CHAPTER ONE

INTRODUCTION

1.1 General

Advances in technology have brought in several benefits. Among the most often cited are improved quality and productivity. The opportunity to improve construction productivity exists, /however and evidence suggests that sectors of the construction industry have experienced long-term productivity growth as a result. Research has shown that technology tends to have a greater impact on labor productivity versus factor productivity measures. For instance, investment in new equipment technology may improve an organization's labor productivity, but its factor productivity may actually decline if the relative saving in labor costs and gains in output. However evidence shows that improvements in equipment technology and materials have appositive impact on construction productivity.

• Equipment and Materials Technology

Construction equipment and materials have witnessed significant changes over the past several decades. However, the construction industry has lacked documented evidence of how improved technologies in construction have resulted in productivity improvement. This relation was examined by measuring productivity changes over time for individual construction activities and then comparing equipment and material technology changes for these same activities. The activities that experienced improvement in the equipment and materials technology traits experienced more improvements in labor productivity than those activities that did not, and this finding was statistically significant (Table 1-1). Activities experiencing an improvement in energy, control, functional range, and information processing had at least twice as great of improvement in labor productivity than activities experiencing no improvement in the technology factors. Likewise, it was found that activities experiencing improvement to modularization, unit weight, and installation encountered at least twice the improvement in labor productivity compared to those activities with no likewise material improvements. (al mohawis , 2011).

Table 1-1 Change in Equipment and Materials Technology versus Changes in Labor Productivity: (CIIR , 2008).

Technology Characteristics	Change in Labor Productivity		
Equipment Technology characteristic	No Change in Equipment Technology Characteristic%	Change in Equipment Technology Characteristic%	Difference%
Energy	3.60	39.80	36.20
Control	14.9	46.60	31.70
Functional Range	13.5	51.80	38.30
Information Processing	21.0	56.40	35.40
Material Technology Characteristic	No change in Material Technology Characteristic	Change in Material Technology Characteristic	Not significant
Modularization	8.10	24.20	16.10
Reduction in unit weight	10.40	48.60	38.20
Installation Flexibility	8.70	23.10	14.40

1.2 Problem Statement

Construction industry in Sudan during the last years developed fast, bringing advanced equipment and materials for use in execution of different construction projects.

It is required to know changes in road construction industry and it is effect on improving quality control. Furthermore, it is important to determine it is impact on easy execution keeping the same construction time and cost and get high production and quality.

In this study, many road construction sites were surveyed and questionnaire was distributed. The purpose was to study the impact on quality and productivity of technical and technological advanced in roads construction.

1.3 Research Objectives

The aim of this study was to determine the impact of advances technology on construction industry. The main objectives of this investigation were as follow:

1- Studying construction industry status and its importance in contribution in Sudan economics.

2- To identify the problems associated with quality control implementation in roads construction projects.

3- Knowing the extent of developing construction industry
4- Investigate if advanced technology in equipment and materials increases productivity and improve quality.5- Determine the level of utilization of advanced technology by companies working in road construction.

1.4 Research Hypothesis

The study is intended to confirm or otherwise the following:

1- Management of companies operating in road construction industry is aware of the importance of using of modern techniques.

2- There is a positive relationship between workers efficiency and use of modern technology.

3- A relationship exists between using modern technologies and duration of project completed.

4- Companies always seek to improve productivity and increase quality.

5- To improve quality companies use materials specifications and conduct necessary tests.

6- Success of any project is measured by the use of modern technologies.

7- Companies aware the important of the maintenance of the equipment and the renewal the equipment of each period.

1.5 Research Methodology

All data used in this research are collected from different sources. Literature and theoretical reviews have been taken from books, articles and papers. The quantitative started with collecting data by standardized questionnaire which will distribute to the employees participants sample, then all outcome data of the survey were analyzed using (SPSS) Statistical Package for the Social Science Software Program.

1.6 Research Structure

This research composed of the following chapters:

Chapter One:

Includes general introduction and advanced construction industry technology and Equipment and Materials Technology. Also show the objective of this research and research hypothesis.

Chapter Two:

Includes literature review which provides general overview of the construction industry, productivity, quality control and previous studies.

Chapter Three:

Includes road construction materials and equipment and some of tests for road materials.

Chapter Four:

Review the analysis of the questionnaire and results.

Chapter Five:

Review the conclusions, recommendations and future studies.

Appendix:

Includes questionnaire model.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of Construction Industry

Construction is the world's largest and most challenging industry. Human resource today has a strategic role for productivity increase of any organization, and this makes it superior in the industrial competition. With the effective and optimum uses of it, all the advantages supplied by the productivity growth can be obtained. Construction is a key sector of the national economy for countries all around the world, as traditionally it took up a big portion in nation’s total employment and its significant contribution to a nation’s revenue as a whole. However, until today, construction industries are still facing number of problems regarding the low productivity, poor safety and insufficient quality.

Construction Industry work covers work on new or existing commercial, industrial or domestic buildings or structures includes: (O’Grady, 2007).

- the construction or erection of a building or structure that is or is to be fixed to the ground and wholly or partially fabricated on-site;
- any preliminary site preparation work (including pile driving) for the construction or erection of any such building or structure;
- the alteration, maintenance, repair or demolition of any building or structure, excluding electrical or metal trades maintenance or repair work;
- the laying of pipes and other prefabricated materials in the ground, and any associated excavation work;
- the construction, erection, installation, extension, alteration or dismantling of a transmission or distribution line, or plant, plant facility or equipment used in connection with the supply of electricity; or an air-conditioning, ventilation or refrigeration system;
- the construction, erection, installation, extension, alteration, service, repair, replacement of parts or dismantlement of a lift or escalator;
- Electrical or metal work associated with other engineering projects.

2.2 Characteristics of Construction Industry

About 80% of the population lives in the rural areas. The buildings and other small infrastructure facilities for this major part of the population are constructed by the informal sector. The informal construction sector comprises of unregulated and unprotected individuals engaged in economic activities that include the supply of labor, materials and building components to the formal construction sector directly in response to needs of clients. It also includes works carried out by individuals and groups on a self-help basis without contracting. Since the construction industry is a fundamental economic activity which permeates most of the sectors of the economy it has a major role to play in achieving social economic development objectives of any country; local firms and Professionals should be fully involved in the process. The sector has indirect impact on the growth or stagnation of the overall economy. Furthermore, the development of a strong construction industry should be supported by sectoral and macro- economic policies geared towards stimulating growth and competitive position of the local actors. (O'Grady , 2007)

2.3Types of Construction Projects

In general, there are three types of construction:

1. Residential Building Construction
2. Industrial and Commercial Building Construction
3. Infrastructure and Heavy Construction

Each type of construction project requires a unique team to plan, design, construct and maintain the project.

2.4 Benefits of Construction Industry Development

Construction industry development is a deliberate and managed process to improve the capacity and effectiveness of the construction industry to meet the national economic demand for buildings and other physical infrastructure facilities, and to support sustainable national economic and social development objectives, while ensuring. Increased value for money to industry clients as well as environmental responsibility in the delivery process. The viability and competitiveness of domestic construction enterprises. Optimization of the role of all participants and stakeholders through process, technological, institutional enhancement and through appropriate human resource development.

2.5 Productivity in the Construction Industry

Productivity is the one of the most important factor that affects overall performance of any small or medium or large construction industry. There are number of factors that directly affect the productivity, thus it is important for any organization to study and identify those factors and take an appropriate action for improving the productivity. At the micro level, if we improved productivity, ultimately it reduces or decreases the unit cost of project and gives overall best performance of project. There are number of activities involved in the construction industry. Thus the effective use and proper management regarding labors is very important in construction operations without which those activities may not be possible. The measure of the rate at which work is performed is called "productivity". It is a ratio of production output to what is required to produce it. The measure of productivity is defined as a total output per one unit of a total input.(Gundecha , 2012).

$$\textbf{Productivity} = \frac{\textbf{Output}}{\textbf{Input}} \qquad (2\text{-}1)$$

In construction, the output is usually expressed in weight, length, or volume, and the input resource is usually in cost of labor or man-hours. There are many standards available in the construction industry for contractors as reference values for purposes of construction cost estimation. These standards may vary in values but most are similar in principle. Because of the diversity of the construction industry, a single index for the entire industry is neither meaningful nor reliable. Productivity indices may be developed for major segments of the construction industry nationwide if reliable statistical data can be obtained for separate industrial segments. For this general type of productivity measure, it is more convenient to express labor productivity as constant dollars per labor hours since dollar values are more easily aggregated from a large amount of data collected from different sources. The use of constant dollars allows meaningful approximations of the changes in construction output from one year to another when price deflators are applied to current dollars to obtain the corresponding values in constant dollars. However, since most construction price deflators are obtained from a combination of price indices for material and labor inputs, they reflect only the change of price levels and do not capture any savings arising from improved labor productivity. Such deflators tend to overstate increases in construction costs over a long period of time, and consequently understate the physical volume or value of construction work in years subsequent to the base year for the indices. (Gundecha , 2012)

2.5.1 Significance of Productivity

Productivity has a great significance in construction. Labor productivity constitutes a significant part of production input for construction projects. In the construction industry, many external and internal factors are never constant and are difficult to anticipate. This factor leads to a continuous variation in labor productivity. It is necessary to make sure that a reduction in productivity does not affect the plan and schedule of the work and does not cause delays. The consequences of these delays could result in serious money losses. Further, considerable cost can be saved if productivity is improved because the same work can be done with less manpower, thus reducing overall labor cost (Thomas, 1991).

2.5.2 Labor Productivity

Productivity in construction is often broadly defined as output per labor hour. Since labor constitutes a large part of the construction cost and the quantity of labor hours in performing a task in construction is more susceptible to the influence of management than are materials or capital, this productivity measure is often referred to as *labor productivity*. However, it is important to note that labor productivity is a measure of the overall effectiveness of an operating system in utilizing labor, equipment and capital to convert labor efforts into useful output, and is not a measure of the capabilities of labor alone. For example, by investing in a piece of new equipment to perform certain tasks in construction, output may be increased for the same number of labor hours, thus resulting in higher labor productivity.

Construction output may be expressed in terms of functional units or constant dollars. In the former case, labor productivity is associated with units of product per labor hour, such as cubic yards of concrete placed per hour or miles of highway paved per hour. In the latter case, labor productivity is identified with value of construction (in constant dollars) per labor hour. The value of construction in this regard is not measured by the benefit of constructed facilities, but by construction cost. (Joun, 2010)

2.5.3 Productivity at Job Site

Contractors and owners are often concerned with the labor activity at job sites. For this purpose, it is convenient to express labor productivity as functional units per labor hour for each type of construction task. However, even for such specific purposes, different levels of measure may be used. For example, cubic yards of concrete placed per hour is a lower level of measure than miles of highway paved per hour. Lower-level measures are more useful for monitoring individual activities, while higher-level measures may be more convenient for developing industry-wide standards of performance.

In order to develop industry-wide standards of performance, there must be a general agreement on the measures to be useful for compiling data. Then, the job site productivity data collected by various contractors and owners can be correlated and analyzed to develop certain measures for each of the major segment of the construction industry. Thus, a contractor or owner can compare its performance with that of the industry average.

Job-site productivity is influenced by many factors which can be characterized either as labor characteristics, project work conditions or as non-productive activities. The labor characteristics include:

- age, skill and experience of workforce
- leadership and motivation of workforce

The project work conditions include among other factors:

- Job size and complexity.
- Job site accessibility.
- Labor availability.
- Equipment utilization.
- Contractual agreements.
- Local climate.
- Local cultural characteristics, particularly in foreign operations.

The non-productive activities associated with a project may or may not be paid by the owner, but they nevertheless take up potential labor resources which can otherwise be directed to the project. The non-productive activities include among other factors:

- Indirect labor required to maintain the progress of the project
- Rework for correcting unsatisfactory work
- Temporary work stoppage due to inclement weather or material shortage
- Time off for union activities
- Absentee time, including late start and early quits
- Non-working holidays
- Strikes

Each category of factors affects the productive labor available to a project as well as the on-site labor efficiency. (Gundecha , 2012).

2.5.4 Equipment Productivity

Once the equipment needs for an activity have been identified, the next step is to conduct an equipment productivity analysis to select the optimum size. The objective is to determine the number of units and the size of equipment that would permit the constructor to accomplish the activity with a duration resulting in the lowest cost.

Because most civil engineering construction projects are awarded based on lowest cost, it is of utmost importance to the constructor to select the proper equipment spread providing the lowest construction cost for the project. The project is segmented into various activities; therefore, the lowest cost must be determined for each activity. The selection of the appropriate type and size of construction equipment often affects the required amount of time and effort and thus the job-site productivity of a project. It is therefore important for site managers and construction planners to be familiar with the characteristics of the major types of equipment most commonly used in construction.

2.6 Construction Quality Control

Construction quality control involves testing and inspection of materials and works. The process is corruption prone because the cost of material and workmanship is substantial in construction projects. Hence, there is an incentive for unscrupulous contractors to cover up substandard materials or works through offering bribes to the site staff. Common malpractice revealed in past corruption cases includes manipulation in sampling of materials for testing, substitution of test samples, falsification of test reports, and false or selective reporting of field tests.

▪ Quality Control (QC**)** is checking for conformance materials specifications and methods of construction or workmanship.

▪ Control on the correct plan interpretation, proper engineering construction methodology, and strict compliance of the standard specifications.

▪ Includes all procedures, which are necessary to insure that the materials used, and workmanship employed conform to the standard of quality specified.

▪ Instituted during the course of construction as a preventive tool, not as a corrective measure. Preventive measures are always more economical.

▪ A technique that ensures to fulfill the requirements for quality in any operational procedures.

▪ A process that is done to eliminate causes of unsatisfactory performance of the works. (Isely,2008)

Quality is the symbol of human civilization, and with the progress of human civilization, quality control will play an incomparable role in the business. It can be said that if there is no quality control, there is no economic benefit. Construction projects are an extremely complex process, involving a wide range. There are plenty of factors affecting the quality of construction, such as design, materials, machinery, topography, geology, hydrology, meteorology, construction technology, methods of operation, technical measures, management systems, and so on. Because of the fixed project location, large volume and different location of different projects, the poor control of these factors may produce quality problems.

During controlling the whole process of construction, only accord with the required quality standards and user promising requirements, fulfilling quality, time, cost, etc., construction companies could get the best economic effects. Construction companies must adhere to the principle of quality first, and insist on quality standards, with the core of artificial control and prevention, to provide more high quality, safe, suitable, and economic composite products.

The quality of the construction process is the quality of integrated action due to human, material, machinery, process methodology and work environment, also known as process quality, which reflects the quality of products. In order to ensure the quality of construction project, the quality of each process must be controlled, which is the focus of quality control during construction.

2.6.1 Human Control

As the main activity part of production process, the overall quality and individual ability of human will determine the results of all quality activities. So, human are considered as both the controlled targets and controlling motivation of other quality activities. (Cheng Hu) The contents of human control includes the overall quality of organization and individual's knowledge, ability, physical condition, psychological state, quality consciousness, behavior, concept of organizational discipline, and professional ethics.

2.6.2 Materials Control

(Including raw materials, finished products, semi-finished products, components and parts) are material conditions of construction, and material quality is one of necessary conditions to ensure construction quality.

2.6.3 Control of Construction Machinery and Equipment

Construction machinery and equipments are essential facilities for the modern construction, reflecting the construction power of the enterprise, and having a direct impact on the project progress and quality. Actually, the quality control is to make the type and performance parameters of construction machinery and equipment match the conditions, technology and other factors of the construction site.

(1) The contractor should select construction machinery and equipment in accordance with advanced technology, economic rationality, production application, reliable performance and safety, with the applicability and reliability to a specific project.

(2) The performance parameters should be made sure correctly in accordance with the requirements of construction and quality assurance. For example, the strength of tensile force of lifting jack must be larger than the maximum tension required in the procedures.

(3) Construction machinery and equipment should be regularly calibrated, so as not to mislead the operator. Besides, mechanical equipment selected must be matched with the adapting operation workers.

2.7 Quality Documentation

The plans and contract specify the minimum requirements for the quality of materials and work to be furnished or performed under the contract. The Project Manager must assure that the materials incorporated and work performed by the Contractor is in close conformance with contract requirements.
The Project Manager must be continually observant to verify that necessary inspection, sampling, testing, and measurements are performed and inspection reports, test results, calculations, and other confirming data are prepared promptly.

The Contractor is not allowed to incorporate materials into the project without acceptable conformance documents. This condition may be temporarily waived only if the material must be installed for immediate traffic safety, but no payment will be made for the value of the materials, or the costs of incorporating them, until acceptable conformance documentation is received and/or testing is performed.

For each project, the Project Manager must become familiar with the quality compliance requirements for all of the materials that are to be incorporated into the project. The Project Manager must also assure that the Contractor is aware of quality documentation that it needs to submit or sampling and testing that it must perform. The Project Manager may provide the Contractor a copy of the Test Summary which shows the needed quality requirements.

2.7.1Total Quality Control

Quality control in construction typically involves insuring compliance with minimum standards of material and workmanship in order to insure the performance of the facility according to the design. These minimum standards are contained in the specifications described in the previous section. For the purpose of insuring compliance, random samples and statistical methods are commonly used as the basis for accepting or rejecting work completed and batches of materials. Rejection of a batch is based on non-conformance or violation of the relevant design specifications. Procedures for this quality control practice are described in the following sections.

An implicit assumption in these traditional quality control practices is the notion of an acceptable quality level which is a allowable fraction of defective items.

Materials obtained from suppliers or work performed by an organization is inspected and passed as acceptable if the estimated defective percentage is within the acceptable quality level. Problems with materials or goods are corrected after delivery of the product.

2.7.2 Quality Control by Statistical Methods

The use of statistics is essential in interpreting the results of testing on a small sample. There are two types of statistical sampling which are commonly used for the purpose of quality control in batches of work or materials (Quality Control and Safety during Construction):

(1) The acceptance or rejection of a lot is based on the number of defective (bad) or nondefective (good) items in the sample. This is referred to as sampling by attributes.

(2) Instead of using defective and nondefective classifications for an item, a quantitative quality measure or the value of a measured variable is used as a quality indicator. This testing procedure is referred to as sampling by variables.
The construction of control charts is based upon statistical principles. The charts used in this research require normal distribution of data. The centerline in Figure (2-1) could represent an estimate of the mean, standard deviation or other statistics. The curve to the left of the vertical axis should be viewed relative to the upper and lower control limits. There is very little area under the curve below the lower control limit (LCL) and above the upper control limit (UCL). This is desirable as areas under a curve for a continuous distribution represent probabilities. Since a process or a property is out of statistical control when a value is outside the control limits, quality control requires that the probability for such an event to occur is small. (Botezatu , 2006).

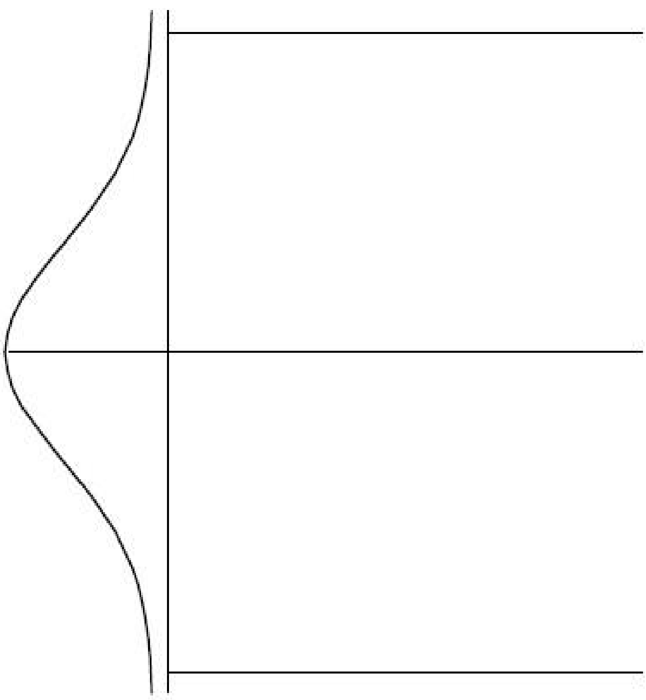

Figure 2-1: Basic Form of Control Chart (Botezatu , 2006).

2.8 Technical Change and Its Impact on Construction Productivity

Characteristics of technical change among construction equipment, materials, and information systems and among construction activities and processes have been extensively in the study. Understanding how distinct characteristics among construction equipment, materials, and information systems are related to improvements in construction labor productivity may help aid the development of future innovations. Much research is needed, however, to lead to an understanding of how technical change has improved the quality characteristics of the construction industry's output and the potential impact that this has on the industry's productivity measures. (Goodrum,2009).

2.9 Technology Impact on Construction Industry

In this research, we will see the impact of technologies on construction and contract we will see in detail how the technologies help to complete the project with low cost, avoid disputes between contractor and owner and without mistakes. Moreover, the impact of technologies on communication system will be covered in this research that will show how it's consequential effects on the successful of completing projects. Furthermore, technologies is improving day by day so the future has a lot of technologies that will play important role in advancing projects construction, contracts and the relationship between the owner and the contractor. In this research we will see how nanotechnology is one of most important future technologies and its effects on civil engineering. (al zahrany , 2011).

2.10 Leveraging Technology to Improve Construction Productivity

The research examined how historical changes in construction equipment, materials and information technologies influenced improvements in construction productivity. Historical data that were analyzed demonstrated significant improvements in labor productivity.

The improvements were primarily due to changes in the functional range of construction equipment, reductions in the unit weight of selected construction materials, and the automation and integration of project information systems. Labor productivity improvements associated with the use of these technologies ranged from 30 – 45 percent.

The field test showed that not only did improvements in material tracking improve productivity at the construction workface and the retrieval of materials in the lay down areas, but also improved the predictability and reliability that materials would be available when needed. (Research Team Construction Industry Institute (CIIR, 2008).

CHAPTER THREE

ROAD CONSTRUCTION, MATERIALS AND EQUIPMENT

3.1 Introduction

The Organization for Economic Co-operation and Development (OECD) defines a road as "a line of communication (travelled way) using a stabilized base other than rails or air strips open to public traffic, primarily for the use of road motor vehicles running on their own wheels," which includes "bridges, tunnels, supporting structures, junctions, crossings, interchanges, and toll roads, but not cycle paths. In urban areas roads may diverge through a city or village and be named as streets, serving a dual function as urban space easement and route. Modern roads are normally smoothed, paved, or otherwise prepared to allow easy travel. Historically many roads were simply recognizable routes without any formal construction or maintenance.

Road construction requires the creation of a continuous right-of-way, overcoming geographic obstacles and having grades low enough to permit vehicle or travel. And may be required to meet standards set by law or official guidelines. The process is often begun with the removal of earth and rock by digging or blasting, construction of embankments, bridges and tunnels, and removal of vegetation (this may involve deforestation) and followed by the laying of pavement material. A variety of road building equipment is employed in road building. Roads are designed and built for primary use by vehicular and pedestrian traffic. Storm drainage and environmental considerations are a major concern. Erosion and sediment controls are constructed to prevent detrimental effects. Drainage lines are laid with sealed joints in the road easement with runoff coefficients and characteristics adequate for the land zoning and storm water system. Drainage systems must be capable of carrying the ultimate design flow from the upstream catchment with approval for the outfall from the appropriate authority to a watercourse, creek, river or the sea for drainage discharge.

3.2 Pavement Types

Because of their different inherent mechanisms for carrying and distributing load, pavements are generally classified into one of three categories: flexible, rigid, and composite. Flexible pavements either have a hot-mix asphalt (HMA) surface or a bituminous surface treatment (BST). All rigid pavements have Portland cement concrete (PCC) as their surface layer, however, they differ significantly in terms of their reinforcement and joint design. The most common types of rigid pavements are jointed plain concrete pavements (JPCP), jointed reinforced concrete pavements (JRCP) and continuously reinforced concrete pavements (CRCP). Composite pavements basically refer to a combination of an HMA surface on a PCC slab. New pavements are sometimes constructed in a composite fashion; however, the term generally refers to pre-existing rigid pavements that have been overlaid with hot-mix asphalt. Each of these pavement types is unique in the way that it responds to traffic and environmental loadings.

3.2.1 Rigid Pavements

Rigid pavements consist of a PCC surface layer placed typically over some type of granular (or stabilized) base/subbase layer. The PCC surface layer is placed in a particular design configuration that is intended to match the most appropriate materials and construction practices with the prevailing traffic, environmental, and contractor experience conditions. Like flexible pavements, the rigid (PCC) pavement structure is intended to protect the underlying subgrade soil from overstress while minimizing the rate at which it deteriorates. Unlike flexible pavements, the bulk of the applied axle loads are carried by the PCC slab itself. In engineering mechanics terms, this method of load-carrying is referred to as bending and it is very similar to the way a beam or bridge carries its load. Since most of the load is carried by the PCC slab, it is difficult to justify the need for (or cost of) a base or subbase layer from a structural standpoint. However, when the effects of environment and its interaction with traffic loads are considered, the benefits of an underlying base/subbase layer are undeniable. Basically, they help maintain uniform support of the slab, 2) minimize the damaging effects of prolonged moisture exposure, and 3) serve as an additional layer of insulation against frost penetration. As with the case of flexible pavements, stabilized base courses are also used effectively to increase the load-carrying capacity of rigid pavements. Furthermore, the fact that the layer is bound means that the potential for material erosion is reduced even further, although not totally. (Huang, 2004).

3.2.2 Flexible Pavements

Flexible pavements consist of a bituminous surface course placed over a series of other structural paving layers. The flexible pavement design philosophy is twofold: to provide sufficient total pavement thickness above any given material (including the subgrade soil) to prevent permanent deformation, and to provide enough HMA surface, binder, and stabilized base thickness to limit the development of fatigue (alligator) cracking. This layered system distributes the load over the weaker materials in the lower layers of the pavement system, including the subgrade soil, Materials that are commonly used in each layer .

The specific types of materials used, their thicknesses, and their relative positions within the pavement structure have a great influence on the structural response of the pavement and, therefore, its performance.

Surface layers consisting of HMA are the most common type of pavement surface in the world. In fact, HMA is very effective in providing load-carrying capacity, resisting distortion, providing a smooth riding surface, minimizing the intrusion of moisture from the surface, resisting traffic wear and retaining its anti-skid properties. It is also comparatively economical and easy to construct. Bituminous surface treatments (BSTs) consist of one or two layers of a spray application of asphalt cement (or emulsion) followed by the embedment of a crushed rock. BSTs are effective in many of these roles; however, they provide essentially no load-carrying capacity and are more prone to moisture infiltration than HMA surfaces. The best use of BSTs has been on pavements with lower traffic volumes. Base layers generally consist of either granular or stabilized materials.

Granular base courses are essentially unbound cohesion less layers of aggregate (or crushed rock) that are uniformly graded and compacted to optimum density. Another type of improved granular base layer is one in which the gradation is modified to permit improved subsurface drainage while maintaining the intended load distribution characteristics. These permeable bases are growing in popularity, especially in areas where subsurface moisture leads to problems with reduced layer strength and asphalt stripping.

A stabilized base course refers to a layer of select aggregates that is bound together by some type of bituminous material (i.e., asphalt cement, emulsion or cutback) or cementitious material (i.e., Portland cement). The increased cost of the stabilization process is usually offset by the improved load distribution, structure capacity and moisture susceptibility characteristics. Like base layers, subbase layers consist of either granular or stabilized materials. Because they are lower in the pavement structure where the wheel load stresses are significantly reduced, the overall quality requirements (strength, gradation, compaction, aggregate soundness, etc.) are not as strict. Both granular and stabilized subbase courses perform similar functions as their base course counter parts. However, stabilized subbase materials may be bound together with lime as well as either bituminous or cementitious materials. (Huang,2004).

Table 3-1 Materials That are Commonly Used in Pavement Layers

Surface Layer	**Base Layer**	**Subbase Layer**
Hot-mix asphalt	Granular	None
Bituminous Surface Treatment	Stabilized (as phaltor cement) Stabilized	Granular (asphalt, cement, lime)

In figure 3-1, responses 1, 3, and 4 represent the vertical compressive stresses on the HMA surface, base and subgrade soil, respectively. Each of these vertical stresses can contribute to the permanent deformation of the layer(s) beneath them. If deformation exists only in the HMA surface layer, then any one or combination of the following could be the culprit:

- The HMA surface layer was overloaded.
- Loading was exerted during a hot period (when the HMA layer was "soft").
- There was a problem with the stability of mix.
- There was a problem with the temperature susceptibility of the asphalt.

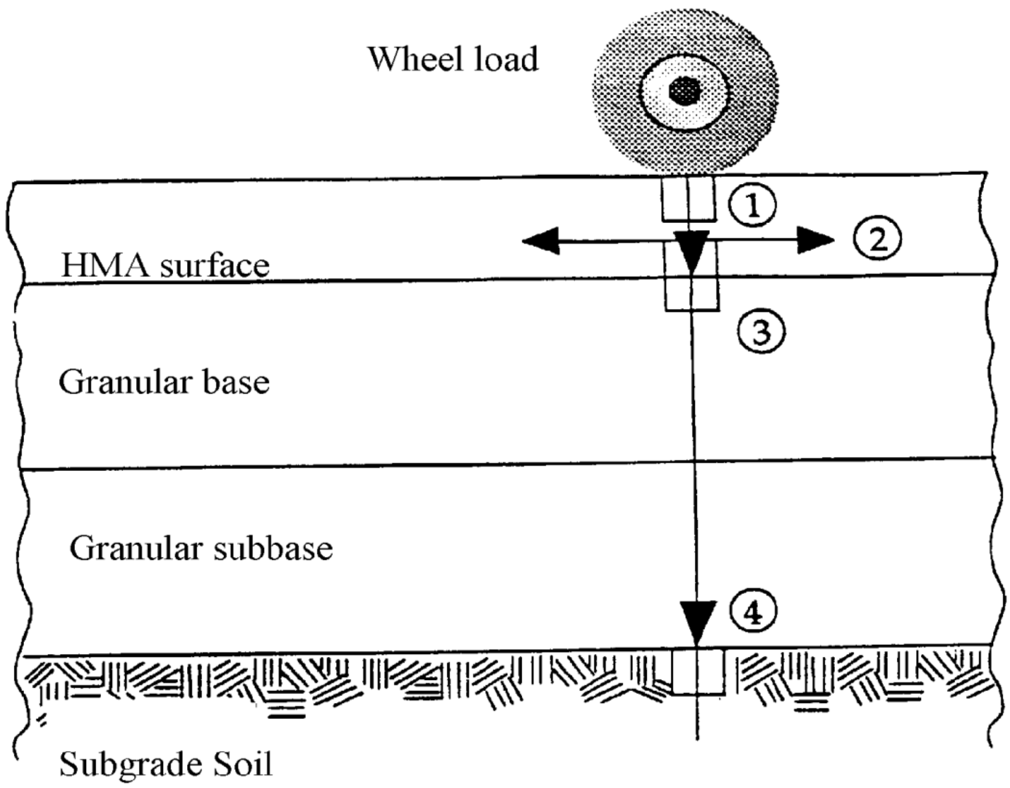

Figure 3-1: Distribution of Wheel Load (Huang,2004).

3.3 Pavement Materials

3.3.1 Stabilized Soils

To the road engineer, the definition of soil stabilization which is perhaps of most interest is that ascribed to the chairman of the American Highway Research Board in 1938: "A stabilized fill, sub-grade, road surface or road base is one that will stay put, and stabilizing is the process by which it has been made that way." Any treatment used to improve the strength of a soil by reducing its susceptibility to the influence of water and traffic is soil stabilization, whether the process is performed in situ or applied to the soil before or after it is placed in the roadway or embankment.
In practice the methods by which soils may be stabilized for highway purposes can be divided into the following main groups:

▪ **Mechanical Stabilization** is by far the most widely used method of stabilization, relies for stability on the inherent properties of the soil material. Its popularity is based on the fact that it makes possible the maximum usage of locally available materials in highway embankments, sub-bases, road bases and surface courses. If a soil cannot be made stable simply by compaction, then additional soil or other aggregate materials may be admixed to produce a mixture having the required stability characteristics.

▪ **Cement Stabilization** is a process in which cement is mixed with the soil to cause it to harden into a compact mass. A properly designed cement-stabilized soil will not soften in the presence of water and will withstand detrimental forces resulting from frost action. It is second in importance and usage after mechanical stabilization.

These is mainly helped because cement is readily available in most countries as a home product, is manufactured on such a large scale for concrete construction that its price is comparatively low, involves less care and control than many other methods of stabilization and any soil can be stabilized with Portland cement if enough cement is used in combination with the right amount of water and proper compaction. All cement-treated soil mixtures are very often and incorrectly called soil cement mixtures. In fact, there are three different types of cement-treated soil mixtures of which soil-cement is just one. The other two are termed plastic soil-cement and cement-modified soil. It is important that the engineer should distinguish between the three so that he will know how and when each may be used most advantageously.

▪ **Lime and Lime-Pozzolan Stabilization** is the methods of stabilization were the functions of the additives are twofold. They may be used to modify the soil properties-principally by chemically changing the soil gradation-or they may also cause the soil to harden into a compact mass having properties and uses similar to those of a cement-stabilized soil. Lime is most often produced by calcining lime stones, but chalk and oyster-shells are also calcined for this purpose. The limes that are produced are of two types, high-calcium or calcitic lime and dolomitic or high-magnesium lime. The difference between them is that high-calcium limes contain less than about 5 per cent magnesium oxide, while most dolomitic quicklime's contain between 25 and 45 per cent MgO. A pozzolana is a siliceous or siliceous and aluminous material which possesses little cementitious value but in the presence of moisture form compounds with cementitious properties. The pozzolanic materials can be divided into natural (materials of volcanic origin such as tuff and trass) and artificial (ground bricks, pulverized blast-furnace slag and burnt shale – but the material with the greatest possibility as a road construction material is pulverized fuel ash) pozzolanas.

▪ **Bituminous Stabilization** is the process in which bituminous materials - bitumen's or road tars - are mixed with soil to waterproof the particles and provide the additional cohesion necessary for stabilization. This method is believed to be the first modern stabilization used, but in spite of this is not very popular because there is still not enough knowledge regarding the exact influences of the many variables involved in stabilizing a soil with a bituminous material.

3.3.1.1 Soil Classification Tests (B.S.1377)

(i) In-situ Moisture Content

This test determines the moisture content of soil as percentage of its dry mass. Test should be carried out in a Laboratory.

(ii) Specific Gravity of Soil

Specific gravity of soil measures the mass of soil per unit volume.

(iii) Particle Size Distribution (By wet sieving & pipette method)

This test covers the quantitative determination of the particle size distribution in soil from the coarse sand size down to clay size.

3.3.1.2 Compaction Test - Proctor Test

This test covers the determination of the mass of dry soil per cubic meter when the soil is compacted over a range of moisture contents, giving the maximum dry density at optimum moisture content. In this test, a 2.5 kg rammer falls through a height of 300 mm giving 27 blows to each of three layers.

3.3.1.3 California Bearing Ratio (CBR) Test (ASTM D1883)

California Bearing Ratio is obtained by measuring the relationship between force and penetration when a cylindrical plunger is made to penetrate the soil at a standard rate.

3.3.2 Aggregates and Granular Materials

One definition of an aggregate is that it is a material such as broken stone, slag, gravel, sand or other like which, when held together by a binding agent, forms a substantial part of such materials as concrete, asphalt, coated macadam or like. This definition means that any hard material, whether it is natural or artificial, may be classified as an aggregate. In practice, however, the materials suitable for use as road aggregates may be limited in a particular area.

By far the majority of road aggregates are formed from natural rock. Geologists have classified rocks into three main groups, based on their method of origin; these are known as igneous, sedimentary and metamorphic rocks.
Igneous rocks were formed at or below the earth's surface by the cooling of molten material, called magma, which erupted from, or was trapped, beneath the earth's crust.
Igneous rocks formed at the earth's surface when the magma came into contact with the atmosphere are called extrusive rocks, while those formed below the earth's surface are intrusive rocks. Extrusive magma cooled rapidly at the earth's surface and as a result the rocks formed are very often glassy or vitreous (without crystals) or partly crystalline and partly vitreous. In contrast with the extrusive rocks, the intrusive rocks are entirely crystalline, having been formed as a result of the magma cooling slowly under the protective cover of the earth's crust. Igneous rocks can also be separated on the basis of their being acidic or basic depending of silica (SiO) content. In preparing bituminous mixtures, acidic aggregates can be difficult to coat with binder in contrast with the hydrophobic or “water-hating” aggregates formed from a rock such as basalt.

Sedimentary rocks were formed when the products of disintegration and/or decomposition of any type of rock were transported and redeposit, and then consolidated or cemented into a new rock type. Sedimentary rocks may be sub-divided by various means, but from the highway engineer's point of view the most convenient one is that based on the predominant rock mineral. This allows three main rock sub classifications, the calcareous, siliceous and argillaceous groups. Calcareous rocks were formed as the result of great thicknesses of the remains of small marine animals being deposited on the ocean floors. It is most suitable as an aggregate for bituminous surfacing. The predominant mineral is calcite, CaCO, and this renders the rocks basic and in general it is most suitable as an aggregate for bituminous surfacing. Some types of calcareous rocks, are however too porous to be used as road aggregates. Siliceous rocks were formed from deposits of sand and silt which became lithified as a result of pressure by overlying strata, or by the deposition of cementing material between the grains. The predominant mineral in these rocks is either quartz or chalcedony, both SiO, and this may tend to make adhesion between these aggregates and bituminous binders relatively difficult.

Aggregates can also be divided in groups like basalt, flint, gabbro, granite, grit stone, hornfels, limestone, porphyry, quartzite and schist group. Each one of these groups has a specific number of members.

The aggregates used in construction in general must be clean, hard, not due to changes under the action of weather agents, of uniform quality and free of decomposed materials, of organic matter and other harmful substances. The use of non-traditional granular materials, such as demolition products, crushed concrete, slag of steelworks, not foreseen in the project of the highway, may be approved as long as the proposal for its use is duly justified.

3.3.2.1 Aggregate Gradation

For QC/QA testing, aggregate samples are typically taken from the stockpile, cold feeder belt, hot bins (if applicable), and extracted asphalt mixture. The gradation of the aggregate from the asphalt mixture is of most importance since this is the end product; however, the aggregate gradation must be controlled at the other points to ensure that the gradation of the final product is satisfactory. Since the RAP may have a significant amount of material passing 0.075 mm (No.200) (generally referred to as the P200 fraction) sieve, the P200 in the total gradation must be monitored closely.

The aggregate and RAP stockpiles should be sampled and tested during the mix design process and approved for use. Once production begins, it is only necessary to sample new aggregate material that is added to the aggregate stockpile since the overall stockpile gradation has already been determined. The new material added to the stockpile must have the same gradation as the original stockpile, within reasonable tolerances; otherwise the gradation of the final mixture is affected. Causes in gradation variations at the stockpile include changes at source, segregation during hauling or stockpiling, and sampling and testing errors. No new RAP should be added to the RAP stockpile which was used for developing the mix design.

The second typical location for taking aggregate samples is the cold feeder belt. This belt contains the combined aggregate being fed into the HMA facility.
The third location for sampling aggregate is in the HMA batch plant hot bins (drum mix plants do not have aggregate hot bins). Causes for variability here include improper gradation fed from cold feeder, erratic feed from dust collector system, changing production rate (screening efficiency changes with production rate), blinding screens, holes in screens or bin walls, and sampling and testing errors. The hot bins, if operated correctly, will partially correct for gradation fluctuations coming into the plant.

The fourth location for determining gradation is from the produced HMA. The sample is normally taken from loaded trucks but can be taken behind the asphalt paver. This test, which is performed on the finished product, must be controlled because it is the one on which acceptance of the mixture is normally based.

Variability of gradation at this point (for a batch plant) could involve incorrect hot bin gradations, incorrect percentage of material from each hot bin, change in RAP composition, segregation of aggregate traveling through the plant or in the storage silo, and sampling and testing errors. For a drum mix plant, the causes of variability at this point include improper cold feed gradation, erratic feed from the dust collector, change in RAP composition, segregation of aggregate traveling through the plant or in the storage silo, and sampling and testing errors.
Evaluation of the gradation at several locations allows the engineer to troubleshoot the gradation problem and quickly identify the location where it is occurring. For instance, if the stockpile gradation is satisfactory but the cold feed gradation changes, then the problem areas are likely to be segregation of mixture, improper loading of cold feed bins, or sampling and testing errors.
These items can be quickly checked and modifications made to correct the problem.

Figure 3-2: Stacked Sieves used for A gradation and Size Test

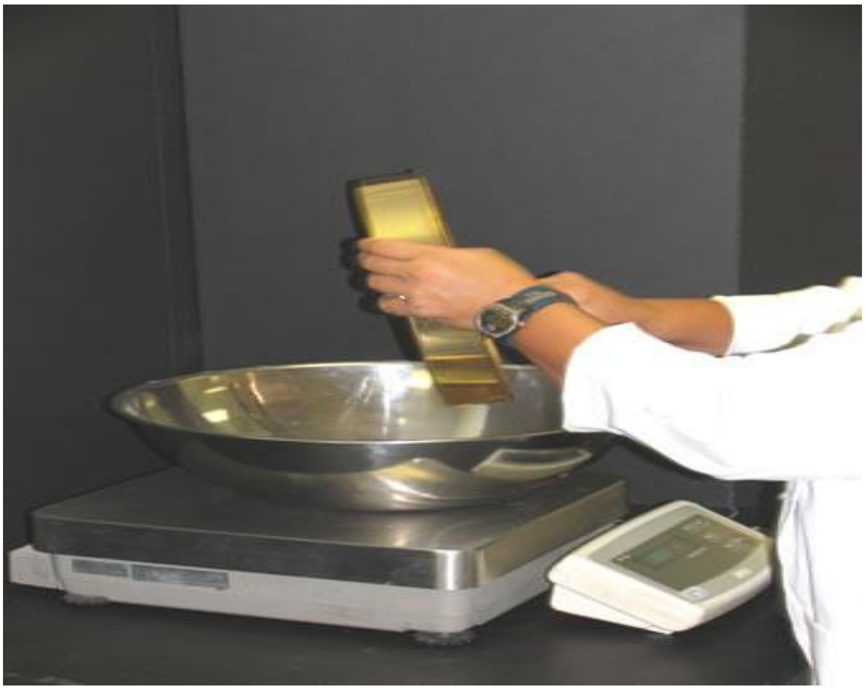

Figure 3-3: Weighing the Aggregate Retained on A sieve

3.3.2.2 Soundness Test (ASTM C88)

Test Procedure:

1- Place aggregate in solution at 70◦ F (21◦ C) for 16-18 h, covered to a depth of at least 1\2". Cover container to reduce evaporation and contamination.

2- After immersion drain for 15 minutes and dry in oven constant weight.

3- Cool and repeat step 1. Continue immersing and drying for 5 cycles.

4- Wash and dry. Make visual examination. Sieve fine aggregate on which it was retained before test: sieve coarse aggregate as follows:

Aggregate Size	Sieve used to Determine Loss
11\2" to 3|4 " (19.0 mm)	5\8" (16.0mm)
3\4" to 3|8 " (9.51mm)	5\16" (8.0mm)

3.3.2.3 Los Angeles Abrasion Test (*LAA*) (ASTM C 131)

The Los Angeles machine consists of a large cylinder made of 12mm thick steel, 508mm long by 711mm diameter (internal dimensions). Its axis of rotation is mounted horizontally within a strong support frame. An internal shelf, 90mm in depth and 25mm thick, is welded across the inside of the cylinder. The whole machine is very robust and heavy.

3.3.3Bituminous Materials and Mixtures

The most common type of flexible pavement surfacing is hot mix asphalt (HMA). Hot mix asphalt is known by many different names such as hot mix, asphalt concrete (AC or ACP), asphalt, blacktop or bitumen. HMA is distinguished by its design and production methods and includes traditional dense-graded mixes as well as stone matrix asphalt (SMA) and various open-graded HMAs. Typically agencies consider other types of asphalt-based pavement surfaces such as fog seals, slurry seals and BSTs to be maintenance treatments and are therefore covered in the Maintenance & Rehabilitation section. Reclaimed asphalt pavement (RAP) is generally considered a material within HMA, while forms of in-place recycling are considered separately.
A dense-graded mix (Figure 3.3)) is a well-graded HMA intended for general use. When properly designed and constructed, a dense-graded mix is relatively impermeable. Dense-graded mixes are generally referred to by their nominal maximum aggregate size.

They can further be classified as either fine-graded or coarse-graded. Fine-graded mixes have more fine and sand sized particles than coarse-graded mixes. They work well for structural, friction, leveling and patching needs and are suitable for all pavement layers and for all traffic conditions.

Stone matrix asphalt (SMA) (Figure 3.4)), sometimes called stone mastic asphalt, is a gap-graded HMA originally developed in Europe to maximize rutting resistance and durability. The mix goal is to create stone-on-stone contact. Since aggregates do not deform as much as asphalt binder under load, this stone-on-stone contact greatly reduces rutting. SMA is generally more expensive than a typical dense-graded HMA because it requires more durable aggregates, higher asphalt content, modified asphalt binder and fibers. In the right situations it should be cost-effective because of its increased rut resistance and improved durability. Other benefits include wet weather friction (due to a coarser surface texture), lower tire noise (due to a coarser surface texture) and less severe reflective cracking.

Figure 3-4: Bituminous Mixtures Types: Dense-Graded HMA

Figure 3-5 Bituminous Mixtures Types: SMA Surface

3.3.3.1 Asphalt Testing

Testing of the asphalt mixture during production is essential to ensure that a satisfactory product is obtained. The tests that should be performed during manufacture and placement of HMA may include aggregate gradation, asphalt content, temperature, and mixture properties of laboratory samples, theoretical maximum density, and in-place density. In a hot-mix asphalt (HMA) paving mixture, asphalt and aggregate are blended together in precise proportions. The relative proportions of these materials determine the physical properties of the mix, and ultimately, how the mix will perform as a finished pavement. When a sample of HMA is tested in the laboratory, it can be analyzed to determine its probable performance in the pavement structure; as well as, conformance with VDOT specifications. The laboratory tests used are:

1- Ignition Method of Determining Asphalt Content
2- Maximum Specific Gravity (Rice, MSG, or Gmm)
3- Bulk Specific Gravity of Mixture (Gmb)
4- Sieve Analysis
5- Tensile Strength Ratio (TSR)

These tests are used to determine the following characteristics of the mixture: Asphalt Content, Voids in Total Mix (VTM), Voids Filled with Asphalt (VFA), Voids in the Mineral Aggregate (VMA), Fines to Asphalt Ratio (F/A), Aggregate Gradation, and Stripping Potential.

• Marshall Method of mix Design

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is measured when the specimen is loaded diametrically at a deformation rate 53 of 50 mm per minute. There are two major features of the Marshall method of mix design. (i) density-voids analysis and (ii) stability-flow tests. The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60°C. The flow value is the deformation that the test specimen undergoes during loading up to the maximum load. Flow is measured in 0.25 mm units. In this test, an attempt is made to obtain optimum binder content for the type of aggregate mix used and the expected traffic intensity.

Figure 3-6 Marshall Stability & Flow Test Setup

3.4 Role of Pavement on Construction Layers

The surface layer of a pavement exposed to vehicular traffic must be tough to resist distortion and provide a smooth riding surface. It must be waterproof and transversely sloped to shed surface water to the roadside, thus protecting the entire pavement structure and the subgrade soil from the detrimental effects of moisture. It must also resist wear caused by traffic an retain its anti-skid properties. Although typically unbound, the base and subbase layers are considered structural elements of the pavement. In conjunction with the overlying surface, they distribute wheel loads over a relatively large area of the subgrade or foundation soil. A pavement "base" is defined as a support layer immediately underneath the wearing surface. The base is a deliberately constructed layer of greater strength than the natural soil. There can be more than one base course. The term "subbase" is generally used to describe the bottom-most base course. The natural soil on which the pavement is built is normally referred to as the "subgrade" or "roadbed" soil. The top six inches or so of the subgrade soil are usually compacted prior to placing the base or subbase. The subgrade soil (although not considered a structural layer of the pavement) ultimately carries all traffic loads. Thus, the function of a pavement structure is to support a wheel load on the pavement surface and to spread or distribute the load to the subgrade soil without overtaxing its strength or that of various overlying pavement layers.

Unbound (unstabilized) aggregate bases and subbases are permeable pavement layers that will allow subsurface and/or surface moisture to enter the structure. This leads to wetter (weaker) materials and the possibility of soil particles infiltrating the base ad subbase layers, thereby reducing their long-term strength. If water enters the base/subbase layers and cannot drain away, severe hydrostatic pressures from wheel loads can develop. These pressures lead to undue stress on all pavement and soil layers and in flexible pavements, can result in alligator cracking, rutting and potholes. In rigid pavements, it can result in pumping, the development of voids beneath the slab and, of course, severe cracking and slab breakup. Asphalt and other treated (stabilized) bases are not as affected by moisture as unbound aggregate bases. They are stiffer and have increased capacity for spreading loads and reducing the compression stress on the natural soil; thus, less total pavement thickness is required. However, some HMA mixes may be moisture sensitive and which over time can reduce their capacity for spreading loads, as designed.

3.5 Factors Affecting Pavement Performance

A significant advance in highway engineering is the realization and demonstration that the problems of the structural design of pavements are similar to the problems of designing other complex engineering structures. When pavements were first introduced, the proper thickness was determined by guesswork, rule of thumb and/or opinion based on experience. Almost the same situation once prevailed in determining the dimensions of masonry arches and iron and steel structures. Those early techniques have long since yielded to more fundamental engineering analyses and, similarly, the structural design of pavements has evolved into more reliable engineering-based procedures. The factors that affect pavement performance should be clearly understood when designing or evaluating pavements, these factors can be classified under the following seven categories:

• Traffic loadings.
• Subgrade soil support.
• Materials of construction.
• Structural characteristics.
• Construction and maintenance variation.
• Moisture.
• Maintenance and rehabilitation programs.

3.6 Recycled Asphalt Pavement (RAP)

Recycling is one of the several alternatives available for rehabilitation of pavements. Other methods include overlay and complete removal and replacement. Recycling is increasingly being used because of the following advantages: (a) reduced cost of construction, (b) conservation of aggregate and binders, (c) preservation of existing pavement geometrics, (d) preservation of environment, and (e) conservation of energy. Different recycling techniques are available to address specific pavement distress and/or pavement structural requirements. The four primary recycling methods most commonly used are hot mix recycling, hot in-place recycling, cold in-place recycling, and full depth reclamation. The choice of a particular technique depends on engineering considerations (such as pavement distress and structural strength), availability of necessary equipment, availability of experienced contractor, initial cost, construction impact on traffic, and long term maintenance costs.(FHWA ,2009).

Recycling or reuse of pavement material is a very simple but powerful concept. Recycling of existing pavement materials to produce new pavement materials results in considerable savings of material, money, and energy. At the same time, recycling of existing material also helps to solve disposal problems. Because of the reuse of existing material, pavement geometrics and thickness can also be maintained during construction. In some cases, traffic disruption is less than that for other rehabilitation techniques. The specific benefits of recycling can be summarized as follows:

1. Reduced costs of construction.
2. Conservation of aggregate and binders.
3. Preservation of the existing pavement geometrics.
4. Preservation of the environment.
5. Conservation of energy.
6. Less user delay.

Several studies have shown that it costs highway agencies less if the pavements are kept at a certain acceptable level of serviceability. According to World Bank Sources, (5) each $1.00 spent during the first 40 percent drop in quality will cost $4.00 to $5.00 if delayed until the pavement loses 80 percent of its original quality (figure 3-3).

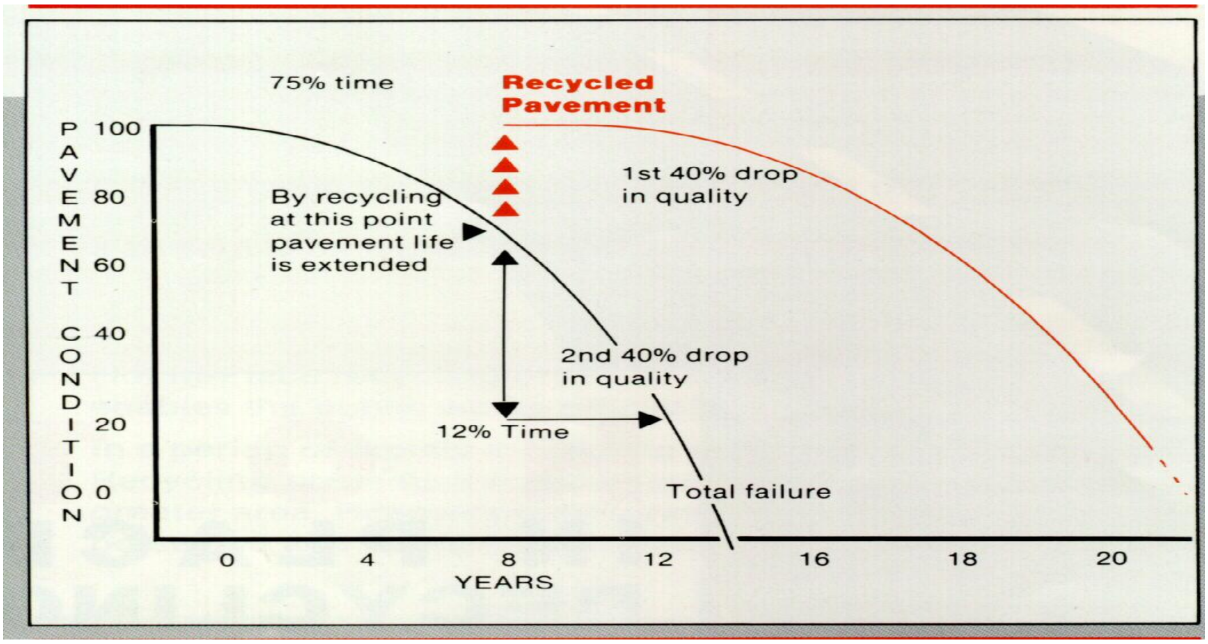

Figure 3-7: Plot of Pavement Condition Versus Time. (FHWA ,1993).

• Recycling Methods and Process

The Asphalt Recycling and Reclaiming Association define four different types of recycling methods: (1) hot recycling; (2) hot in-place recycling; (3) cold in-place recycling; and (4) full depth reclamation.

1- Hot mix asphalt recycling

Hot mix asphalt recycling is the process in which reclaimed asphalt pavement (RAP) materials are combined with new materials, sometimes along with a recycling agent, to produce hot mix asphalt (HMA) mixtures. Both batch and

drum type hot mix plants are used to produce recycled mix. The RAP material can be obtained by milling or ripping and crushing operation.
The mix placement and compaction equipment and procedures are the same as for regular HMA. Typically, 10 to 30 percent RAP is used in recycled hot mixes. Figure 3-4 shows introduction of RAP material in a drum plant. The advantages of hot mix recycling include equal or better performance compared to conventional HMA, and capability to correct most surface defects, deformation, and cracking.

Figure 3-8: Hot in-place Recycling Operation with Application of Overlay (Repaving).

2- Hot in-place recycling (HIR)

HIR consists of a method in which the existing pavement is heated and softened, and then scarified/milled to a specified depth. New HMA (with/without RAP) and/or recycling agent may be added to the scarified RAP material during the recycling process. HIR can be performed either as a single pass or as a multiple pass operation. In single pass operation, the scarified in-place material can be combined with new material if needed or desired. In multiple pass operation, the restored RAP material is recompacted first.

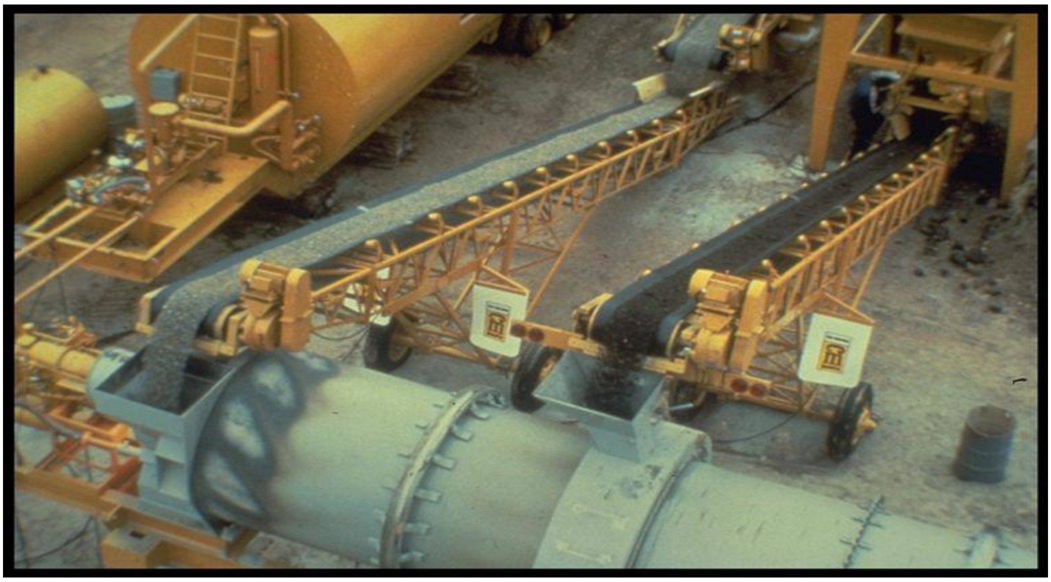

Figure 3-9: Introduction of RAP Material in A drum Plant.

3- Cold In-Place Recycling (CIR)

CIR involves reuse of the existing pavement material without the application of heat. Except for any recycling agent, no transportation of materials is usually required, and aggregate can be added, therefore hauling cost is very low. Normally, an asphalt emulsion is added as a recycling agent or binder. The emulsion is proportioned as a percentage by weight of the RAP. Fly ash or cement or quicklime may also be added. These additives are effective for over asphalted and low stability mixes. The process includes pulverizing the existing pavement, sizing of the RAP, application of recycling agent, placement, and compaction. The use of a recycling train, which consists of pulverizing, screening, crushing and mixing units, is quite common. The processed material is deposited in a windrow from the mixing device, where it is picked up, placed, and compacted with conventional hot mix asphalt laydown and rolling equipment. The depth of treatment is typically from 75 to 100 mm (3 to 4 in). The advantages of cold in-place recycling include significant structural treatment of most pavement distress, improvement of ride quality minimum hauling and air quality problems, and capability of pavement widening. Figure 3-6 shows a typical CIR operation with a milling machine, a crusher and screening plant, and a mix-paver. (Federal Highway Administration, 1993).

Figure 3-10: Cold In-Place Recycling

4- Full Depth Reclamation (FDR)

FDR has been defined as a recycling method where all of the asphalt pavement section and a predetermined amount of underlying base material is treated to produce a stabilized base course. It is basically a cold mix recycling process in which different types of additives such as asphalt emulsions and chemical agents such as calcium chloride, Portland cement, fly ash, and lime, are added to obtain an improved base. The four main steps in this process are pulverization, introduction of additive, compaction, and application of a surface or a wearing course. If the in-place material is not sufficient to provide the desired depth of the treated base, new materials may be imported and included in the processing. New aggregates can also be added to the in-place material to obtain a particular gradation of material. This method of recycling is normally performed to a depth of 100 mm to 300 mm (4 to 12 in).

The train consists of recycling machine hooked to a water tanker and steel drum roller with pad foot shell. The advantages of full depth reclamation are that most pavement distresses are treated, hauling costs are minimized, significant structural improvements can be made (especially in base), material disposal problems are eliminated, and ride quality is improved.(ARRA, 1996).

3.7 Material and Equipment Utilization

Good project management in construction must vigorously pursue the efficient utilization of labor, material and equipment. Improvement of labor productivity should be a major and continual concern of those who are responsible for cost control of constructed facilities. Material handling, which includes procurement, inventory, shop fabrication and field servicing, requires special attention for cost reduction. The use of new equipment and innovative methods has made possible wholesale changes in construction technologies in recent decades. Organizations which do not recognize the impact of various innovations and have not adapted to changing environments have justifiably been forced out of the mainstream of construction activities.

3.8 Road Construction Equipment

It is important for design engineers and construction engineers to be knowledgeable about construction equipment. Construction equipment is an integral part of the construction process. The cost of construction is a function of the design of the construction operation. Typically, construction equipment is used to perform essentially repetitive operations, and can be broadly classified according to two basic functions: (1) operators such as cranes, graders, etc. which stay within the confines of the construction site, and (2) haulers such as dump trucks, ready mixed concrete truck, etc. which transport materials to and from the site. In both cases, the cycle of a piece of equipment is a sequence of tasks which is repeated to produce a unit of output. For example, the sequence of tasks for a crane might be to fit and install a wall panel (or a package of eight wall panels) on the side of a building; similarly, the sequence of tasks of a ready mixed concrete truck might be to load, haul and unload two cubic yards (or one truck load) of fresh concrete.

In order to increase job-site productivity, it is beneficial to select equipment with proper characteristics and a size most suitable for the work conditions at a construction site. In excavation for building construction, for examples, factors that could affect the selection of excavators include:

1. **Size of the job:** Larger volumes of excavation will require larger excavators, or smaller excavators in greater number.
2. **Activity time constraints:** Shortage of time for excavation may force contractors to increase the size or numbers of equipment for activities related to excavation.
3. **Availability of equipment:** Productivity of excavation activities will diminish if the equipment used to perform them is available but not the most adequate.

4. **Cost of transportation of equipment:** This cost depends on the size of the job, the distance of transportation, and the means of transportation.
5. **Type of excavation:** Principal types of excavation in building projects are cut and/or fill, excavation massive, and excavation for the elements of foundation. The most adequate equipment to perform one of these activities is not the most adequate to perform the others.
6. **Soil characteristics:** The type and condition of the soil is important when choosing the most adequate equipment since each piece of equipment has different outputs for different soils. Moreover, one excavation pit could have different soils at different stratums.
7. **Geometric characteristics of elements to be excavated:** Functional characteristics of different types of equipment make such considerations necessary.
8. **Space constraints:** The performance of equipment is influenced by the spatial limitations for the movement of excavators.
9. **Characteristics of haul units:** The size of an excavator will depend on the haul units if there is a constraint on the size and/or number of these units.
10. **Location of dumping areas:** The distance between the construction site and dumping areas could be relevant not only for selecting the type and number of haulers, but also the type of excavators.
11. **Weather and temperature:** Rain, snow and severe temperature conditions affect the job-site productivity of labor and equipment. (

3.8.1 General Equipment Considerations

The method and equipment used in road construction is an important economic and design factor in road location and subsequent design. A road to be built by an operator whose only equipment is a bulldozer requires a different design than a road to be built by a contractor equipped with hydraulic excavator, scrapers, and bulldozer.

3.8.2 Automation of Equipment

The introduction of new mechanized equipment in construction has had a profound effect on the cost and productivity of construction as well as the methods used for construction itself. An exciting example of innovation in this regard is the introduction of computer microprocessors on tools and equipment. As a result, the performance and activity of equipment can be continually monitored and adjusted for improvement. In many cases, automation of at least part of the construction process is possible and desirable. For example, wrenches that automatically monitor the elongation of bolts and the applied torque can be programmed to achieve the best bolt tightness. On grading projects, laser controlled scrapers can produce desired cuts faster and more precisely than wholly manual methods.

3.8.3 Equipment Cost

The cost of the project must include the cost of equipment needed to build the project. The constructor must be able to determine, as accurately as possible, the duration of each piece of equipment required for each activity of the project. He or she must then be able to apply cost factors to this time commitment.
The cost factor should represent the actual equipment cost experienced by the constructor. If the cost is too low, the equipment will not pay for itself. If the rate is too high, it may result in not being competitive. To know the true equipment cost requires accurate record keeping. The constructor can lease equipment or purchase equipment. If equipment is leased, determining equipment cost is straightforward, because the rental rate will be established. If the equipment is to be purchased, the anticipated owning and operating (O&O) cost will need to be determined.
Associated Equipment Distributors publishes an annual compilation of nationally averaged rental rates for construction equipment. The following need to be taken into consideration when considering the leasing option:

1- Time Basis of the Rates Quoted: It is common practice in the industry to base rates on one shift of 8 h/d, 40 h/week, or 176 hr/month. If these hours are exceeded, an extra fee can be charged.

2- Cost of Repairs: The lessor usually bears the cost of repairs due to normal wear and tear, and the lessee bears all other costs. Normal wear and tear would be expected to result from the use of the equipment under normal circumstances. This can lead to disputes, because in many cases, normal wear and tear is difficult to distinguish.

3- Operator: Unless specifically stated otherwise, the operator is not included in the rental rates.

4- Fuel and Lubricants: Unless specifically stated otherwise, the lessee is responsible for the cost of fuel, lubricants, and all preventive maintenance work while the equipment is being rented.

5- Condition of Equipment: It is standard practice for the equipment to be delivered to the lessee in good operational condition and to be returned to the lessor in the same condition less normal wear and tear.

6- Freight Charges: Unless specifically stated otherwise, the rental rates are f.o.b. the lessor's shipping point.

7- Payment and Taxes: Normally, rental rates are payable in advance, and no license, sale, or use taxes are included in the rates.

8- Insurance: It is standard practice for the lessee to furnish the lessor a certificate of insurance prior to equipment delivery.

3.8.4 Preventive Maintenance for Equipment

Preventive maintenance (PM) is necessary for sound equipment management and protection of a company's assets. Minimum corporate PM standards should be established. Specific maintenance procedures should be available from the equipment department on most major pieces of equipment. If specific standards are not available, the manufacturer's minimum maintenance recommendations need to be used. A functioning PM program will comprise the following:

1- The PM program will be written and have specific responsibilities assigned. Company, division, and/or area managers will have the responsibility of seeing that the program works as designed.

2- Periodic service and inspections on all equipment in operation will be performed, documented, and reported (in writing). Each division/area will implement the service and inspection using the equipment manufacturers' recommendations as guidelines. For major pieces of equipment, this will be defined by the equipment department.

3- A systematic method of scheduling and performing equipment repairs will be implemented.

4- A fluid analysis program with regular sampling (including, but not limited to, testing for aluminum, chromium, copper, iron, sodium, silicon, plus water and fuel dilution) will be implemented.

5- All necessary permits will be acquired.

6- Federal, state, and local laws that affect the trucking industry will be followed.

3.9 Major Types of Road Construction Equipment

The selection of the appropriate type and size of construction equipment often affects the required amount of time and effort and thus the job-site productivity of a project. It is therefore important for site managers and construction planners to be familiar with the characteristics of the major types of equipment most commonly used in construction.

3.9.1 Dump Truck

Dump trucks or production trucks are those that are used for transporting loose material such as sand, dirt, and gravel for construction. The typical dump truck is equipped with a hydraulically operated open box bed hinged at the rear, with the front being able to be lifted up to allow the contents to fall out on the ground at the site of delivery. Dump trucks come in many different configurations with each one specified to accomplish a specific task in the construction chain.

3.9.2 Standard Dump Truck

The standard dump truck is a full truck chassis with the dump body mounted onto the frame. The dump body is raised by a hydraulic ram lift that is mounted forward of the front bulkhead, normally between the truck cab and the dump body. The standard dump truck also has one front axle, and one or more rear axles which normally have dual wheels on each side. The common configurations for standard dump trucks include the six wheeler and ten wheeler.

3.9.3 Transfer Dump Truck

For the amount of noise made when transferring, the transfer dump truck is easy to recognize. It’s a standard dump truck that pulls a separate trailer which can be loaded with sand, asphalt, gravel, dirt, etc. The B box or aggregate container on the trailer is powered by an electric motor and rides on wheels and rolls off of the trailer and into the main dump box. The biggest advantage with this configuration is to maximize payload capacity without having to sacrifice the maneuverability of the short and nimble dump truck standards.

3.9.4 Semi Trailer end Dump Truck

The semi end dump truck is a tractor trailer combination where the trailer itself contains the hydraulic hoist. The average semi end dump truck has a 3 axle tractor that pulls a 2 axle semi trailer. The advantage to having a semi end dump truck is rapid unloading.

3.9.5 Semi Trailer Bottom Dump Truck

A bottom dump truck is a 3 axle tractor that pulls a 2 axle trailer with a clam shell type dump gate in the belly of the trailer. The biggest advantage of a semi bottom dump truck is the ability to lay material in a wind row. This type of truck is also maneuverable in reverse as well, unlike the double and triple trailer configurations.

3.9.6 Double and Triple Trailer

The double and triple bottom dump trucks consist of a 2 axle tractor pulling a semi axle semi trailer and an additional trailer. These types of dump trucks allow the driver to lay material in wind rows without having to leave the cab or stop the truck. The biggest disadvantage is the difficulty in going in reverse.

3.9.7 Side Dump Trucks

Side dump trucks consist of a 3 axle trailer pulling a 2 axle semi trailer. It offers hydraulic rams that tilt the dump body onto the side, which spills the material to the left or right side of the trailer. The biggest advantages with these types of dump trucks are that they allow rapid unloading and carry more weight than other dump trucks.
In addition to this, side dump trucks are almost impossible to tip over while dumping, unlike the semi end dump trucks which are very prone to being upset or tipped over. The lengths of these trucks impede maneuverability and limit versatility.

3.9.8 Compaction and Grading Equipment

The function of compaction equipment is to produce higher density in soil mechanically. The basic forces used in compaction are static weight, kneading, impact and vibration. The degree of compaction that may be achieved depends on the properties of soil, its moisture content, the thickness of the soil layer for compaction and the method of compaction. Some major types of compaction equipment are includes rollers with different operating characteristics. The function of grading equipment is to bring the earthwork to the desired shape and elevation. Major types of grading equipment include motor graders and grade trimmers. The former is an all-purpose machine for grading and surface finishing, while the latter is used for heavy construction because of its higher operating speed.

3.9.9 Drilling and Blasting Equipment

Rock excavation is an audacious task requiring special equipment and methods. The degree of difficulty depends on physical characteristics of the rock type to be excavated, such as grain size, planes of weakness, weathering, brittleness and hardness. The task of rock excavation includes loosening, loading, hauling and compacting. The loosening operation is specialized for rock excavation and is performed by drilling, blasting or ripping. Major types of drilling equipment are percussion drills, rotary drills, and rotary-percussion drills. A percussion drill penetrates and cuts rock by impact while it rotates without cutting on the upstroke. Common types of percussion drills include a jackhammer which is hand-held and others which are mounted on a fixed frame or on a wagon or crawl for mobility. A rotary drill cuts by turning a bit against the rock surface.

3.9.10 Mixing and Paving Equipment

Basic types of equipment for paving include machines for dispensing concrete and bituminous materials for pavement surfaces. Concrete mixers may also be used to mix Portland cement, sand, gravel and water in batches for other types of construction other than paving. A truck mixer refers to a concrete mixer mounted on a truck which is capable of transporting ready mixed concrete from a central batch plant to construction sites. A paving mixer is a self propelled concrete mixer equipped with a boom and a bucket to place concrete at any desired point within a roadway. It can be used as a stationary mixer or used to supply slip form pavers that are capable of spreading, consolidating and finishing a concrete slab without the use of forms. A bituminous distributor is a truck-mounted plant for generating liquid bituminous materials and applying them to road surfaces through a spray bar connected to the end of the truck. Bituminous materials include both asphalt and tar which have similar properties except that tar is not soluble in petroleum products. While asphalt is most frequently used for road surfacing, tar is used when the pavement is likely to be heavily exposed to petroleum spills.

3.9.11 Cement Concrete Paver Machine

These offered construction equipment is made up of premium quality raw material and advanced technology. Moreover, the offered products are fabricated in compliance with the laid down quality benchmarks, which ensures high standards of the same. These products are widely appreciated for their striking features such as:

1- Low wear rate
2- Durability

3- Resistance against corrosion
4-Sturdy construction
5- Precision designs

3.9.12 Concrete Paver Machine

The offered products are fabricated using high-grade raw material to comply the set quality standards. We have made these machines available in different specifications to cater to the diverse demands of the clients. Our clients can also avail complete customized range, as per their specifications. The offered products can be efficiently used to cater to the variegated demands of construction sector. These Concrete Paver Machines are hugely used to owing to their attributes such as:

- Compact design
- Easy to handle
- Less space requirement
- Low wear rate
- Durability
- Resistance against corrosion
- Sturdy designs

3.9.13 Front Loader

Also known as a front end loader, bucket loader, scoop loader, or shovel, the front loader is a type of tractor that is normally wheeled and uses a wide square tilting bucket on the end of movable arms to lift and move material around. The loader assembly may be a removable attachment or permanently mounted on the vehicle. Often times, the bucket can be replaced with other devices or tools, such as forks or a hydraulically operated bucket.

Larger style front loaders, such as the Caterpillar 950G or the Volvo L120E, normally have only a front bucket and are known as front loaders, where the small front loaders are often times equipped with a small backhoe as well and called backhoe loaders or loader backhoes. Loaders are primarily used for loading materials into trucks, laying pipe, clearing rubble, and also digging. Loaders aren’t the most efficient machines for digging, as they can’t dig very deep below the level of their wheels, like the backhoe can.

The deep bucket on the front loader can normally store around 3 – 6 cubic meters of dirt, as the bucket capacity of the loader is much bigger than the bucket capacity of a backhoe loader. Loaders aren’t classified as excavating machinery, as their primary purpose is other than moving dirt. In construction areas, mainly when fixing roads in the middle of the city, front loaders are used to transport building materials such as pipe, bricks, metal bars, and digging tools. Front loaders are also very useful for snow removal as well, as you can use their bucket or as a snow plow. They can clear snow from the streets and highways, even parking lots. They will sometimes load the snow into dump trucks which will then haul it away.

By comparing various types of machines for excavation, for example, power shovels are generally found to be the most suitable for excavating from a level surface and for attacking an existing digging surface or one created by the power shovel; furthermore, they have the capability of placing the excavated material directly onto the haulers. Another alternative is to use bulldozers for excavation.

The choice of the type and size of haulers is based on the consideration that the number of haulers selected must be capable of disposing of the excavated materials expeditiously. Factors which affect this selection include:

1. **Output of excavators:** The size and characteristics of the excavators selected will determine the output volume excavated per day.
2. **Distance to dump site:** Sometimes part of the excavated materials may be piled up in a corner at the job-site for use as backfill.
3. **Probable average speed:** The average speed of the haulers to and from the dumping site will determine the cycle time for each hauling trip.
4. **Volume of excavated materials:** The volume of excavated materials including the part to be piled up should be hauled away as soon as possible.
5. **Spatial and weight constraints:** The size and weight of the haulers must be feasible at the job site and over the route from the construction site to the dumping area.

3.9.14 Hydraulic Excavator

The hydraulic excavator is a relatively new technology in forest road construction. This machine basically operates by digging, swinging and depositing material. Since the material is placed, as opposed to pushed and/or side cast, excellent control is achieved in the placement of the excavated soil. This feature becomes more important as the side slope increases. Fill slope lengths can be shortened through the possibility of constructing a catch wall of boulders along the toe of the fill. This feature is particularly important when side slopes increase to over 40 percent.

Production rates for hydraulic excavators are given in Table 3-2. Production rates are shown for three different side slope classes. The values given are for a medium sized excavator with a 100 kW power rating (e.g., CAT 225, Liebherr 922).

Table 3-2Production rates for hydraulic excavators in relation to side slopes, constructing a 6 to 7 m wide subgrade.

Side slope %	**Production rate** meter / ...hour
0 - 40	12 – 16
40 - 60	10 – 13
> 60	8 – 10

The excavator production rate approaches the dozer production rate as side slope increases. There are now indications that excavator production rates are higher than dozer production rates on slopes steeper than 50 percent. This difference will increase with increased rock in the excavated material. The bucket of the excavator is much more effective at ripping than the dozer blade. Excavators are also more effective at ditching and installing culverts.

3.9.15 Bulldozer

Probably the most common piece of equipment in forest road construction is the bulldozer equipped with straight or U-type blades. These are probably the most economical pieces of equipment when material has to be moved a short distance. The economic haul or push distance for a bulldozer with a straight blade is from 17 to 90 meters depending on grade. The road design should attempt to keep the mass balance points within these constraints.

The road design should consider the following points when bulldozers are to be used for road construction.

1. Roads should be full benched. Earth is side cast and then wasted rather than used to build up side cast fills.
2. Earth is moved down-grade with the aid of gravity, not up-grade.
3. Fill material is borrowed rather than pushed or hauled farther than the economic limit of the bulldozer.
4. Rock outcrops should be bypassed. Unless substantial rock blasting is specified requiring drilling and blasting equipment, solid rock faces should be avoided (This, however, is primarily a road locator's responsibility.)

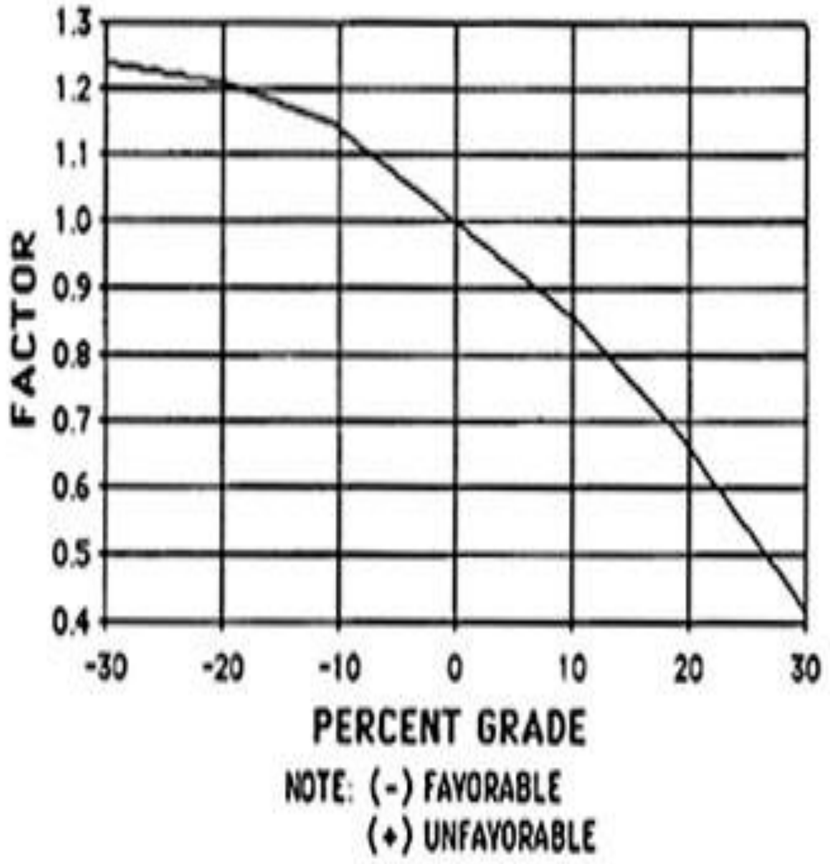

Figure 3-11. Adjustment factors for bulldozer production rates in relation to grade. (Caterpillar Performance Handbook, 1984).

When using bulldozers, the practice of balancing cut and fill sections should be used only when:

- Side slopes do not exceed 45 to 55 percent
- Proper compaction equipment is available such as a "grid roller" or vibrating or tamping roller.

3.10 Latest Advanced Equipment Used in Road Construction

3.10.1 CBR-Test 50 Machine, ASTM D1883

This bench mounting machine comprises a twin column frame incorporating a motorized drive system. Two speeds are provided, 1.0 mm/min for BS and 1.27 mm/min for ASTM tests. Rapid adjustment of the platen is provided which enables daylight to be taken up quickly and also close control of application of a seating load.

Figure 3-12: EL24-9150 series CBR-Test 50 with Accessories

3.10.2 Multispeed 50 kN cap.ty Compression Tester

- High stiffness two column frame with load capacity up to 50 kN
- Load application moving the lower beam against the fixed upper beam
- Accurate load measurement with 250N load cell
- Accurate measurement of lower beam position with linear potentiometric displacement transducer 50 mm stroke
- Test speed from 0.1 mm/min up to 51 mm/min (test speed according EN12002 is 2mm/min)
- Horizontal span: 380 mm
- Max vertical span without testing jig: 800 mm
- Power rating 1100 W
- Net weight: 120 kg
- Dimensions (l x w x h): 500 x 570 x 1300 mm

Figure 3-13: Front View of the Complete System

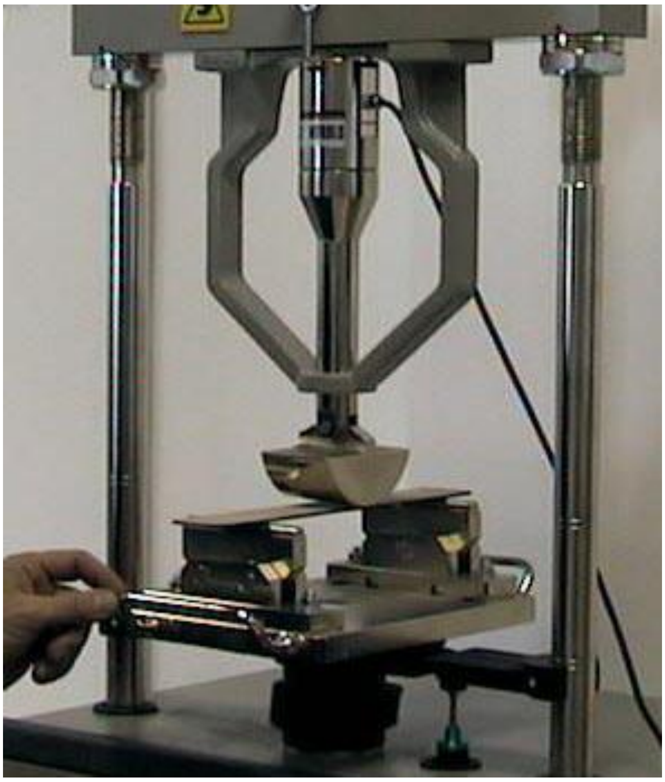

Figure 3-14: Detail of Sample During Test Execution.

3.10.3 Dynamic Test of Soil Machine

Building and road Research Institute, work several tests to determine the validity of the material used for paving roads using modern and high quality equipment to keep pace with global progress in the field of road engineering .
Building Research and Road Institute - University of Khartoum, was acquired via a proxy Kintrawles Italian Sudan (Anterbor) device tests dynamics of soil and materials, paving roads and airports at a cost of about $ 100,000 a talk which is controlled via software device and the first of its kind in the Sudanese universities can engineers and researchers to conduct Test pressure the central trio of soil dynamic test tonnage and also refer flex modulus (Resilient Modulus) of the soil and road paving materials using the results of these tests for the design of foundations prone to seismic vibration loads and pavement flexible ways by global design and normative ways. The expert engineer from the company attended to install and test the machine and training of cadres to use it. (Figure 3-15). (BRRT, 2014).

Figure 3-15: Dynamic Tests of Soil

3.10.4 Micro Paver Program for Pavement Maintenance Management Systems Program (PMMS)

Pavements represent a huge investment and it is very important to protect them. Initiating a PMMS can be the base to help in protecting these pavements. With this tool, decision-makers can act to preserve these road assets.
A pavement maintenance management system can be defined as a systematic methodology to assist in making decisions to provide, evaluate and maintain pavements in an acceptable condition. Its objective is to facilitate the coordination of activities and assess the consequences of decisions in a consistent manner, in order to preserve pavements in the best possible condition with available funds.
Pavement maintenance management system is also a scientific tool for managing the pavements so as to make the best possible use of resources available or to maximize the benefit for society.
Thus, PMMS can be used in directing and controlling maintenance resources for optimum benefits. (V. K, 1995).

3.10.5 Advanced Paver Machine

Tiger-Stone is A Dutch paver laying machine that can produce brick roads. Paving bricks are put onto the angled plain. As the electric crawler moves forward along a sand base layer, all the stones are packed together by gravity.

Figure 3-16: Tiger-Stone Machine

3.10.6 Screening and Mixing Machine

Backers have developed universal screening and mixing machinery for specific application in road construction and civil engineering. They perfectly combine modern screening and mixing technology in one machine and offer the user greatest possible flexibility. Backers' screening and mixing machinery is ideally suitable for reprocessing unusable soils, soil stabilization, earth recycling or liquid soil production.

Figure 3-17: Star Screen and Mixing Machine in Soil Stabilization

CHAPTER FOUR

QUESTIONNAIRE DATA AND RESULTS

4-1 Introduction

The field of statistical quality control can be broadly defined as those statistical and engineering methods that are used in measuring, monitoring, controlling, and improving quality.
Statistical methods play a vital role in quality improvement. Some applications are outlined below:

1. In product design and development, statistical methods, including designed experiments, can be used to compare different materials, components, or ingredients, and to help determine both system and component tolerances. This application can significantly lower development costs and reduce development time.

2. Statistical methods can be used to determine the capability of a manufacturing process. Statistical process control can be used to systematically improve a process by reducing variability.

3. Experimental design methods can be used to investigate improvements in the process. These improvements can lead to higher yields and lower manufacturing costs.

4. Life testing provides reliability and other performance data about the product. This can lead to new and improved designs and products that have longer useful lives and lower operating and maintenance costs.

4.2 Method of preparation of the questionnaire

The questions in the questionnaire was divided into two parts, the first part relates to general characteristics of the company such as experience and type of activity, while the second part deals with questions about the technical and technological aspects in road construction .The main part was to identify research community contractors and consultants working in road construction field.

4.3Research Community

Were identified research community contractors and consultants working in the road construction companies.

The sample:

40 sample were distributed a questionnaire on the roads companies but has been answered 36 of them.

The questionnaire was analysed by using Statistical Package for Social Science program (SPSS).

4-4 Questionnaire Results and Discussion

Was shown and analyze data using statistical SPSS program and the results were as follows:

Table 4-1 and Fig 4-1 show the experience in years of companies indicating that 61.1% of the companies had more than 10 years experience while the percentage of companies with experience less than 10 years was 38.9% reflecting a ratio of about two to one respectively, therefore most of the companies it is experience more than 10 years.

Table (4-1): Company Experience

Valid	Frequency	Percent%
Less than 10 years	14	38.9
10 years or more	22	61.1
Total	36	100.0

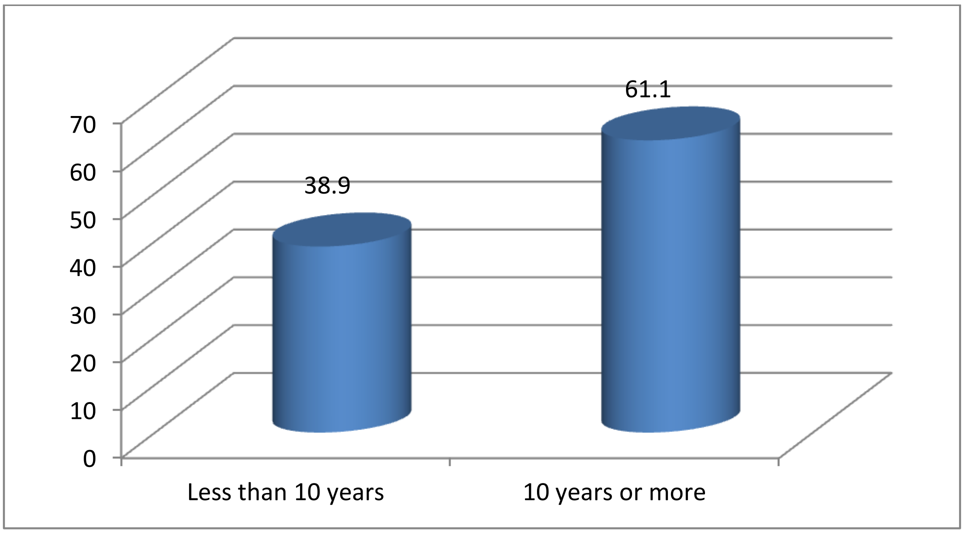

Figure 4-1: Company Experience

Table 4-2 and Fig 4-2 show nationality of the labors in companies, and the result explain that about eighty one are Sudanese labors while 19.4%, are Sudanese &foreign labors .therefore the most companies have Sudanese labors.

Table 4-2: Nationality of Staff and Workers

Valid	Frequency	Percent%
Sudanese	29	80.6
Foreign	0	0
Both	7	19.4
Total	36	100.0

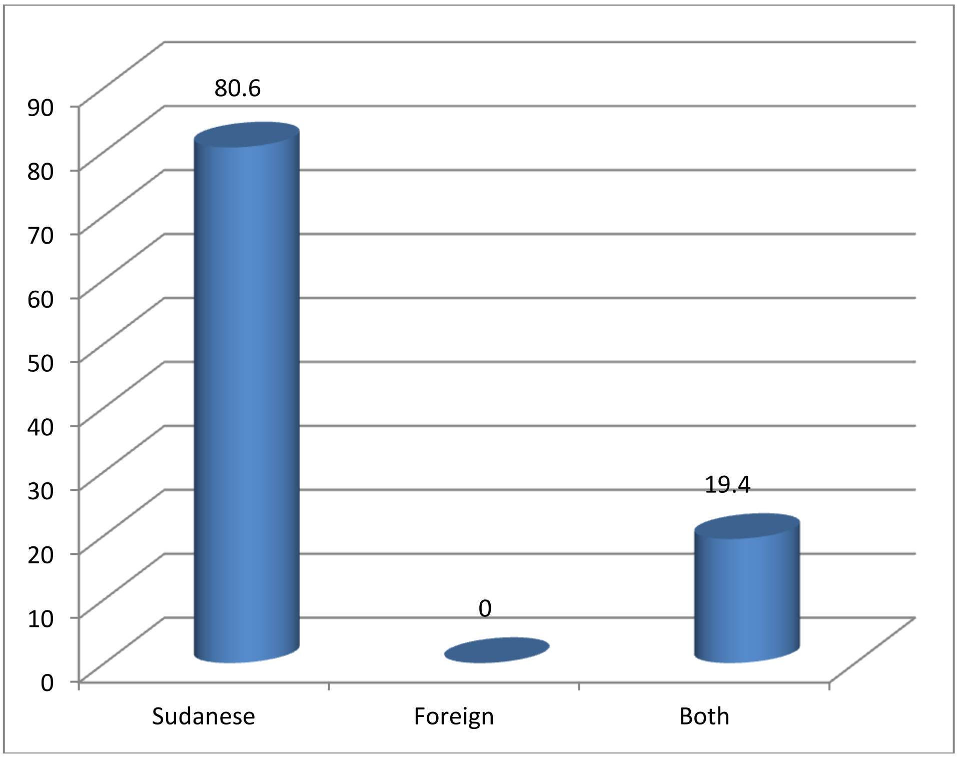

Figure 4-2: Nationality of Staff and Workers

Table 4-3 and the Fig 4-3 show the type of companies, the result found the type of the companies it is Contractor and it is percentage 55.6%. Consultant companies it is percentage 44.4%, therefore most of these companies is Contractor companies.

Table (4-3) Company's Role in Construction Industry

Valid	**Frequency**	**Percent%**
Consultant	16	44.4
Contractor	20	55.6
Total	36	100.0

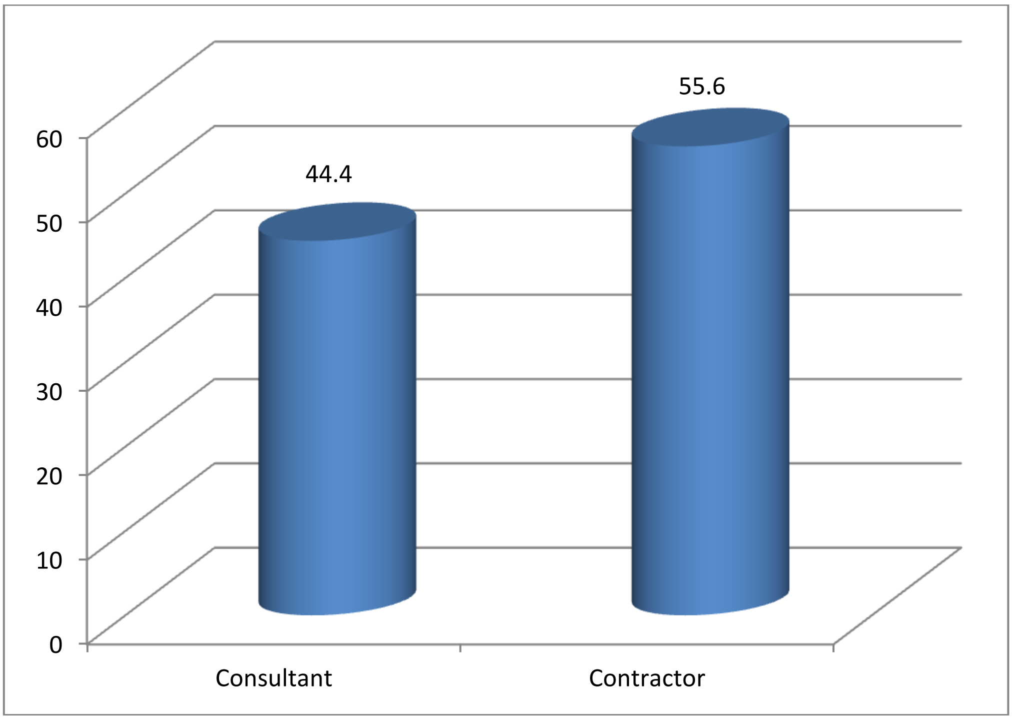

Figure 4-3: Company's Role in Construction Industry

Table 4-4 and the Fig 4-4 show the type of the sector, the result found the Private sector it is percentage 69.4%. , Public Sector it is percentage 30.6panies.

Table 4-4: Public and Private Organization

Valid	Frequency	Percent%
Public Sector	11	30.6
Private sector	25	69.4
Total	36	100.0

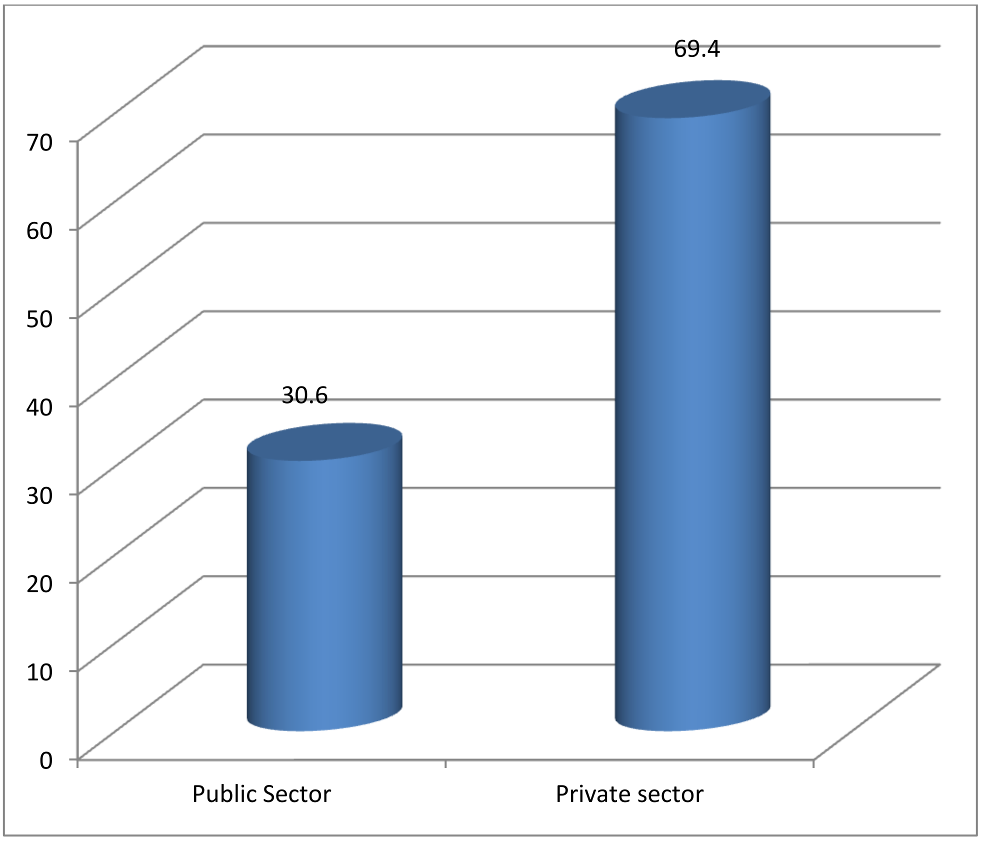

Figure 4-4: Public and Private Organization

Table 4-5 and Figure 4-5 show the Ownership of Equipment According to the Type of Sector, the result is most of companies which have equipment are public companies by 83% percent.

Table 4- 5 Ownership of Equipment According to the Type of Sector

	Companies own	**Companies Rent**		
	Frequency	Frequency	**Percent %**	
Public Sector	25	2	69.4	5.5
Private Sector	5	4	13.8	11.3
Total	30	6	83.2	16.8
Total	**36**		100%	

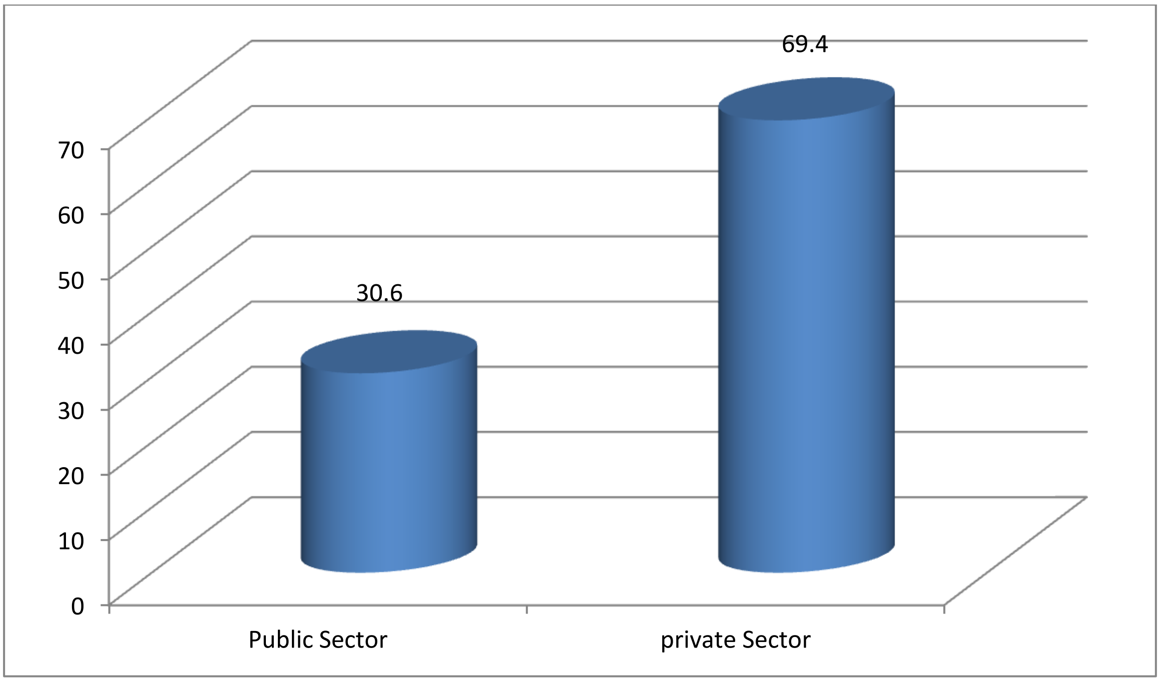

Figure 4-5 Ownership of Equipment According to the Type of Sector

Table 4-6 and Fig 4-6 show the advanced technology needed for construction, the result found for both large and small projects was77.8% and for large projects was 22.2%, therefore most of them are advanced technology needed for both large and small projects.

Table 4-6: Project Size and Required Technology for Construction (according to works progress)

Valid	Frequency	Percent%
For large projects	8	22.2
For small projects	0	0
For both large and small projects	28	77.8
Total	36	100.0

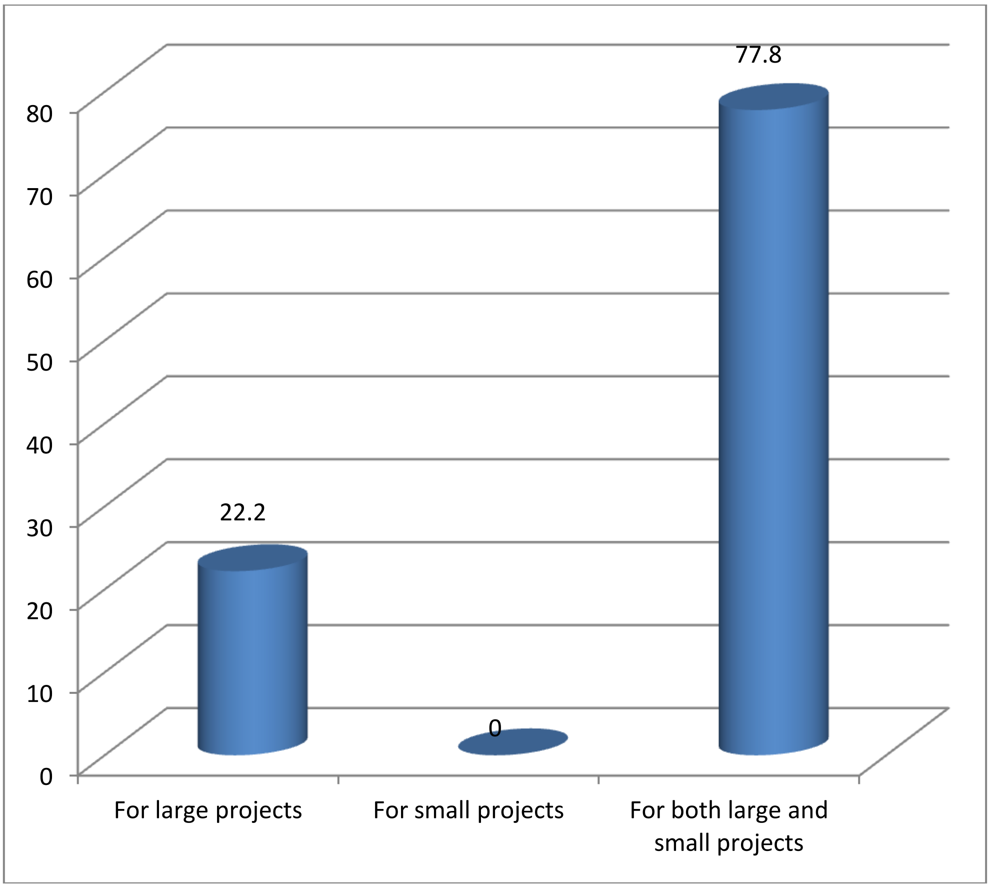

Figure 4-6: Project Size and Required Technology for Construction

Table 4.7 and Fig 4.7 show the improvement in quality and productivity required, companies is Always is 77.8% and companies is Based on Project Type 19.4% and Based on Level of Risk is 2.8% , therefore most of the companies it is Always improvement in quality and productivity required .

Table 4-7: Requirements to Improve Quality and Productivity

Valid	Frequency	Percent%
Always	28	77.8
Based on Project Type	7	19.4
Based on Level of Risk	1	2.8
Total	36	100.0

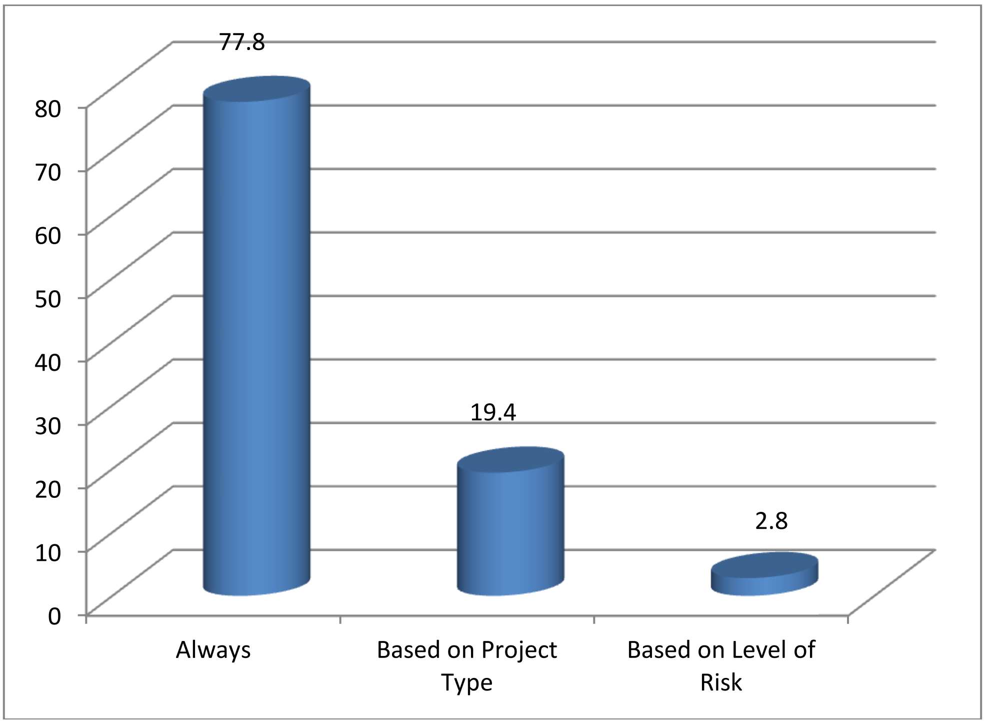

Figure 4-7: Requirements to Improve Quality and Productivity

Table 4-8 and Fig 4-8 show the company use advanced technology and techniques in any project, companies is yes is 55.6.8% and companies is in a few projects 38.9% and no is 5.6% , therefore most of the companies it is company use advanced technology and techniques in any project .

Table 4-8: Using of Advanced Technology and Techniques in Companies

Valid	Frequency	Percent%
Yes	20	55.6
In a few projects	14	38.9
No	2	5.6
Total	36	100.0

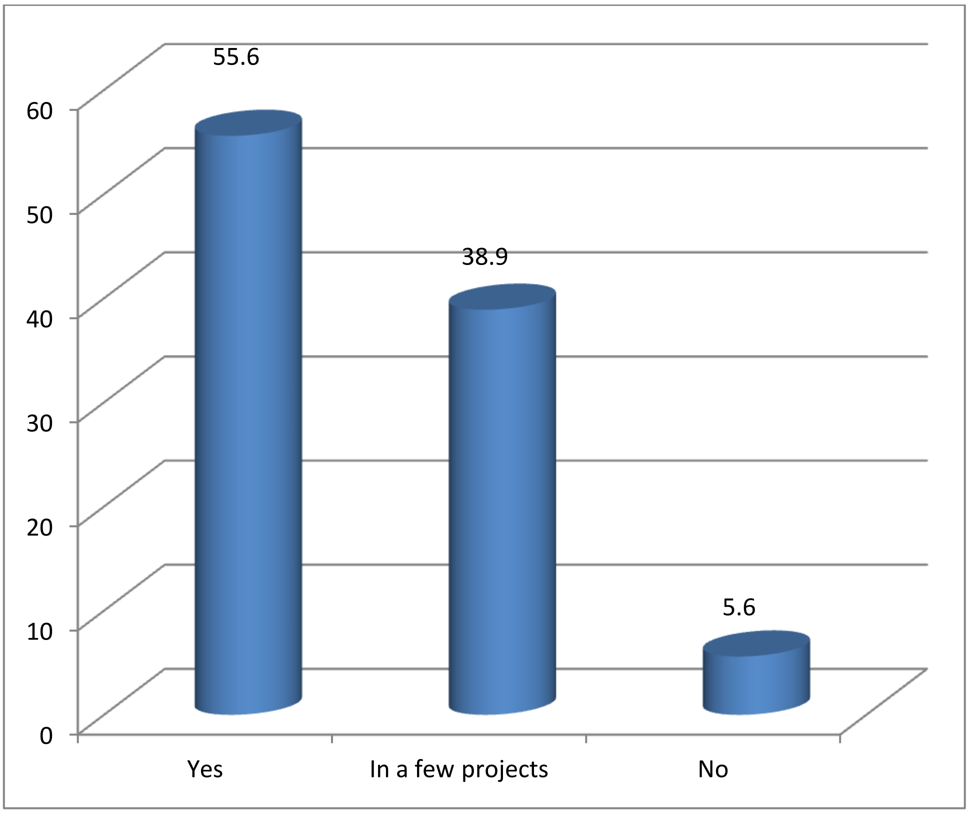

Figure 4-8: Use of Advanced Technology and Techniques in Construction

Table 4-9 and Fig 4-9 show the measured of productivity in companies, companies is Always is 50% and companies is Sometimes 44.4% and Never is 5.6% , therefore most of the companies it is Always measure productivity.

Table 4-9: Productivity Measurement

Valid	Frequency	Percent%
Always	18	50.0
Sometimes	16	44.4
Never	2	5.6
Total	36	100.0

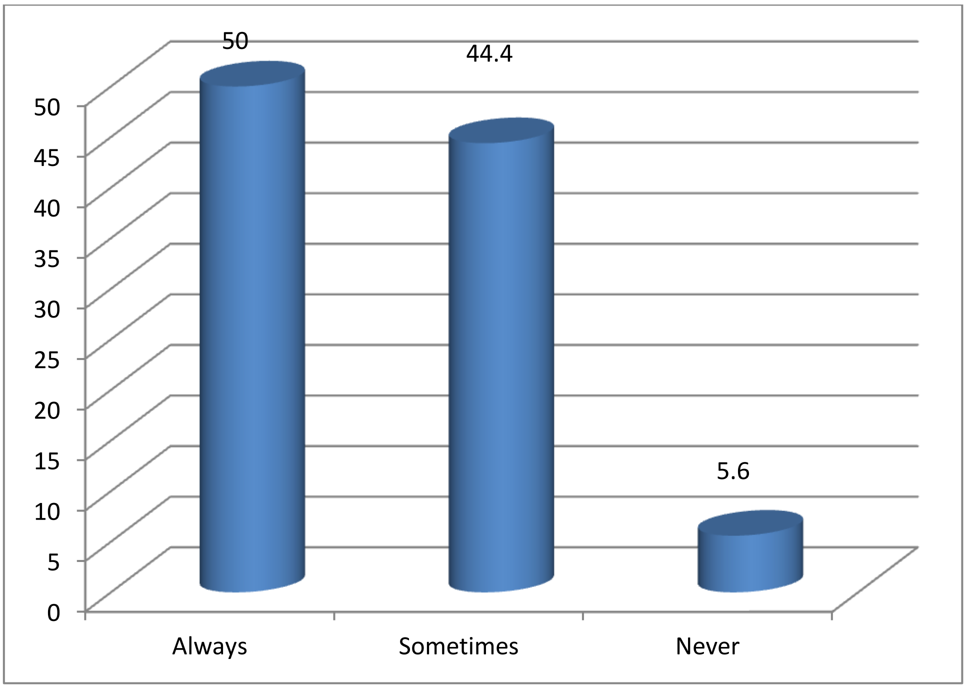

Figure 4-9: Productivity Measurement

Table 4-10 and fig 4-10 explain the methods that used to measure productivity, most of companies used Computation of equipment and labor productivity to measure productivity.

Table 4-10: Methods Used in Productivity Measurement

Valid	Frequency	Percent%
Computation of equipment productivity	7	19.4
Computation of materials productivity	6	16.7
Computation of labor productivity	2	5.6
Other methods	0	0.0
Computation of equipment productivity and Computation of materials productivity	2	5.6
Computation of equipment productivity and Computation of labor productivity	3	8.3
Computation of materials productivity and Computation of labor productivity	1	2.8
Computation of equipment productivity and Computation of labor productivity .	13	38.9
Computation of equipment productivity and Computation of labor productivity and Computation of labor productivity and Other methods	1	2.8
Total	35	100.0

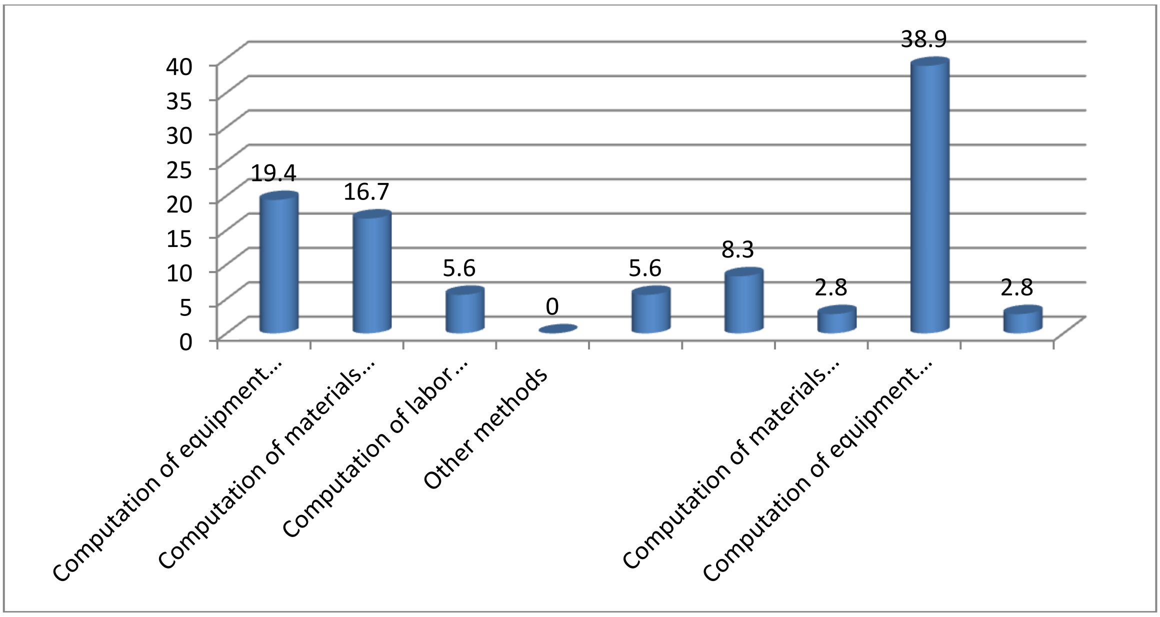

Figure 4-10: Methods Used in Productivity Measurement

Table 4-11and Figure 4-11 show Factors Affecting Productivity Increase, the result is from that is 30.6% from companies Believe that the important factor to increase productivity is Applying advanced technical and technological procedures and employing laborers with high skill and Making all necessary material tests.

Table 4-11: Factors Affecting Productivity Increase

Valid	Frequency	Percent %
Applying advanced technical and technological procedures	8	22.2
Employing labors with high skill	6	16.7
Making all necessary material tests	6	16.7
Other methods	0	0
Applying advanced technical and technological procedures and Employing laborers with high skill	3	8.3
Employing laborers with high skill and Making all necessary material tests	1	2.8
Applying advanced technical and technological procedures and Employing laborers with high skill and Making all necessary material tests	11	30.6
Applying advanced technical and technological procedures and Employing laborers with high skill and Making all necessary material tests and Other methods	1	2.8
Total	36	100.0

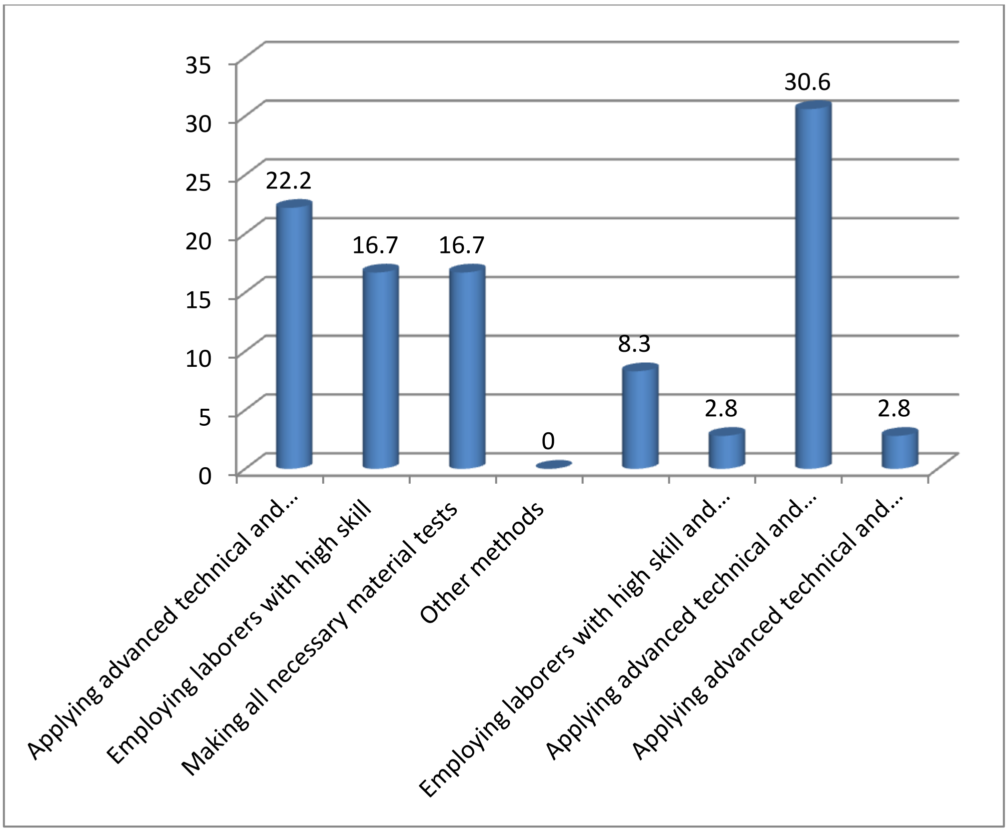

Figure 4-11: Factors Affecting Productivity Increase

Table 4-12 and figure 4-12 explain methods applied to improved quality, the result from that is most of companies using materials with appropriate characteristics and conducting all the important tests for materials used to improved quality.

Table 4-12: Methods Applied to Improve Quality

Valid	Frequency	Percent %
Using materials with appropriate characteristics	4	11.1
Conducting all the important tests for materials used	18	50.0
Other methods	1	2.8
Do not carry out quality control for our projects	0	0
Using materials with appropriate characteristics and Conducting all the important tests for materials used	10	27.8
Using materials with appropriate characteristics and Do not carry out quality control for our project	1	2.8
Conducting all the important tests for materials used and Do not carry out quality control for our projects	1	2.8
Using materials with appropriate characteristics and Conducting all the important tests for materials used and Do not carry out quality control for our projects	1	2.8
Total	36	100.0

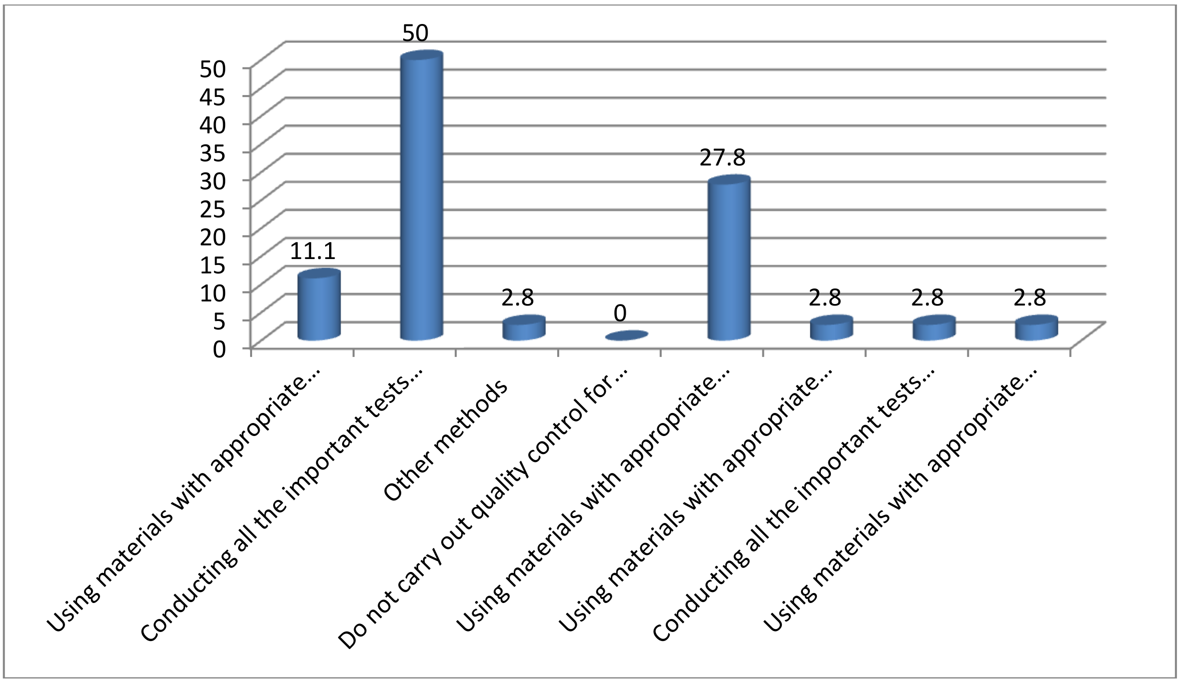

Figure 4-12: Methods Applied to Improve Quality

Table 4.13 and Fig 4.13 show the percentage of success in the plans execution in companies , (80% to 90%) is 36.1% and (70% to 80%) is30.6% and (90 % to 100%) is 19.4% and (less than 70%) is 13.9% , therefore most of the companies have is the percentage of success in the plans execution by (80% to 90%).

Table 4-13: Percentage of Success in Projects Execution

Valid	Frequency	Percent%
90 % to 100%	7	19.4
80% to 90%	13	36.1
70% to 80%	11	30.6
less than 70%	5	13.9
Total	36	100.0

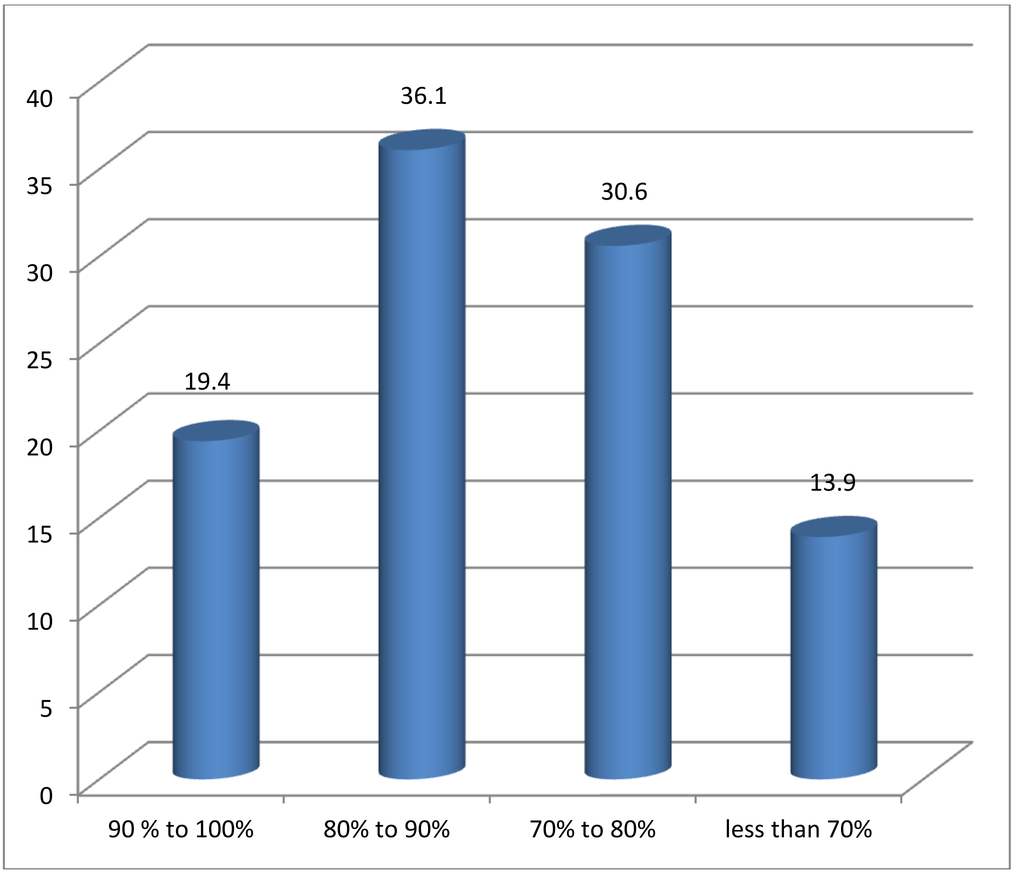

Figure 4-13: Percentage of Success in Projects Execution

Table 4-14 and Figure 4-14 show managerial effects related to failure projects , the result is most of companies believe that poor planning is main reason related to failure projects .

Table 4-14: Managerial Effects Related to Failure Projects

Valid	Frequency	Percent%
Poor planning	13	36.1
Poor monitoring and controlling	7	19.4
Poor advanced technology	3	8.3
Other reasons	3	8.3
Poor planning and Poor monitoring and controlling	1	2.8
Poor planning and Other reasons	1	2.8
Poor planning and Poor monitoring and controlling and Poor advanced technology	7	19.4
Poor planning and Poor monitoring and controlling and Other reasons	1	2.8
Total	36	100.0

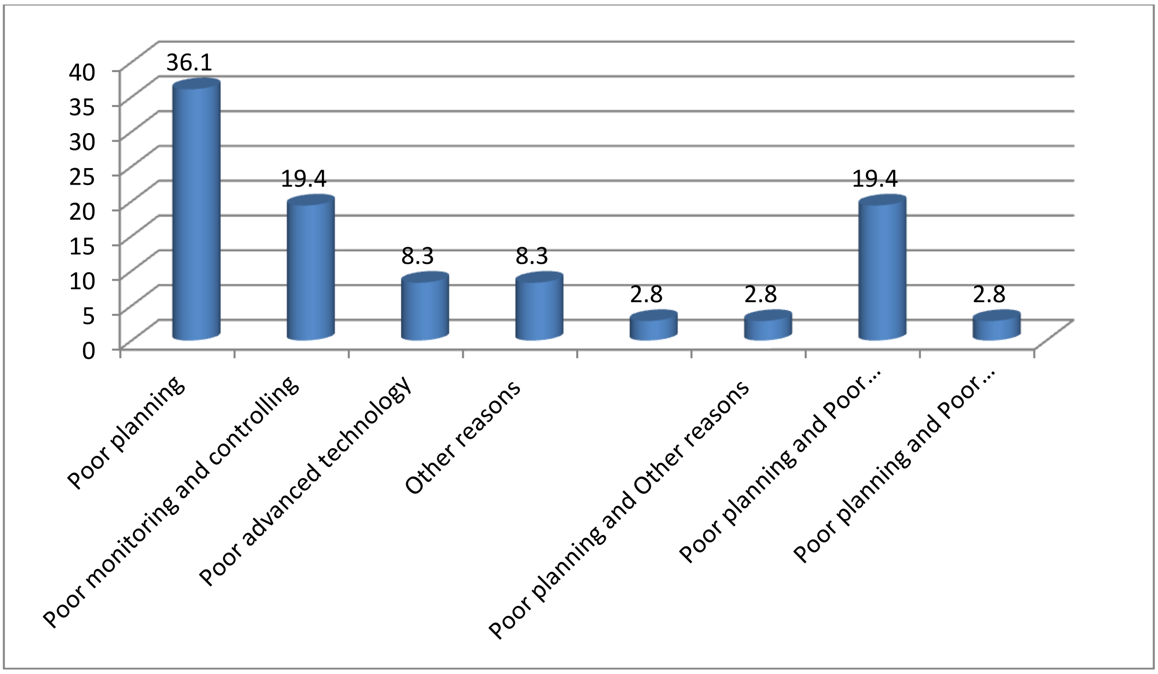

Figure 4-14: Managerial Effects Related to Failure Projects

Table 4.15 and Fig 4.15 show , the using of advanced techniques .companies strongly agree is 30.6% and the companies agree 47.2% , and disagree is 22.2, therefore most of them it is it is opinion Success of any project depends on using advanced techniques and technology.

Table 4-15: Role of Advanced Techniques on Project Success

Valid	Frequency	Percent%
Strongly Agree	11	30.6
Agree	17	47.2
Disagree	8	22.2
Strongly disagree	0	0
Do not know	0	0
Total	36	100.0

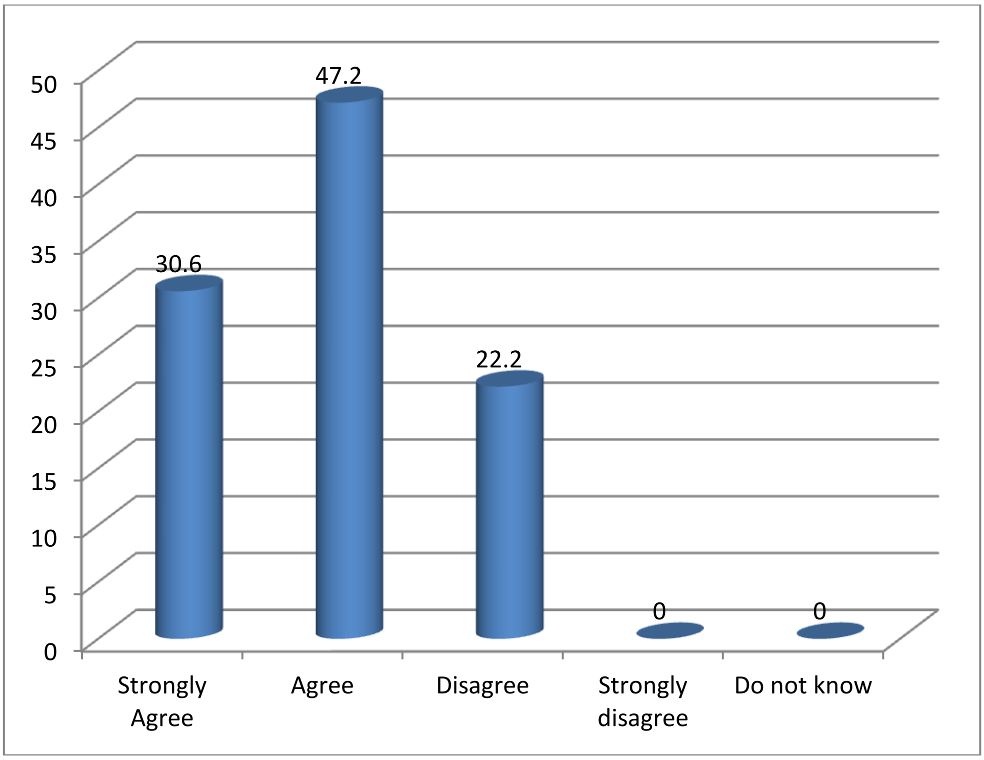

Figure 4-15: Role of Advanced Techniques on Project Success

Table 4.16 and Fig 4.16 show the using of modern equipment in implementation of works, the companies agree is 61.1% and the companies strongly agree 38.9%, therefore most of them it is opinion Use of modern equipment in implementation of works.

Table 4-16: Use of Modern Equipment in Construction

Valid	Frequency	Percent%
Strongly Agree	14	38.9
Agree	22	61.1
Disagree	0	0
Strongly disagree	0	0
Do not know	0	0
Total	36	100.0

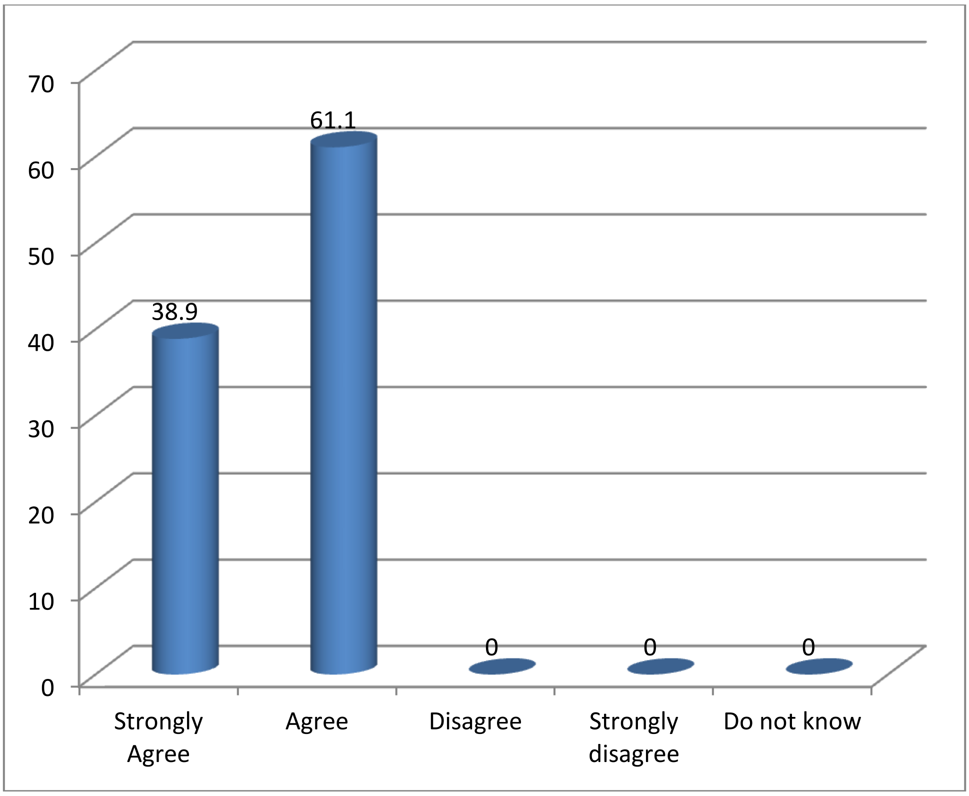

Figure 4-16: Use of Modern Equipment in Construction

Table 4.17 and Fig 4.17 show the using of advanced technology to reduce implementation defects, the companies agree is 55.6 % and the companies strongly agree 33.3%,and disagree is 5.6% therefore most of them it is opinion Using advanced technology to reduce implementation defect.

Table 4-17: Used Advanced Technology to Reduce Deficiency

Valid	Frequency	Percent%
Strongly Agree	12	33.3
Agree	20	55.6
Disagree	2	5.6
Strongly disagree	0	0
Do not know	2	5.6
Total	36	100.0

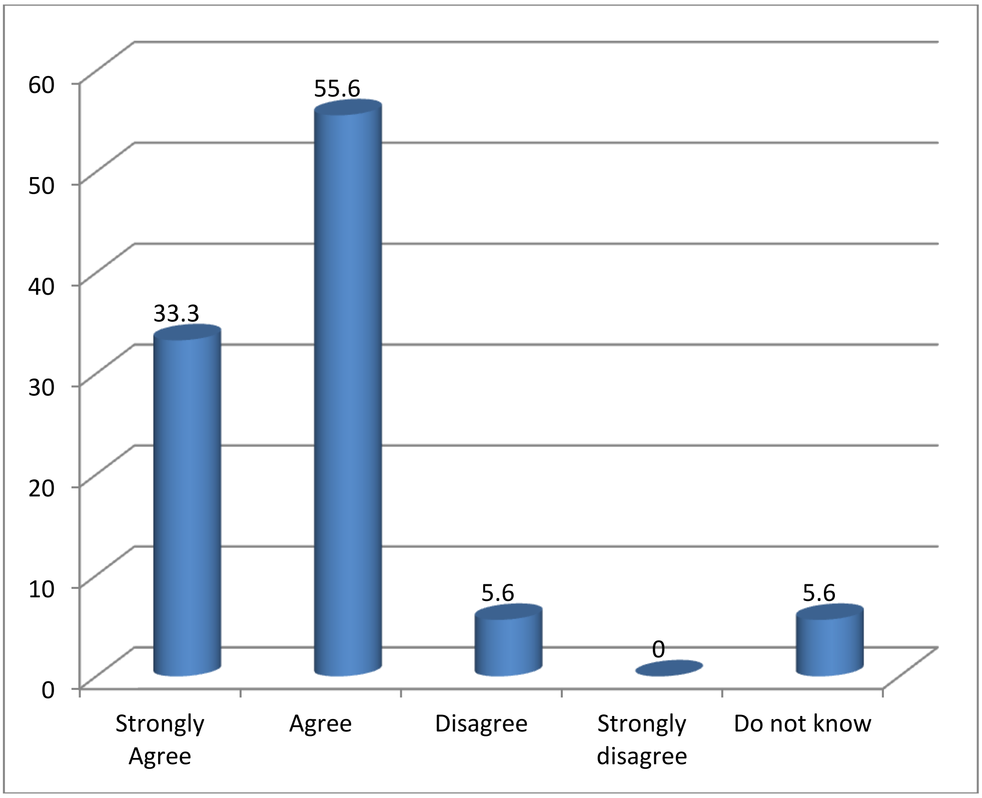

Figure 4-17: Used Advanced Technology to Reduce Deficiency

Table 4.18 and Fig 4.18 above explain use of advanced technology to reduce construction time, the companies agree is 63.9 % and the companies strongly agree 27.8%,and disagree is 5.6% , and strongly disagree is 2.8%, therefore most of them it is opinion Use of advanced technology to reduce construction time.

Table 4-18: Use of Advanced Technology to Reduce Construction Time

Valid	Frequency	Percent%
Strongly Agree	10	27.8
Agree	23	63.9
Disagree	2	5.6
Strongly disagree	1	2.8
Do not know	0	0
Total	36	100.0

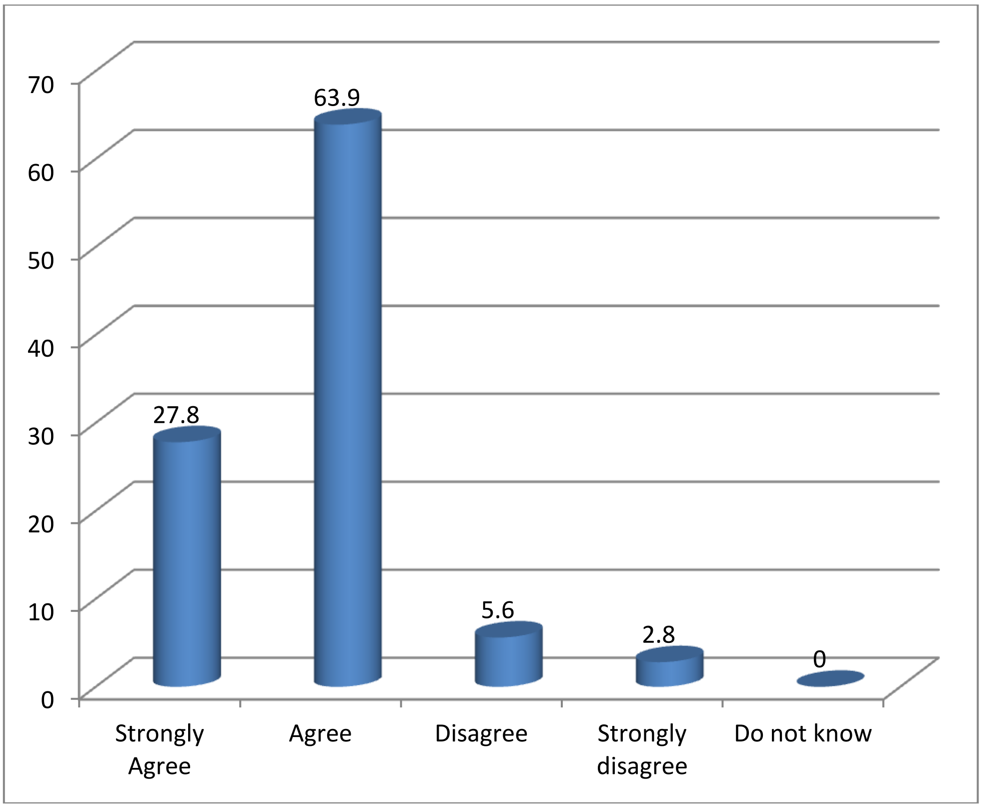

Figure 4-18: Use of Advanced Technology to Reduce Construction Time

Table 4.19 and Fig 4.19 show the skill level of labor using the equipment, the companies strongly agree is 61.1 % and the companies agree is 36.1%, and do not know is 2.8%, therefore most of them it is opinion skill level of labor using the equipment.

Table 4-19: Labor Skill in Using Equipment

Valid	Frequency	Percent%
Strongly Agree	22	61.1
Agree	13	36.1
Disagree	0	0
Strongly disagree	0	0
Do not know	1	2.8
Total	36	100.0

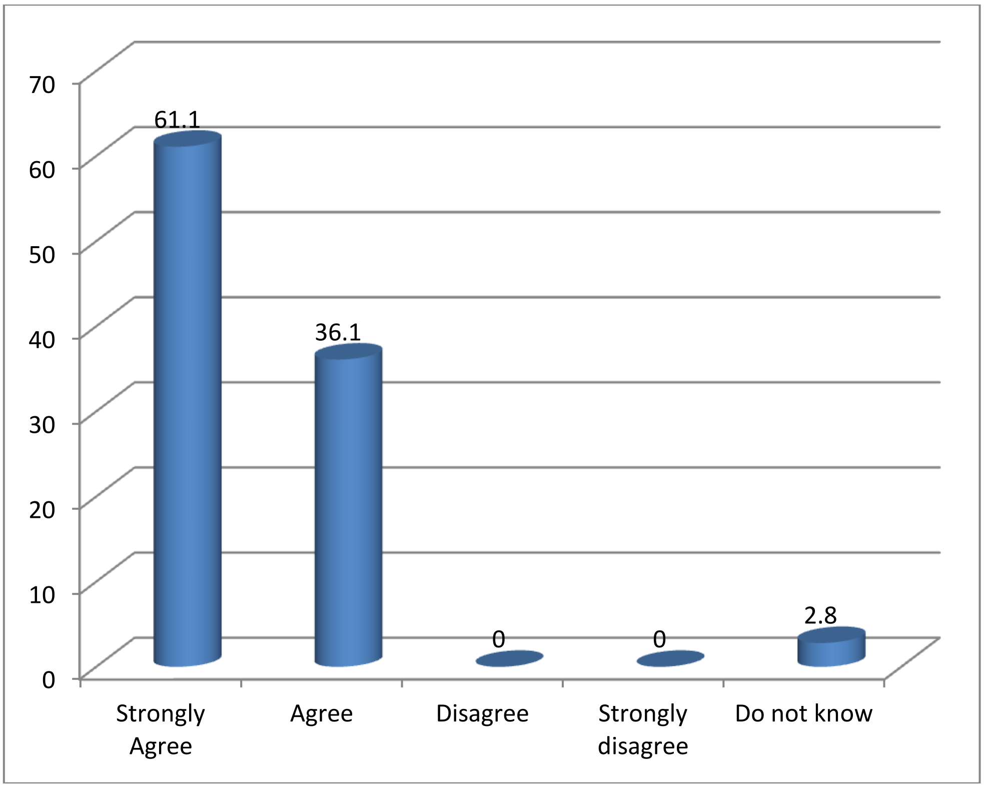

Figure 4-19: Labor Skill in Using Equipment

Table 4.20 and Fig 4.20 show the presence of specification section in the company responsible for selection of appropriate equipment for each project, the companies strong agree is 52.8 % and the companies agree is 44.4%, and do not know is 2.8.

Table 4-20: Presence of Specification Department Responsible for Selection of Appropriate Equipment

Valid	Frequency	Percent%
Strongly Agree	19	52.8
Agree	16	44.4
Disagree	0	0
Strongly disagree	0	0
Do not know	1	2.8
Total	36	100.0

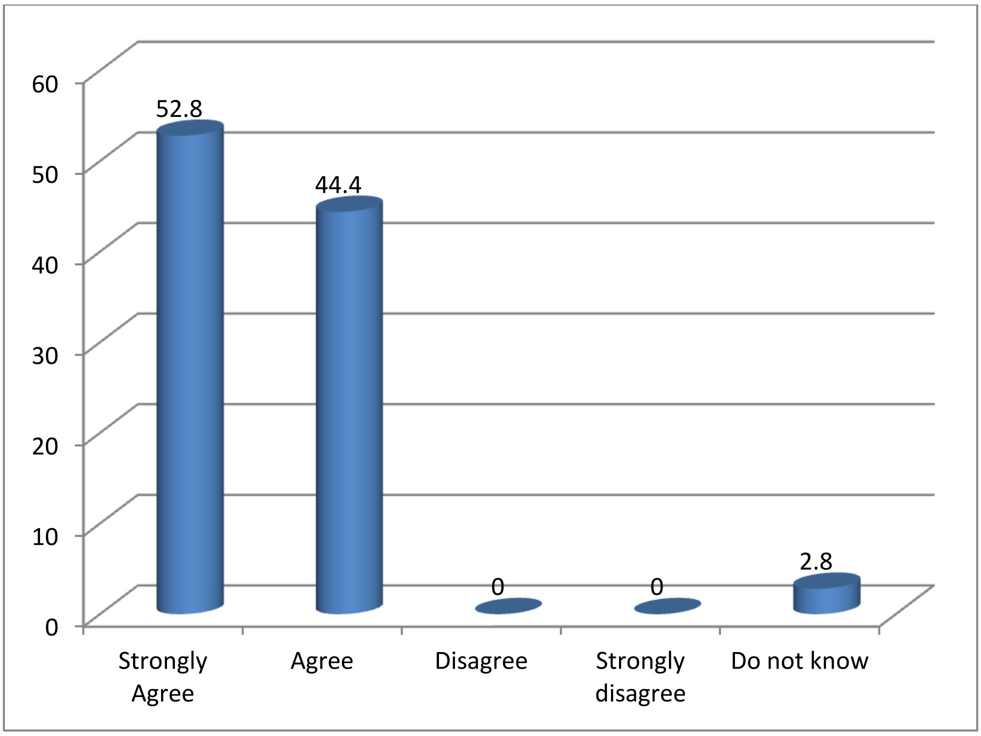

Figure 4-20: Presence of Specification Department Responsible for Selection of Appropriate Equipment

Table 4.21and Fig 4.21 show the usage of old machinery is increase the time of project, the companies strongly agree is 41.7 % and the companies agree 38.9%, and disagree is 16.7% , and strongly disagree is 2.8%, therefore most of them it is opinion usage of old machinery is increase the time of project.

Table 4-21: Use Old Machinery Prolongs Construction Time

Valid	Frequency	Percent%
Strongly Agree	15	41.7
Agree	14	38.9
Disagree	6	16.7
Strongly disagree	1	2.8
Do not know	0	0
Total	36	100.0

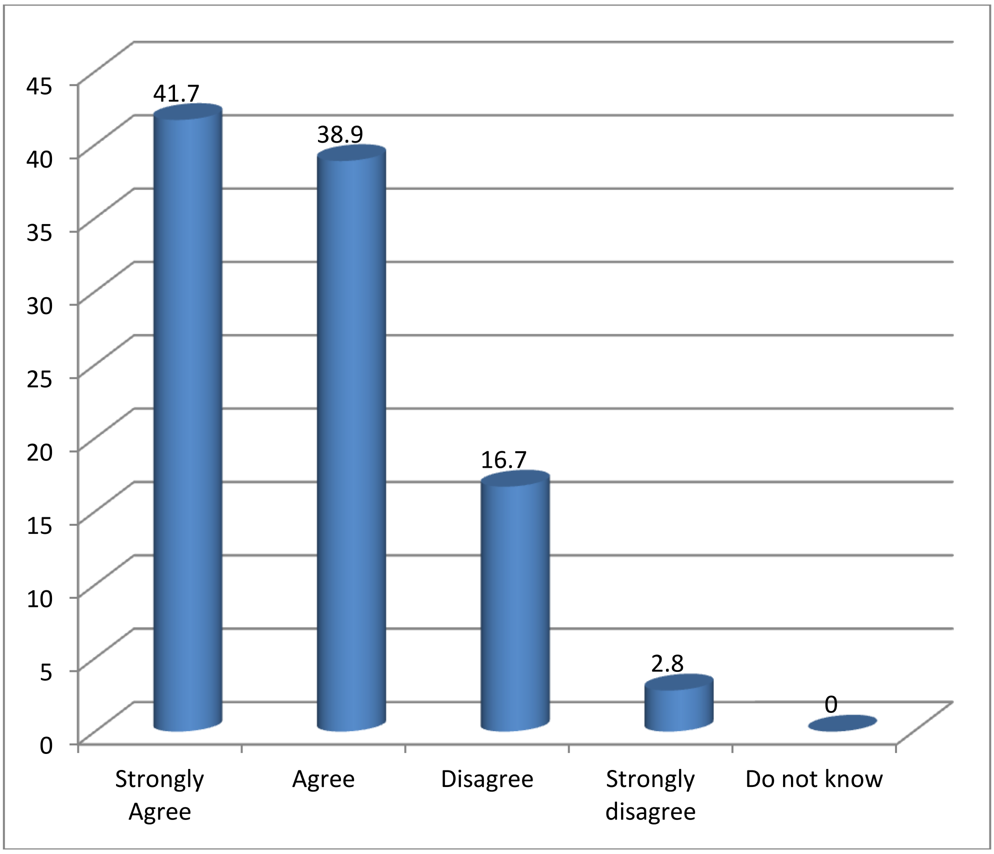

Figure 4-21: Use Old Machinery Prolongs Construction Time

Table 4.22 and Fig 4.22 show the use of appropriate equipment leads to efficient utilization of construction materials, the companies agree is 55.6 % and the companies strongly agree 30.6 %, and disagree is 5.6%, and strongly disagree is 2.8%, and do not know is 5.6%, therefore most of them it is opinion Use of appropriate equipment leads to efficient utilization of construction materials.

Table 4-22: Use of Appropriate Equipment Leads to Efficient Utilization of Construction Materials

Valid	Frequency	Percent%
Strongly Agree	11	30.6
Agree	20	55.6
Disagree	2	5.6
Strongly disagree	1	2.8
Do not know	2	5.6
Total	36	100.0

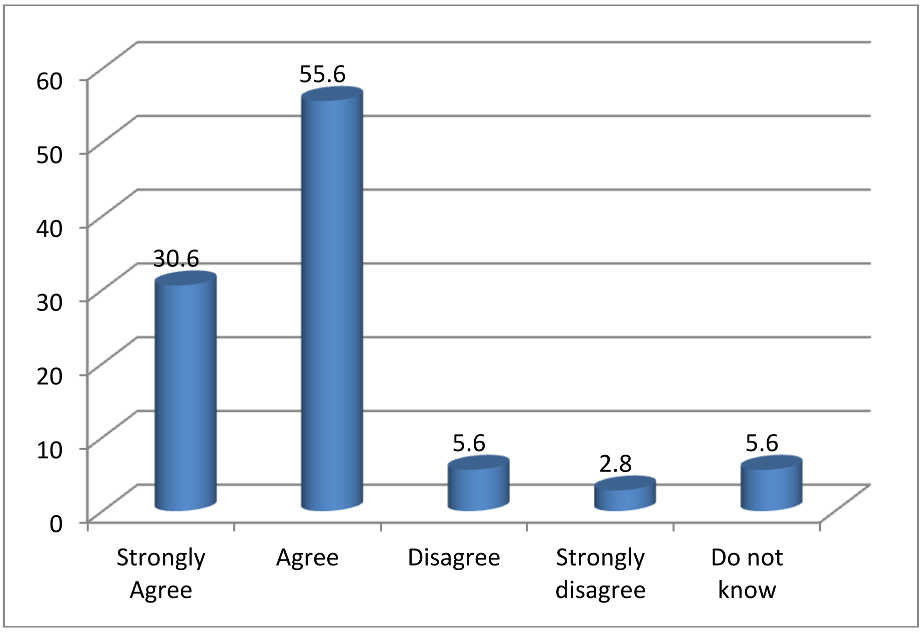

Figure 4-22: Use of Appropriate Equipment Leads to Efficient Utilization of Construction Materials

Table 4.23 and Fig4.23 show the construction company offers training courses for labors on using advanced technology, the companies agree is 52.8 % and the companies strongly agree 30.6 %, and disagree is 8.3% , and do not know is 8.3% , therefore most of them it is opinion construction company offers training courses for labors on using advanced technology.

Table 4-23: Availability of Training Courses for Labors on Using Advanced Technology

Valid	Frequency	Percent%
Strongly Agree	11	30.6
Agree	19	52.8
Disagree	3	8.3
Strongly disagree	0	0
Do not know	3	8.3
Total	36	100.0

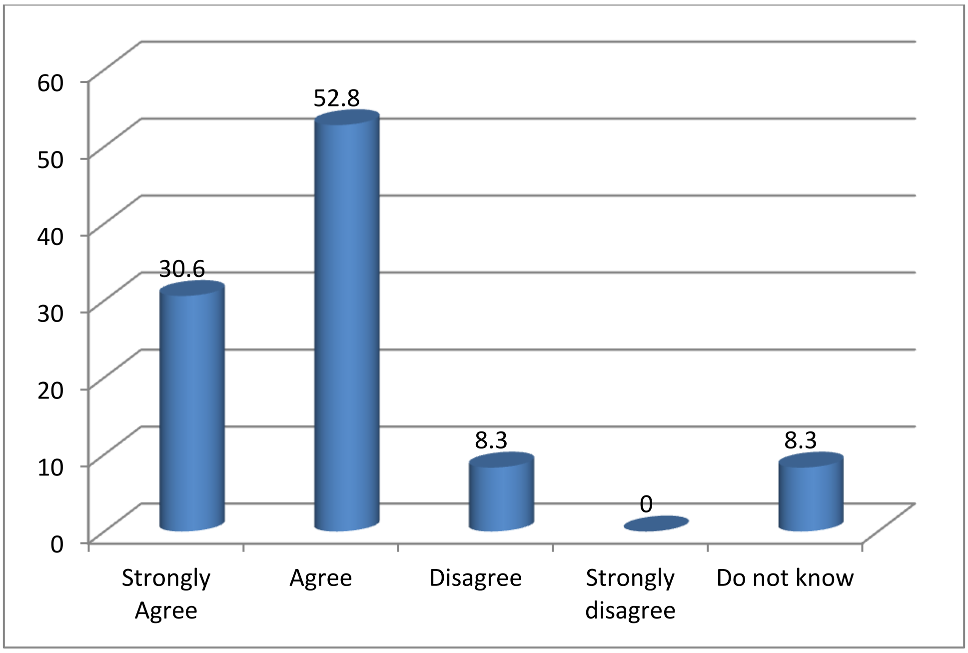

Figure 4-23: Availability of Training Courses for Labors on Using Advanced Technology

Table 4.24 and Fig 4.24 show the Labor training raises their efficiency and hence leads to improved productivity and quality, the companies strongly agree is 55.6 % and the companies agree 36.1 %, and disagree is 5.6% , and do not know is 2.8% .

Table 4.24: Labor Training Raises Efficiency Leading to Improved Productivity and Quality

Valid	Frequency	Percent%
Strongly Agree	20	55.6
Agree	13	36.1
Disagree	2	5.6
Strongly disagree	0	0
Do not know	1	2.8
Total	36	100.0

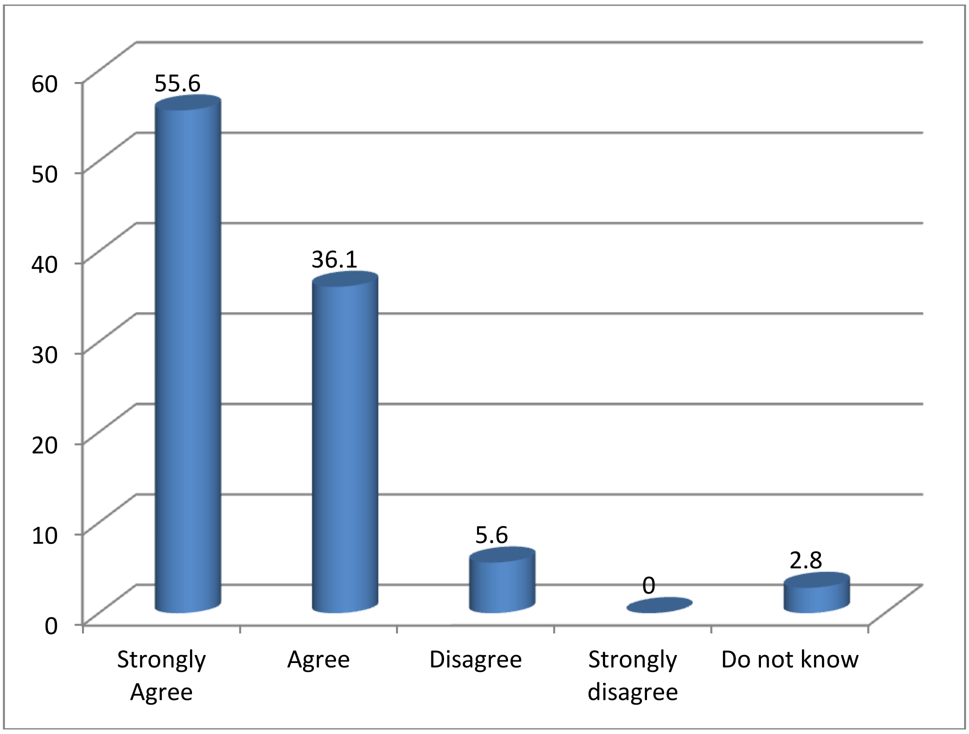

Figure 4.24: Labor Training Raises Efficiency Leading to Improved Productivity and Quality

Table 4.25 and Fig 4.25 show the company makes periodic maintenance of equipment, the companies agree is 22.2 % and the companies strongly agree 22.2 %, and disagree is 22.2% ,and strongly disagree is 5.6% ,and do not know is 5.6% , therefore most of them it is opinion makes periodic maintenance of equipment.

Table 4.25: Application Periodic Equipment Maintenance

Valid	Frequency	Percent%
Strongly Agree	8	22.2
Agree	16	44.4
Disagree	8	22.2
Strongly disagree	2	5.6
Do not know	2	5.6
Total	36	100.0

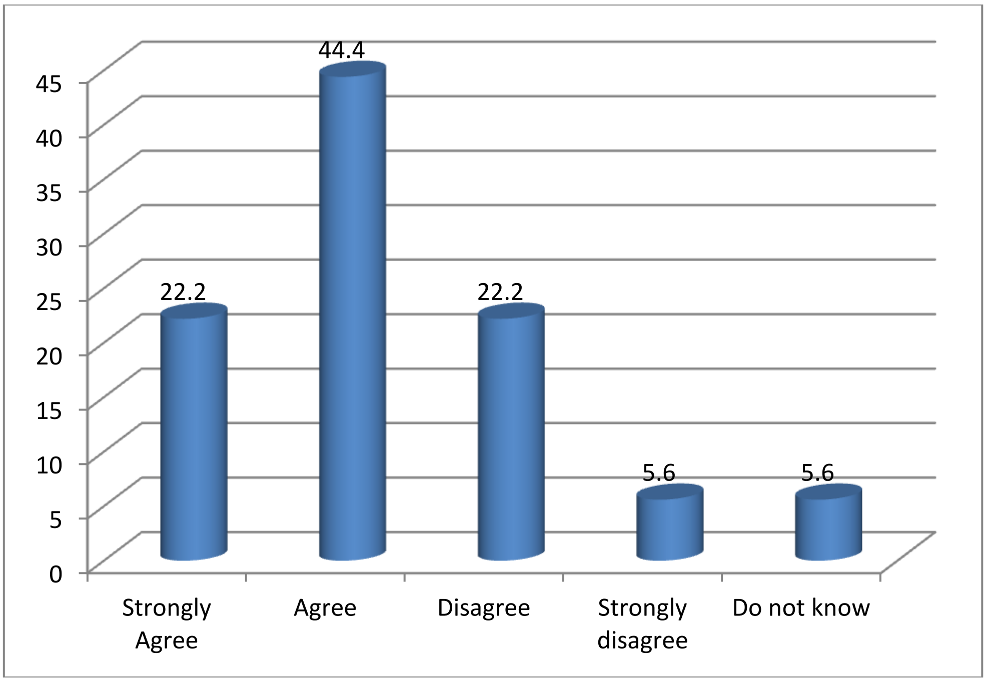

Figure 4.25: Application Periodic Equipment Maintenance

Table 4.26 and Fig 4.26 show the company specifies the equipment needed and adds new ones frequently (every----years), the companies agree is 44.4 % and the companies strongly agree 11.1 %, and disagree is 25%,and strongly disagree is 8.3% ,and do not know is 11.1% , therefore most of them it is opinion the company specifies the equipment needed and adds new ones frequently (every----years).

Table 4.26: Periodic Specification and Addition of Required Equipment

Valid	Frequency	Percent%
Strongly Agree	4	11.1
Agree	16	44.4
Disagree	9	25.0
Strongly disagree	3	8.3
Do not know	4	11.1
Total	36	100.0

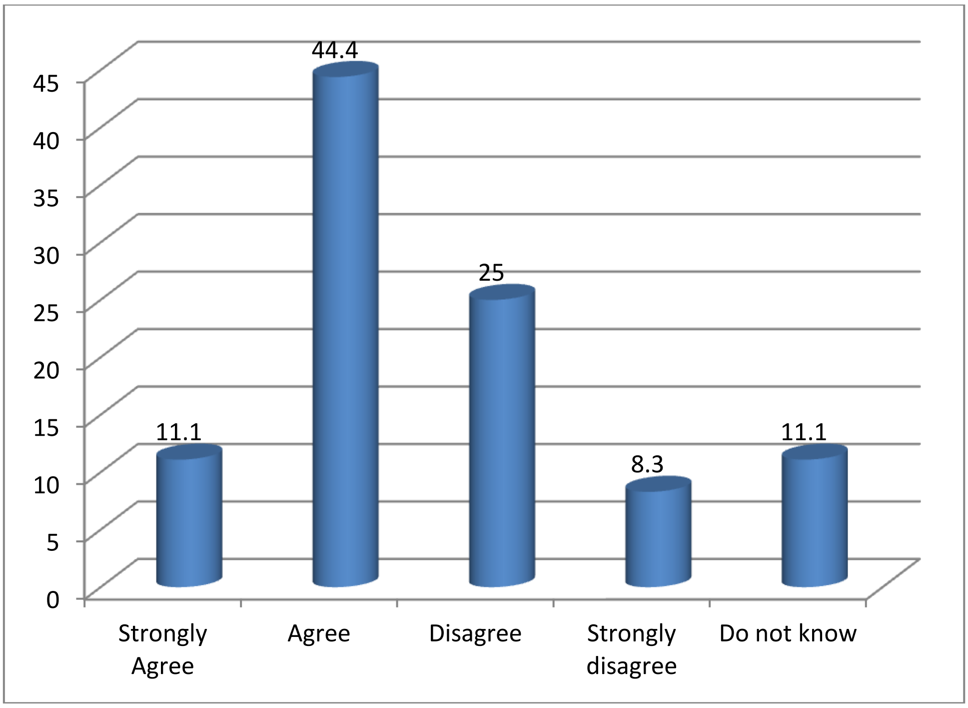

Figure 4.26: Table 5-25: Periodic Specification and Addition of Required Equipment

Table 4.27 and Fig 4.27 show the company conducts material tests before using to check compliance with standards and specifications, the companies agree is 55.6 % and the companies strongly agree 36.1 %, and disagree is 5.6% ,and strongly disagree is 5.6% ,and do not know is 5.6% , therefore most of them it is opinion the company conducts material tests before using to check compliance with standards and specifications.

Table 4.27: Conducting Material Tests to Compare with Standards and Specifications before Using

Valid	Frequency	Percent%
Strongly Agree	13	36.1
Agree	20	55.6
Disagree	2	5.6
Strongly disagree	0	0
Do not know	1	2.8
Total	36	100.0

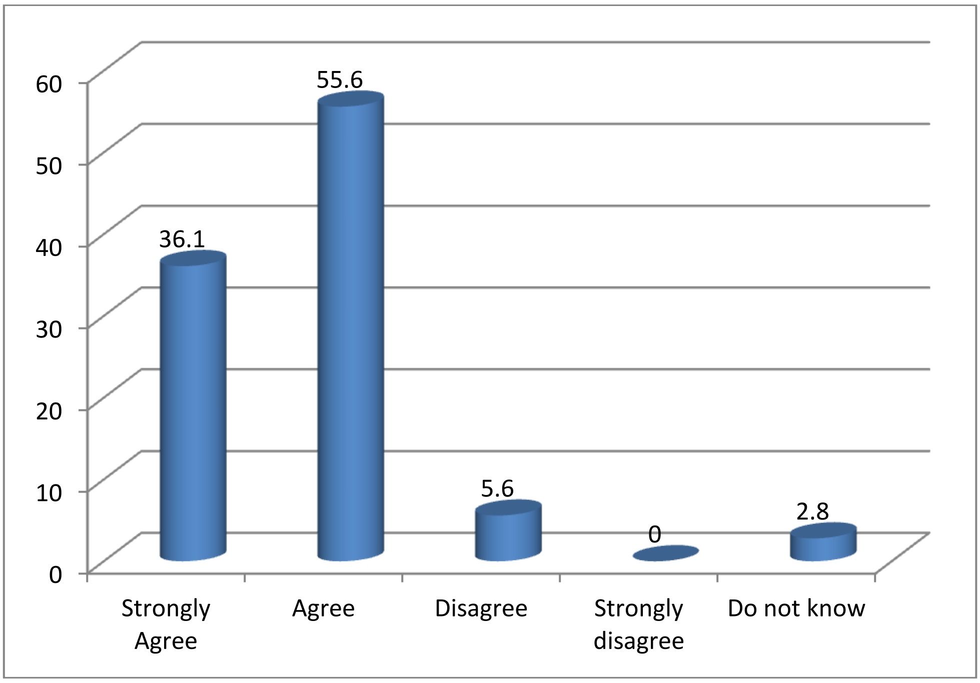

Figure 4.27: Conducting Material Tests to Compare with Standards and Specifications before Using

Table 4.28 and Fig 4.28 show the technological advances have improved durability of materials and allowed construction in moist and cold conditions, the companies agree is 47.2 % and the companies strongly agree 33.3 %, and disagree is 8.3%, and do not know is 11.1%, therefore most of them it is opinion technological advances have improved durability of materials and allowed construction in moist and cold conditions.

Table 4.28: Effect of Technological advances on Improve Durability of Materials Allowing Construction in Severe Weather

Valid	Frequency	Percent%
Strongly Agree	12	33.3
Agree	17	47.2
Disagree	3	8.3
Strongly disagree	0	0
Do not know	4	11.1
Total	36	100.0

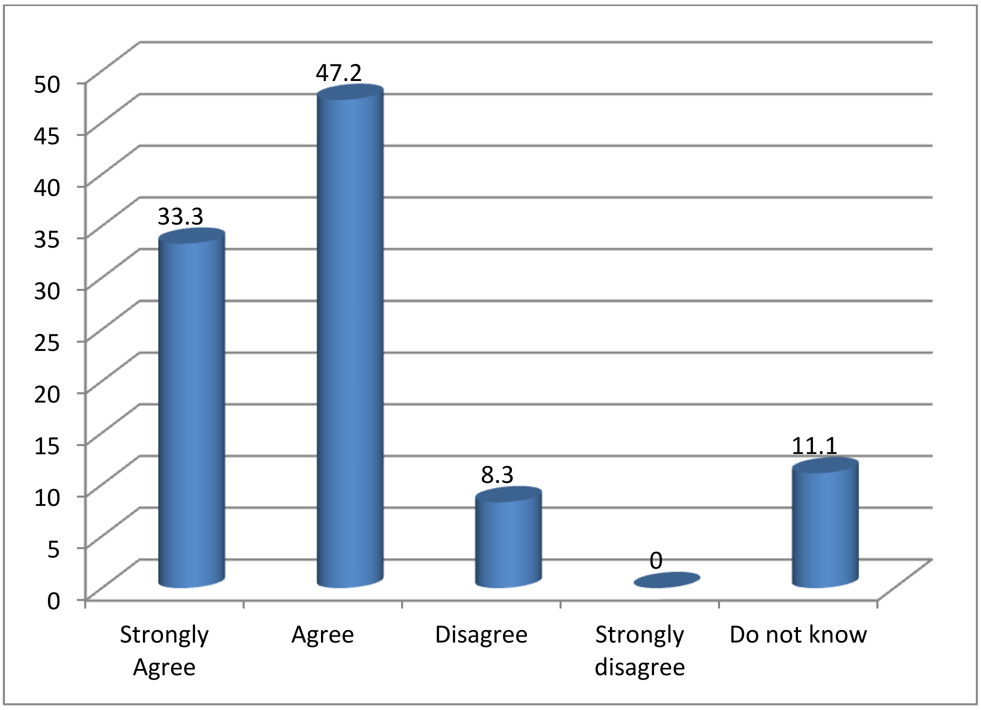

Figure 4.28: Effect of Technological advances on Improve Durability of Materials Allowing Construction in Severe Weather

Table 4.29 and Fig 4.29 show the Advanced technology caused reduced labor costs, the companies agree is 41.7 % and the companies strongly agree 47.2 %, and disagree is 8.3%, and do not know is 2.8% , therefore most of them it is opinion makes periodic maintenance of equipment.

Table 4.29: Effect of Advanced Technology on Reduced Labor Costs

Valid	Frequency	Percent%
Strongly Agree	17	47.2
Agree	15	41.7
Disagree	3	8.3
Strongly disagree	0	0
Do not know	1	2.8
Total	36	100.0

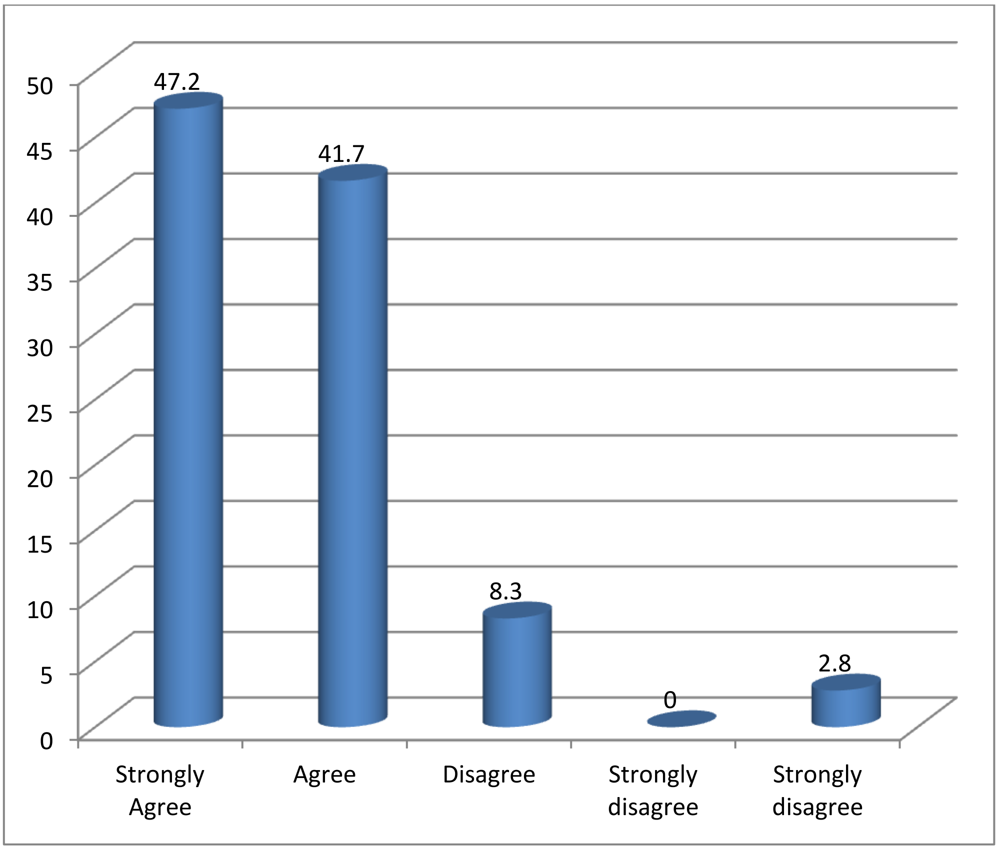

Figure 4-29: Effect of Advanced Technology on Reduced Labor Costs

4.5 Hypothesis Test

To test the validity of hypotheses test was used Chi-square and we get on the calculated value of the Chi square of the following equation

$$\chi^2 = \frac{\sum (O_i - E_i)^2}{E_i} \quad (4\text{-}1)$$

Where χ^2 = Chi square

O_i =Observed Frequencies

E_i = Expected Frequencies

Standard Deviation $$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2}. \quad (4\text{-}2)$$

Mean $$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i = \frac{1}{n}(x_1 + \cdots + x_n). \quad (4\text{-}3)$$

Was also used statistical treatment and descriptive analytical access to the results help in understanding the phenomenon under study were used circles calculations in the descriptive side so as to describe the direction of the respondents towards the ferry Is it negative or positive, and this is done by comparing the center obtained from the actual data with the default center, which It is calculated using the weights of the following statements by the way (for Lickert triple scale):

(Strongly agree-I agree-neutral-I do not agree-strongly disagree)
Their weight are 1-2 -3- 4- 5
Mean=total weight/number of weights 1**+2+3+4+5/5 = 15/5 = 3**
Increased the actual value of Middle from the center premise value, this indicates that the positive trend of the answers subjects and vice versa.

Tables below explain chi square values:

Table 4-30 Test for Hypothesis 1:

Management of Road Construction Awareness Important of Using Modern Techniques

	Chi-Square	d.f	Asymp. Sig.	Mean	Std. Deviation	Median
1- Did your company use advanced technology and techniques in any project?	14	2	0.00*	2.50	.609	3.00
2-Use of modern equipment in implementation of works	1.778	1	0.18**	4.39	.494	4.00

*Significant different at the 0.05 level.

**Not significant different at the 0.05 level.

Table 4-31: Test for Hypothesis 2:

Relationship between workers Efficiency and Use of Modern Technology

	Chi-Square	d.f	Asymp. Sig.	Mean	Std. Deviation	Median
1-Skill level of labor using the equipment	18.5	2	0.00*	4.53	.774	5.00
2-Your company makes periodic maintenance of equipment	18.444	4	0.00*	3.72	1.059	4.00

There is significant different at the 0.05 level and mean is above of 3, therefore there is a positive relationship between the workers efficiency and the use of modern technology.

Table 4.32: Test for Hypothesis 3: Test for Duration of Construction Project and Use of Modern Technology

	Chi-Square	d.f	Asymp. Sig.	Mean	Std. Deviation	Median
1-Use of advanced technology to reduce construction time	34.444	3	0.00	4.17	.655	4.00
2-usage of old machinery is increase the time of project	14.889	3	0.00	4.19	.822	4.00

There is significant different at the 0.05 level and mean is above of 3, therefore There is a positive relationship between the use of modern technologies and the time that project is completed.

Table 4-33 Test for Hypothesis 4 :(Companies always seeking "to improve productivity and increase quality

	Chi-Square	d.f	Asymp. Sig.	Mean	Std. Deviation	Median
1-When is improvement in quality and productivity required?	33.5	2	0.00*	1.25	.500	1.00
2-In your implemented projects, do you measure productivity?	12.667	2	0.00*	2.44	.607	2.50

*Significant different at the 0.05 level.

Table 4-34 Test for Hypothesis 5 To improve the quality companies are using certain materials specifications and characteristics as well as to conduct the necessary tests.

	Chi-Square	d.f	Asymp. Sig.	Mean	Std. Deviation	Median
The company conducts material tests before using to check compliance with standards and specifications	27.778	3	0.00*	4.22	.797	4.00

*Significant different at the 0.05 level.

Table 4-35 Test for Hypothesis 6

The success of any project is measured by the use of modern technologies.

	Chi-Square	d.f	Asymp. Sig.	Mean	Std. Deviation	Median
Success of any project depends on using advanced techniques and technology	3.5	2	0.17**	4.08	.732	4.00

** Not significant different at the 0.05 level.

Table 4-36 Test for Hypothesis 7

Companies Aware the Important of the Maintenance of the Equipment and the Renewal the Equipment of Each Period.

	Chi-Square	d.f	Asymp. Sig.	Mean	Std. Deviation	Median
Your company makes periodic maintenance of equipment	18.444	4	0.00*	3.72	1.059	4.00
The company specifies the equipment needed and adds new ones frequently (every----years)	16.5	4	0.00*	3.36	1.150	4.00

*Significant different at the 0.05 level.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Successful use of technology to improve construction quality and productivity involves more than the technical characteristics of the technology. Many factors simultaneously have an impact on construction quality and productivity, including work force characteristics and management practices as well as innovations in technology.

The study examined how the changes in road construction equipment and materials influenced improvements in road construction quality and productivity. The improvements were primary due to using advanced in the functional range of construction equipment, reductions in unit weight of selected construction materials.

Technologies have many positive effects and benefit on construction project. One of the most significant impact on construction project is the productivity and this can happen by improving the quality and performance of materials, equipment and information technology system.

5.2Conclusions

Within the scope of this study the following conclusions may be drawn from evaluation and analysis of the information acquiring questions of the questionnaire:

1- Success of any project depends on using advanced techniques and technology.

2- Most of the companies measured productivity by computation of equipment productivity.

3- The important factor to increase productivity is using advanced technology.

4- The popular method applied to improve quality is conducting all the important tests for materials used.

5- There is a positive relationship between workers' efficiency and use of modern technology.

6- The important managerial reason that relates to failure of projects is poor planning**.**

7- Most of the companies do not use materials with appropriate properties and do not conduct quality control for projects.

8- Advanced technology reduces construction time.

9- Most of the companies have specification department in the company responsible for selection of appropriate equipment for each project type.

10- The use of appropriate equipment leads to efficient utilization of construction materials.

11- Technological advances have improved durability of materials and allowed construction in severe weather condition.

12- Advanced technology resulted reduced labor costs.

13- Most of companies which have modern equipment are public companies.

5.2 Recommendations

1- The most important factor affecting quality and productivity improvement is the use of modern techniques.

2- Changes in equipment, materials, automation and integration of project work functions are related to improvements in construction quality and productivity.

3- All companies working in road construction' should be interest in the use of modern technologies to improve productivity.

4- Labors must be trained on how to deal with the modern equipment.

5- All the company should be conducts material tests before using to check compliance with standards and specifications.

5.3 Future Studies

1- Impact of using technological advanced in road construction industry on cost and time.

2- Importance of training course of labor to use advanced technology.

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APPENDEX