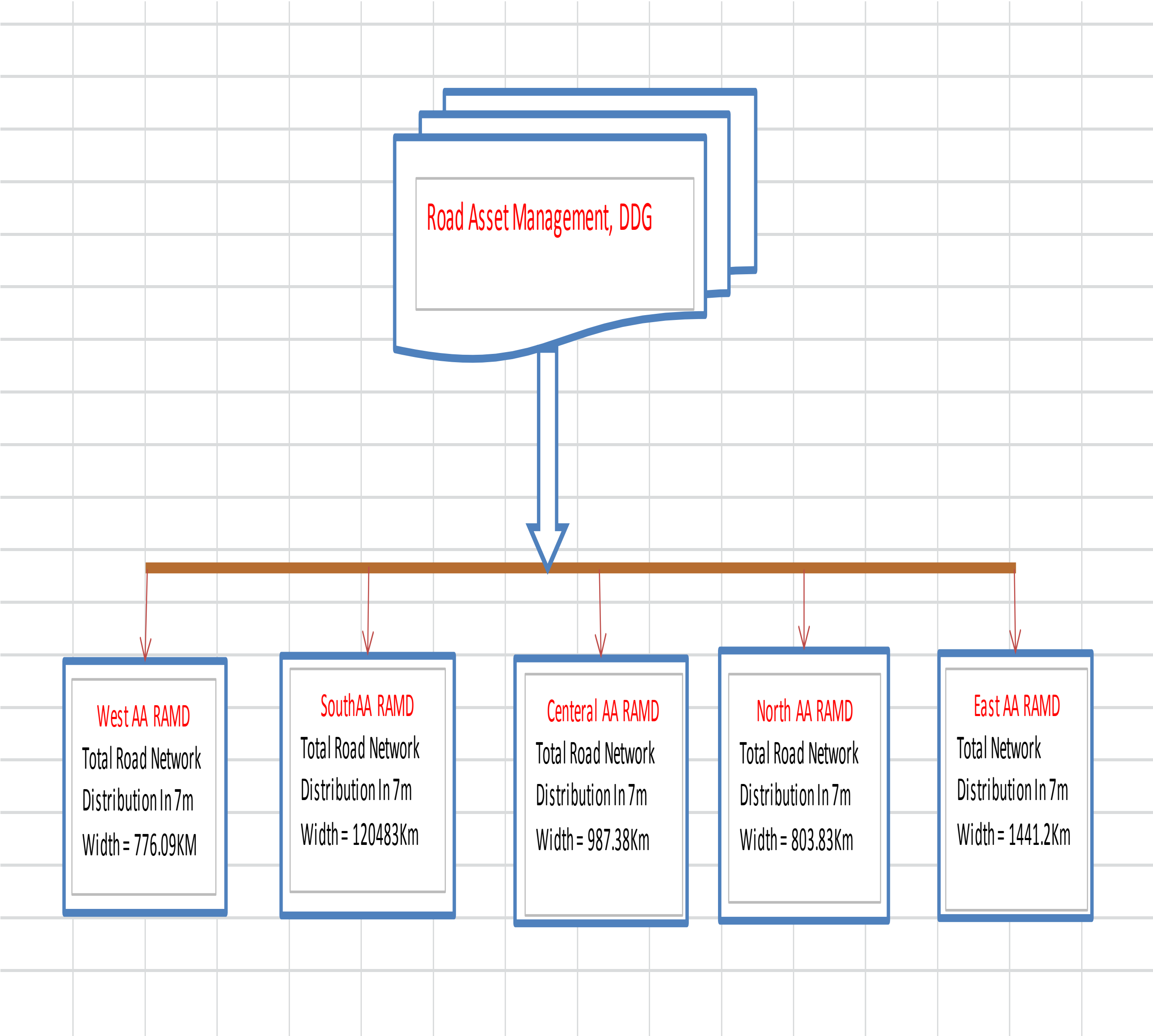
The first office to be established by the Emperor Haile Sellase's government to construct roads was Public Works Department. It was established to construct roads in Addis Ababa and in its surroundings. After a few years, this department was raised to a ministerial level and Addis Ababa also got the chance to establish its road development organizational structure(Jemal, 2015:5).

In 1942, it was decided for Addis Ababa to have a mayor and council. The city roads construction and maintenance was organized under the municipality, to fulfill the road construction activities together with building works the ―Road and Building Works" department was established. This department stayed till the replacement of the Haile Sellase regime by the Derge Regime performing its duties. But no fundamental organizational change of the department was observed during the Derge Regime. In 1993, the existing government, the Ethiopian People Revolutionary Democratic Front (EPRDF) established regional governments and gave them power to administer their regions with autonomy. During this time, Addis Ababa was also established as one of the regions. The Addis Ababa administration during this period established the ―Bureau of Works and Urban Development" and the Bureau organized a department under it to carry out the road construction and maintenance works. The newly established road department constructed and maintained the city roads till the establishment of the Addis Ababa City Roads Authority in March 15, 1998 by regulation No. 7/1998 to be administered by board of directors to construct, maintain and administer the road works in Addis Ababa by the city administration (Jemal, 2015:5-6).

4.2.3.1 Asset Management system implementation in AACRA

Asset Management implementation within the Addis Ababa City Roads Authority is at the planning stage. They are currently organizing the Asset management office under the Road Asset Management Vice President Director General. Sub cities in Addis Ababa are designatedunder each road asset management directorate. Under the Central RAMD, designated offices are: Kirkos, Lideta , Arada and Ring Road and the offices under Eastern RAMD are: Bole sub city and Ring road, the Southern RAMD are : Nifasilk Lafto, Akaki kality and Ring road, offices designated under Northern RAMD are : Gulele, Yeka and Ring road.Figure 4.10 below presents the Addis Ababa City Roads Authority's road asset management office distribution.

Figure4.10: Addis Ababa City Roads Authority road asset management distribution



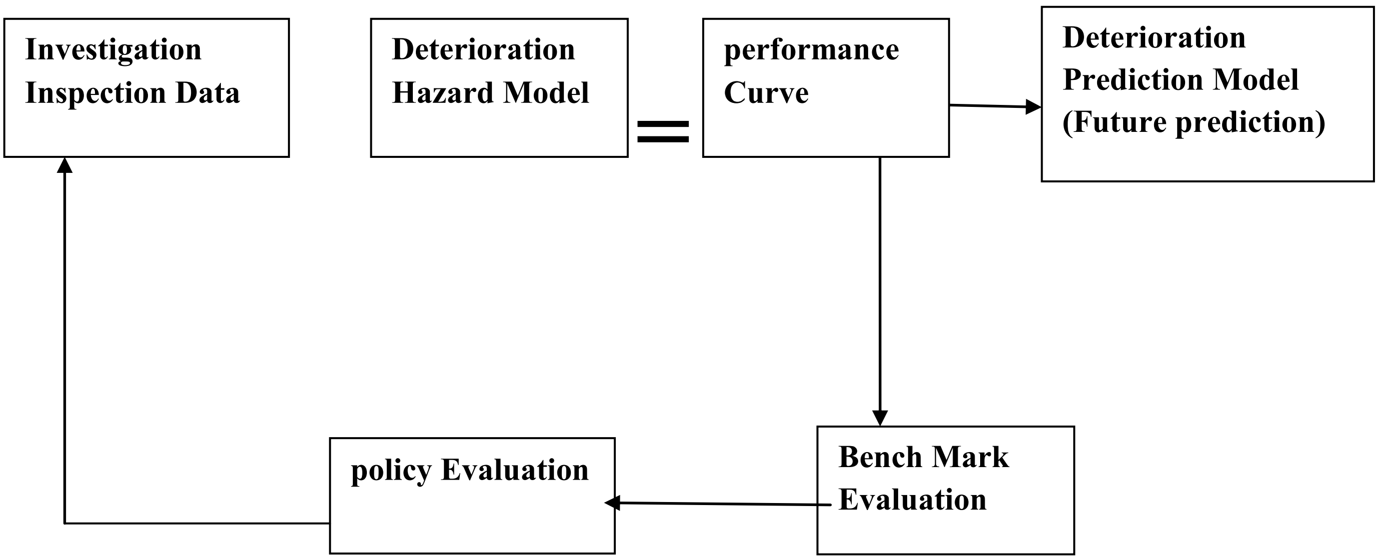
Source: AACRA Road Asset Management Directorate

In the past, the Addis Ababa City Roads Authority had utilized pavement management system but the system failed due to lack of trained professionals, poor systematic follow up and under utilization of the system. Since 2006-2008E.Cthe data were manually collected stored in excel sheet. Currently they are in the process of applying Pavement management system and Maintenance management system utilizing the Kyoto model (Japanese government cooperation).

The ―Kyoto model" pavement asset management system proposes regularly monitors by comprehensive perspective of routine works at management cycle of maintenance state and budget execution intended for routine works, and has hierarchical structure by strategic management cycle to point out improvement to routine works by policy evaluation. The pavement maintenance work is expressed by hierarchical management cycle, and the entire of work process is modeled by using logic model. Meanwhile, various data groups necessary for pavement maintenance work are used as an evaluation index of logic model for policy evaluation as well as being reference for decision making of routine works and being as archive of pavement data base (Hamzah).

This model will help AACRA to make decision scientifically based on performance curve or past results of the pavement, helps to store and retrieve pavement inventory and condition data, to predict pavement deterioration through its pavement deterioration prediction model and for most it will help the organization to cross check its policy based on bench mark evaluation and investigation inspection data if the organization developed an asset management policy. The flow chart illustrated on Figure 4.11.

Figure 4.11: Illustration of flow chart of Kiyoto model



Source: Hamzah,

Integration of road asset management system is an application of suitable asset management software which will integrate all individual road management systems. The system processed data obtained from different individual road asset management systems and generates a report fordecision making purposes. Along with the integration of the individual system a central database for these individual systems within an overall Asset Management data base which integrate and use to retrieve for decision making purposes is still at the planning phase. But in the process of setting asset management system AACRA is planning to set up an asset management data base.

Organizational culture has traditionally prompted agencies to create database/information management systems that support specific applications such as pavement, bridge, sign, equipment, finance, and other management systems. These independent, legacy, stovepipe systems have to be linked in order to efficiently support Asset Management. Data base management which is established in AACRA is excel sheet which is traditional managing and storing asset data. The history of the roads in the organization is not defined and evaluated and not known explicitly.But now they are developing an asset management database which will be developed under Kyoto model pavement management system even if the PMS has own data storage.

As stated in the detail literature review different countries transportation organizations and states department of transportation's has good practice regarding usage of individual management systems, data management and data integration.For example some of the states in US like Virginia department of transportation information is stored in corporate database with GIS platform and it is updated annually. The department Integrate the individual management systems like Pavement Management System and Bridge Management Systems. First the department kept the data of the two in separate database but feed to central database once a year. On the other hand Maryland State Highway Administration three sources of data are merged to create the Project Selection Tool (PST) these are Road way inventory database, pavement performance database and construction history database then the data contained in PST program are integrated with the MDSHA pavement management database. And other countries like Australia, England, New Zealand and etc have utilized individual management systems and integrated those systems in to one central data base

4.2.3.2 Data collection in AACRA

As stated in the literature the pavement condition data is an important component in developing effective maintenance and rehabilitation strategies for many reasons. First, identifying appropriate maintenance andrehabilitation alternatives rely on pavement information such as thickness, current condition, traffic, climate conditions, etc. The pavement data includes many factors, for example, pavement current condition, pavement historical performance, pavement materials, pavement thicknesses, traffic information, pavement geometry, and environmental data.

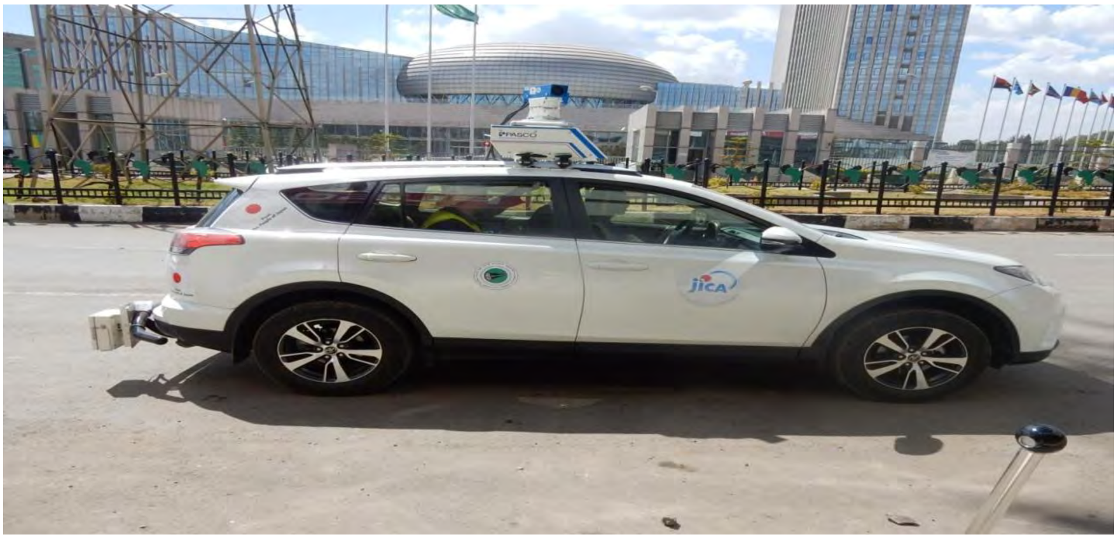
In the literature review it is cited that there are different types of data collection methods one of them is automated method which involves the use of a multipurpose vehicle which is equipped with a distance measuring device, digital video cameras (downward and/or forward looking), a gyroscope, laser sensors, computer hardware and potentially GPS antennas in order to capture, store, and process the collected data.In Automated data collection some of state of the art equipment including Automated Road Analyzer (ARAN), Heavy Weight Deflectometer (HWD) and Weigh in Motion traffic equipment are used to assess the structural and functional conditions of the pavement. From the ARAN testing: roughness (ride), rut depth, surface macro texture and surface distress results were collected. From the HWD testing: layer modulus and remaining structural life were calculated and reported. From the Weigh in Motion study the current axle loading was determined for evaluating remaining life this has reported on literature review.

AACRA had been collecting road data manually since 2006-2008 E.C. Previously data collectionwere not practiced and so AACRA did not know the conditions of the roads under their jurisdiction other than budgeting for construction of new roads currently they are in training and trial of applying automated roadcollection equipment called pavement condition surveyvehicle as displayed below in Figure 4.12(a) and 4.12 (b).

Figure 4.12(a): Pavement condition survey vehicle in AACRA

source: Road Asset management data base directorate (AACRA, 2009)

Figure 4.12(b): Pavement condition survey vehicle in AACRA



Source: Road Asset management data base directorate (AACRA, 2009)

In the developed world they use state of the art equipments the technology developed as the literature review stated. In Maryland data annually collected in network-level including bridge quality, rutting, and friction for all directional kilometers under the responsibility of MDSHA.All these data are collected using automatic data collection equipments like Automated Road Analyzer(ARAN), Falling weight Deflectometer(FWD), Ground-penetrating radar(GPR), drilling/coring rigs, and manual visual surveys (using the paver pavement condition index(PCI)).

4.2.3.3 Project Selection in AACRA

As tried to express in the literature review project selection is a level of decision making that entails the evaluation of the attributes of different candidate projects for the purpose of funding and implementation. In ACCRA project selection is done based on the economical, political and social aspects of the roads in network and in addition the severity of the asset is also taken in to consideration while selecting project for funding and implementation. But there is no scientific way of analyzing the condition of the roads for implementation and funding by using different models and management systems. Still now the they make decisions based on traditional way.

On the other hand different countries and state departments has been implementing project selection process for their networks. In District of Colombia department of transportation individual management systems are used to made project selection most of the time.MDSHA the project selection process, the treatments applied to any of the pavement groups are categorized into seven groups on the basis of their life expectancy. The treatment groups are 15, 12, 8, 5, +4, and +2 years, as well as ―do nothing.” Whereas in Virginia department of transportation project selection for the main asset types have been defined by an expert panel composed of representatives from Asset management division and the districts on various maintenance and rehabilitation strategies. The criteria are documented in the individual management systems(e.g. pavement or bridges) and in their respective guidelines and manuals.Whereas in New Zealand the decision making process for determining priorities is based on life cycle costing procedures, which includes deterioration modeling to determine useful lives. Whole-of-life costing considers all costs over the lifetime of an asset, discounted to the present.

4.2.3.4 Decision Making Level Application in AACRA

According to Flinch and Bryant Asset management decision processes are the individual decisions that need to be made at every level of decision making, whether that is of a strategic, network, or project focus. Decision processes can therefore be concerned with budget allocations, network optimization, works ' programming, and selection of alternative implementation methods, among others. Decisions made at the different levels of Asset Management are heterogeneous and the supporting data needs are bound to be quite different. Decision making levels are not explicitly defined in AACRA road asset management directorate but they made decisions on the network level.

In the developed countries they have formally identified decision making levels for example MDSHA have Strategic Level Decisions regarding key program performance objectives, including percentage of roads with an acceptable ride quality, percentage of Maryland‘s National Highway System mileage with acceptable ride quality, and average service life of State Highway Administrationpavements. Program Level Development of strategies for investment that meet a defined objective such as maximizing condition or minimizing costs. The strategy provides direction in how to invest in the pavement network. Project-Selection Level Selection of individual roadway projects by district to match up against the strategy. Project-Design Level Detailed project-level design subject to the treatment level and project costs defined in the previous level. Whereasin Virginia department of transportation they have formally identified and decision making levels. Strategic Level Decisions regarding cross-agency issues and funding allocation across the highway maintenance, mobility management, and operation programs. Program Level Operation of the programs (i.e., highway maintenance) to achieve established State network performance targets. Project Level Works related to district maintenance engineers, such as identification of funding for various projects.

4.3 QUESTIONNAIRE AND INTERVIEW IN AACRA

4.3.1Questionnaire Response and Quality of Respondents

The study was focused on Investigation of Road Asset Management practices in Ethiopia considering AACRA as a case study. Accordingly, the scope of this research is limited within the AACRA Road Asset Management Directorate. In this regard all Asset management professionals, team leaders and Management bodies were considered in thisstudy survey. The number of participants was 15 all the AACRA Road Asset Management Directorate professionals, team leaders and management staff. A total the total of 15 questionnaires were distributed: 11 were distributed for Asset management professionals and teams leaders , 3 to data collectors, 1 for Road Asset management Data Base Director General. Out of the distributed 15 questionnaires, 11 professionals and team leaders responded to the survey which were 11 (73.33%), 1 (6.67%), 3 (20%), from Road asset management Database Director General and Data collector , respectively. This is overall response rate of 100%, which acceptable for the analysis of the data. The details of respondents' response are summarized in Table 4.3 and Table 4.4 show respondents' position and distribution of questionnaires and distribution of questionnaires and response rates respectively.The questionnaire and semi-structured interview is attached in the Appendix A and B.

Table 4.1: Respondent_s position and Distribution of questionnaires

Organization	Road asset management Vice president	Road asset management database director	Road Asset management professional or team leader	Data collector	Total
AACRA	-	1	11	3	15
Total	-	1	11	3	15

Table 4.2: Distribution of questionnaires and responses rate

Respondents	Distributed questionnaire in number	Semi Structured interview in number	Returned Semi structured interviews and questionnaire in number	Questionnaire and Semi structured interviews ,%
Road asset management Vice president director general	-	-	-	-
Asset management professional/team leader	8	3	11	73.33
Road Asset management database director general	-	1	1	6.67
Data collector	3	-	3	20
Total	11	4	15	100

4.3.2Asset Management Implementation in AACRA

The responses revealed that most of the responding professionals, team leaders and data collectors seven (7) in aggregateare still at the planning phase. Furthermore four (4) of the respondents indicatedthat they have already implemented an Asset Management system.The responses also revealed that most of the individual management systemshave not been utilized, the most predominant ones among them being:- pavement, bridge, and maintenance managementsystems. Other systems include safety (SMS), congestion (CMS) management systems. ACCRA has now in the development of the pavement management system with Kiyoto Model (JICA). Furthermore most of the responding professionals revealed that the level of integration of these individualsystems within an overall Asset Management framework does not exist yet. Table 4.3 below shows respondent rates.

Table 4.3: Respondents rate for Asset Management Implementation

Response Types	Number of Respondents	Percentage (%)
Yes	4	36.36
Planning	7	63.63
Don't Know	0	0.00
Total	11	100.00

4.3.3Asset management system components implementation in AACRA

Based on the Literature Review the respondents ratedthe components of Asset management system; goals and policies, asset inventory, condition assessment, performancemonitoring, alternatives analysis/program optimization, short/long range plans andprogramimplementation of Asset Management Systems. Each of the above criterion is explained below and the results are depicted in Figure 4.13.

Goals and Policies:- As understood during the Literature Review the sequence of Asset Management begins with the goals and policies of a Road Administrationand the available budget Goals, objectives and enabling policies frame an asset management process in AACRA. As resulted during the survey 54.5%, 18.2% and 27.3% of the respondents evaluated the implementation rate of the Goals and Policies component as low, medium and high (low and very low categorized under low ,high and very high categorized under as high) respectively.

Condition Assessment:- This is the process of continuous or periodic inspection, assessment, measurement andinterpretation of the resultant data to indicate the condition of a specific asset. The condition was evaluated considering Depreciation and Remaining Useful Life of the specific assets; and Capital Expenditure andMaintenance programs. These result showed that27.3%, 27.3% and 45.5% of the respondents rated Condition Assessment component as low, high and medium respectively.

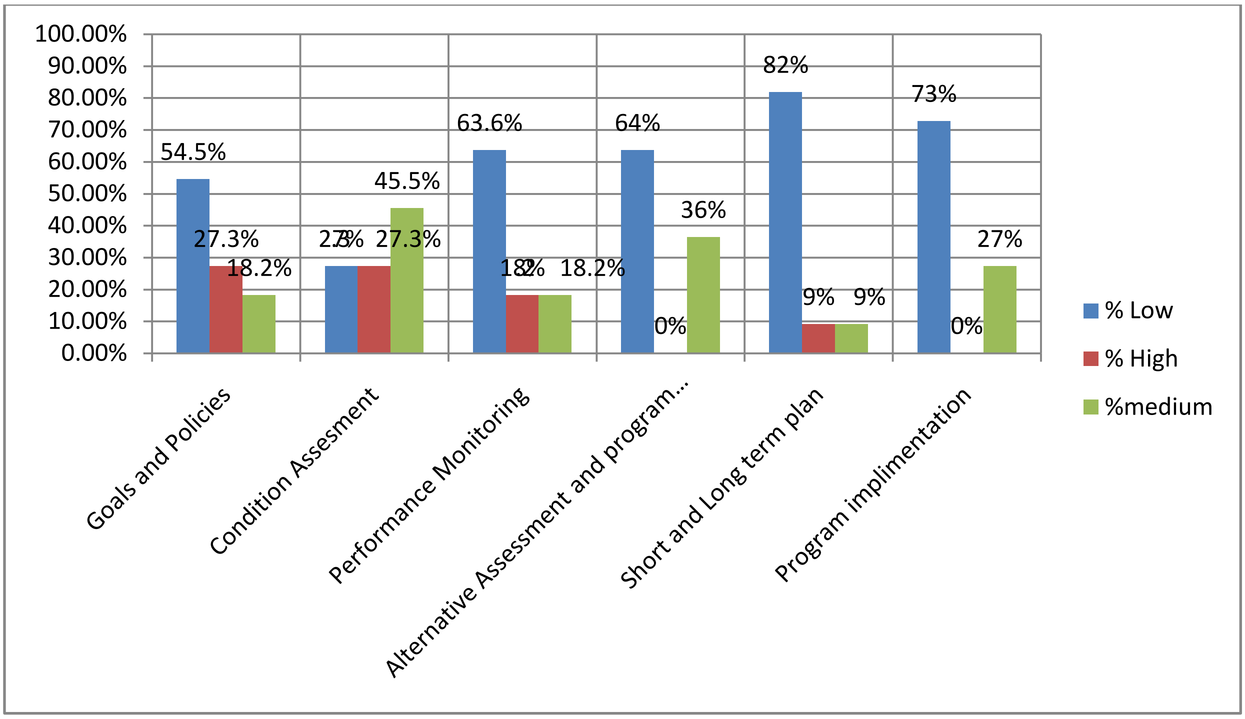
Performance Monitoring:- This is an important aspect of the use of asset management systems and is the need to monitor performanceof the asset against defined and required outcomes or targets of performance. The performance Monitoring Component Implementation rated as 63.6%, 18.2% and 18.2% as low, medium and high respectively.

Alternative Assessment and Program optimization:- The transportation asset management (TAM) systems typically include alternative analysis and program optimization modules or routines that help agencies to specify a limited number of alternatives to meet the overall objectives of their asset management system cost effectively.Alternative assessment and program optimization component of asset management system rated by the respondents were 64%, 0% and 36% as low, high and medium respectively.

Short and Long Term Plan:- Asset management planning is a comprehensive process to ensure delivery of services when road infrastructure is provided in a financially sustainable manner. In this case, short and long term plan component of asset management were rated as 82%,9% and 9% respectively as low, high and medium.

Program Optimization:- Once planning and project selection are completed programs are implemented. These programs can relate to different types of actions (e.g., major rehabilitation or maintenance activities) as well as defining the different organizational units that are responsible for different actions. Program optimization was rated by respondents as 73% , 0% and 27% in respect of low, high and medium.Figure 4.13 graphicallypresents, Asset management components implementation rate.

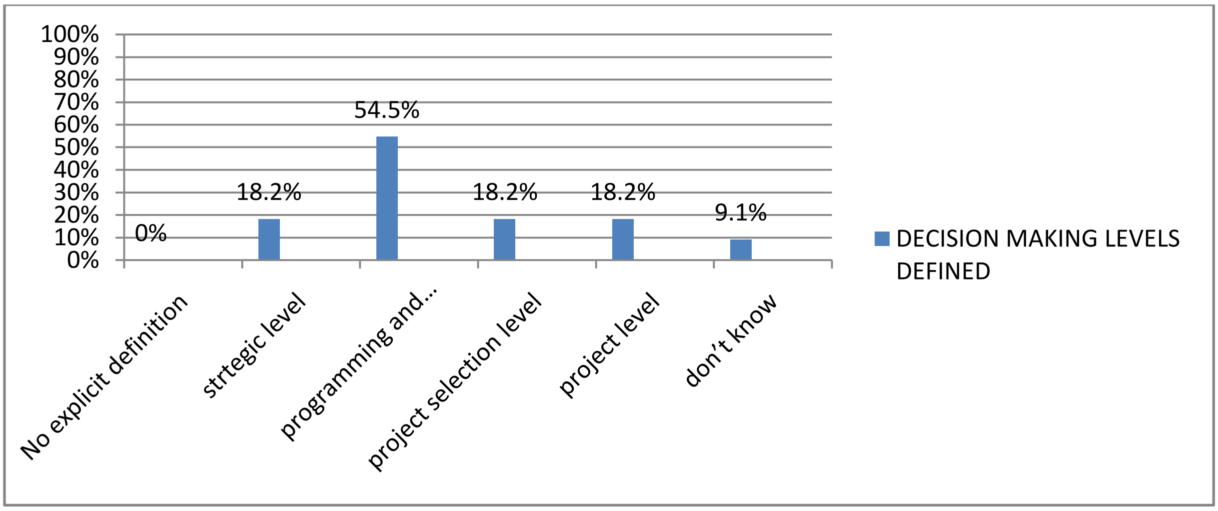
Figure 4.13: Asset Management System Components implementation



4.3.4 Decision Levels and Processes in AACRA

When asked to report on their defined decisionmaking levels, most of the responding professionals in AACRA indicated that they have not explicitly definedlevels in line with the criteria as defined in the literature. The main identified levels were programming and budgeting. It confirms that theorganization had focused its attention to these intermediate levels mostly programming and budgeting level connectingthe generic strategic decisions of the strategic level to the actual projectimplementation at the project level. Figure 4.14 below illustrates the decision making levels as defined.

Figure 4.14: Decision making levels



4.3.5 Data Collection Procedures in AACRA

Most of the responding professionals(54.5 percent) had revealed that AACRA has already invested timeand money in developing Asset Management roadway inventories and databases.Whereas the remaining professionals reported that AACRA is planningfor it. Most respondents revealed that AACRA have also been collecting data predominantly for theirpavements and bridges. Traffic items and roadside assets were also reportedto have been collected to a great extent as presented on Figure 4.13.Figure 4.15summarizes the data collection methods used for the acquisitionof such data. Whereas for some assets (e.g., drainage) the collection wasreported to have been mostly performed manually. There is a trendtoward using a combination of manual and automatic methods. According to the respondents 72.7% of the professionals revealed that data collected in AACRA were both manuallyand Automated where as 27.3% respond only manual collection is used. However, most of the respondents revealed that all types of maintenance are not practiced according to the data collected whereas some of the respondents reported that AACRA is planning to implement preventive, routine, and periodic maintenance and also rehabilitation.Figure 4.15 below presentsdata collection methods used in respect of manual, automated and both and Table 4.16presents types of roadway assets.

Figure 4.15: Data collection methods used

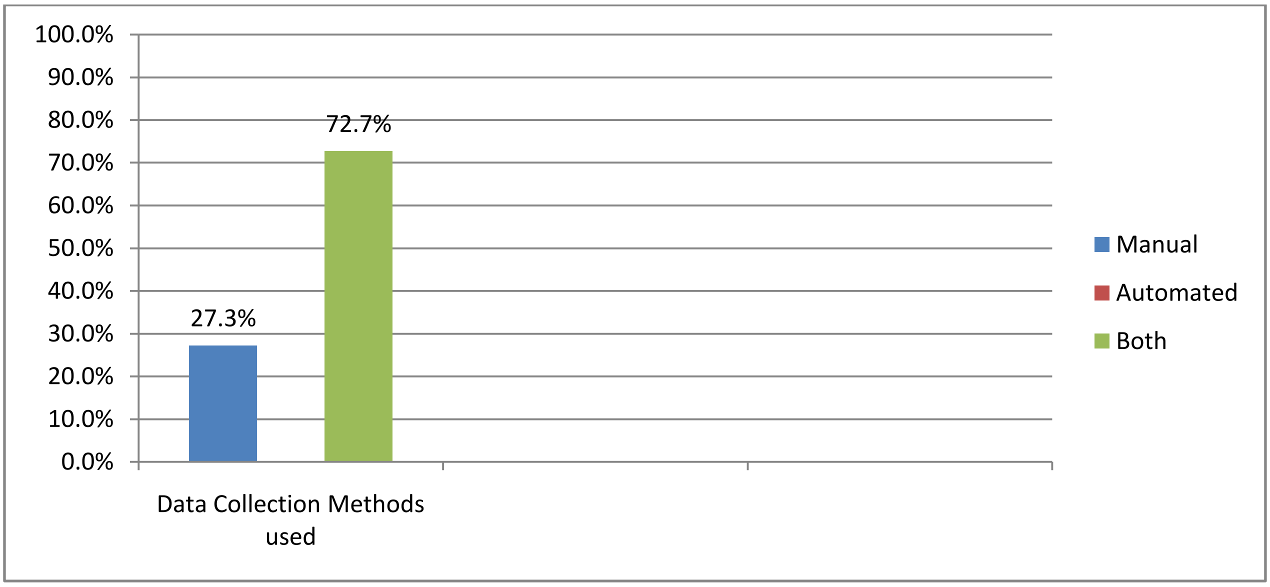
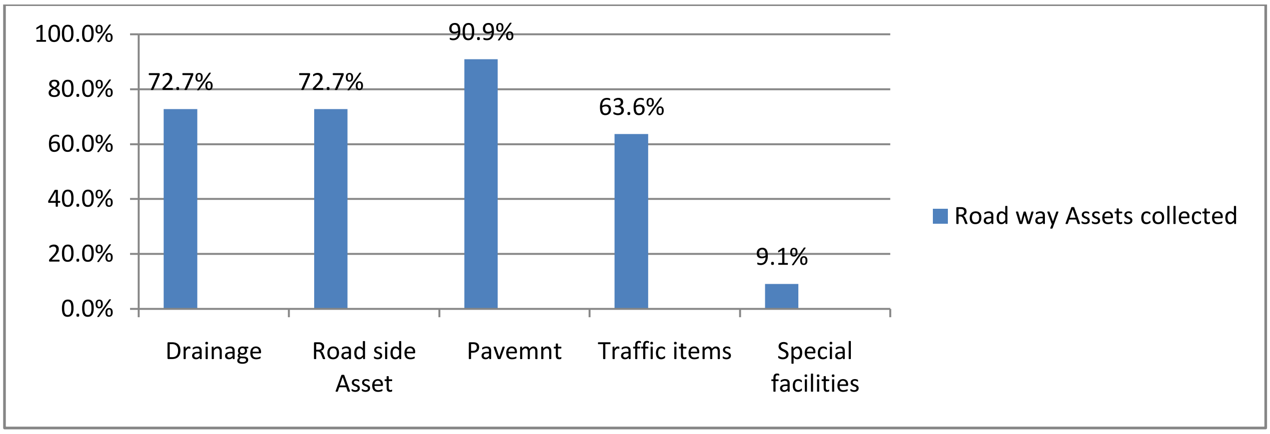


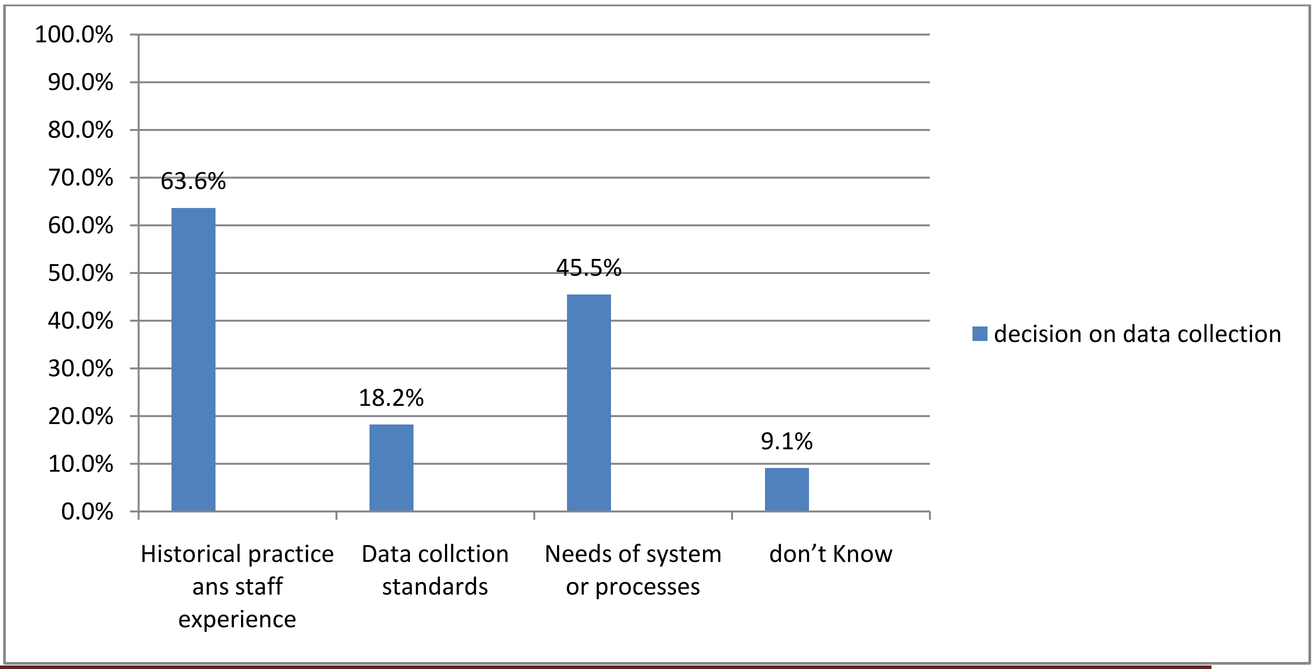
Figure 4.16: Types of Roadway Asset Collected



4.3.6 Data Collection Rationale in AACRA

According to most of the respondents, the condition of the assets assessed is always on AACRA road network. However, AACRA neither identified nor formally documented any relationship between the roadway data collected to support project selection and the decision made. The respondents were also asked to provide information about their rationalebehind data collection. These results are summarized in Figure 4.17 below. The responsesconfirmed that their data collection stillbase on decisionson past practices and staff experience. However, some respondents also notedthat data collection practices have been based on data collection standardsand input requirements of utilized management systems or other defined decisionprocesses

Figure 4.17: Data collection decision rational



4.3.7 Problems and Challenges Arise in Implementing Road Asset Management In AACRA

Problems and challenges that arise during the implementing of Road Asset Management were assessed to answer the research question number three. Seventy three (73%) percent of the respondents explained that there is lack of an organized Road asset management department and ninety one (91%) percent of the respondents said that there is lack of professional associations, conferences and short courses to get updated in state -of the- art techniques of asset management is one of the problems. This implies that if AACRA does not have an organized Asset management office; it lacks influence on the potential to improve the physical performance and function of a road and its systems, as well as to increase the users' level of satisfaction, in order tominimize life cycle cost of the Authority's asset and to improve efficiency in maintained and operating of the same.

4.3.8 Causes of Problems in Implementing Road Asset Managementin AACRA

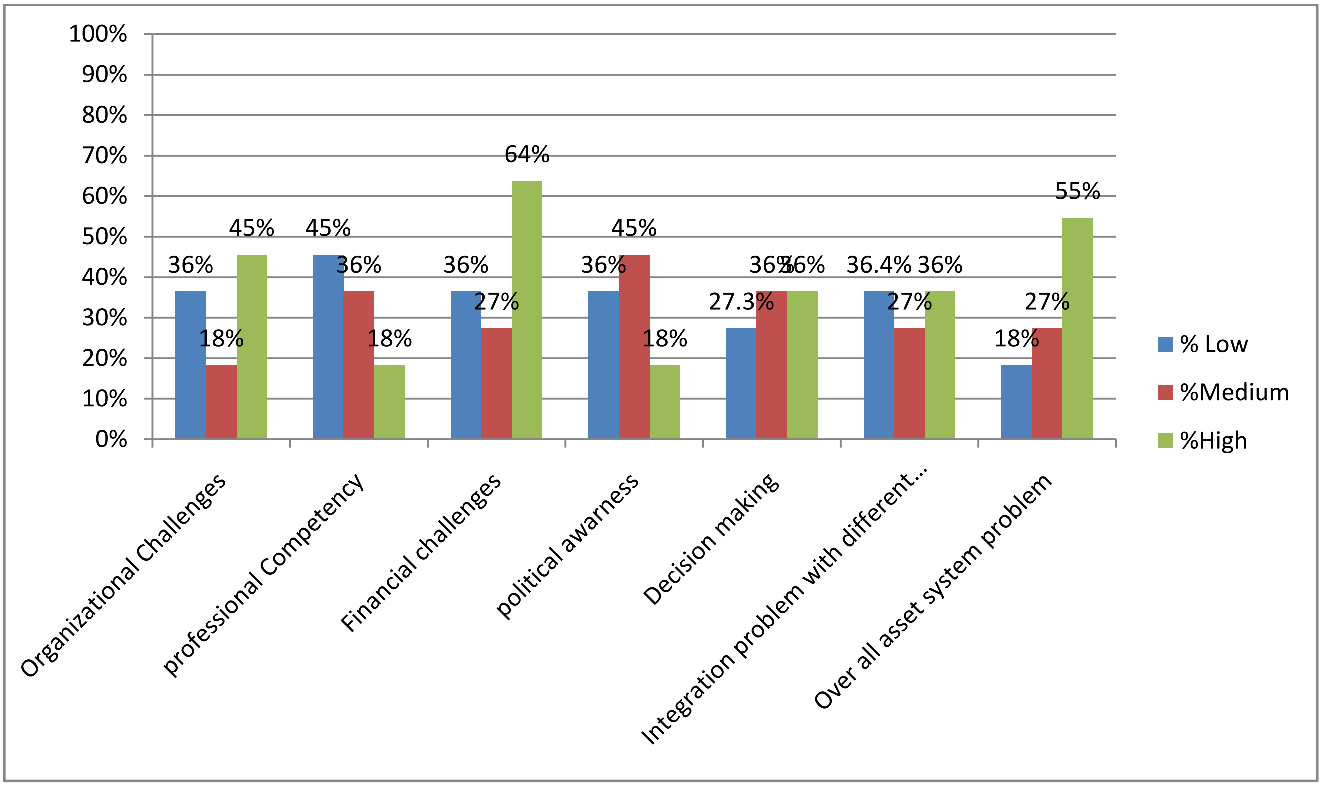
The respondents rated different factors as causes of problems in Asset management implementation. As shown below in Figure 4.18 below, the asset system problem are:- financial challenges, over all asset system problem, organizational challenges, professional competencyand integration are the major causes of the problems. However, to prevent or to minimize the above explained problems and challenges it needs to minimize the root causes of the problems. To get competent professionals in Road Asset management universities have to provide intensive courses in Asset management by establishing appropriate departments at graduate and under graduate level and share experience from other countries and professional associations how to develop this competency.

Integration with pertinent government organization need to be developed. Fortunately a Federal Integrated Infrastructure Coordinating Agency (FIIDCA) has been established recently which is a good start. In this regard, AACRA should take the initiative and need to get long term plan that will make it easy to include in the inception of the project and design.(As mentioned in the foregoing, AACRA) has five recently established regional office for effective and efficient road resources management. The regional offices will be accountable to the Deputy Director General of AACRA for road access. The new offices will increase the capacity of the Authority in securing and managing the roads, enabling the

Authority to interact more with stakeholders; sub cities, Ethio - Telecom, Addis Ababa Water and Sewerage Authority and Ethiopian Electricity Power Authority.AACRA is also working on a drainage master plan with a 62.5 million Br loan from the World Bank and lack of political awareness regarding asset management system practice has been costing countries enormously. Since delays in executing maintenance generally leads to increased severity of deficiencies (i.e., to poor or very poor conditions) and can eventually lead to a need for complete pavement rehabilitation or reconstruction in later years.

Addis Ababa City Roads Authority needs its top-level agency commitment (at the very highest levels) in support of asset management to be apparent in every case.Asset management officials should identify and need to change the culture of the organization to think of asset management as a key business area as a key challenge. The organization had a management position or office responsible for asset management should work on creating the organizational culture. Financial challenge is the major cause of problem rated as 64%. The experience of other countries found, asset management practices andprocesses have been used successfully to obtain fundingfor transportation infrastructure, when competing for fundswith other government programs, and even during budgetdeclines if the asset management system used fully and operational it will help to minimize financial challenges. Overall asset management system problem is the major problem rated 55% it can be averted by creating awareness of decision makers and political official that how much benefit will be saved if the system is operated even if the costs are accrued. So it will create aplatform to solve the financial burden to set up the asset management systems in expense of future M$R and user cost savings. Figure 4.18 presents the causes of problems for Asset management implementation in AACRA.

Figure 4.18: Causes of problems for Asset management implementation



4.3.9 INTERVIEW IN AACRA

4.3.9.1 Data Management

Once the data have been acquired through one or more methods and technologies they are stored in various formats and storage media. Data formats include: paper format, electronic databases, and geo-referenced database systems (such as Geographic Information Systems, GIS). The storage media employed can be paper forms (still in use in many agencies), hard disks, magnetic tapes, CDs, DVDs and combinations of thereafter. According to interview made with Road asset managementData Base Directorate Director, the data management in ACCRA since 2006 to 2008 is done as follows:- data collected in paper format converted in -to Excel sheet and stored. The same answer is given by the team leaders who made an interview with the researcher.

4.3.9.2 Data Integration

Integration of road asset management system is an application of suitable asset management software which will integrate all individual road management systems.Data integration alternatives include two main approaches: a fused database and many interoperable databases. In the first case the integration strategy leads to the creation of one database that contains all integrated data; in the second case existing or newly created databases are linked together and the integration of the data is achieved with the use of queries that provide a view of the linked data. On the other hand, the GIS software and related functionalities can alternatively be incorporated in the databases as external software that enhances the analytical and reporting capabilities of the system. According to the Road Asset Management Directorate Director, the organization has neither applied asset management integration software nor individual management systems until the period of the interview. But according to the interview with the team leaders the organization is developing a model called Kyoto Model with Japanese government cooperation called (Jica). There is also planning to integrate those models developed by Jica which are in separate asset management data bases.

4.3.9.3 Data used to Prioritize Projects

The next question forwarded to the interviewees was to rate the importance of identified roadwayassets for selection in respect of location, Attributes/characteristics, structural condition, functional condition, initial agency costs, life-cycle costs, usage and customer or user feedback. The Team leaders pointed out that the project selection between two projects is made mostly based on location, structural condition, budget and functional condition. whereas the Asset Management Directorate Director informed that the most important factors are location, structural and functional condition. A project which has economical, political and social impact will be given priority. For example if the road from Bole Airport to 4- Arat kilo has 10 pot holes where as the road from Mexico to Sarbet has 20 potholes, the priority will be given to the former rather than to the latter because of its political use. Since many dignitaries are using the Bole-Arat kilo Road. Similarly, the roads around Merkato area will get priority because of economical influence. Generally location is ranked first because political and economical importance. The results confirm to common sense, personal judgments and also showthat the responding officials had predominantly the same perception of thedata that would prioritize project selection between different assets.

4.3.9.4 Decision made to go for Rehabilitation or Maintenance

According to literatures reviewed,TAM systems typically include alternative analysis and program optimization modules or routines that help agencies to specify a limited number of alternatives to meet the overall objectives of their asset management system cost effectively. For example, an agency managing roadways may set as an objective a maximum percentage (say 10%) of the network mileage/kilometer that will be allowed to fall below a certain minimum desired level of service (also specified by the agency). A set of rehabilitation and maintenance alternatives may then be developed to meet this objective, and the alternatives analyzed to determine the optimal set of alternatives (e.g., the set of alternatives that can be used to meet the specified objective at the lowest life cycle cost). TAM best practice will use methods and criteria that reflect stated policy objectives, performance measures and targets to prioritize projects. Also, projects will be evaluated in terms of realistic estimates of life cycle costs, benefits and performance impacts. According to Team leaders and the Data base Directorate Director there is no explicit way of analyzing alternatives and get a decision based on scientific way of analysis like life cycle cost. Similarly, there is no economic evaluation method used to evaluate the pavement economic viability.

AACRA does not know the value of the asset in their network rather than doing the straight -line depreciation.Government accounting procedures were viewed in several cases as inappropriate for assigning value to assets and as a driver for asset management decisions. In these cases, asset management approaches were used to assign a value to assets.Asset management systems are much more appropriate fordetermining asset valuation than are straight-line depreciationaccounting rules.

4.4 SUMMARY OF FINDIGS AND DISCUSSIONS

In this section, the findings of the survey and desk study were compared, summarized and discussed from the perspectives of literature review about Road asset management practice.

There is no Asset Management components implementation practice in its fullest sense in Addis Ababa Roads Authority- like Goals and policies which guides how to practice asset management system. Condition assessment of the road in their network should be explicitly defined and categorized, performance monitoringin which most common asset management performance measuresrelate to condition, function, and capacity of theassets. In some cases, these categories of performancecharacteristics could provide the basis for cross-asset evaluation and investment prioritization. Alternative analysis, programoptimization and short and long term plans also are not practiced well in the organization.

Road Asset Management implementation in AACRA is still at its initial stages. Most of individual management systems are not used in the organization however, the organization is currently planning and developing.

Data collection methods used in AACRA are both manual and automated but the automated method of data collection is on trial base in AACRA.

The integration of individual management systems is not there in AACRA since they do not have the individual management systems in the first place but they are planning to develop. The same is true forroadway inventories and databases.

The data management method used in AACRA is traditional way of storing the collected data manually on paper based then converted in to Excel sheet and stored in computers but roadway inventories and database is not available yet. However, currently they are planning and developing individual management system and Automated data collection methods.

The most important criteria used for project selection in AACRA are Location, Structural severity, budget and function are used but there is no explicit way of analyzing the severity. Mostly it is done by personal judgment.

Data collection decisions in AACRA are predominantly based on past practices and personnel experience. But they do not mostly base their data collection decisions on data collection standards andinput needs of management systems or processes behind the rationalizationof data collection.

AACRA do not formally identifiedand documented existing links between the data they collect and the projectselection decisions they support. Similarly, asset management approaches arenot used to assign a value to assets. Asset management systems are much more appropriate for determining asset valuation than straight-line depreciation accounting rules.

Decision making levels are not explicitly defined in AACRA rather than the Programming and budgeting level which connects the strategic level to the actual project implementation at the project level.

Asset management training has been an important aspect of asset management strategy. It is noted that agood asset management program requires knowledgeablestaff capable of understanding the data-collection processand what the data mean but AACRA lacks it.

There is no very active asset management professional associations and user groups, spearheaded by local officials, have no developed asset management materials, guide lines and training programs aimed at both public officials and practicing transportation professionals.The absence of a specific organization creates difficulty in asset management practice.

Organizational challenges, financial challenges, Over all Asset Management system, Political Awareness and professional competency are the major causes of problems for road asset management practice in AACRA.It needs top-level agency commitment (at the very highest levels) in support of asset management to be apparent in every case.Asset management officials should identify and need to change the culture of the organization to think of asset management as a key business area as a key challenge. The organization had a management position or office responsible for asset management should work on creating the organizational culture.As the experience of other countries found, asset management practices andprocesses have been used successfully to obtain fundingfor transportation infrastructure, when competing for fundswith other government programs, and even during budgetdeclines if the asset management system used fully and operational it will help to minimize financial challenges.And also competent professionals in the area have to be produced. This can be done by opening Asset management department undergraduate and graduate levels and sharing experience from other countries professionals or associations on how to develop competency.

Finally, the result obtained in the survey and desk study is analyzed and discussed with the comparison of literature review. Based on this analysis and discussion, conclusion and recommendation given.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL

The main objectives of this research was to study the Road Asset Management (RAM) and the existing practices taking the Addis Ababa city Roads Authority (AACRA) as a case study and make recommendations based on the findings.This chapter presents conclusions and recommendations based on the outputs of the study by combining the research results from both the casestudy and survey study based in line with the objectives mentioned.Accordingly, in this chapter the main conclusions for this research are summarized.Recommendations will also be forwarded to improve the Asset management practices to pertinent government organizations in Ethiopia in general and in the Addis Ababa Roads Authority in particular to develop asset management system , to preserve their asset, to increase their assets lives and to create integration and ultimately optimize life cycle costs of asset management .

5.2 CONCLUSIONS

There is lack of Asset Management components implementation practice in its fullest sense in Addis Ababa Roads Authority. Theimplementation stage of an asset Management system is still at the planning stage. Most of the individual management systemshave not been utilized, the most predominant among them being pavement, bridge, and maintenance managementsystems. Other systems include safety (SMS), congestion (CMS) management systems.

The data management followed in AACRA since 2006 to 2008 E.C has been collection of data in paper format which is converted in to Excel sheet and stored.

Data collection decisions in AACRA are predominantly based on past practices and personnel experiences. But they were not based on data collection decisions mostly on data collection standards andinput needs of management systems or processes behind the rationalization of data collection. TheAACRA do not still formally identifiedand document existing links between the data they collect and the projectselection decisions they support. Data collection methods used in AACRA are both manual and automated but the automated method of data collection is on trial base.

Location is given a first rank to prioritizing projects in respect of political and economic impact than structural condition, functional condition, initial agency cost, life-cycle costs, usage and customer or user feedback.

Decision making levels in AACRA are not explicitly defined rather than programming and budgeting decision making level.The value of the asset in their network are not explicitly known rather than doing the straight - line depreciation.Government accounting procedures were viewed in several cases as inappropriate for assigning value . In these cases, asset management approaches were used to assign a value to assets. Asset management systems are much more appropriate fordetermining asset valuation than straight-line depreciationaccounting rules.

The main problems faced in applying asset management practice are lack of organized Asset management department, lack of professional associations, conferences, short courses to acquire state-of-the- art techniques of Road asset management.

Organizational challenges, financial challenges, Political awareness, over all asset management system and professional competency are the major causes of problems for road asset management practice in AACRA.It needs top-level agency commitment (at the very highest levels) in support of asset management to be apparent in every case.Asset management officials should identify and need to change the culture of the organization to think of asset management as a key business area.

5.3 RECCOMENDATIONS

Based on the output this research, the following recommendations have been forwarded for use by pertinent policy makers at AACRA as well at government level.

- Higher educational institutions need to be established in Ethiopia regarding Asset Management and accordingly courses should be offered at undergraduate and graduate levels; to produce competent and qualified professionals in area.

- Conferences need to be prepared to provide trainings and short courses for the employee of Asset management related organizations in order to share knowledge experiences from other international organizations.

- Creating integration with pertinent government organization like; Ethiopian Electricity Power Authority, Ethio-telecommunication Authority, Water and Sanitary Authority, etc. to preserve the asset from excavation and damage.

- Need to determine asset valuation through asset management system than straight-line depreciation accounting rules.

- Applying different individual management systems like: pavement, bridge and other management systems;

- Integration and development of individual management systems by creating database and data management systems for further decision making by top managers.

- Decision making models and project selection methods need to be developed in the AACRA.

- Data collection methods should be done based on international experience, individual management systems data need and standard Automated equipments need to be used to analyze the severity of the deterioration.

- Up-to-date condition of the asset should be surveyed and inventoried and database should be created to know the history of the roadway assets.

- A set of rehabilitation and maintenance alternatives should be developed to meet this objective, and the alternatives analyzed to determine the optimal set of alternatives (e.g., the set of alternatives that can be used to meet the specified objective at the lowest life cycle cost).

- Data collection decisions should be done based on independent management systems in accordance to data requirements or standard way of data collection.

- Top-level management in the organization should be committed in support of asset management to be apparent in every case.Asset management officials should identify and need to change the culture of the organization to think of asset management as a key business area

- AACRA should create Asset Management Practice Manuals and Guidelines.

5.4 (a)PROPOSED FRAMEWORK FOR EFFECTIVE AND EFFICIENT ASSET MANAGEMENT IMPLIMENTATION

The findings fromthe literature review , the survey analysis and Desk study allowed for the recommendation of the framework for effective and efficient Asset management as illustrated on Figure 5.0 and 5.1.

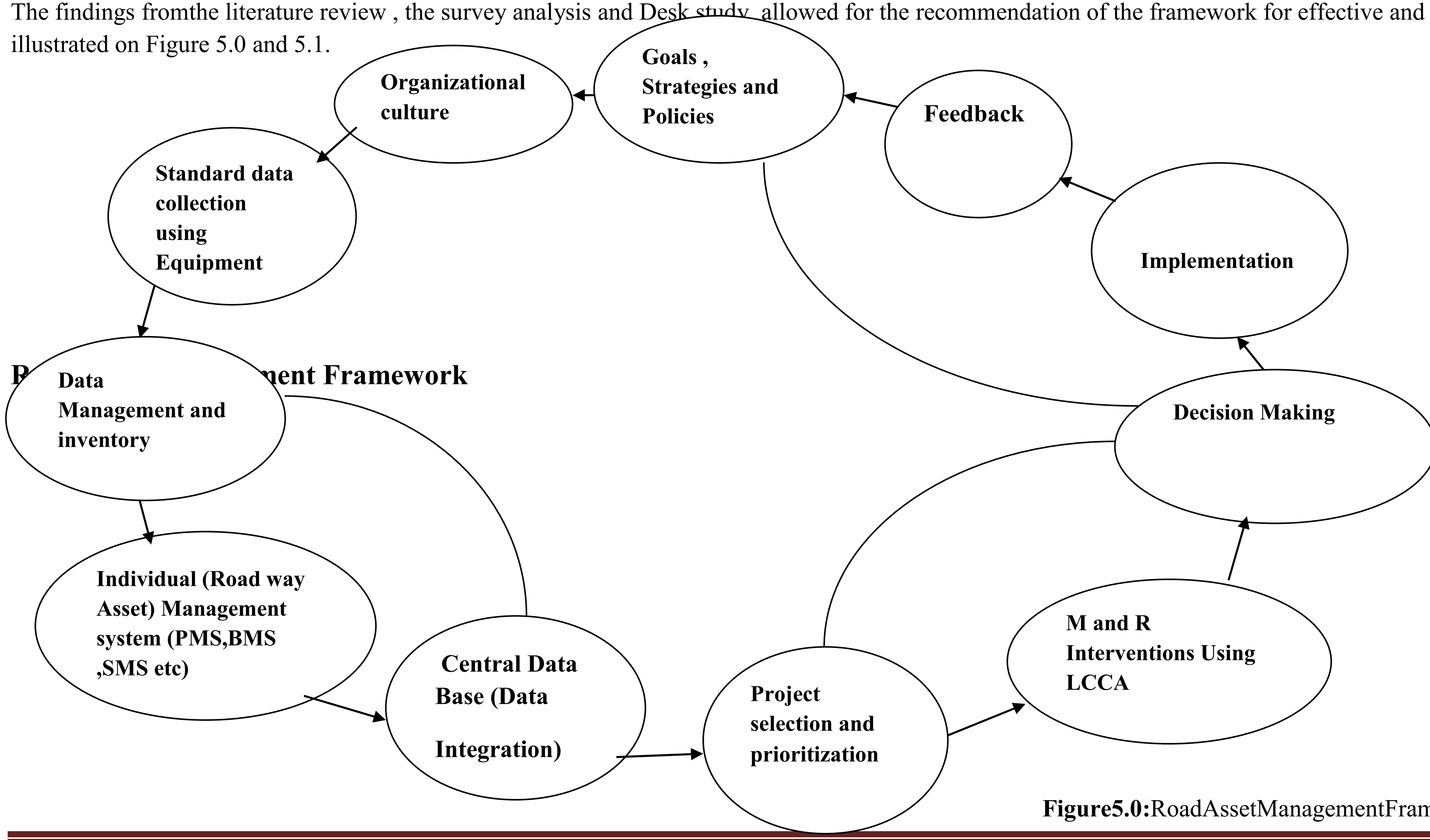


Figure5.0: RoadAssetManagementFramework

5.4(b) PROPOSED FRAMEWORK FOR EFFECTIVE AND EFFICIENT ASSET MANAGEMENT IMPLIMENTATION

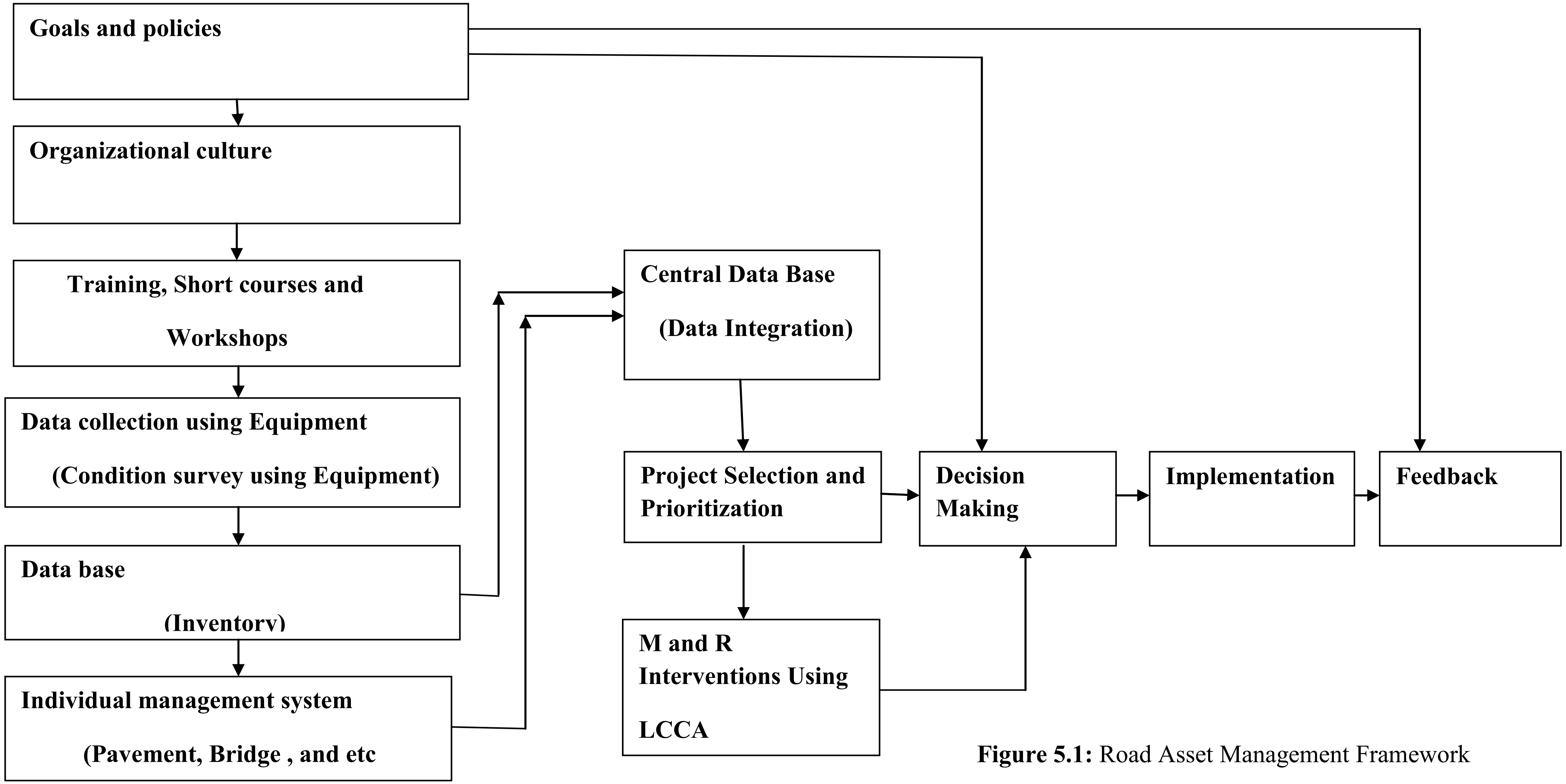


Figure 5.1: Road Asset Management Framework

5.5PROPOSED ORGANIZATIONAL STRUCTURE

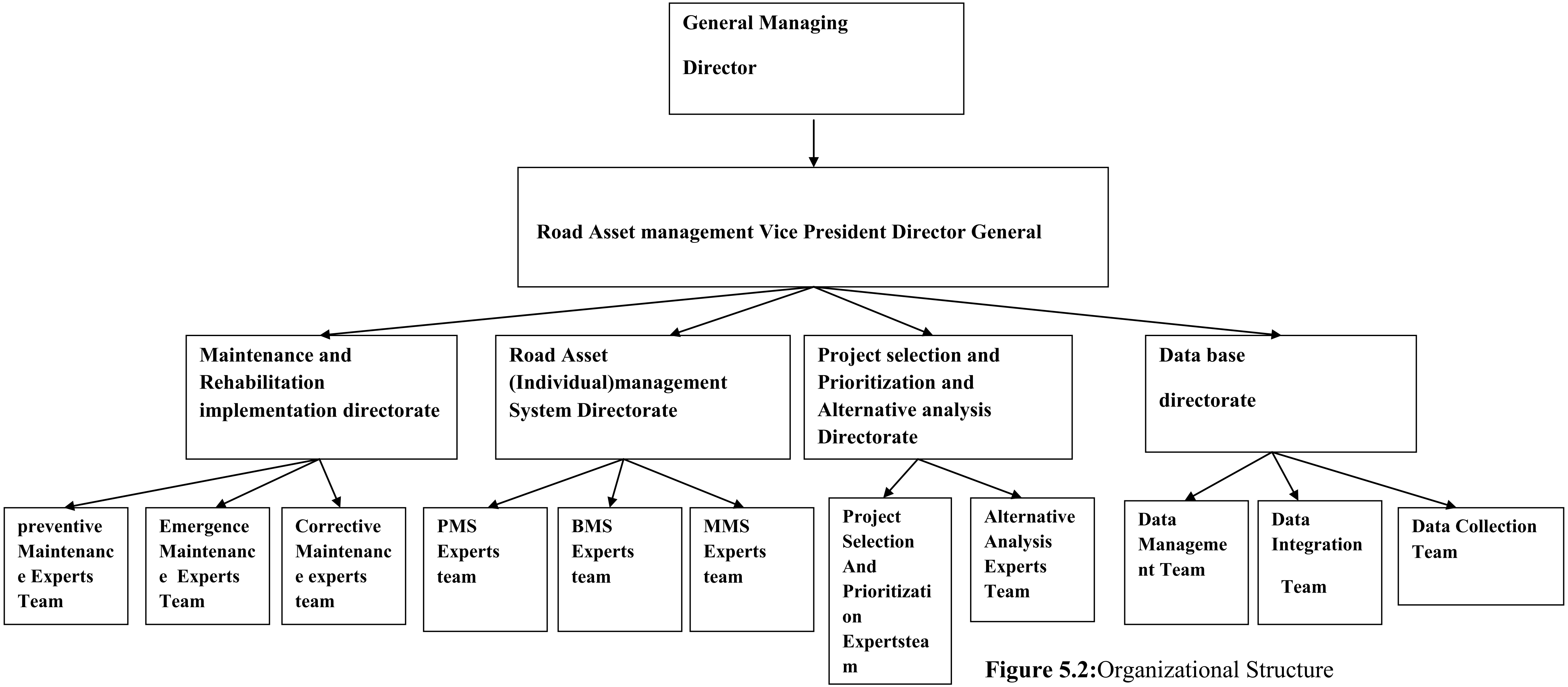


Figure 5.2: Organizational Structure

According to literature review, Survey, Desk study and FHWA(1999) in order for an agency to evaluate its asset management system the Road Asset Management Directorate Directors shouldask (and reply to) the following questions:

- What are our goals and policies?
- What is included in our inventory of assets?
- What is my Asset
- Where it is located
- What material it's made of
- What is its thickness
- What is its climate
- How much traffic is it operating
- What is the value of our assets? What are their functions? What services do they provide?
- What was the past condition and performance of our assets? What is the current and predictedfuture condition and performance of our assets?
- How can we preserve, maintain, or improve our assets to ensure the maximum useful life and provide acceptable service to the public?
- What resources are available? What is the budget level? What is the projected level of futurefunding?
- What investment options may be identified within and among asset component classes? What are their associated costs and benefits?
- Which option, or combination of options, is ―optimal?"
- What are the consequences of not maintaining our assets? How can we communicate the impact of the condition and performance of our assets on the system and end user?
- How do we monitor the impact of our decisions? How do we adjust our decision-making framework when indicated?
- How can we best manage our assets in order to least inconvenience the motoring public whenwe repair or replace these facilities?

By applying the above proposed frameworks illustrated on Figure 5.0 and 5.1 and organizational structure illustrated on Figure 5.2 with the key questions need to be answered by the organization they can set effective and efficient asset management for their asset.

5.6PROPOSED FUTURE RESEARCH AREAS

1**.** Research on the development of decision making tool for the project financing is required. To utilize the data and information acquired and to provide simple tools that can be utilized by maintenance directorate. Tools include flow chart diagrams and decision tress. These streamlined maintenance and rehabilitation intervention decisions need to be supported by life cycle costing in order to convince decision makers.

2.Research on the development of deterioration prediction model of road assets is required

3.Reserach is required on the development of asset valuation practice through asset management system

4.Reserach on the assessment of Integration problem between pertinent government organization like the Ethiopia Electricity Power Authority, Ethio Telecom, Water and sanitary Authority and Addis Ababa City Roads Authority will be significant.

5. Research is required on the optimization of pavement maintenance strategies

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APPENDIX A - QUESTIONNAIRE

Dear /Sir

I kindly request your participation and support in A RESEARCH ONINVESTIGATION OF ROAD ASSET MANAGEMENT PRACTICES IN ETHIOPIA THE CASE OF ADDIS ABABA CITY ROADS AUTHORITY (AACRA)"which is being conducted as partial fulfillment of MSc in construction technology and management.Any information you will provide will remain confidential and your participation is greatly appreciated.

General information

The main objective of this research is to investigate the Asset management practice in Ethiopia the case of AACRA and also find possible waysfor improvement if found necessary.

The intention of the survey

The purpose of this survey is to obtain the necessary data for utilization in the research which is conducted under the umbrella of the Construction Technology and Management at Addis Ababa institute of Technology. All data gathered during the survey will be kept confidential and only used for academic purposes .

The attached questionnaires were developed based on literature reviews. You can **tick,write in words** or **rank** on the space provided.

The identity of the respondents shall be kept confidential. I would like to extend my gratitude for your helpfulness taking your precious time to respond to questionnaire.

SUGGESTIONS FOR COMPLETION OF QUESTIONNAIRE

1. Please note that your response is anonymous and will be treated in absolute confidentiality.

2. The questionnaire comprises five Sections (SECTION 1, 2 and 3) and would take approximately 20 to 25 minutes to complete.

3. Where applicable, definitions of terms and specific assumptions are included to facilitate your response.

4. Should your company or organization wish to receive a copy of the final research report, you are welcome to write to:

Mr. Yetnayet Bihon; phone +251 913236118; Email: bihonyetnayet@gmail.com

OBJECTIVES OF THE RESEARCH

- To investigate the effect of asset management practices on sustainability of the road networks in Ethiopia;

- To study and identify the factors affecting Asset Management practices in the Ethiopian Roads Authority which has already implemented system;

- To observe and scrutinize the pavement management system software applicationin AACRA for the purposes of the establishment of Asset Management;.

- To investigate the asset valuation practices at the AACRA; and

- To recommend state of the art practices of asset management for the AACRA with possible recommendation of its replication in pertinent government organizations in Ethiopia.

THANK YOU

Section1:Organization and Respondent's position

Organization

☐ ERAAACRA ☐

Respondent's position

☐ President or general Manager of the authority

☐ Road Asset Management Vice president

☐ Road Asset Management Data base Director General

☐ Road Asset Management Deputy Head

☐ Asset Management Professional or Team Leader

Section 2: General Agency Information on Asset Management, Decision Levels, and Decision Processes

1. Has your organization implemented or is planning to implement an Asset Management System (please check one of the following)?
   a) Yes, it has already implemented an Asset Management System.
   b) No, it has no plan to implement an Asset Management System.
   c) It is planning to implement an Asset Management System but it does not have one yet.
   d) Don't know.

2) How do you rate the road asset management system components implementation in your organization. Indicate in the spaces provided in the following table.

AMS components	Level of implementation				
	Very low(1)	Low(2)	Medium(3)	High(4)	Very high(5)
Goals and policies					
Condition assessments					
Performance monitoring					
Alternative assessment and program optimization					
Short and long range plan					
Program implementation					

3) Please check the management systems your agency/organization is currently using(please check all that apply)

   a) Highway Development and Management (HDM 4) Tool.
   b) Pavement management systems (PMS).
   c) Highway Safety management systems (SMS).
   d) Traffic Congestion management systems (CMS).
   e) Maintenance Management systems (MMS).

Please list any other management systems used by your agency/organization:

....
....
....
....

4) Did your organization integrate the management systems you checked in Question No 3 with asset management frame work.

   a) Yes   b) No   C) Planned   d) don't know

5) Please specify the decision making levels that have been explicitly defined in your organization (check all that apply):

   a) No explicit definitions for decisionmaking levels (skip to Question 4).
   b) Strategic level (i.e., concerning policy of decisions for the overall network).
   c) Programming and budgeting level (i.e., concerning overall resource allocations for design,maintenance and rehabilitation throughout the entire network).
   d) Project selection level (i.e., selection of individual projects or groups of projects for fundingand/or implementation)
   e) Project level (i.e., design concerning specific treatments or actions for the selected projects).
   f) Don‘t know what decision levels are defined.

Section 3: Information regarding data collection, management and integration and their relation to the Project Selection decision level of Roadway Assets

1) Does your agency/organization have an Asset data collection method in asset management system?

   a) Yes   b) No   c) Partially   d) I don‘t know

2) If yes, which data collection method is used by your organization in the inventory of road assets?

   a) Manual (which employs two or more data collectors and a distance-measuring device)

b) Automated (involves the use of a multipurpose vehicle equipped with a distance measuring device as well as combinations of video cameras)

d) Both

If you checked the automated data collection method list the type of Automated equipments you used

....
....
....
....

3) Please indicate if your agency collects data for each of the following road way asset types(please check all that apply)

a) Drainage b) Roadside assets c) Pavementsd) Trafficitems e) Special facilities

4) Does your organization have an Asset Management roadway inventory/ database or is planning to develop one (please check one)?

a) Yes, it already has an Asset Management database.

b) No, it does not have an Asset Management database.

c) It is planning to develop an Asset Management database but it does not possess one.

d) Don't know.

5) Which one of the following statements best describes how your agency/organization decides which data (and their related level of detail) will be collected to support theproject selection decisions? Check all that apply:

Data collection decisions are:

a) Based on historical practice and staff experience.

b) Based on widely accepted data collection standards..

c) Based on specific needs of individual or integrated management systems/decision processesto be supported.

d) Don't know exactly.

Please list any other consideration(s) that your agency's data collection decisions are based on:

....
....
....
....

6) Does your organization apply all types of maintenance methods like preventive, routine periodic maintenance and rehabilitation based on the data collected.

a) Yes b) No c) Planned d) I don't Know

7) Please rate and write your criteria according to their level of importance forselecting projects that are candidates for funding and implementation withinyour agency/organization:

....

....

....

....

....

8) How many times does the condition of the asset is assessed in your organization?

a) Always b) Rarely c) Not assessed

9) Has your organization identified and/or formally documented any relationshipbetween the roadway data collected to support Project Selection and the decisionsmade? Please check one:

a) Only identified.
b) Identified and formally documented.
c) Neither identified nor formally documented
d) Don't know

10) Which analytical method do use for pavement economic viability in your organization?

a) Life cycle cost analysis (LCCA)
b) Cost-benefit analysis (CBA)
c) Cost effectiveness analysis (CEA)
d) Economic impact analysis (EIA)
e) Financial analysis (FA)

If there is any other method you used please describe?

....

....

....

Section 4 Factors affecting the implementation of asset management

1) Are there any problems and challenges in Asset Management practice in your organization?

a) Yes b) No c) I do not know

2) If your answer for question 10 is yes, what problems and challenges happen in your organization?

a) Lack of organized asset management department.

b) Lack of Professional associations, Conferences, Short courses to get updated information about road asset management

Please mention if there are any other problems and challenges present in asset management practices of your organization;

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

3) Please rate the following causes to problems arising in asset management implementation

AMS components	Level of effect				
	Very low(1)	Low(2)	Medium(3)	High(4)	Very high(5)
Organizational challenges					
Professional competency					
Financial challenges					
Political awareness					
Decision making					
Integration problem					
Over all asset system problem					

Please provide any other thoughts, information or contacts concerning Road asset management practice in Ethiopia.

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

THANK YOU

APPENDIX B - INTERVIEW SCHEDULE

PREFACE

I wish to thank you for your participation in this research. The interview you are about to answer to questions is regarding a research for a degree of **Master of Science in Construction technology and Management.** This research is being done to investigate Asset Management Practices in Ethiopia The case of AACRA.

ORIENTATION AND INTRODUCTION FOR PARTICIPANTS IN RELATION TO THEINTERVIEW QUESTIONS:

1. First of all, I would like say thank you for your valuable time and cooperation to answer the following interview questions.
2. Please note that your response is anonymous and will be treated in absolute confidentiality.
3. The interview comprises some questions and may take approximately 25 to 30 minutes to complete.

4. Should your company or organization wish to receive a copy of the final research report, you are welcome to contact **Mr. Yetnayet Bihon ; phone +251 913236118; Email:bihonyetnayet@gmail.com**.

Organization and Respondent's position

Organization

☐ ERAAACRA ☐

☐ President or general Manager of the authority

☐ Vice president of Road asset management

☐ Road Asset management data base director

☐ Asset management deputy head

☐ Asset management professional or Team leader

1. Once the data have been acquired by one or more methods and technologies they are stored in various formats and storage media. Data formats include: paper format, electronic databases, and geo-referenced database systems (such as Geographic Information Systems, GIS). The storage media employed can be paper forms (still in use in many agencies), hard disks, magnetic tapes, CDs, DVDs and combinations of thereafter.
what is the mechanism you follow to manage the data collected in your organization?

....
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....

2. Integration of road asset management system is an application of suitable asset management software which will integrate all individual road management systems.Data integration alternatives include two main approaches: a fused database and many interoperable databases. In the first case the integration strategy leads to the creation of one database that contains all integrated data; in the second case existing or newly created databases are linked together and the integration of the data is achieved with the use of queries that provide a view of the linked data. Or GIS software and related functionalities can alternatively be incorporated in the databases as external software that enhances the analytical and reporting capabilities of the system .What data integration system you use in your organization?

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....

3. What data are used to prioritize and select between two projects for example between two pavement projects and how much important is it?

Road way asset data	Level of importance						
	Very low	Low	Medium	High	Very high	Not imp	Don't know
Location							
Attributes/characteristics (i.e., materials, service life, geometry, etc.)							
Structural condition (i.e., how adequate it is for its purpose)							
Functional condition (i.e., how well it can serve the public)							
Initial agency cost (construction/provision)							
Life-cycle costs (including M&R and user costs)							
Usage (i.e., how many users utilize it on a specific time basis, e.g., a day)							
Customer/user feedback and/or complaints							

4. How decisions are made in your organization to finance a project maintenance or rehabilitation need?

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....

5. Which economic evaluation analysis method you use in your organization to evaluate the pavement economic viability?

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THANK YOU

Appendix C Asset Management Systems Benefits and Cost

Table4.3: Benefits of Asset management System

Category	Elected representatives (strategic level)	Top Management (Tactical level)	Technical level people (Operational Level)	Public (User and non user Level)
Budget allocation process	• Assurance of best expenditure of funds	• Improved allocation process within a program area • Assurance of best use of available Budget • Providing a basis for allocating funds among different districts or agencies • Justifying capital spending and maintenance programs to the elected council or legislature • Use of standard accounting concepts and terms to provide understandable information to the decision makers		
Asset Inventory		• Defining the ―management fee" as a percentage of the spending on capital and maintenance work	• Ability to build more accurate information • Ability to track the performance of treatment strategies • Ability of a wide range of staff to query database • Integrated harmonized database (consistent data) • Provision of up-to-date accurate information on the Condition	
Road Performance	Improved road performance	Improved road performance	Improved road performance	• Satisfaction of using improved assets • Improved road serviceability • Savings in user costs (traveltime, vehicle operation, andsafety) • Reduction of environmentalimpacts(air, noise, an annoyance)
		• Savings in agency costs (construction and M&R)		

<table>
<tr><th>Category</th><th>Elected Representatives
(Strategic Level)</th><th>Top Management
(Tactical Level)</th><th>Technical Level People
(Operational Level)</th><th>Public (User & Non- user Level)</th></tr>
<tr><td rowspan="3">Management Tools</td><td colspan="3">• Realization of the magnitude of the investment that the agency has a better chance of making correct decisions on spending funds</td><td rowspan="3"></td></tr>
<tr><td rowspan="2">• Actual operation of the system being able to defend/justify programs of maintenance and rehabilitation
• Reduction of pressure (fromconstituents) to make arbitrary
• program modificationsObjective answers to theimplications of:
✓ lower levels of funding
✓ lower standards</td><td colspan="2">• Common definitions and standards for maintenance and rehabilitation Economic modeling
✓ Provision of an estimate of the economic effect of spending
✓ scenarios (scenario analysis)
✓ Ability to manage assets on an economic basis (cost-benefit,
✓ engineering economics)
✓ Prioritization of maintenance needs on the basis of future costs
✓ rather than current condition (life cycle cost)
✓ Selection of the best maintenance and rehabilitation measures or
✓ strategies</td></tr>
<tr><td>• Comprehensive, comparative assessment of:
✓ current status of the network
✓ expected future status
✓ Objectively based answers to:
✓ what level of funding is
✓ required to keep the current status
✓ the implications of greater or lesser budgets
✓ the implications of deferred work
✓ the implications of lower standards</td><td>• Satisfaction of providing best value for available funds
• Capability of assessing the implications of:
✓ less funds, lower standards
• Capability of making the case for higher standards
• Capability of quantifying the assessment of the condition
• Improved credibility of decision-making process when dealing with top management</td></tr>
</table>

Category	Elected Representatives (Strategic Level)	Top Management (Tactical Level)	Technical Level People (Operational Level)	Public (User & Non-user Level)
Staff Development	• Improved knowledgeof pavement conditionsand needs	• Improved knowledge of pavementconditions and needs	• Improved recognition of variousadministrative and operatingelements of the organization ✓ Broad multi-disciplinaryknowledge ✓ Provision of access to accuratedata, state-of-art IT, and analysistools needed for cost-effectivemanagement • Improved knowledge of pavementconditions and needs • Upgrade skills	
Communication		• Improved communication ✓ Common benchmarks ✓ Improved internal and external communications • Adoption of accounting practices		
		• Ability to defer lobbying pressuresfrom special interest groups	• Improved communication with design, construction, maintenance, planning, and research.. • Enabling front line staff to become more involved in the decision making process	• Understanding of agencies business via performance monitoring reports
Application of Technology			• Increased awareness of available technology and how to use it Better utilization of manpower ✓ Time saving in evaluating development alternatives	

Table 4.4: Costs of Asset Management System Implementation

Category	Elected Representatives (Strategic Level)	Top Management (Tactical Level)	Technical Level People (Operational Level)	Public (User & Non-user Level)
Data acquisition		• Data collection	• Data collection, processing, storage and analysis	
Management System		• Software development/acquisition and installing theSystem • Computer hardware, staff • Operating costs of the system		
Others		• Organizational changes • Staffing	• Making changes in procedures • Extra time and effort toupgrade skills and learn newprocedures • Training and education costs	• Increase of user costs andenvironmental impacts due to: ✓ Frequent preventive M&Rworks ✓ Increase of driving speed ✓ Inducing additional trafficproduced by high quality road

Source: Mizusawa and MC Neil