COMPARISON OF DISTRICT ROADS GEOMETRIC AND PAVEMENT STRUCTURAL ELEMENTS INTEGRITY ATTAINED INDEPENDENTLY DURING ROAD CONSTRUCTION BY EQUIPMENT-BASED AND LABOUR-BASED TECHNOLOGY: A CASE OF EASTERN UGANDA

BY

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DECLARATION

I hereby declare that the work herein with the exception of information reference to which permission is given, is purely my work, and has never been submitted to any institution for academic purpose.

Sign:………………………………………………………. Date:…………….

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This dissertation is hereby submitted with the approval of the following supervisors:

Dr. U. Bagampadde Sign:…………………….. Date:…………….

Dr. J. A. Mwakali Sign:……………………. Date:…………….

DEDICATION

To my parents, thanks for your parental advise, care and guidance since my childhood. To my beloved wife Janet Apiyo thanks for your care, encouragement, and endurance during this hard time at the university. Special thanks to all my children Barnabas, Jonathan, Mercy, Christine, Pamela and Brian, a boy who blessed this academic period as a new family member. I wish you all a bright future. To my late daughter Laker Patricia thanks for all you did to me. Patricia, I missed to see all your potentials in my life but you are with me in heart and spirit. I will ever remember you. May God rest your soul in eternal peace.

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LIST OF ABBREVIATIONS

EBT	Equipment-Based Technology
GE	Geometric Elements
GPS	Geographic Positioning System
HIV/AIDS	Human Immune Virus / Acquired Immune Deficiency Syndromes
LBT	Labour-Based Technology
MOWT	Ministry of Works and Transport
PSE	Pavement Structural Elements
UNDP	United Nation Development Programme
4WD	Four wheel drive

ABSTRACT

This research compared district roads geometric and pavement structural elements integrity attained independently by equipment-based and labour-based technology during road construction. By Labour-based technology, hand tools such as hoes, spades, pickaxes, and axes among others are use in roads construction. However, by Equipment-based technology, road works equipments such as motor grader, wheel loader, roller, and compactor among others, are use in roads construction. This research was to determine which of Labour-based and Equipment-based technology in road construction best suit the integrity of district roads geometric and pavement structural elements. This research specific objective was to develop a comparative assessment of the effectiveness of equipment-based and labour-based technology in attaining the integrity of district roads geometric and pavement structural elements. This research was limited to District Class II district road and was done in Kapchorwa, Mbale, Sironko, Kumi, Soroti and Katakwi district.

The Class II district road geometric and pavement structural elements including the procedures and instruments used to measure their integrity was confirmed by documentary and descriptive research design. In descriptive research design, data was obtained using pre-tested self-administered questionnaires. The respondents were district engineers, supervisors of works, and county engineering assistants. The Class II district road geometric and pavement structural elements confirmed were considered the research dependent variables. Percentage analysis technique was applied to analyze data obtained by questionnaire. To compare the technologies, Katero-Kapkoc and Kapchorwa-Kawai road in Kapchorwa district were selected among the roads under construction as the study sample elements by stratified random sampling method. Those roads were under construction by labour-based and equipment-based technology respectively. Road geometric and pavement structural elements data was obtained by carrying quality assurance. The data obtained was described using histogram, analyzed based on computed statistical parameters and compared using limit of agreement method. GenStas 2003 statistical software was used in data analysis.

Based on the standard road design specifications provided by ministry of works and transport, it was found that other than vertical and horizontal alignment, Labour-based technology suit all district roads geometric and pavement structural elements more than Equipment-based technology. It was recommended that to ensure conformity of dependent variables to specifications in use, control of roadwork activities need to be adopted. Further study be carried to determined cost effectiveness of the technologies in road construction.

CHAPTER ONE

INTRODUCTION

1.0 Background

Road infrastructure significantly facilitates socio-economic development as shown by Warr (2005). According to World Bank (1996), the poor condition of roads in Uganda has hindered socio-economic development yet it is the dominant mode of transport. The effects of poor road condition are still pronounced in the rural areas linked mainly by district roads. According to Ministry of Works and Transport (2007), district roads condition in Uganda as at June 2007 was as shown in Table 1.1.

Table 1.1: District Roads Condition in Uganda as at June 2007

FFEDER ROAD CONDITION	TOTAL LENGTH (Km)	REMARK
Good	10,100	A good road allows accessibility throughout the year.
Fair	6,500	A fair road allows accessibility throughout the year but in wet season to only 4WD motor vehicles.
Poor	500	A poor road allows accessibility only in the dry season.
Bad	900	A bad road does not allow accessibility at all.

Source: (Ministry of Works and Transport Annual Report of 2007)

In order to address this situation, government of Uganda under Poverty Eradication Action Plan considered roads infrastructure investment among the top funding priorities. This was intended to achieve the road sector medium term objective that would in turn boost sustainable integrated socio-economic development. The road sector medium term objective is geared towards constructing standard roads able to provide required accessibility. In addition to funding commitment, government of Uganda also mandated Ministry of Works and Transport (MOWT) to establish and implement effective strategies in order to achieve the road sector medium term objective. Moreover, MOWT in an effort to accomplish its tasks instituted and enforced a number of strategies in line with International Labour Organisation (2004) rural accessibility planning. Among the strategies enforced was to execute road construction by Labour- Based Technology (LBT) while slowly phasing out conventional Equipment-Based Technology (EBT). This strategy was intended to increase household income by employing community members in Labour-based road works. Road construction by LBT involves use of hand tools such as hoes, spades, pickaxes, axes, and rakes among others. On the other hand, road construction by EBT involves use of road works equipments such as motor grader, wheel loader, roller, compactor, and bulldozer among others.

To strengthen application of LBT in road construction, a number of measures were applied. This include policy formulation promoting LBT, formulating and effecting labour laws promoting employment of local labourers, increased funding for labour-based road works, capacity building in labour-based road works, and empowering local councils to effectively administer LBT application. In Uganda, LBT application in district roads construction is still more rooted in some Danish government supported districts. These include: Kapchorwa, Kumi, Sironko, Soroti, Katakwi, and Mbale. On the other hand, districts such as Nakapiripirit, Moroto, Kotido, Palisa, Lira, Gulu, Pader and Kitgum though supported by the Danish government still apply to a great extend EBT in road construction and maintenance. Despite advocacy for increase LBT application in road construction, much is still required about its quality output compared to EBT in the construction of district roads. Specifically, the integrity of roads constructed or maintained by application of LBT need to be determined.

Hence, the reliability and practicability of the road sector medium term objective through increased LBT application in road construction and maintenance remain questionable.

1.1 Statement of the Problem

In Uganda, the major constraint to socio-economic development is poor road accessibility as argued by Minters (2003). Despite all efforts by Uganda government to ensure adequate road accessibility, increased LBT application as a strategy to achieve the road sector medium term objective was advocated for prematurely. Labour-based technology was not viewed primarily as an asset generation technology with secondary employment benefits during road construction. This perception derailed the main objective of introducing LBT in road construction. The primary factor to qualify increase LBT application in road construction was consequently not considered. This primary factor is the conformity of LBT in the construction of district roads as compared to EBT. Hence, it is not certain whether increase LBT application in roads construction to achieve the road sector medium term objective is viable.

The above gap need to be addressed in order to achieve the country's integrated socio-economic development level desired in the short and long term. The district roads pavement structural elements (PSE) achieved during roads construction are wearing course, base, and sub-base. On the other hand the district roads geometric elements (GE) achieved during road construction are camber fall, drainage dimensions, back and side slopes, shoulder width, carriageway width, miter angle, super-elevation, super-elevation runoff, horizontal and vertical alignments. The ability of a road to provide required accessibility relies on the conformity of its GE and PSE to the operational road design specifications in use. The road GE and PSE conformity to operational road design specifications on the other hand depends on technology applied during road construction. Since the two road construction technologies differ, there is need to compare the integrity of GE and PSE elements they independently achieve during road construction before strongly advocating for LBT in roads construction. Data of GE and PSE integrity attained by the technologies can be obtained by carrying quality assurance on constructed roads. This would then facilitate comparing the technologies in road construction based on Ministry of Works and Transport specifications for district roads GE and PSE integrity.

1.2 Objectives of the Study

The main objective of this research was to determine which of Equipment-based and Labour-based technology during road construction optimally achieve district roads geometric and pavement structural elements conforming to MOWT specifications. The specific objective of this research was to develop a comparative assessment of the effectiveness of EBT and LBT in achieving district roads geometric and pavement structural elements during road construction.

1.3 Research Hypotheses

In Uganda, LBT and EBT are the two technologies applied in road construction and maintenance. To date EBT is the dominant technology in road construction. Its output is so far satisfactory. This was evidenced by the good performance of constructed roads in Uganda early before wider application of LBT in district roads construction. Since road performance depends on its GE and PS, EBT seems to produce road GE and PSE that conform to standard road design specifications in use. However, this is not the case for LBT yet. Different tools were used when applying the technologies in road construction. This implies conformity of GE and PSE integrity achieved by the technologies to standard road design specifications in use seem to differ. The research hypothesis for this research therefore states that, labour-based and equipment-based technology in road construction output district roads geometric and pavement structural elements with the same integrity. Meanwhile the null hypothesis states that, labor-based and equipment-based technology in road construction output district roads geometric and pavement structural elements have different integrity.

1.4 Significance of the Study

The result of this research will help to determine the most appropriate technology to apply in district roads construction to achieve GE and PSE of required integrity. The merits from determining an optimal technology in district roads construction include the followings:

- this will ensure quality in road works ,
- guarantee desired accessibility from constructed roads,
- ensure value for money in road construction, less constraints on the road maintenance budget in the long run,
- ensure proper guarding of huge capital invested in road infrastructure by guaranteeing longer road maintenance cycle and
- facilitate achieving the road sector medium term objective and will provide a view on the extent to which the operational road design specification is achievable by the technologies, and
- Determine the best technology in executing a specific roadwork activity. This according to International Labour Organization (2006) makes it easy to apply appropriately a combination of the technologies and output high quality road infrastructure.

Above all, this research will facilitate the success of Poverty Eradication Programme by selecting the optimal technology in road.

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1.5 Scope of the Study

This research was conducted in eastern Uganda in Kapchorwa district where both EBT and LBT are being applied largely in road construction. Important information on LBT and EBT in this research was obtained from Mbale, Sironko, Kumi, Soroti and Katakwi districts where LBT is being applied to a limited extent in road construction. Figure 1.1 in Appendix 1 show the research area. This research was limited to Class II district roads. A Class II district road provides major internal transport needs of the districts. It link to vital points such as hospitals, markets, administrative centers, and agricultural areas among others. On the other hand, Class I district roads serves national interest in that they satisfy criteria established for secondary and/ or tertiary road system within the national road system. A Class I district road can be upgraded to a national road. While Class III district roads generally have low traffic volume and serve sparsely populated areas within the district. The Class II district road network in the research area is shown in Figure 1.2 in Appendix 1. The roads selected for this research were Katero-Kapkoc and Kapchorwa-Kapwai road. Katero-Kapkoc road was under Labour-based method of road works, while Kapchorwa-Kapwai was under Equipment-based method of road works. Only qualitative data was obtained from those districts where LBT is applied to a limited extent. However, both qualitative and quantitative data were collected from Kapchorwa district.

1.6 Methodology

In conducting this research, qualitative and quantitative research approaches were adopted. Qualitative approach was applied to establish the diverse facts and realities on the road construction technologies and the road GE and PSE. On the other hand, quantitative approach was adopted to quantify the extent to which the road construction technologies suit the Class II district road GE and PSE during road construction.

While qualitative approach utilized documentary research design, quantitative approach adopted both descriptive and correlation research design. In documentary research design, literature was reviewed to increase familiarity of the researcher with the study variables. Descriptive research design facilitated a detailed description of the target population. A correlation research design was used to describe in quantitative terms the extent to which the dependent variables were achieved by the technologies during road construction. Comparison of the technologies was done by limit of agreement method. It involved determining from a bivariate plot of values of Class II district road GE and PSE integrity values that are within acceptable limits. The Class II district road GE and PSE integrity data was obtained by carrying quality assurance on roads constructed independently by the technologies. The optimal technology in attaining Class II District road GE or PSE during road construction is one with more Class II District road GE or PSE integrity data within acceptable limits specified by MOWT.

1.7 Conceptual Frame Work

Labour-based and equipment-based technologies during road construction and maintenance output the road GE and PSE. The road GE and PSE output by the technologies seem to differ since different tools and method were applied during road construction and maintenance. This therefore implies the road GE and PSE attained by the technologies during road construction seem to have different integrity. Conformity of GE and PSE integrity output during road construction to the operational district roads design specifications can therefore form a basis for comparing the technologies. In this way, the technology, which attain road GE, and PSE integrity conforming to MOWT specifications can be stated. Hence, the research conceptual framework to guide this research is summarised in Figure 1.1 below.

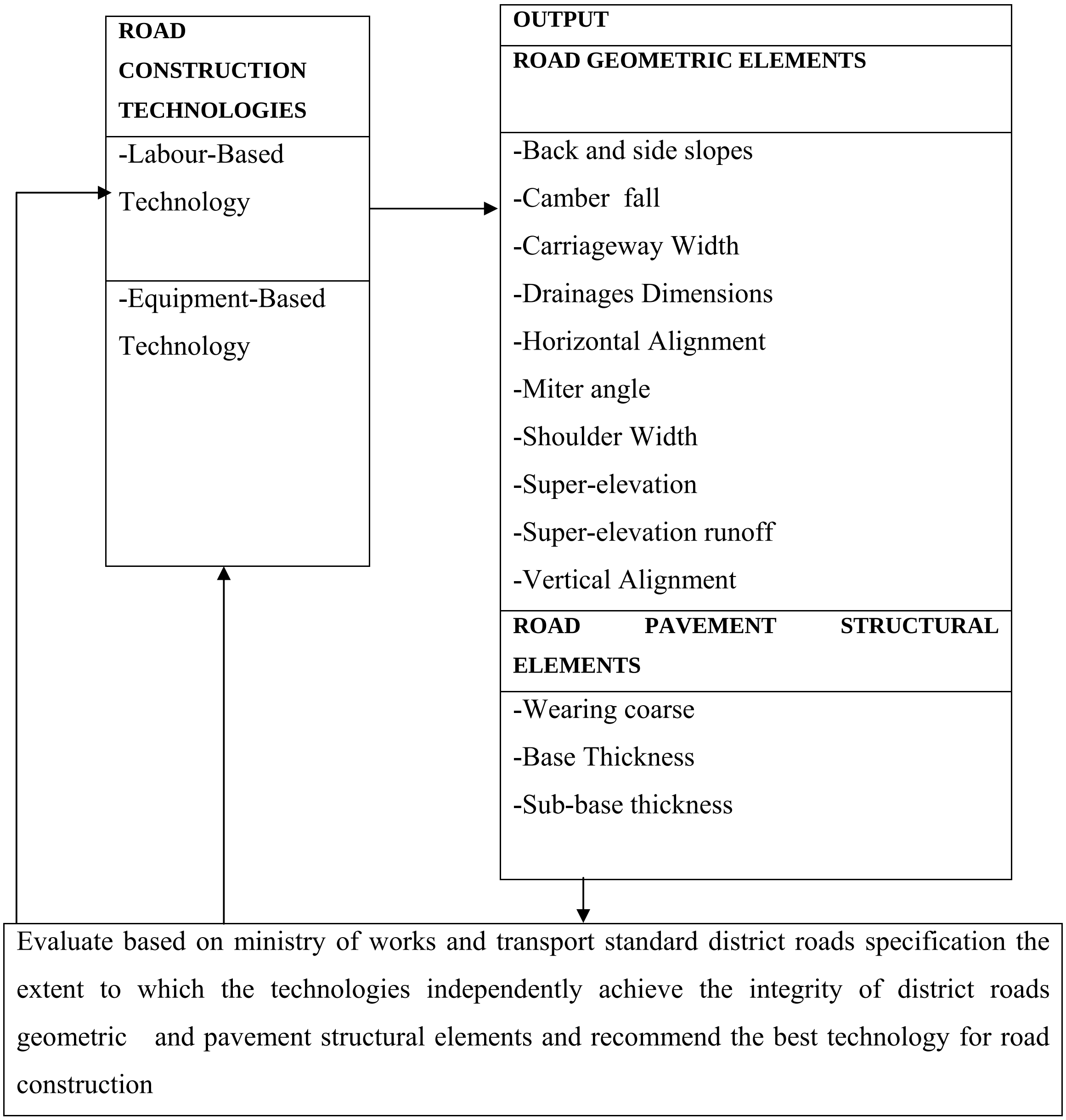


Figure 1.1: Research Conceptual Frame Work

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Literature review in this research was done from theoretical, contextual, and methodological point of view. Theoretical literature review was focused on the assumptions and theories that underpin this research. On the other hand, contextual literature review was based on the relationship between current and ideal ground situations that this research was developed to address. Lastly, from methodological point of view, literature was reviewed to widen the researcher's familiarity with previous studies related to this research. Literature review from methodological point of view help to establish the appropriate research approaches and designs to be adopt in this research.

2.2 Labour-Based Technology in Road Construction

According to Ministry of Works and Transport (2004), road construction is an element in the road project cycle that output the physical road infrastructure. "It is the process by which a road is built according to the established design standard, procedures and work method". Road construction involves intensive utilization of human, monetary, material and machinery resources to implement roadwork activities. Meanwhile Marshall (1987) stressed that the primary objective in road construction is to construct a road able to provide desired ride ability that is dependent on the road geometric and structural integrity often specified prior to road construction. Currently, LBT and EBT are the two technologies employed in road construction. However, in Uganda LBT application in road construction compared to EBT is still limited.

It is therefore evident that road construction proceeds through systematic and well-planned process by employing LBT or EBT to achieve required accessibility from constructed road. This guarantees value for resources utilized. Since in Uganda LBT application in road construction is still limited, it implies that most parts of the country are still in the learning curve as far as labour-based works are concerned. Therefore, conformity of LBT to applicable road PSE and GE specifications need to be established.

2.3 Applicable Class II District roads Pavement structure and Geometric Elements

A road consist of geometric and pavement structural elements. According to Yoder (1975), a pavement is constructed in layers of carefully selected material of varied thicknesses to distribute traffic load so that the resulting stress on the sub grade does not exceed its load bearing capacity. The road GE according to Ministry of Works and Transport (2004), are the physical features that give the road shape and ensure its safe performance. The road GE and PSE according to Ministry of Works and Transport (2002) are determined through road design process and specified in the road design standard. This implies that road performance is dependent on its PSE and GE. Hence, attaining GE and PSE during road construction must be emphasised to achieve the required accessibility from the constructed road. Class II district roads provide major internal accessibility needs in the district. They are potential sample for this research for they are often prioritised for roadwork intervention when preparing annual road work plan in the district. Measurements of Class II district roads GE and PSE integrity can be done after their construction.

In view of GE and PSE constituent materials, quality control also enhances a good road GE and PSE performance. Thus, materials quality control can accurately be done before and during road construction. In this research, materials quality control was assumed done before the road construction. The effects of the road construction technologies on the road construction materials quality was assumed negligible on the performance of the road GE and PSE. Hence, applicable class II district road PSE and GE need to be ascertained. They can be used as dependent variables in this research.

2.3.1 Pavement Structure

According to Ministry of Works and Transport (2002), the PSE of a Class II district road consists of three layers namely; wearing coarse, base, and sub-base. The base and sub-base are load distribution layers constructed from appropriate materials to a given thickness depending on the expected traffic on the road and the sub-grade strength. If high traffic is predicted on the road and the underlying sub grade is weak, the base and sub-base layers are appropriately built. The wearing coarse provides a smooth ridding surface for traffic. According to Huang (1993), a road is not just designed to provide a ridding comfort but its traffic load carrying capacity is of greater importance to consider during its design stage. The road design dictates the road construction materials to be used. Hence, before and during road construction, materials quality is ascertained by carrying quality control tests. The three pavement structural components are built depending on predicted traffic and sub grade strength. Hence, focus should be on the Class II district road PS commonly built during road construction. This will ensure Class II district road samples use in this research are of homogeneous characteristics.

2.3.2 Road Geometric Elements

A Class II district road according to Ministry of Works and Transport (2004) is as shown in Figure 2.1.

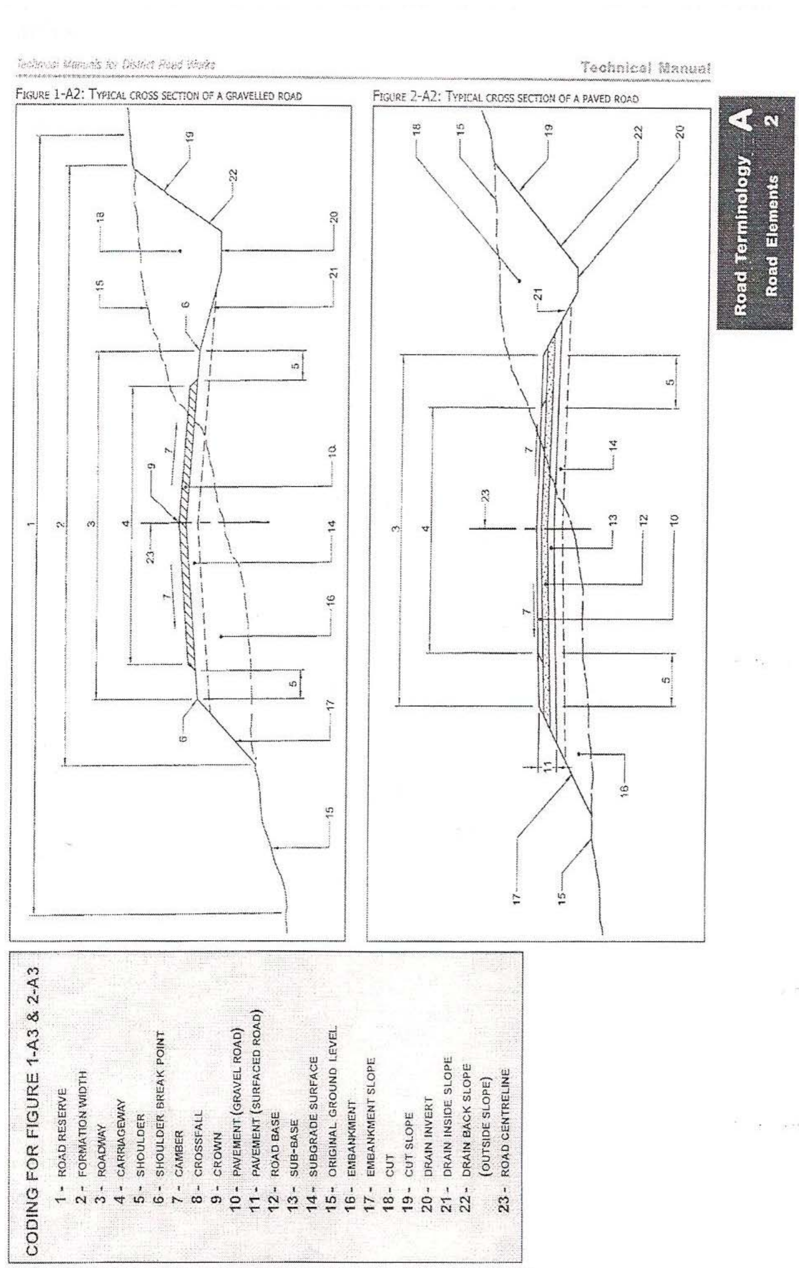


Figure 2.1 Typical Class II District Road Cross Section

Source: District road Manual, Vol 4A 2004

According to Gurcharan and Jagdish (2004) road GE are visible to road users. Their proper design provides optimum efficiency for traffic maneuver with maximum safety. The properties of road GE define their adequacy and the ultimate performance of the road is dependent on it. Speed, safety, and least inconvenience are the major factors considered when designing road GE. For maximum efficiency and safety on the road, GE are a requisite.

Therefore, Class II district roads too should possess appropriate GE that enhances safety and efficient road use. The road GE deteriorates during road performance. Hence in view of this the road maintenance cycle and the road construction technologies output in road construction can be compared if all factors are constant. Hence, road GE can be based on in comparing the road construction technologies.

2.4 Measurement Methods

According to Ministry of Works and Transport (2004), road construction proceeds through defined procedures to achieve the road PSE and GE. To ascertain conformity of the road PS and GE to applicable standard roads design, suitable instruments are used to take measurements.

2.4.1 Measuring Road Geometric and Pavement Structure Elements Integrity

In road construction, after survey and setting out work is complete, road construction follows a logical procedure. Antonious (1990) stipulated that to construct a road, a number of roads construction activities are executed. They are; earth works, embankment construction, ditching and camber formation, drainage construction, compaction, gravelling, and erosion protection among others. Conformity of road PSE and GE to standard road design is vital to achieve an efficient and a safe road performance. In practice, appropriate measurements and procedures to ascertain such conformity should match the technical specifications being used during road construction.

Boundary points of GE and PSE should first be established before taking measurements. The PSE boundary points include carriageway break points and interfacial point. The interfacial point is defined depending on the materials used in construction of the road GE and PSE by a change from one material to another. The boundary points of road GE include road centerline, shoulder break points, and side and back slope edges. On ascertaining boundary points, measurements procedures need to be established. Measurement is often done along the road centerline, across the carriageway, and along drainages. After ascertaining both boundary points and measurements procedures, measurements of physical properties can then be done within boundary points at stipulated interval.

2.4.2 Instruments for Measuring Road Geometric and Structure Elements

According to Howe and Muller (1995), road GE and PSE conformity to specifications and standard roads design need to be established during and after road construction. To establish conformity of road GE and PSE to standard roads design, measurement of physical properties defining road GE and PSE standard specification must be done. Ministry of Works and Transport (2004), shows that physical properties defining conformity of road GE and PSE can be physically measured. The specified instruments used in practice are; measuring tape, spirit level, camber boards, slope templates, straight edge, hammers, chisels, pegs, drainage template, survey protractor, and a Geographical Positioning System (GPS) machine. Those instruments have a reliable accuracy, can produce consistent results, are readily available in the local market, provide instant results, and are easy to use. Any measuring instrument that conforms to the theoretical or practical principles of measuring PSE and GE physical properties should be used.

Also any instruments not mentioned above but commonly used when conduction quality assurance during and just after road construction may be used for taking measurements. However, the instruments identified for quality assurance need to be ascertained whether they are readily available, reliable, and research assistants can be trained to use them. Where an instrument is inadequate for one reason or another, any instrument that operates under same governing theoretical and practical principles may be made and used to take measurements.

2.5 Roads Geometric and structure Elements Quality Assurance

Quality assurance according to Roberts *et al*. (1991) refer to those measurement and tests necessary to make a decision on acceptance of a project and hence to ensure that the product being evaluated is indeed what is specified. Thus in road construction, quality assurance involves establishing the extent to which technical specifications in use have been adhered to. To ascertain adherence to technical specifications, field measurements and tests are carried out. Since road performance depends on its PSE and GE, quality assurance is a requisite. Quality assurance therefore needs to be done by taking measurements directly on site using appropriate instruments at suitable s. Ministry of Works and Transport (2004), affirmed that in carrying quality assurance acquaintance with the right instruments and procedures are paramount to minimising errors. The team to do quality assurance checks must be trained on the procedures to follow and how to use the instruments. Linear and angular measurements are common on site measurements done in quality assurance. The common linear measurements are length, width, height, and depth. Hence, training research assistants on how to use instruments and procedures to follow whenever carrying quality assurance should be considered.

On the other hand, Huang (1993) argued that, pavement performance is governed by stiffness of its constituent materials. Material stiffness is defined by the compactive and shear strength of the materials. This implies in carrying pavement quality assurance, in addition to linear measurement, compactive and shear strength of the pavement materials are a requisite. However, sufficient compactive strength can only be attained by EBT in roads construction. Shear strength is not affected by either EBT or LBT. Hence, to ensure the same platform in comparing the quality output of EBT and LBT, compactive strength cannot be reliably considered. Also description of the road past performance gives a view of the quality output attained by the road construction technology applied in road construction. Consequently, if an appropriate road performance description method can be established, the extent to which road PSE and GE are attained during road construction can be ascertained. Amin (n.d), argued that to be able to describe a given situation, descriptive research deign is appropriate and questionnaire survey is useful in data collection. Descriptive research design follows a detailed description of a research target population, samples, sampling method, data collection instruments and methods and data analysis.

Therefore, descriptive research design can ensure accuracy and consistency in proper planning to predetermine quality assurance gang, data collection method, the instruments required, the procedure to follow, and the training needed for research assistants. The benefits of specialisation can be maximised by adopting descriptive research design. Performance description of roads constructed by LBT and EBT can be done following descriptive research design. However, descriptive research design can only provide opinions on the extent to which PSE and GE attained by the technologies conform to the specifications in use. Hence quality assurance that involves taking measurements of the physical properties describing the GE and PSE need to be done to quantify the extent to which PSE and GE attained by the technologies conform to specifications in use.

2.6 Comparison of Equipment- based and labour-based Technologies

According to Howe and Muller (1995), technology is the science and art of getting things done through the application of skills and knowledge. It is a spectrum, with ideas at one end and techniques and things at the other, with design as a middle term. It does not just mean tools or techniques; but also a process and product. The underlying principle behind a road construction technology is based on the techniques applied to achieve specified geometric and structural parameters during road construction. The road GE and PSE are not precisely achieved as specified during road construction. However, standard road design and specifications in use provide for acceptable lower and upper limits.

2.6.1 Equipment- based Technology

According to International Labour Organisation (2002), EBT is a road construction technique, which involves the use of heavy road works equipment and/or machines. With the current increased technological advancement, high equipment productivity and quality output have been noted in road construction when applying EBT. However, other than masonry work, all other road work activities can be done by EBT. Therefore, when applying EBT in road construction, a mix of labour and equipment is required in executing masonry works. Equipment-based technology maximises use of modern road works equipment to construct road infrastructure. It can achieve long-term quality requirements in road construction if appropriately applied. Therefore, EBT can achieve the required quality in road construction depending on the version of equipment used. The actual quality attained by EBT is dependent on how well the underlying techniques are applied. Since equipment-based roadwork method cannot be applied to masonry work, a mix of labour and equipment is required.

2.6.2 Labour- based Technology

According to Taigman and Jan de veen (1998), LBT involve intensive labour utilisation and the use of local hand tools to construct road infrastructure. All road works can effectively be executed by LBT except compaction. United Nation Development Programme (1999), indicated that pilot labour-based road works in Kenya, Tanzania, Zimbabwe, Zambia, South Africa and Srilanka showed that LBT can achieve appreciable quality output in roads construction. However, this was subject to the fact that the conditions under which LBT was applied are favorable for the technology. Those included intensive supervision, labour availability, appropriate wage rate, and optimal task. This implies that, LBT technique requires high supervision to achieve desired quality output, it is an efficient technology in road construction provided labour is available and control modalities are fully established and operationalised. Ampadu (1999) also urged that, a number of factors affect progress of labour-based roadwork. These factors are scope of work such as gravelling reshaping, culverts installation, labour availability and consistency in project funding among others. A successful application of labour-based roadwork is therefore difficult since some factors affecting it may be beyond control of the roadwork supervisors.

2.6.3 Feasibility of the Technology to be Adopted

An acceptable road construction technology is that which is technically, economically, and socially feasible to apply in road construction. Ministry of Works and Transport, (1999) argued that major costs incurred in application of EBT include those incurred on spare parts, equipment consumables, equipment hire, equipment down time, supervision and machine operations. For LBT application major cost are wages, cost of hand tools required, materials, supervision, delays, and machine hire typically for compaction. Thus, for equal volume of road works, EBT seems more costly than LBT.

Leonard (1991), stressed that the actual cost of equipment cannot be ascertained until the equipment finishes its useful life or until it is sold. The actual equipment costs include major elements such as depreciation, interest, maintenance and repairs, insurance and taxes, tyres, fuel, lubricants and operation. All those associated costs must be accurately established to aid operational planning. This is difficult in practice since a number of variables must be considered to determine equipment cost. Hence, cost comparison of EBT and LBT can only be based on accuate information.

Also according to Ministry of Works and Transport (2004), for equal volume of road works, EBT is generally faster than LBT. However, high road machines productivity can be countered by employing sufficiently large number of labour force and adopting appropriate tasks rates in applying labour-based technology in road construction. Therefore, for equal volume of road works, LBT and EBT can achieve the same time frame required.

Ampuda (1999), shows that in Ghana LBT achieved superior time frame in routine road maintenance task compared to EBT. This implies that in routine road maintenance works, LBT can effectively achieve lower work time frame compared to EBT. However, under favorable working conditions, the technologies can achieve the same time frame for same road works activities.

In Uganda, the government policy favours application of LBT in preference to EBT. This is because LBT application creates employment that is consistent with the employment creation policy supported by Poverty Eradication Programme. LBT application supports private sector development and therefore utilises the country human resource much more effectively than EBT. Hence, its application in road construction is a welcome idea. Application of LBT seems to have been lineated to supporting other government labour policies that can effectively be achieved by applying LBT in road works. This in road construction cannot be a justified ground to effectively compare EBT and LBT. This is because it mismatches the primary purpose of introducing labour-based roadwork. Comparison based on creation of employment is rather a ground for EBT or LBT preference. In this research, comparison of EBT and LBT cannot be based on creation of employment.

2.6.4 Road works Activities

According to Ministry of Works and Transport (1999), executable road work activities by labour-based method have got associated controlling instruments. Earth works are controlled by drainage template, camber board, pegs and measuring tapes. Alignment and spreading of material are controlled by the use of pegs and ropes. On the other hand, all road works activities executed by EBT are entirely controlled by the conventional equipment, machine operators, and instruments such as the survey theodolite. Thus, conformity to the standard road design and specifications is dependent on the road construction technology applied. Hence, comparison of EBT and LBT in road construction can effectively be done basing on the same road works activities executable by either technology. This provide the same platform to compare the conformity of EBT and LBT to the standard road design and specifications used in the road construction.

2.6.5 Quality output

Road construction by LBT and EBT involves use of different equipment and tools. However, EBT is an old technology with appreciable quality output. Since different tools and equipment are used, the quality output of the technologies seems to be different. However, it is insufficient to merely appreciate the quality output of a technology. Quantifying the technologies' actual quality output based on same roadwork activities provides a much more conclusive evidence of the technologies' quality output. Comparing LBT and EBT in road construction can be based on MOWT specification for the given road.

2.6.6 Road works procedure

According to Ministry of Works and Transport (2004), all road works by LBT proceed after control or setting out with the help of pegs, ropes, and tape measures. On the other hand, road works by EBT are often executed basing on the accuracy of the equipment as well as the instrument being used and operator experience. Road works procedures are much more controlled in LBT than in EBT. Therefore, proper conformity to road works procedure seems to be more observed in labour-based road works than in equipment-based road works. It is therefore reasonable to conclude that roadwork by LTB conforms better to the standard road design and specifications than that by EBT. Control measures in road construction are a requisite and often all required procedures to attain conformity to standard roads design are given in the specifications. Lack of adequate control is attributed to failure to attain quality standard required.

2.6.7 Environmental impact

Ministry of Works and Transport (2003), shows that EBT has adverse environmental impact in view of dust produced, high noise level, high exhaust gas from machines, destruction of flora and fauna compared to LBT. World Bank (1996) suggested that other than erosion, the single most important direct environmental impact associated with construction and maintenance of rural roads caused majorly by rain, LBT position is within range of fair environmental impact. This implies that, LBT is less hazardous to the environment compared to EBT. Where LBT negative impacts on the environment are observed, little resources may be required to restore the environment. LBT is therefore an environmentally more friendly technology to apply in road construction compared to EBT.

2.6.8 Gender in Road Works

Ministry of Works and Transport (2003), indicates that gender mainstreaming is highly recognised when applying LBT than EBT. The Ministry further urged that, an equal work force proportion is often strived during employment in labour-based road works. This is not the case in equipment-based road works. Thus in view of women emancipation effort, LBT tends to support the strategy of women involvement in the construction industry more than EBT. The conformity of road GE and PSE to specifications is most paramount road construction. Hence, women emancipation effort can not be a factor on which the choice of an optimal technology to apply in road construction can be based.

2.7 Application of Technologies in Uganda- A Case of Kapchorwa

The approved road workplan for Kapchorwa district for the financial year 2007/2008 shows that Katero-Kapkoc and Kapchorwa-Kapkwai road were planned for construction. These roads were to be constructed by applying LBT and EBT, respectively. The road works activities to be carried in both roads were shaping, side and miter drains construction, vertical, and horizontal alignment, and gravelling. All road works are applied based on MOWT specification for district roads. This specification stipulates the integrity of road GE and PSE together with the lower and upper limit acceptable for satisfactory performance of the road after construction. The MOWT specification for district roads is shown in Table 2.1 in Appendix 2.

2.8 Summary of Literiture Review

From the literature reviewed, it was noted that EBT and LBT differ in quality output. This is because in executing road works, different tools and equipment are used. The actual outputs of the two-road construction technologies have not been quantified. Quantifying conformity of road GE and PSE attained independently by EBT and LBT to standard road design and specifications can provide a direct measure of how best the road works activities are done by the technologies. In order to quantify conformity of road GE and PS achieved by EBT and LBT in roads construction to specifications, limit of agreement method can be used.

Qualitative and quantitative data are required to compare the technologies. Qualitative data can be collected from stakeholders directly involved in road construction in the districts using questionnaire surveys. On the other hand, quantitative data can be collected by carrying quality assurance test on roads constructed independently by a road construction technology. The analysis of qualitative data can follow percentage data analysis method. While for quantitative data; statistical methods and limit of agreement method can be used. Interpretation of quantitative and qualitative data should be based on the operational standard road design and MOWT specified limits of GE and PS integrity.

The choice of the appropriate road construction technology cannot only be based on the technology's secondary advantages such as being environmentally friendly, pro-gender and employment creation. It is rather based on the road GE and PSE integrity achieved by the technologies during road construction and maintenance. Basing on road construction cost in comparing the technologies may bias quality. However, cost effectiveness in term of accessibility level the technologies provide can be used in comparing the road construction technologies. The effects of EBT and LBT on material quality during road construction can be assumed negligible. Finally, there is need to quantify the extent to which LBT and EBT during road construction conform to the operational road design standard.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

In carrying out this research, descriptive, documentary, and comparison research criteria were used. Descriptive criterion was based on theories and road construction practices, procedures, instruments used to measure physical properties defining road GE and PSE, and quality assurance planning and execution in road works. On the other hand, comparison criterion was based on theories relating to data analysis, interpretation and comparison of quality assurance results of Class II district roads GE and PSE attained by the technologies.

3.1 Research Design

In this research, qualitative and quantitative research approaches were used. Qualitative research approach was used to identify the procedures and instruments used in practice to measure physical properties defining Class II district roads GE and PSE. Quantitative research approach quantified the relationship between the road geometric and structural elements attainable by the technologies during road construction. Qualitative and quantitative research approaches employed different research designs. While qualitative research approach adopted documentary research design, quantitative research approach adopted descriptive and correlation research design.

In documentary research design, literature was reviewed to identify procedures and instruments used to measure physical properties defining Class II district road geometric and structural elements. Descriptive research design qualified and described those procedures and instruments identified in documentary research design. This was intended to ensure that data collected from Class II district road samples are of homogeneous characteristic and those roads conform to the MOWT standard road design and specifications.

Correlation research design was used to compare Class II district road geometric and pavement structural elements attainable by the technologies during road construction. Correlation research design quantified the extent to which the technologies suit Class II district road geometric and pavement structural elements in road construction. Comparison of the technologies was based on conformity of Class II district road geometric and pavement structural elements attained by the technologies to MOWT operational standard road design and specifications. The standard road design specified by MOWT and used in this research is shown in Table 2.1 in Appendix 2.

3.2 Research Area

This research was carried mainly in eastern Uganda in the district of Kapchorwa. This was because at the time of carrying this research, both technologies were being applied in road construction. In Kapchorwa district, qualitative and quantitative data were collected. However, to boost this research, qualitative data were also collected from Mbale, Kumi, Katakwi, Sironko, and Soroti district. Those districts are also currently applying both technologies in road construction.

3.3 Description of the Population

The population for this research were Class II district roads and stakeholders directly involved in roads construction in all the districts selected. Class II district roads were chosen because they provide the major district internal accessibility needs by linking to administrative centres, schools, hospitals, agricultural area, markets and national roads. Due to their great linkages in providing internal accessibility, Class II district roads are of great importance to the districts as far as accessibility is concerned. Consequently, Class II district roads under construction by the technologies were available and could be used in carrying this research. The Class II district roads sample used had the requisite characteristics like: super elevation run off, super-elevation, drainage dimension, mitre angle, back and side slopes, camber fall, carriageway width, shoulder width, horizontal alignment, vertical alignment, wearing course thickness, base thickness and sub-base thickness. These characteristics were considered dependent variables.

Stakeholders considered, were those directly involved in road construction. They included district engineers, supervisors of work and county engineering assistants. They were chosen as key informants based on their experience and knowledge in applying EBT and LBT in road construction.

3.4 Sampling Strategy and Sampling Size

Two sampling strategies were used in this research. Class II district roads sample was obtained by Stratified random sampling while stakeholder sample was obtained through census. The roads to be used as sample in this research were selected by stratified random sampling. In stratified random sampling, the total number of Class II district roads under construction in Kapchorwa district was first obtained. A sample frame was then established by categorising these Class II district roads under construction in two proportions. The two (2) proportions constituted roads under construction independently by EBT and LBT. Two (2) roads were under labour-based road work while the other two (2) were under equipment-based method of road works. Those roads proportions formed the population sub groups which were to be represented equally in ration in the sample frame. Class II district road sample frame elements were then determined using a random number table as sample elements. In using the random number table, sample frame elements were assigned numbers and randomly selected. While randomly selecting sample elements, equal representation in ration from the population subgroups in the sample was observed. The elements selected were used as samples in the research. Obtaining the sample elements using random number table was based on a ninety five percent (95%) confidence level that sample statistical parameters will be close to the population statistical parameters. On the other hand, all district engineers, supervisors of works and county engineering assistants from the research area were used as sample elements to ensure that their view is generalisable. They were considered key informants and they provided qualitative data in this research.

The stakeholder's sample size equaled the stakeholder's number in this research. The road sample size in this research was determined using a statistical method for determination of sample size to estimate the population mean. This Statistical method involved determining the minimum sample size required for a maximum error to prevent the research from being wasteful. It was employed with the view to get a large enough sample that is representative of the population to accurately estimate the population parameters and consequently ensure generalisability of the research findings. In employing the statistical method to determine the sample size, 95% confidence level was considered statistically adequate. The sample standard deviation was first obtained from a pilot study in Kapchorwa district. The pilot study was carried out basing on five (5) dependent variables of this research. The variables used were camber fall, carriageway width, shoulder width, back and side slopes. Three (3) roads were selected from five (5) roads under separate construction by the technologies. The sample standard deviation obtained from the pilot study was considered the population standard deviation in calculating the sample size. The sample size was then computed based on the expression below.

$$X \pm Z_{\alpha/2} \frac{S}{\sqrt{n}}$$

$$L = Z_{\alpha/2} \frac{S}{\sqrt{n}}$$

$$\therefore n = \frac{\left(Z_{\alpha/2}\right)\sigma^{2}}{L^{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.1$$

Where X is the population mean,

L is the maximum error,

δ is the population standard deviation,

S is the sample standard deviation,

n is the sample size and

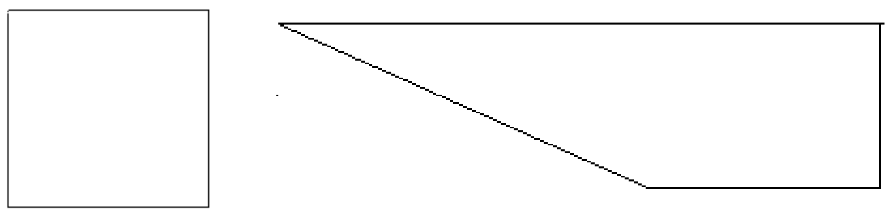
α is the confidence level.

The sample size obtained was two (2). The two roads selected as sample elements from the sample frame elements determined using random number table were Katero-Kapkoc road and Kapchorwa-Kawai road in Kapchorwa district. On the other hand, all the district engineers, supervisors of works and county engineering officers from the research area provided qualitative data. The total number of district engineers, supervisors of works and county engineering assistants in the research area was 34. Hence key informants used in this research were 34 in number.

3.5 Data Collection Tools

In this research, qualitative and quantitative data were collected. Qualitative data included stakeholders' views and documented information from literature, reports, and MOWT manuals. Quantitative data included geometric and pavement structural elements data from the sampled roads. Stakeholders' views were obtained using pre-tested self-administered questionnaire forms. The questionnaire used is shown in Appendix 3. In collecting data by questionnaire, stakeholders were requested to fill required information in the forms provided to them. Filled questionnaire forms were collected after two (2) weeks. Questionnaire forms were used because they are flexible in soliciting variety of primary data, inexpensive to develop and use and can solicit information faster as urged by Amin (n.d). Hence, given the period to carry this research, the use of questionnaire for soliciting qualitative data was found to be effective.

Quantitative data was collected by carrying quality assurance during the construction of the sampled roads. Measurements was carried on five (5) kilometer stretch of each sample road using the instruments below.



Drainage Template **Camber Board**

Figure 3.1 Key Instruments Used in Labour-Based Road Works

The drainage template is used for checking the depth and width of the drainages. Its dimensions conform to the drainage dimensions in the specifications in used during road construction. The camber board is used for checking camber fall, back slope, and side slope. These instruments were used in this research because they are most commonly used, and simple to use when carrying quality assurance on a constructed road. Their accuracy and reliability qualified their use in carrying this research. The instruments used to carry measurements on every road geometric and pavement structural element from the sampled roads are shown in Table 3.1(a) in Appendix 3. The instruments are specified in MOWT specification for Class II feeder roads and also by this research key informant. The integrity of Class II district road geometric and pavement structural elements were measured on interval scale.

3.6 Data Quality Control

To ensure quality data was collected and used, the annual roadwork plan of Kapchorwa district for the fiscal year 2007/2008 was scrutinised to determine the road work activities that were to be undertaken. This was intended to provide a guide on the data to be collected for this research. The data collection methods described in Table 3.1(b) in Appendix 3 were fully followed. Measurements of Class II district GE and PSE integrity was done during construction of the sampled roads. This was to avoid collecting wrong data arising from the road being open to traffic. Research assistants were recruited from among the trained labour-based contractors' team for data collection. This was intended to utilise their skills in data collection for this research. The research assistants were also trained and oriented in data collection procedures, use of data collection instruments, data recording in predesigned forms and their storage in hardcopy in the field. Data storage in soft copies was also adopted.

The instruments used for collecting Class II district roads data were those specified for quality assurance in the MOWT Technical Manual (2004) for both EBT and LBT road works. The validity of those instruments used in data collection was checked based on their theoretical validation. For instance, camber board diagonal was measured and the slope checked based on Pythagoras theorem. Errors in measurements arising from the expansion and contraction of instruments due to temperature changes were corrected by an appropriate correction factor as argued by Amin (nd). To ensure reliability of the questionnaire used in this research, use of both open and closed ended questions was adopted. The contents validity of the questionnaire was checked by pre-testing the questionnaire. This was to ensure invalid questions (items) are adjusted in the questionnaire. Questionnaire pre-testing was done three (3) times while computing its content validity index using equation 3.2 below each time.

Those items with average content validity index below 0.6 were removed from the questionnaire as shown by Amin (n.d).

CVI=NIDV/TNI …………….3.2

Where CVI is the Content Validity Index

NIDC is number of items declared valid in the questionnaire

TNI is total number of items in the questionnaire

Qualitative data in this research were sorted, coded and presented in tabular form to avoid mixing of data that would result in to wrong findings. With the instruments stipulated in Table 3.1 (a), Figure 3.2 in Appendix 3 shows the research assistants taking measurements following the methods in Table 3.1(b) on sampled roads from Kapchorwa district.

3.7 Data Analysis

Qualitative data in this research were presented in tabular form and their analysis was done using percentage analysis method. All percentages were computed based on grand totals. Statistical analysis was done using GenStat 2003 statistical software. Quantitative data analysis was done in four steps as detailed in the subsections that follow.

3.7.1 Description of Data

Description of data was done by displaying the data pictorially using histograms and computing their statistical parameters such as coefficient of variation, mean, standard deviation, and variance. Pictorial display of data also enabled the distribution of the road geometric and pavement structural elements data attained by the technologies studied.

3.7.2 Relationship between Data

The relationship between the same dependent variable attained by the technologies was established by correlation statistical method as similarly argued by Hines *et al* (2004). In using correlation statistical analysis, Pearson Moment Correlation Coefficient of each dependent variable attained by the technologies was computed. This was done to show how the GE and PSE attained by the technologies are related. A positive Pearson Moment Correlation Coefficient value indicated a high correlation between the dependent variable values attained independently by LBT and EBT in road construction. However, a negative value indicated a small correlation between the dependent variable values attained by LBT and EBT when independently applied in road construction.

3.7.3 Establishing Equality of Population and Sample Means

The population mean of a given dependent variable was taken as the mean value of that variable as specified by MOWT. To determine whether the population mean was truly the sample mean, inferential statistics was emplyed. A null hypothesis was tested using Student t statistics. A two-sided test basing on a five percent (5%) level of significance for estimating population mean was done. The probability obtained was then used to state whether the population mean equaled the sample mean. If the probability obtained is far less than one (1), it implied that the population mean was not equal to the sample mean. Hence, the given dependent variable values were sparsely distributed around the population mean.

3.7.4 Proportion of Dependent Variable within Specified MOWT Limits

To determine the percentage proportion of each dependent variable values that lie within MOWT specified lower and upper limits, limit of agreement method was used. This method involves plotting specified limits of the dependent variable in a bivarite plot of the dependent variable. The bivarite plot is a plot of chainage along the x-axes and the dependent variable values attained independently by EBT and LBT on the y-axes. The dependent variable values within MOWT specified limits were then counted and expressed as percentages. On comparing the percentage attained by EBT and LBT, inference was then drawn with 95% degree of confidence that either EBT or LBT suits the dependent variable considered more accurately.

3.8 Ethical Consideration

To ensure ethics in conducting this research, the following were observed:

- All precautions necessary to avoid expected harm to subjects were communicated and adopted before and during data collection. More so, harm from moving vehicles on the road was controlled by use of road work signs placed at appropriate points along the road section where quality assurance was being carried ;
- Prior permission was sought from the local authorities in the research area before collecting data;
- The purpose, expected outcome and significance of this research was fully presented to all those who were directly involved;
- Research assistants were cautioned to avoid falsifying data. The undesirable consequences of such acts were clearly explained to create awareness and cautions; and
- Lastly, confidentiality of respondents was observed in data collection by self-administered questionnaire forms.

3.9 Limitations

The limitation encountered in carrying this research was insecurity in some parts of the research area. This affected carrying the research smoothly. To overcome this, security from security organs was sought.

CHAPTER FOUR

PRESENTATION, ANALYSIS AND DISCUSSION OF RESULTS

4.0 Introduction

This research determined based on MOWT specification, the extent to which EBT and LBT suit the applicable Class II district road geometric and pavement structural elements during road construction. This chapter presents and describes how the objectives of this research were achieved. The presentation and description covers:

1. The procedures used in practice to measure physical properties that describes Class II district road geometric and pavement structural elements;
2. The instruments used in practice to measure physical properties describes Class II district road geometric and pavement structural elements; and
3. The comparative effectiveness of EBT and LBT in attaining Class II district road geometric and pavement structural elements during road construction.

The presentation and description of the procedures and instruments used to measure GE and PSE physical properties was based on qualitative data. However, presentation and description of comparative effectiveness of EBT and LBT in attaining road GE and PSE during road construction was based on quantitative data.

4.1 Respondents Bio-data

The respondents' biography obtained is summarised in Table 4.1 below. The respondents' biography was coded as one (1), two (2), and three (3) to specify their category. Code 1 referred to district engineers, 2 supervisors of works and 3 county engineering assistants. From Table 4.1, the targeted sample size was 34 and all of them responded. This represented 100% response rate in data collected by questionnaire.

Table 4.1: Summary of Respondents Bio-data

KEY INFORMANTS	RESPONDENTS	
	CODE	**RESPONSE NUMBER**
District Engineers	1	6
Supervisor of Works	2	6
County Engineering Assistants	3	22

4.1.1 Analysis and Discussion of Results

According to Amin (n.d), 100% response rate when collecting data by questionnaires imply that the response obtained is representative of the population. Hence, the respondents' biography obtained was typically that of the target population and was considered valid. Therefore, the targeted respondents provided reliable information that was used in this research.

4.2 Class II District Roads Structural Integrity and Geometry

Table 4.2 below shows the summary of response distribution on the actual Class II district road geometric and pavement structural elements attained during construction by LBT and EBT.

Table 4.2: Specified and Actual Class II District Road Structural Integrity and Geometry

SPECIFIED CLASS II DISTRICT ROAD PSE AND GE BY MOWT	GE/PSE CODE	ACTUAL CLASS II DISTRICT ROAD PSE AND GE	NUMBER OF RESPONSES	PERCENTAGE RESPONSE
Camber fall	1	Camber fall	34	100
Vertical Alignment	2	Vertical Alignment	34	100
Drainage Dimensions	3	Drainage Dimensions	34	100
Horizontal Alignment	4	Horizontal Alignment	34	100
Super-elevation	5	Super-elevation	34	100
Carriageway Width	6	Carriageway Width	34	100
Back and Side Slopes	7	Back and Side Slopes	34	100
Shoulder width	8	Shoulder width	34	100
Miter Angle	9	Miter Angle	34	100
Super-elevation runoff	10	Super-elevation runoff	34	100
Wearing Course	11	Wearing Course	34	100
Base	12	Base	0	0
Sub base	13	Sub base	34	100

4.2.1 Analysis and Discussion of Results

By percentage analysis, the actual Class II district road structural pavement and geometry consistent with MOWT specifications are those in Table 4.2 except the base. Therefore, other than the base as a pavement structural element, comparison of the technologies in road construction was based on all actual Class II district road geometric and pavement structural elements shown in Table 4.2.

4.3 Measurement of Geometry and Structural Integrity

Table 4.3 below shows the procedures used in practice to measure actual Class II district road geometric and pavement structural elements. From Table 4.3, it is evident that different procedures are used to measure road GE and PSE integrity.

Table 4.3: Measurement of Physical Properties of Actual Class II District Road Geometric and Pavement Structural Elements

GE AND PS	GE/ PS CODE	SPECIFIED AND APPLICABLE PROCEDURES FOR MEASUREMENT	NUMBER OF RESPONSE S	PERCENTAGE RESPONSE
Camber fall	1	Identify and peg carriageway break points and road centerline and measure inclination angle at 20m interval.	31	90
Vertical Alignment	2	Identify road centerline and peg and take levels along road centerline at 20m interval and at 5m interval along vertical curves.	23	68
Drainage Dimensions	3	Identify and peg shoulder break points and drainage centerline and measure drainage dimension s on both sides of the road at 20m interval.	34	100
Horizontal Alignment	4	Identify road centerline and peg and take measurement along road centerline and measure distance at 20m interval on longitudinal profile and at 5m interval along horizontal curves.	21	61
Super-elevation runoff	5	Identify and peg beginning and end of circular curve and measure and peg specified super-elevation length along straights from the beginning and end of circular curve. Measure from end of super-elevation length required of super-elevation runoff from end of super-elevation length along straights at 10m interval.	17	50
Carriageway Width	6	Identify carriageway break points and peg and measure carriageway width at 20m interval along the road.	34	100
Back and Side Slopes	7	Identify and peg side drains bottom width and shoulder break points and measure slopes on both sides of the road at 20m interval.	34	100
Shoulder width	8	Identify and peg shoulder and carriageway break points and measure distance between break points on both sides of the road at 20m interval.	34	100
Mitre Angle	9	Identify and peg side drain, and miter drain centerline and measure mitre angle in the direction opposing of side drain water flow the angle between miter and side drain centerline.	34	100
Super-elevation	10	Identify and peg beginning and end of circular curve, measure and peg specified super-elevation length along straights from the beginning and end of circular curve and measure super-elevation angle at 5m interval along the road.	20	59
Wearing Course	11	Identify and peg carriageway break points and road centerline and measure wearing course thickness thrice across carriageway at 20m interval along the road.	34	100
Sub base	12	Identify and peg sub base break points and road centerline and measure sub base thickness thrice across sub base at 20m interval along the road.	15	50

4.3.1 Analysis and Discussion of Results

For each of the actual Class II district road geometric and pavement structural elements in Table 4.3, the percentage response on the procedures used to measure their integrity isequal to or above 50%. Amin (n.d), argued that where percentage response is greater than 50% it imply a majority view. Hence, the procedures for measuring physical properties of actual Class II district road geometric and structural pavement elements in Table 4.3 above were adopted in this research.

4.4 Instruments for Measuring Physical Properties of Actual Class II District road Structural Integrity and Geometry

Table 4.4 below shows the response distribution on the instruments used for measuring physical properties of actual Class II district road geometric and structural pavement elements.

Table 4.4: Instruments for Measuring Physical Properties of Actual Class II District Road Structural Integrity and Geometry

PAVEMENT STRUCTURAL COMPONENTS AND GEOMETRIC ELEMENTS	GE/PS CODE	SPECIFIED INSTRUMENTS FOR MEASURING PROPERTIES OF CLASS II DISTRICT ROAD GEOMETRIC AND PAVEMENT STRUCTURAL ELEMENTS	NUMBER OF RESPONSES	PERCENTAGE RESPONSE
Camber fall	1	Camber Board, Spirit Level, Tape measure, Straight Edge and Peg.	20	58.8
Vertical Alignment	2	Ranging rod, String, Tape measure, pegs, and GPS machine.	25	73.5
Drainage Dimensions	3	Ditch template, Tape measure, String and Peg.	34	100
Horizontal Alignment	4	Ranging rod, String, Tape measure, pegs and GPS machine.	24	70.6
Super-elevation runoff	5	Tape measure, Strings, and Pegs.	34	100
Carriageway Width	6	Tape measure, Strings, Straight edge and Pegs.	34	100
Back and Side Slopes	7	Tape measure, Slope Template, and Pegs.	34	100
Shoulder width	8	Tape measure, String, and Pegs.	34	100
Mitre Angle	9	Bonding rod, String, Protractor, and Pegs.	22	64.7
Super-elevation	10	Tape measure, Straight edge, spirit level, and Pegs.	34	100
Wearing Course	11	Tape measure, Hammer, Pegs and chisels.	34	100
Sub base	12	Tape measure, Hammer, Pegs and chisels.	34	100

4.4.1 Analysis and Discussion of Results

From percentage analysis all the responses are above 50%. This implies that the instruments specified in Table 4.4 are commonly used in practice to measure physical properties of actual Class II district road geometric and pavement structural elements. Hence, the methods in Table 4.4(a) were used. This enabled easy data collection method to be used and also quality data for this research.

4.5 Structural Integrity and Geometry of the Roads Studied

Table 4.5 below shows respondents' views on how the road geometric and pavement structural elements integrity are measured when carrying quality assurance. Table 4.5 also shows the property measured when carrying measurements on the road after construction.

Table 4.5: Road Structural Integrity and Geometry

GE/PS	GE/PS CODE	RESPONSE ON THE PROPERTY DEFINING ADEQUACY OF CLASS II DISTRICT ROAD GE AND PS	NUMBER OF RESPONSE	PERCENTAGE RESPONSE
Camber fall	1	Inclination angle, measured on both sides of the road centerline at 20m interval along road centerline.	25	74
Vertical Alignment	2	Gradient between two points at 20m s, measured along road centerline at 20m interval along straight and at 5m interval along vertical curve.	30	88
Drainage	3	Drainage cross sectional area, measured along drainage centerline at 20m interval along the drainage length.	34	100
Horizontal Alignment	4	Radius of horizontal curve, and length of circular curve measured along road centerline at 20m interval on longitudinal profile and at 5m interval along horizontal curves,	34	100
Super-elevation runoff	5	Length, measured from the beginning or end point of curve along straights at 10m interval.	18	53
Carriageway Width	6	Width, measured at 25m interval along the road.	34	100
Back and Side Slopes	7	Slope of side drains, measured at 25m interval along the road.	34	100
Shoulder width	8	Width, measured at 20m interval on both side of the carriageway along the road .	34	100
Mitre Angle	9	Angle, measured at 20m along the mitre drain.	25	74
Super-elevation	10	Carriageway inclination angle, measured at 5m s along the road.	34	100
Wearing Course	11	Thickness, measured along the road within shoulder break points at 20m interval along the road.	26	76
Sub base	12	Thickness, measured along road within shoulder break points at 20m interval along the road.	34	100

4.5.1 Analysis and Discussion of Results

Since percentage response on the actual Class II district road geometric and pavement structural elements are above 50%, it implied this was a majority view. Therefore, the physical properties defining the actual Class II district road geometric and pavement structural elements in Table 4.5 were considered in comparing LBT and EBT in road construction.

4.6 Standard Road Design and Specifications

Table 4.6 below shows key informants view on the limits within which the actual road GE and PSE attained by the technologies during road construction lies and the specified limits by MOWT.

4.6.1 Analysis and Discussion of Results

From Table 4.6, LBT achieves actual Class II district roads geometric and pavement structural elements much closer to MOWT specification than EBT. This implied, the quality output of LBT seems to be superior to that of EBT. However, this only provides a clue on the technologies quality output in road construction. The technologies quality output could properly be assessed based on field data collected on the roads constructed by applying the technologies. Hence, field data from quality assurance was required to aid comparison of the technologies.

Table 4.6: Pavement Structural and Geometric Data by Equipment-Based and Labour-Based Technologies

APPLICABLE CLASS II DISTRICT ROAD PS AND GE		EQUIPMENT-BASED TECHNOLOGY		LABOUR-BASED TECHNOLOGY	
		SPECIFIED	ATTAINED	SPECIFIED	ATTAINED
GEOMETRIC ELEMENTS					
Camber fall		8%	7-9%	8%	8%
Vertical Alignment	Min Vertical Gradient	2%	3-6%	2%	2-4%
	Max Vertical Gradient	7-10%	8-12%	7-10%	7-10%
	Absolute Max vertical gradient length	500-200m	500-300m	300-300m	500-200m
Drainage Dimensions	Depth	300mm	300mm	300mm	300mm
	Bottom width	400mm	400mm	400mm	400mm
	Top width	1200-1500mm	1200-1300mm	1200-1300mm	1000-1400mm
Horizontal Alignment	Radius of horizontal curve	20m	20m	25m	25m
Super-elevation		8%	7-9%	8%	8%
Carriageway Width		5.4m	4.5-5m	5.4m	5.4m
Back and Side Slopes		1:3	1:2	1:3	1:3
Shoulder width		1200mm	1200-1400mm	1000-1200mm	1000-1200mm
Mitre Angle		45degrees	30-50 degrees	45degrees	43-48 Degrees
Super-elevation runoff		40-60m	35-70m	40m	40-65m
PAVEMENT STRUCTURAL COMPONENTS					
Wearing Course thickness		100mm	110-120mm	100mm	90-100mm
Sub base		varies	varies	varies	varies

4.7 Constructed Road Maintenance Cycle

The maintenance cycle required of roads constructed by EBT and LBT according to the respondents is shown in Table 4.7 below.

4.7.1 Analysis and Discussion of Results

From Table 4.7, roads constructed by LBT have longer maintenance cycle than those constructed by EBT. This implied LBT suit actual road geometric and pavement structural elements more accurately than EBT. However, this is not conclusive enough in comparing the technologies since traffic categories and road importance have changed over the years. Hence, comparison of the technologies cannot be based on the roads maintenance cycle. Rather field data collected on the actual road geometric and pavement structural elements attained by the technologies is required to aid comparison of the technologies.

Table 4.7 Constructed Roads Maintenance Cycle

EQUIPMENT-BASED TECHNOLOGY				LABOUR-BASED TECHNOLOGY			
RESPONDENTS CATEGORY	MAINTENANCE CYCLE IN YEARS	NUMBER OF RESPONSES	PERCENTAGE RESPONSE	RESPONDENTS CATEGORY	MAINTENANCE CYCLE IN YEARS	NUMBER OF RESPONSES	PERCENTAGE RESPONSE
1	2-3	21	61	1	2-3	4	11.7
2	4-5	8	24	2	4-5	24	70.5
3	5-6	6	3	3	5-6	4	11.7
4	6-7	4	12	4	6-7	2	5.9

4.8 Measurements of Road Geometry and Structural Pavement Integrity

4.8.1 Introduction

To compare LBT and EBT, measurements of GE and PSE integrity from the sampled roads constructed independently by the technologies was obtained. Analysis of road GE and PSE integrity data provided adequate evidence on which technology in road construction is superior to the other.

4.8.2 Road Geometry and Structural Integrity Attained by LBT and EBT

The statistical summary of geometric and pavement structural elements integrity attained independently by the technologies during road construction is shown in Table 4.8 below.

Table 4.8: Geometric and Pavement structural Integrity Date

SUMMARY STATISTICS	BACK SLOPE (%)		SIDE SLOPE (%)		CAMBER FALL (%)	
	ATTAINED BY EBT	ATTAINED BY LBT	ATTAINED BY EBT	ATTAINED BY LBT	FALL EBT	ATTAINED BY LBT
Mean(mm)	1.15	2.90	0.54	0.3	10.51	7.14
Minimum(mm)	0.6	1.8	0.3	0.21	0	6
Maximum(mm)	2.6	3.6	2.54	0.44	14	9
Range(mm)	2	1.8	2.24	0.23	14	3
Standard Deviation	0.25	0.38	0.24	0.04	2.73	0.60
Variance(mm)	0.06	0.14	0.06	0.001	7.51	0.35
Pearson Product Moment Coefficient	0.22		-0.13		-0.01	
Distribution around the Mean= (mean ±2*Standard Deviation) (mm)	Lower limit=1.65 Upper Limit=1.64	Lower limit=3.66 Upper Limit=2.15	Lower limit=1.01 Upper Limit=0.07	Lower limit=0.38 Upper Limit=0.22	Lower limit=15.97 Upper Limit=5.05	Lower limit=8.33 Upper Limit=5.95

Table 4.8: Geometric and Pavement structural elements Data (Continue)

SUMMARY STATISTICS	CARRIAGEWAY WIDTH (mm)		DRAINAGE DEPTH (mm)		DRAINAGE BOTTOM WIDTH (mm)	
	ATTAINED BY EBT	ATTAINED BY LBT	ATTAINED BY EBT	ATTAINED BY LBT	ATTAINED BY EBT	ATTAINED BY LBT
Mean(mm)	4794	5316	589	485	662	538
Minimum(mm)	4200	5100	200	300	200	400
Maximum(mm)	5000	5400	1400	630	1200	900
Range(mm)	800	300	1200	330	1000	500
Standard Deviation	262	110	149	72	277	113
Variance(mm)	68669	12179	22348	5206	76771	12805
Pearson Product Moment Coefficient	-0.3		-0.36		-0.05	
Distribution around the Mean= (mean ±2*Standard Deviation) (mm)	Lower limit=5318 Upper Limit=4270	Lower limit=5536 Upper Limit=5096	Lower limit=887 Upper Limit=291	Lower limit=629 Upper Limit=341	Lower limit=1216 Upper Limit=108	Lower limit=764 Upper Limit=312

Table 4.8: Geometric and Pavement structural elements Field Data (Continue)

SUMMARY STATISTICS	DRAINAGE TOP WIDTH (mm)		HORIZONTAL ALIGNMENT (mm)		MITRE ANGLE (%)	
	ATTAINED BY EBT	ATTAINED BY LBT	ATTAINED BY EBT	ATTAINED BY LBT	ATTAINED BY EBT	ATTAINED BY LBT
Mean(mm)	1690	1473	28.35	25.3	40.43	44.09
Minimum(mm)	600	1000	15	15	30	40
Maximum(mm)	2300	1800	60	45	60	50
Range(mm)	1700	890	45	30	30	10
Standard Deviation	379	152	8.97	6.36	7.82	4.11
Variance(mm)	143468	23020	80.42	40.4	61.17	16.89
Pearson Product Moment Coefficient	-0.05		0.07		0.18	
Distribution around the Mean= (mean ±2*Standard Deviation) (mm)	Lower limit=2448 Upper Limit=932	Lower limit=1777 Upper Limit=1169	Lower limit=46.29 Upper Limit=10.41	Lower limit=38.02 Upper Limit=12.58	Lower limit=56.07 Upper Limit=24.79	Lower limit=52.31 Upper Limit=35.87

Table 4.8: Geometric and Pavement structural elements Field Data (Continue)

SUMMARY STATISTICS	SHOULDER WIDTH (mm)		SUPER-ELEVATION (%)		SUPER-ELEVATION RUNOFF (mm)	
	ATTAINED BY EBT	ATTAINED BY LBT	ATTAINED BY EBT	ATTAINED BY LBT	ATTAINED BY EBT	ATTAINED BY LBT
Mean(mm)	896	1030	10.043	8.304	19.35	46.96
Minimum(mm)	1200	550	7	7	5	40
Maximum(mm)	1500	1250	12	10	40	60
Range(mm)	300	700	5	3	35	20
Standard Deviation	147	86	1.745	0.926	10.77	7.03
Variance(mm)	21579	7459	3.043	0.858	116.06	49.41
Pearson Product Moment Coefficient	-0.02		-0.12		-0.27	
Distribution around the Mean= (mean ±2*Standard Deviation) (mm)	Lower limit=1190 Upper Limit=602	Lower limit=1202 Upper Limit=858	Lower limit=13.533 Upper Limit=6.553	Lower limit=10.156 Upper Limit=6.452	Lower limit=40.89 Upper Limit=2.19	Lower limit=61.02 Upper Limit=32.9

Table 4.8 Geometric and Pavement structural elements Field Data (Completed)

SUMMARY STATISTICS	VERTICAL ALIGNMENT (mm)		WEARING COURSE (mm)	
	ATTAINED BY EBT	ATTAINED BY LBT	ATTAINED BY EBT	ATTAINED BY LBT
Mean(mm)	10	7	90.63	101.59
Minimum(mm)	28	0	78	92
Maximum(mm)	2100	1500	113	117
Range(mm)	2728	1500	35	25
Standard Deviation	148	106	9.03	3.92
Variance(mm)	21956	11194	81.48	15.33
Pearson Product Moment Coefficient	-0.003		0.04	
Distribution around the Mean= (mean ±2*Standard Deviation) (mm)	Lower limit=306 Upper Limit=-286	Lower limit=219 Upper Limit=-205	Lower limit=108.69 Upper Limit=72.57	Lower limit=109.43 Upper Limit=93.75

From the statistical summary, data were not uniformly distributed within limits of the respective geometric and pavement structural elements. There was little relation between road GE and PSE data obtained by LBT and EBT as shown by the Pearson product moment correlation coefficient. A graphical presentation of geometric and pavement structural elements attained by LBT is shown in Figure 4. (1-14 a) in Appendix 4. The graphical presentation of geometric and pavement structural elements attained by EBT is also shown in Figure 4.(1-14b) in Appendix 4. The technologies showed varied road GE and PSE integrity attained during road construction. The conformity of Class II district road GE and PSE integrity attain by the technologies during road construction therefore differ to MOWT specifications.

4.9 Comparison of LBT and EBT Based on Road Structural Integrity and Geometry

4.9.1 Introduction

During road construction, LBT and EBT strive to attain road geometric and pavement structural elements. Performance of the constructed road depends on its geometric and pavement structural elements integrity. For the road to perform, it’s geometric and pavement structural elements must conform to standard road design specifications specified by MOWT.

The standard road design stipulates the mean value required of road geometric and pavement structural elements. It also specify the lower and upper limits of the road geometric and pavement structural elements acceptable for proper road performance. From testing the null hypothesis on all the dependent variable attained by EBT using student t statistics at a 95% confidence, the summary statistic in Table 4.9 was obtained . The dependent variable mean value used was that specified by MOWT. The number of dependent variable values within MOWT specified limits determined the optimal technology in road construction. This was determined by limit of agreement method.

4.9.2 Analysis and Discussion of Results

The null hypothesis (H_{oi}) states that, EBT and LBT in road construction attain Class II Feeder geometric and pavement structural elements of different integrity. The output in Table 4.9 was obtained on testing the null hypothesis at a 0.05 level of significance.

Table 4.9: Summary statistics on Testing Null Hypothesis

STATISTICAL SUMMARY	BACK SLOPE	SIDE SLOPE	CAMBER FALL	CARRIAGEWAY WIDTH
Sample size	201	201	201	201
Mean(mm)	1.15	0.54	10,51	4794
Variance (mm)	0.06	0.06	7.51	68669
Standard Deviation	0.25	0.24	2.73	262
Standard error of the Mean (mm)	0.02	0.02	0.19	18.48
95% Confidence of the mean	(1.11,1.18)	(0.51,0.57)	(10.13,10.89)	(4758,4830)
Test Statistics (t)	-75.87	17.53	12.97	-11.15
Degrees of Freedom	200	200	200	200
Probability that mean of Dependent Variable attained by EBT is Equal to that specified by MOWT	<0.001	<0.001	<0.001	<0.001

Table 4.9: Summary statistics on Testing Null Hypothesis (Continue)

STATISTICAL SUMMARY	DRAINAGE DEPTH	DRAINAGE BOTTOM WIDTH	DRAINAGE TOP WIDTH	HORIZONTAL ALIGNMENT
Sample size	201	201	201	23
Mean (mm)	589	662	1690	28.35
Variance (mm)	22348	76771	143468	80.42
Standard Deviation	149	277	379	8.97
Standard error of the Mean (mm)	10.54	20	27	1.87
95% Confidence of the mean	(568,609.5)	(623.3,700.3)	(1637,1743)	(24.47,32.23)
Test Statistics (T)	-15.29	12.12	18.35	1.79
Degree of Freedom	200	200	200	200
Probability that mean of Dependent Variable attained by EBT is Equal to that specified by MOWT	<0.001	<0.001	<0.001	=0.09

Table 4.9: Summary statistics on Testing Null Hypothesis (Continue)

STATISTICAL SUMMARY	MITRE ANGLE	SHOULDER WIDTH	SUPER-ELEVATION	SUPER-ELEVATION RUNOFF
Sample size	201	201	23	23
Mean(mm)	40,43	896	10.043	19.35
Variance (mm)	61.17	21.597	3.043	116.06
Standard Deviation	7.82	147	1.745	10.77
Standard error of the Mean (mm)	1.63	10	0.363	2.25
95% Confidence of the mean	(37.05,43.82)	(875.9,916.7)	(9.289,10.8)	(14.69,24.01)
Test Statistics (T)	-2.8	-29.3	5.62	-13.65
Degree of Freedom	200	200	22	22
Probability that mean of Dependent Variable attained by EBT is Equal to that specified by MOWT	=0.01	<0.001	<0.001	<0.001

Table 4.9: Summary statistics on Testing Null Hypothesis (Completed)

STATISTICAL SUMMARY	VERTICAL ALIGNMENT	WEARING COURSE
Sample size	201	201
Mean	10	90.63
Variance	21956	81.48
Standard Deviation	148	9.03
Standard error of the Mean	10.45	0.64
95% Confidence of the mean	(-10.16,31.06)	(89.37,91.88)
Test Statistics (T)	0.21	-30.43
Degree of Freedom	200	200
Probability that mean of Dependent Variable attained by EBT is Equal to that specified by MOWT	=0.83	<0.001

From Table 4.9 the probability that the mean of dependent variables attained by EBT was equal to that specified by MOWT were very small. This implied, the mean of dependent variables attained by EBT were different from those specified by MOWT. This further implied that the values of dependent variables attained by EBT are sparsely distributed.

Figure 4.1(c) to 4.14(c) below shows the distribution of Class II district road GE and PSE attained by the technologies during road construction. Other than distribution of road GE and PSE data, Figure 4.1 (c) to 4.14 (c) also shows the limit of agreement of the dependent variables values attained by the technologies. Only the dependent variables values within the upper and lower limits of MOWT specification for Class II feeder roads GE and PSE were accepted.

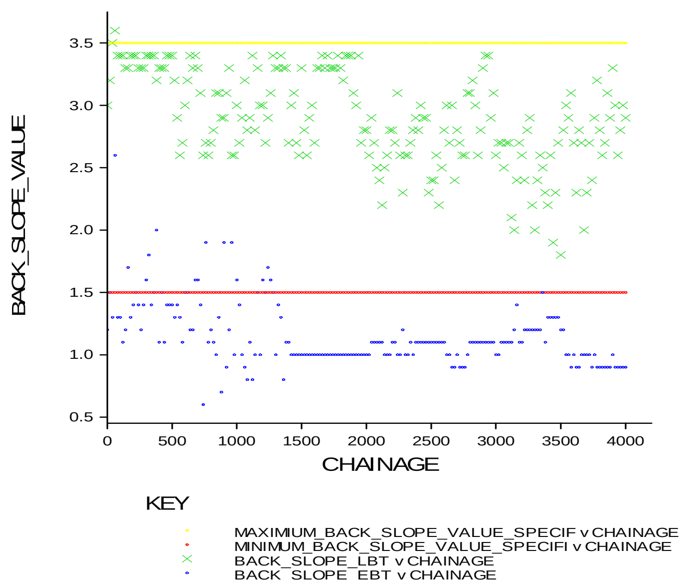


Figure 4.1(c) Limit of Agreement of Back Slope Values Attained by the Technologies

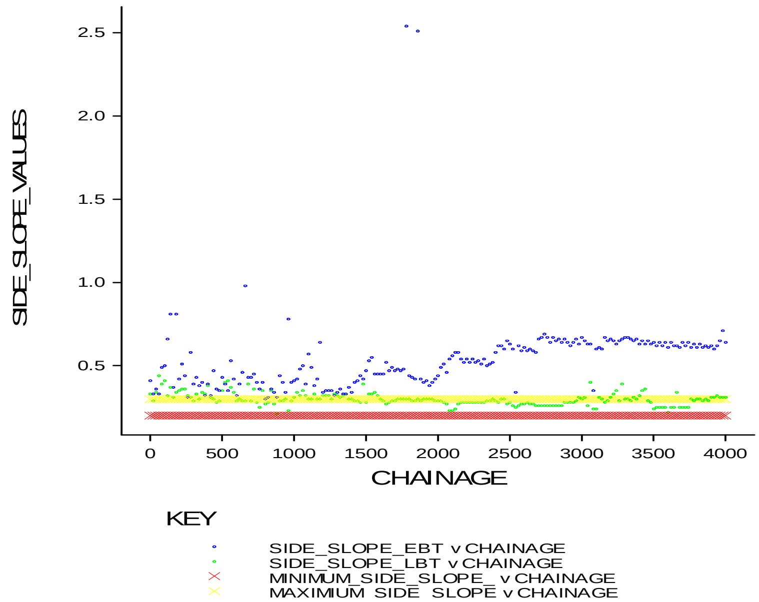


Figure 4.2(c) Limit of Agreement of Side Slope Values Attained by the Technologies

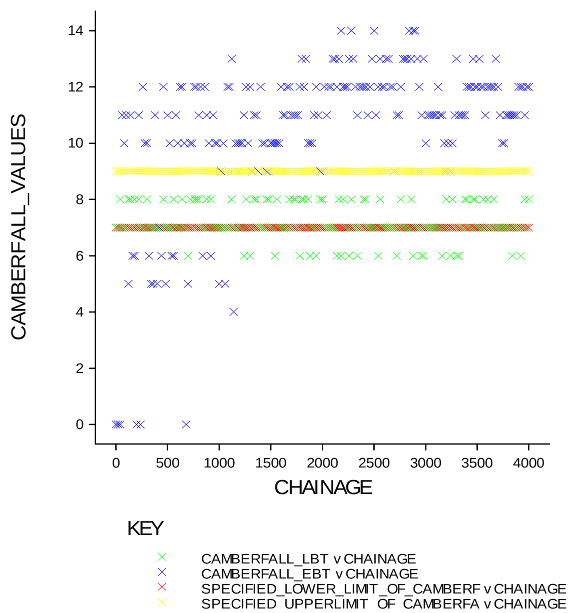


Figure 4.3(c) Limit of Agreement of Camber fall Values Attained by the Technologies

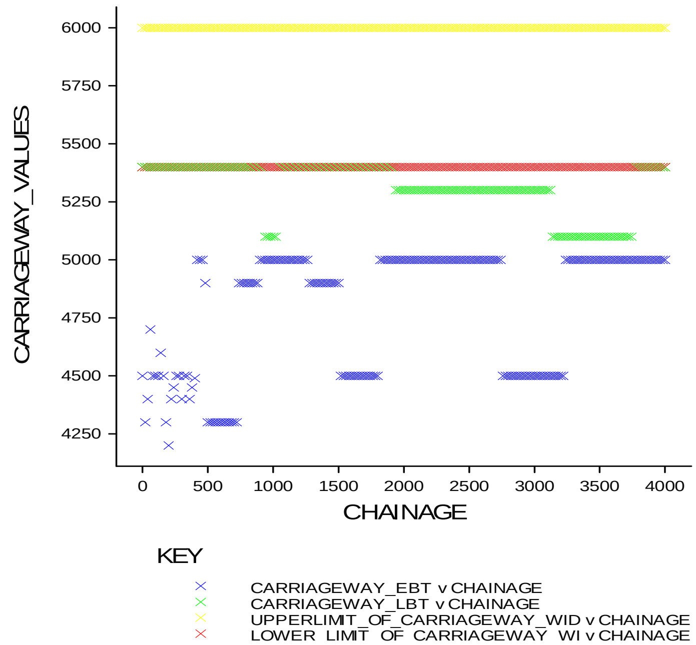


Figure 4.4(c) Limit of Agreement of Carriageway Width Values Attained by the Technologies

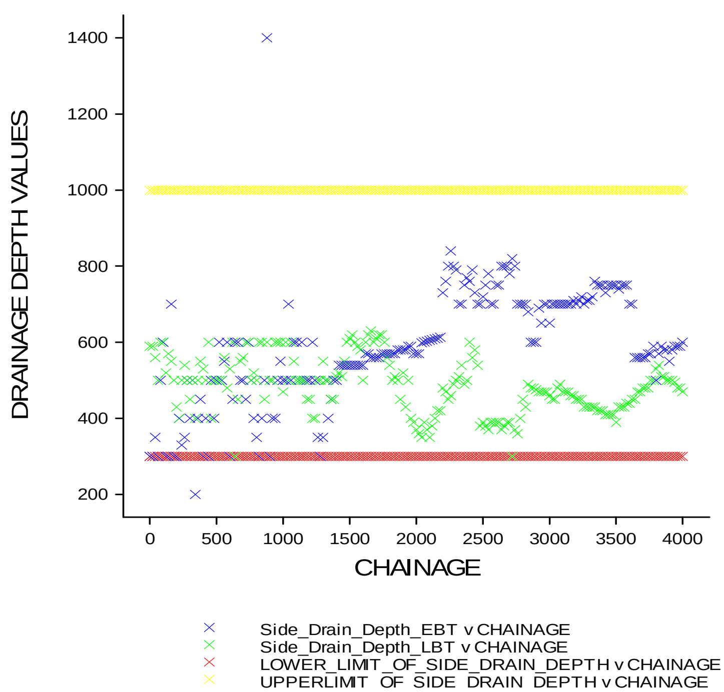


Figure 4.5(c) Limit of Agreement of Drainage Depth Values Values Attained by the Technologies

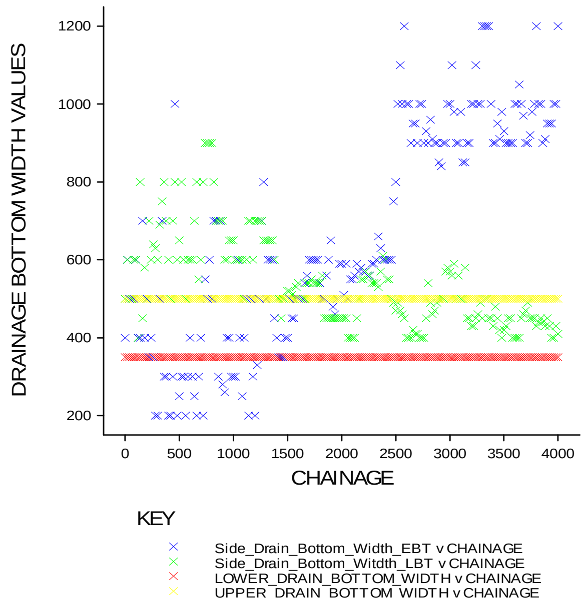


Figure 4.6(c) Limit of Agreement of Drainage Bottom Width Values Attained by the Technologies

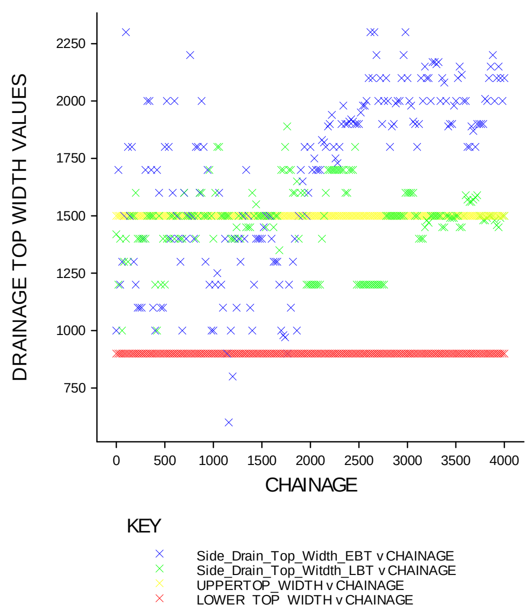


Figure 4.7(c) Limit of Agreement of Drainage Top Width Values Attained by the Technologies

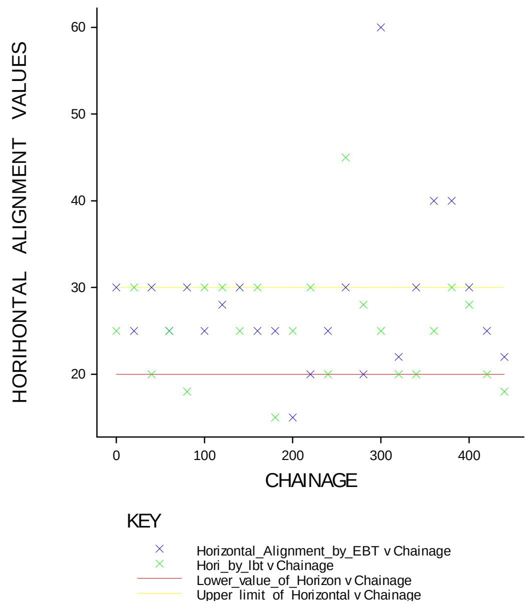


Figure 4.8(c) Limit of Agreement of Horizontal Alignment Values Attained by the Technologies

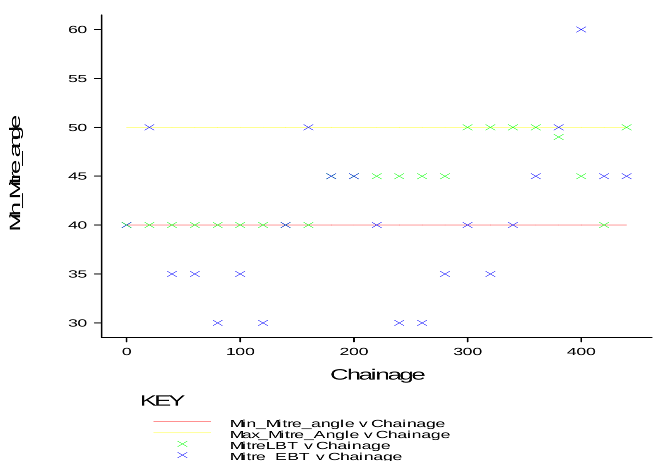


Figure 4.9(c) Limit of Agreement of Mitre Angle Values Attained by the Technologies

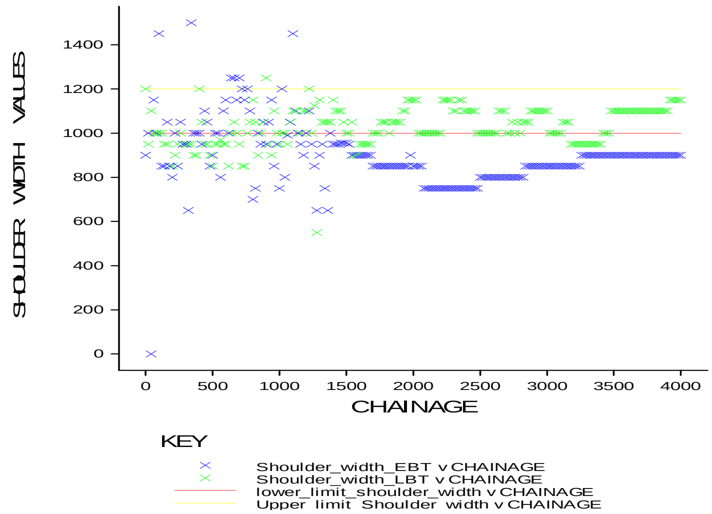


Figure 4.10(c) Limit of Agreement of Shoulder Width Values Attained by the Technologies

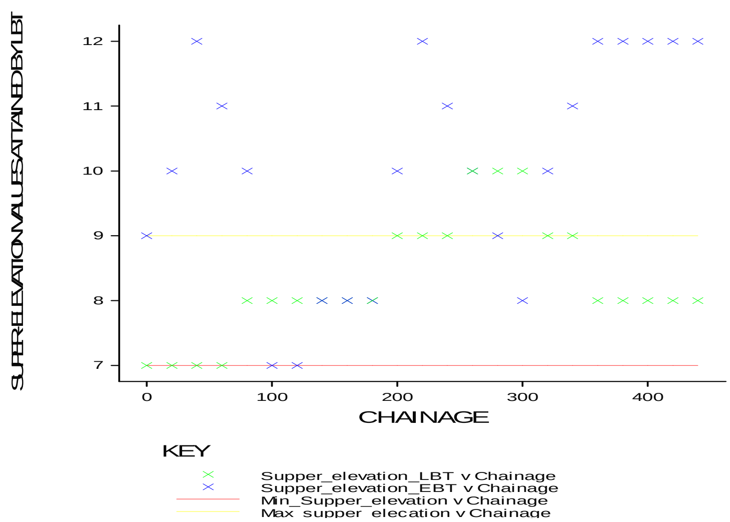


Figure 4.11(c) Limit of Agreement of Super-Elevation Values Attained by the Technologies

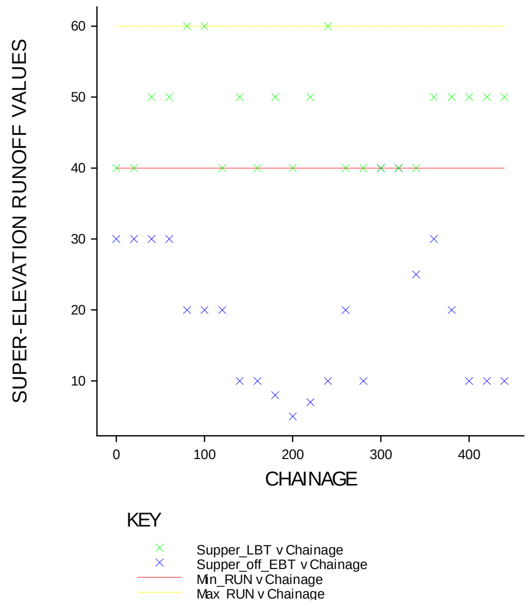


Figure 4.12(c) Limit of Agreement of Super-Elevation Runoff Values Attained by the Technologies

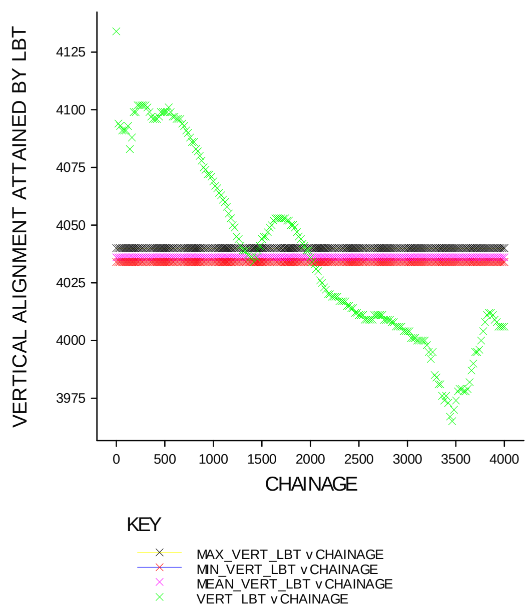


Figure 4.13(c1) Limit of Agreement of Vertical Alignment Values Attained by Labour-Based Technology

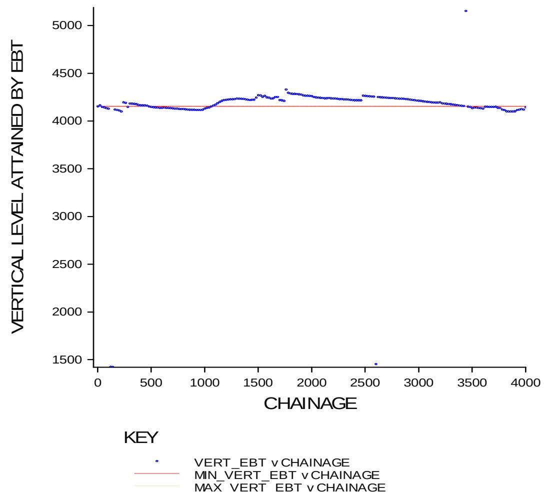


Figure 4.13(c2) Limit of Agreement of Vertical Alignment Values Attained by Equipment-Based Technology

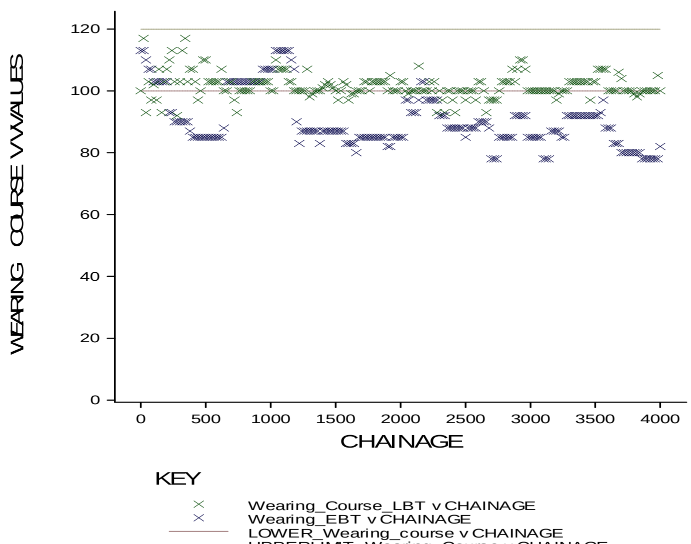


Figure 4.14(c) Limit of Agreement of Wearing Course Values Attained by the Technologies

Generally Figure 4.1 (c) to Figure 4.14 (c) above shows that other than vertical and horizontal alignment, LBT attained all the other dependent variables within limits specified by MOWT than EBT. This implies other than vertical and horizontal alignment with $p>0.05$, LBT is more superior to EBT in attaining all the other Class II district road geometric and pavement structural elements in road construction. Table 4.10 below shows the percentage accuracy of the technologies in attaining Class II district road geometric and pavement structural elements. The percentages were obtained by counting number of acceptable values and expressing them as percentage of the totals.

Table 4.10: Technologies Conformity to MOWT Specification

CLASS II DISTRICT ROAD PAVEMENT STRUCTURE AND GEOMETRIC ELEMENTS	PERCENTAGE ATTAINED BY LABOUR-BASED TECHNOLOGY	PERCENTAGE ATTAINED BY EQUIPMENT-BASED TECHNOLOGY
Back Slope	99.5	14
Side Slope	70	10
Camber fall(Degrees)	70	30
Carriage Way Width(mm)	100	10
Drainage Depth(mm)	100	99
Drainage Bottom width(mm)	60	30
Drainage Top Width(mm)	80	40
Horizontal Alignment(m)	78	82
Mitre Angle(Degrees)	82	57
Shoulder Width(mm)	85	40
Super-Elevation(Degrees)	78	26
Siper-Elevation Runoff (m)	100	0
Vertical Alignment(m)	10	40
Wearing Course Thickness(mm)	70	30

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary of Findings

This research established the extent to which Equipment-based and Labour-based technology suit Class II district road geometric and pavement structural elements during road construction. Generally, Class II district roads are gravel roads with performance expectation based on their geometric and pavement structural elements. The procedures adopted when applying either Equipment-based or Labour-based technology in construction of Class II district road follows the underlying principle of road construction to achieve specified geometric and pavement structural elements. The only difference comes in the tool/equipment used when applying either road construction technology.

It was also observed that when applying Labour-based technology to achieve geometric and pavement structural elements, the soil remains relatively in its insitu status as opposed to Equipment-based technology application. This was due to vibration effect from heavy roadwork equipments when applying Equipment-based technology. Application of Labour-based technology imparts relatively low vibration on the soil. Having the soil in its insitu state seems to contribute to road geometric stability when applying Labour-based technology in road construction.

Finally, application of Labour-based technology in Class II district roads construction involved intensive control of road works activities than when applying Equipment-based technology. Road works activities control when applying Labour-based technology was achieved with the help of pegs, strings, camber boards, and drainage templates. This was not the case when applying Equipment-based technology. The entire roadwork was dependent on the equipment operator’s experience.

5.2 Conclusions

It was found that generally other than horizontal and vertical alignment, Labour-based technology is more superior to Equipment-based technology in attaining all the Class II district road GE and PSE. Also for an equal length of Class II district road under construction independently by the technologies, Labour-based technology attain a greater proportion of the road length conforming to MOWT specifications for Class II district road GE and PSE than Equipment-based technology. labour-based technology is therefore the recommended technology to apply when the need arise to attain all the road GE and PSE other than horizontal and vertical alignment during road construction.

5.3 Recommendations

The following were recommended in this research to realise the potential of Equipment-based technology in road construction:

- Every road works activity needs to be properly controlled. This can be done using same tools/equipments used for control purposes when applying Labour-based technology in road construction;
- Over relying on the road equipments operators should be minimised. The experience of Road equipments operator's or their theoretical knowledge should only serve as a guarantee of their ability to produce specified road PS and GE; and
- Detailed specification of super-elevation runoff length at curves is lacking in MOWT specifications for Class II district roads. This need to be specified for district roads based on the curve properties to provide guidance during road construction.
- The current measurement intervals specified by MOWT for district roads GE and PSE need to be uniform. A single measurement interval if determined and adopted would make carrying quality assurance easy and minimize errors. The recommended measurement interval is 5m.

- During road construction, equipment-based technology can be use in attaining horizontal and vertical alignment. A mix of LBT and EBT is recommended in road construction.
- The current standard road specification for district roads is at least achievable by both LBT and EBT in road construction.

It was also recommended that before fully applying Labour-based technology in roads construction, its cost effectiveness as compared to Equipment-based technology need to be determined.

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APPENDICES

APPENDIX 1

Maps of Uganda showing the Research Area and Class II District Road Network in the Research Area

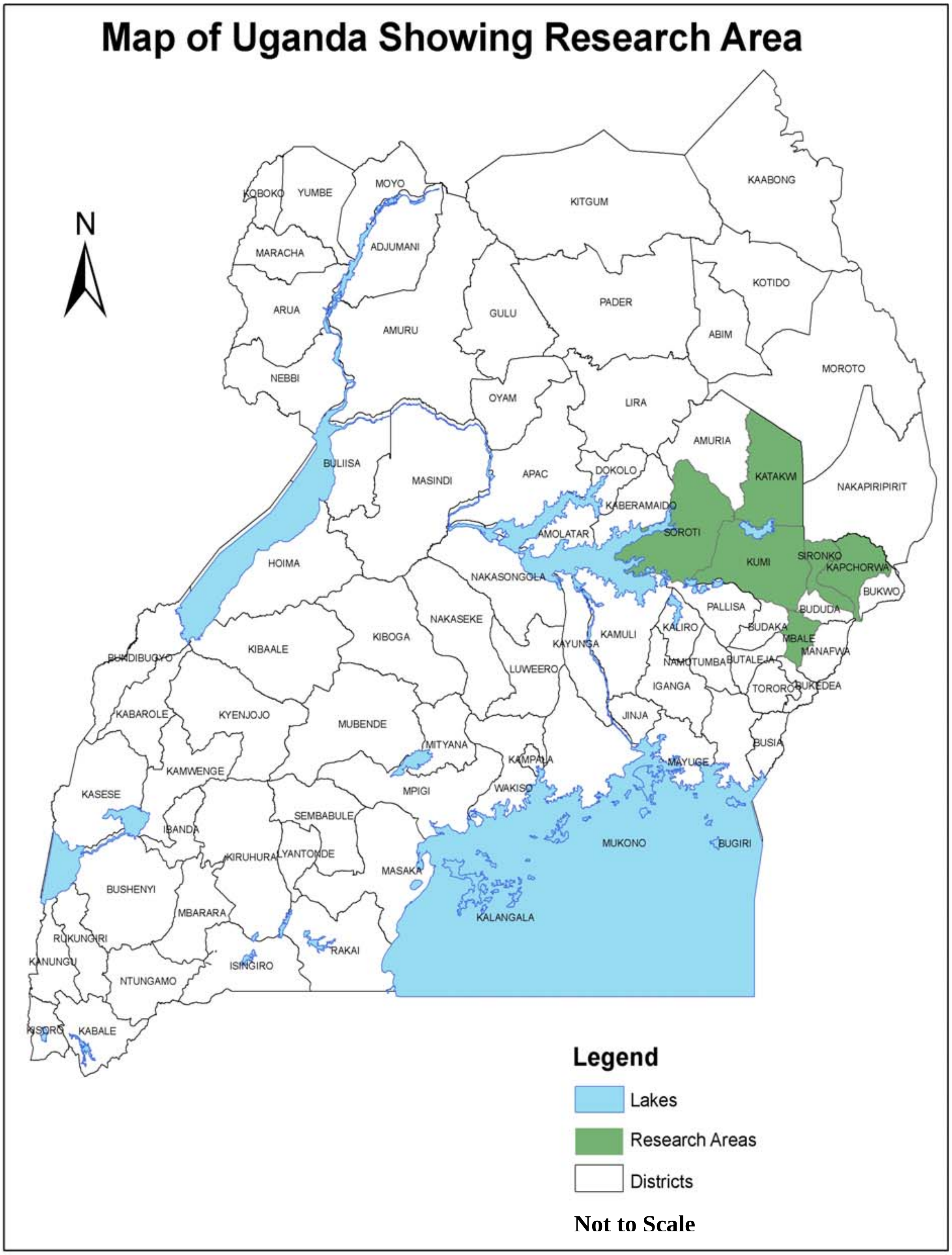

Figure 1.1 Map of Uganda Showing Research Area

Source: National Forestry Authority, Biomass Study 2007

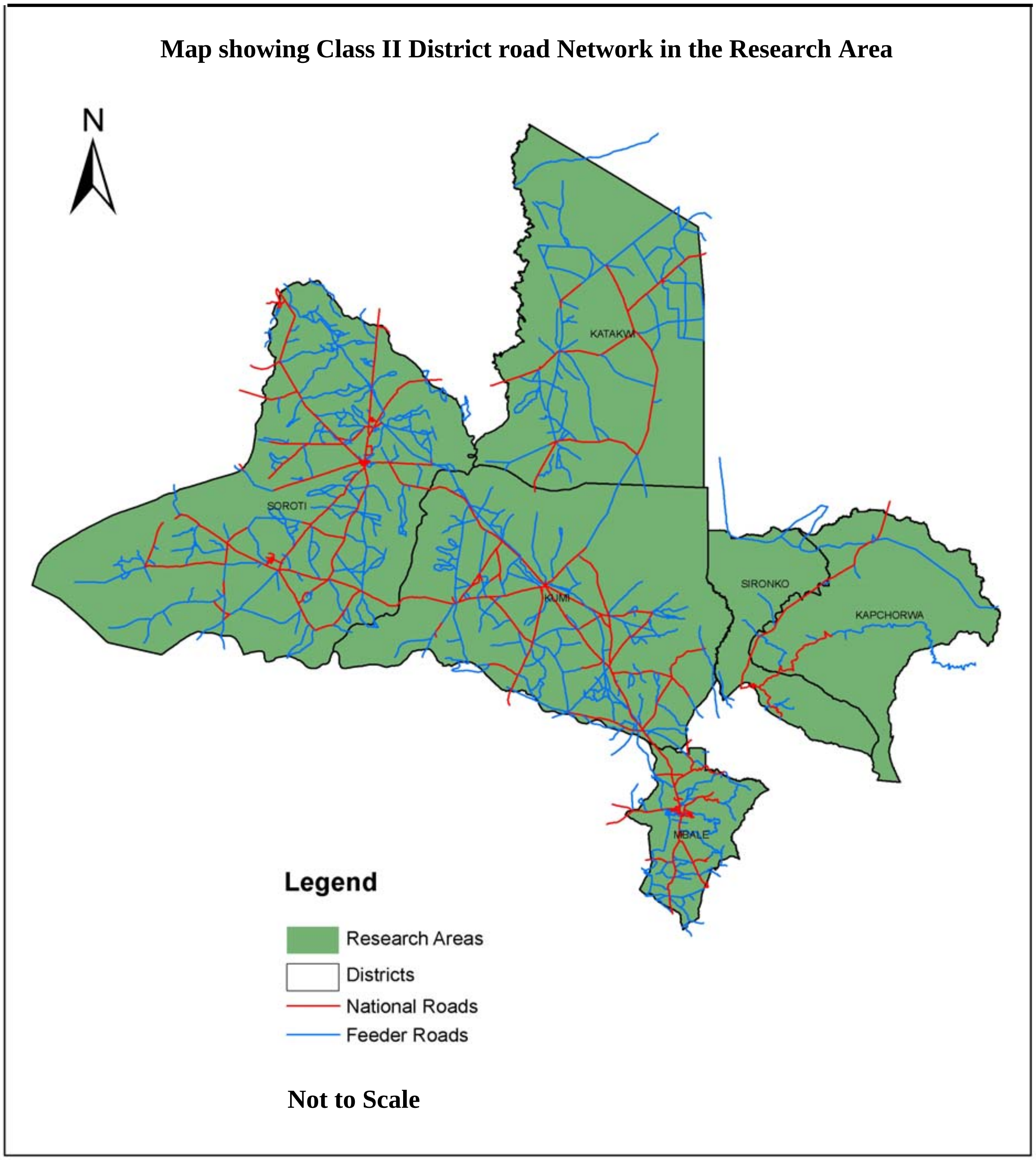

Figure 1.2 Map Showing Class II District Road Network in the Research area

Source: National Forestry Authority, Biomas Study 2007

APPENDIX 2

Ministry of Works and Transport Specification for District Road Class II GE and PSE

Table 2.1: Ministry of Works and Transport Specified Class II District Road Geometric and Pavement Structural Elements Integrity.

APPLICABLE CLASS II DISTRICT ROAD GEOMETRIC AND PAVEMENT STRUCTURAL ELEMENTS		**MOWT SPECIFICATIONS**
GEOMETRIC ELEMENTS		
Camber fall		8%
Vertical alignment	Min Vertical Gradient	2%
	Max Vertical Gradient	7-10%
	Absolute Max vertical gradient length	500-200m
Drainage dimensions	Depth	300mm
	Bottom width	400mm
	Top width	1200-1300mm
Horizontal alignment	Radius of horizontal curve	25m
Super-elevation		8%
Carriageway width		5.4m
Back and Side slopes		1:3
Shoulder width		1200mm
Mitre angle		45degrees
Super-elevation runoff		40-60m
PAVEMENT STRUCTURAL COMPONENTS		
Wearing course thickness		100mm
Base		Varies
Sub base		Varies

APPENDIX 3

Procedures and Instruments for Measuring Physical Properties of Road Geometric and Pavement Structural Elements

Table 3.1 (a): Instruments for Measuring Physical Properties of Actual Class II District Road Geometric and Pavement Structural Elements.

CLASS II DISTRICT ROAD GEOMETRIC AND PAVEMENT STRUCTURAL ELEMENTS	**INSTRUMENTS USED IN PRACTICE FOR MEASURING PHYSICAL PROPERTIES OF ACTUAL CLASS II DISTRICT ROAD GEOMETRIC AND PAVEMENTS STRUCTURAL ELEMENTS**
Camber fall	Camber board, Spirit level, Tape measure, Straightedge and Peg
Vertical alignment	Ranging rod, String, Tape measure, pegs and GPS machine.
Drainage dimensions	Ditch template, Tape measure, String and Peg
Horizontal alignment	Ranging rod, String, Tape measure, pegs and GPS machine
Super-elevation runoff	Tape measure, string, and Pegs
Carriageway width	Tape measure, String, straight edge and Pegs
Back and Side slopes	Tape measure, Slope template and Pegs
Shoulder width	Tape measure, String, and Pegs.
Mitre angle	Bonding rod, String, Protractor, and Pegs
Super-elevation	Tape measure, Straightedge, Spirit level, and Pegs.
Wearing course	Tape measure, Hammer, Pegs and Chisel
Sub base	Tape measure, Hammer, Pegs and Chisel

Table 3.1(b): Procedure for Measuring Integrity of Actual Class II District Road Geometric and Pavement Structural Elements.

CLASS II DISTRICT ROAD GEOMETRIC AND PAVEMENT STRUCTURAL ELEMENTS	PROCEDURE USED TO MEASURE INTEGRITY OF CLASS II DISTRICT ROAD GEOMETRIC AND PAVEMENT STRUCTURAL ELEMENTS
Camber fall	Identify and peg carriageway break points and road centerline and measure inclination angle on both sides of the road centerline at 20m interval.
Vertical alignment	Identify and peg road centerline, take levels along straights at 20m interval and at 5m interval along vertical curves.
Drainage dimensions	Identify and peg shoulder break points, drainage centerline, and measure drainage dimensions on both sides of the road along drainage centerline at 20m interval.
Horizontal alignment	Identify and peg road centerline, and take measurements along road centerline at 20m interval on straights and at 5m interval along horizontal curves.
Super-elevation runoff	Identify and peg beginning and end of circular curve, measure and peg specified super-elevation length along straights from the beginning and end of circular curve at 10m interval along road centerline.
Carriageway width	Identify and peg carriageway break points and measure carriageway width at 20m interval along the road centerline.
Back and Side slopes	Identify and peg side drains bottom width and shoulder break points and measure slopes on both sides of the road at 20m interval.
Shoulder width	Identify and peg shoulder and carriageway break points and measure distance between break points on both sides of the road at 20m interval.
Mitre angle	Identify and peg side drain, and miter drain centerline and measure miter angle in the direction opposing side drain water flow from miter drain centerline at 10m interval.
Super-elevation	Identify and peg beginning and end of circular curve, and measure along circular curve super-elevation angle at 5m interval along the road.
Wearing course	Identify and peg carriageway break points and road centerline and measure wearing course thickness within carriageway breakpoints at 20m interval along the road centerline.
Sub base	Identify and peg sub base break points and road centerline and measure sub base thickness across sub base breakpoints at 10m interval along the road centerline.

Questionnaire Form

Research Title

Comparison of District Roads Geometric and Pavement Structural Elements Integrity Attained Independently During Road Construction by Equipment-Based and Labour-Based Technology

Main Objective

This research was intended to determine the extent to which independently Labour-based and Equipment-based technology can attain Class II District road standard geometric and pavement structural elements.

Purpose of the Study

The research finding will be a basis to choose the best technology in achieving standard road geometric and pavement structural elements in roads construction and achieve quality.

Assurance

Please note that, whatever information provided herein shall be confidential.

Appreciation

Thank you for accepting to be a respondent in this research.

Instructuction

Please carefully study and tick/provide the answer you are sure is correct for each question herein. You can provide any other information you feel is/are pertinent for this research in the last paper provided at the back of this questionnaire form.

Question 1: Biodata

Respondent Name:……………………………..…………………………………………..

Organisation/institution Name:………………………………………………………………..,

Respondent Title:……………………………………..……………………………………….

Year/s of experience:……………………………………………………………………….

Question 2 :Class II District Road Geometric and Pavement Structure Elements

a)-Tick in the box below Class II district road geometric elements you have strived to attain in road construction when applying any of the road construction technology.

Camber fall ☐

Drainage dimensions ☐

Miter drain angle ☐

Back and side slopes ☐

Carriageway width ☐

Shoulder width ☐

Horizontal alignment ☐

Vertical alignment ☐

b)-In the box below, tick that/those pavement layers you have constructed during construction of Class II district road when applying any of the road construction technology.

Wearing course ☐

Base ☐

Sub-base ☐

Question 3: Procedure and Instruments Used to Measure Integrity of Class II district road Geometric and Pavement Structure Elements

a)- For Class II district road pavement structural components below, briefly state the instrument(s) and procedure you used to measure the pavement structural integrity after construction when applying Labour-based technology.

Wearing course:…………………………………………………………………........................

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Base:..

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Sub-base:………………………………………………………………………………………….

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

b)- For Class II district road pavement structural components below, briefly state the instrument(s) and procedure you use to measure the pavement structural integrity after construction when applying Equipment-based technology.

Wearing course:……………………………………………………………………........................
…………………………………………………………………………………………………
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…………………………………………………………………………………………………
Base:...
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Sub-base:……………………………………………………………………………………..
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c)-For Class II district road geometric elements below, briefly state the instrument(s) and procedure you use to measure the integrity of geometric elements after construction when applying Labour-based technology.

Camber fall:………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
Drainage dimensions:…………………………………………………………………….
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
Miter drain angle:………………………………………………………………...........................
…………………………………………………………………………………………………
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…………………………………………………………………………………………………

Back and side slopes:……………………………………………………………………….

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Carriage way width:………………………………………………………………………

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…………………………………………………………………………………………

Shoulder width:……………………………………………………………………………

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Horizontal alignment:……………………………………………………………………..

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Vertical alignment:………………………………………………………………………..

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d)- For Class II district roads geometric elements below, briefly state the instrument(s) and procedure you use to measure the integrity of geometric elements after construction when applying Equipment-based technology.

Camber fall:…………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

Drainage dimensions:……………………………………………………………………….

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Miter drain angle:…………………………………………………………………….........................

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Back and side slopes:……………………………………………………………………….

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…………………………………………………………………………………………

Carriage way width:………………………………………………………………………

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Shoulder width:……………………………………………………………………………

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Horizontal alignment:…………………………………………………………………..

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Vertical alignment:……………………………………………………………………..

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Question 4: Measuring Adequacy of pavement structure and geometric elements of Class II District Road

a)- For Class II district roads pavement structural components below, briefly state the physical property defining them and how it is measured after construction when applying Labour-based technology.

Wearing course:………………………………………………………………………………..

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Base:…………………………………………………………………………………………

…………………………………………………………………………………………

Sub-base:……………………………………………………………………………………….
…………………………………………………………………………………………………
…………………………………………………………………………………………………

b)- For Class II district road pavement structural components below, briefly state the physical property defining them and how it is measured after construction when applying Equipment-based technology.

Wearing course:……………………………………………………………………………..
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…………………………………………………………………………………………………
…………………………………………………………………………………………………

Base:……………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Sub-base:……………………………………………………………………………………….
…………………………………………………………………………………………………
…………………………………………………………………………………………………

c)- For Class II district roads geometric elements below, briefly state the physical property defining them and how it is measured after construction when applying Labour-based technology.

Camber fall:……………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Drainage dimensions:…………………………………………………………………….
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Miter drain angle:……………………………………………………………………….
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Back and side slopes:……………………………………………………………………….
……………………………………………………………………………………………
……………………………………………………………………………………………
Carriage way width:……………………………………………………………………..
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Shoulder width:……………………………………………………………………………
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……………………………………………………………………………………………
Horizontal alignment:…….……………………………………………………………..
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Vertical alignment:……………………………………………………………………….
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d)- For Class II district roads geometric elements below, briefly state the property defining them and how it is measured after construction when applying Equipment-based technology.

Camber fall:………………………………………………………………………………
……………………………………………………………………………………………
…….………………………………………………………………………………………
Drainage dimensions:…….……………………………………………………………
……………………………………………………………………………………………
….…………………………………………………………………………………………
Miter drain angle:……………………………………………………………………….
……………………………………………………………………………………………
……………………………………………………………………………………………
Back and side slopes:……………………………………………………………………….
……………………………………………………………………………………………
……………………………………………………………………………………………
Carriage way width:……………………………………………………………………..
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Shoulder width:………………………………………………………………………………
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Horizontal alignment:…….……………………………………………………………..
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Vertical alignment:……………………………………………………………………….
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Question 5: Comparing the Output Of Labour-Based and Equipment-Based Technology In Class II District Road Construction

a)- For the Class II district roads you have constructed so far in your organisation, fill in the table below your general view, the extent to which the pavement structural components thickness was accurately attained on applying each road construction technology independently.

I-Labour-Based Technology

PAVEMENT STRUCTURE	**STANDARD DESIGN VALUE SPECIFIED (mm)**	**STANDARD DESIGN VALUE ATTAINED (mm)**
Wearing coarse		
Base		
Sub based		

II-Equipment-Based Technology

PAVEMENT STRUCTURE	**STANDARD DESIGN VALUE SPECIFIED (mm)**	**STANDARD DESIGN VALUE ATTAINED (mm)**
Wearing coarse		
Base		
Sub based		

b)- For those Class II district roads you have constructed so far in your organisation, fill in the table below your general view, the extent to which Class II district road geometric elements were accurately attained when applying each road construction technology independently.

I-Labour-Based Technology

PAVEMENT STRUCTURE	**STANDARD DESIGN VALUE SPECIFIED**	**STANDARD DESIGN VALUE ATTAINED**
Camber fall		
Side drain dimension		
Miter drain dimension		
Miter drain angle		
Back slope		
Side slope		
Carriageway width		
Shoulder width		
Horizontal curve length		
Horizontal curve radius		
Super-elevation		
Super-elevation runoff at the beginning of curve		
Super-elevation elevation runoff at the end of curve		
Vertical alignment		

II-Equipment-Based Technology

PAVEMENT STRUCTURE	STANDARD DESIGN VALUE SPECIFIED	STANDARD DESIGN VALUE ATTAINED
Camber fall		
Side drain dimension		
Miter drain dimension		
Miter drain angle		
Back slope		
Side slope		
Carriageway width		
Shoulder width		
Horizontal curve length		
Horizontal curve radius		
Super-elevation		
Super-elevation runoff at the beginning of curve		
Super-elevation elevation runoff at the end of curve		
Vertical Alignment		

c)- For the class II district roads you have constructed so far for your organisation, fill in the table below for each roads construction technology applied.

i-Equipment-Based Technology

No	Road Name	Road Length (km)	Road Code	Year of Constructed	Average annual number of vehicles noted from traffic survey	Commonest Vehicle Class (e.g Lorries) along the road	Year reconstructed again
1							
2							
3							
4							
5							
6							
7							
8							

ii- Labour-Based Technology

No	Road Name	Road Length (km)	Road Code	Year of Constructed	Average annual number of vehicles noted from traffic survey	Commonest Vehicle Class (e.g Lorries) along the road	Year reconstructed again
1							
2							
3							
4							
5							
6							
7							
8							
9							

d)-In all the road works you have carried, state those factors which you feel affected the quality of road works.

1-

……………………………………………………………………………………………

2-

…………………………………………………………………………………………….

3-

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5-……………………………………………………………………………………………..

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e)-Briefly state how the factors you stated above affected the quality of road works.

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f)-What measure did you take to overcome the above factors

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Thank you very much.

Sign:……………………………………………Date:…………………………………….

Figure 3.2 Research Assistants Taking Measurements from Sampled Roads from Kapchorwa District

APPENDIX 4

Histograms of Dependent Variable Attained by LBT and EBT in Road Construction

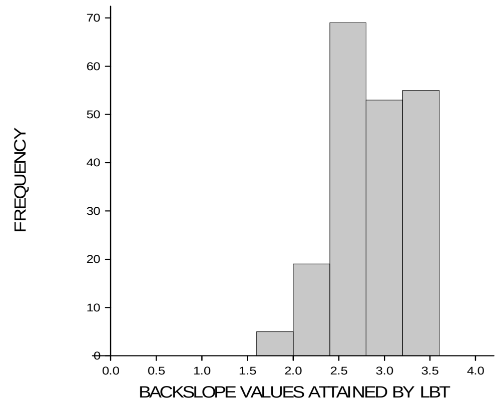

Figure 4.1(a) Histogram of Back slope Attained by Labour-Based Technology

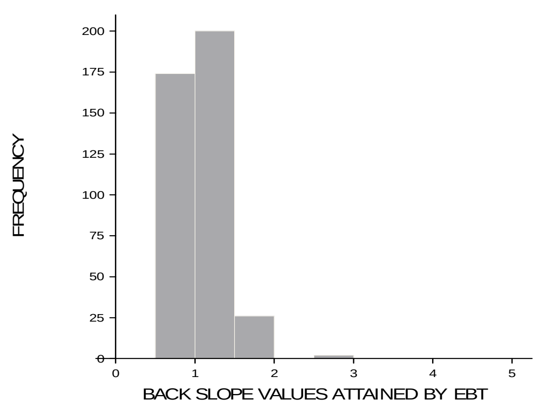

Figure 4.1(b) Histogram of Back slope Attained by Equipment-Based Technology

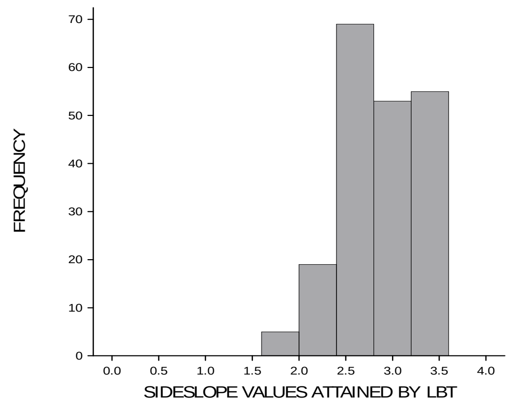

Figure 4.2(a) Histogram of Side Slope Attained by Labour-Based Technology

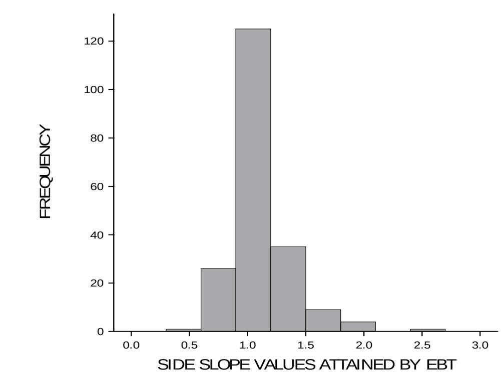

Figure 4.1(b) Histogram of Side slope Attained by Equipment-Based Technology

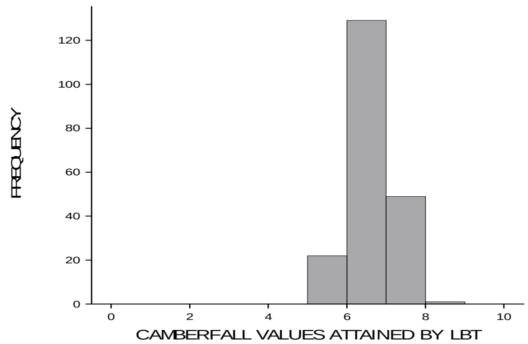

Figure 4.3(a) Limit of Agreement of Camber fall Values Attained by Labour-Based Technology

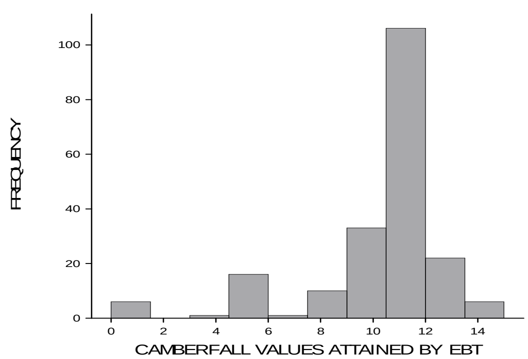

Figure 4.3(b) Limit of Agreement of Camber fall Values Attained by Equipment-Based Technology

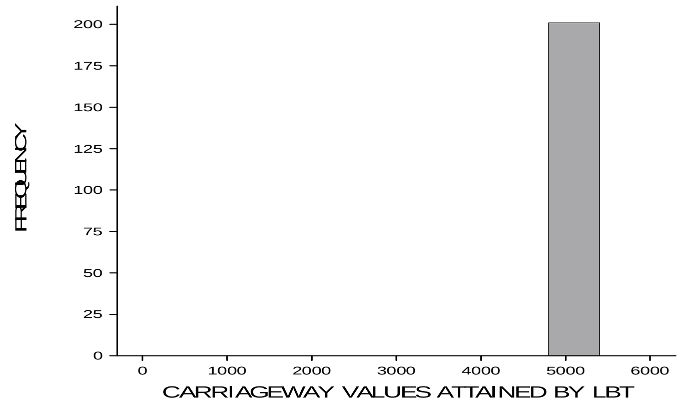

Figure 4.4(a) Carriageway Width Values Attained by Labour-Based Technology

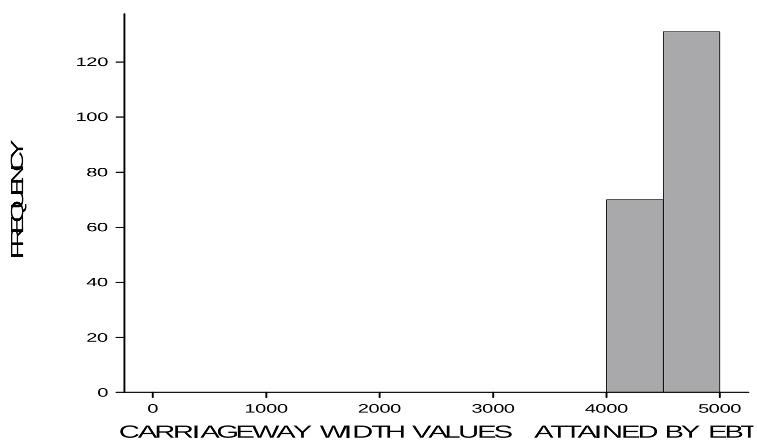

Figure 4.4(b) Carriageway Width Values Attained by Equipment-Based Technology

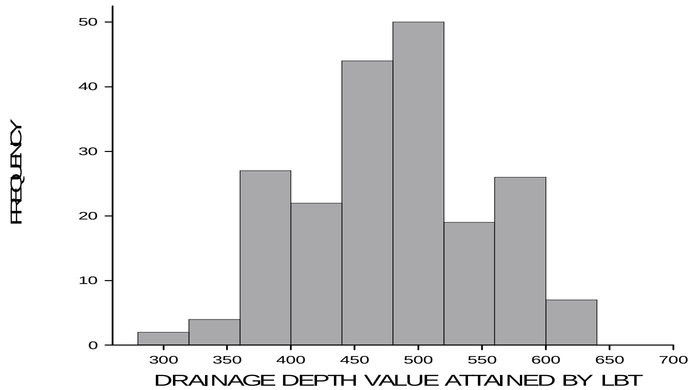

Figure 4.5(a) Drainage Depth Values Attained by Labour-Based Technology

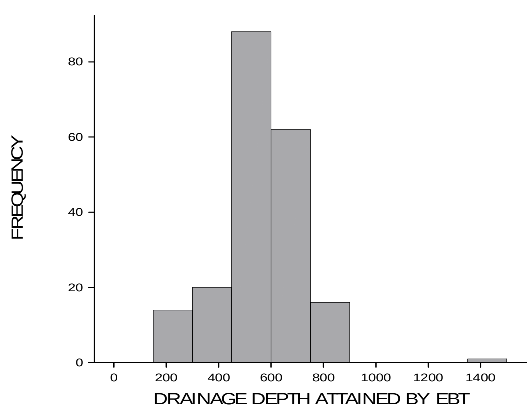

Figure 4.5(b) Drainage Depth Values Attained by Equipment-Based Technology

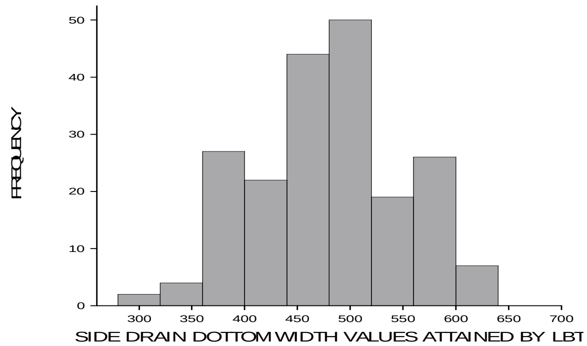

Figure 4.6(b) Drainage Bottom Width Values Attained by Labour-Based Technology

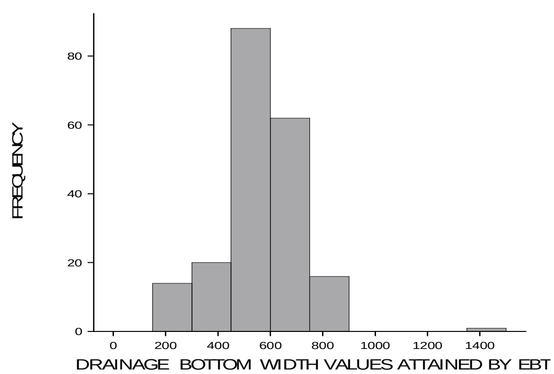

Figure 4.6(b) Drainage Bottom Width Values Attained by Equipment-Based Technology

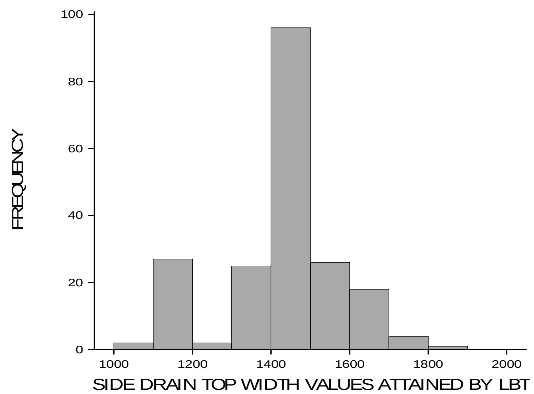

Figure 4.7(a) Drainage Top Width Values Attained by Labour-Based Technology

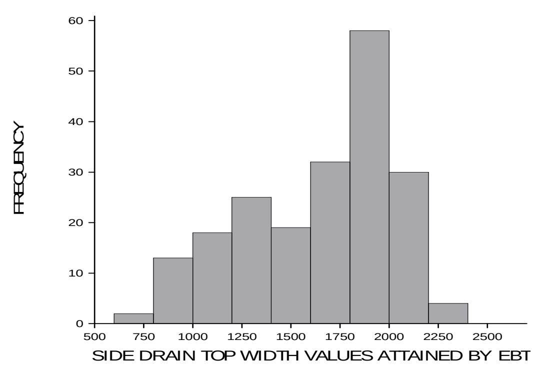

Figure 4.7(b) Drainage Top Width Values Attained by Equipment-Based Technology

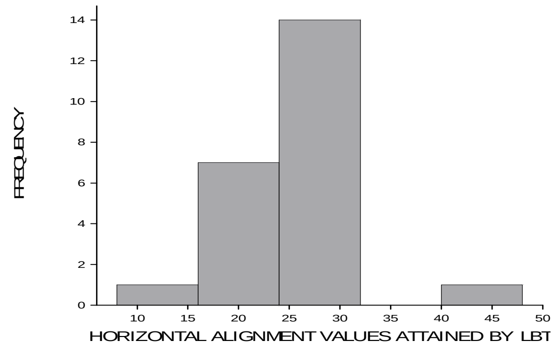

Figure 4.8(a) Horizontal Alignment Values Attained by Labour-Based Technology

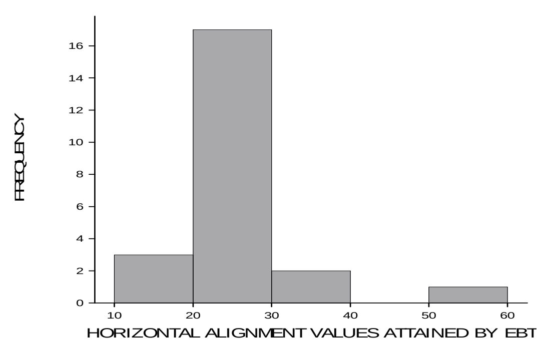

Figure 4.8(b) Horizontal Alignment Values Attained by Labour-Based Technology

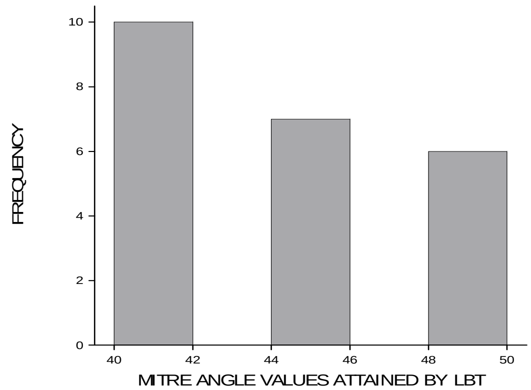

Figure 4.9(a) Mitre Angle Values Attained by Labour-Based Technology

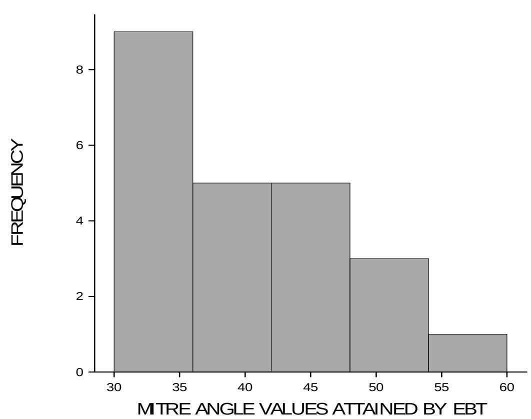

Figure 4.9(b) Mitre Angle Values Attained by Equipment-Based Technology

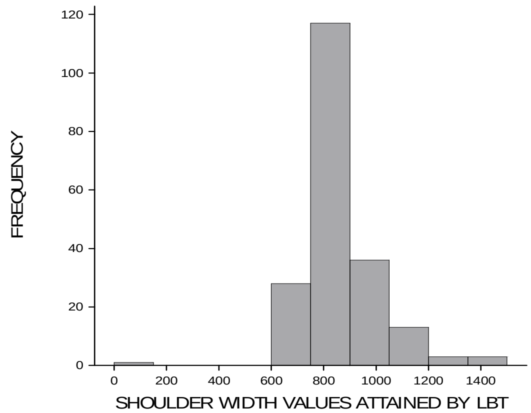

Figure 4.10(a) Shoulder Width Values Attained by Labour-Based Technology

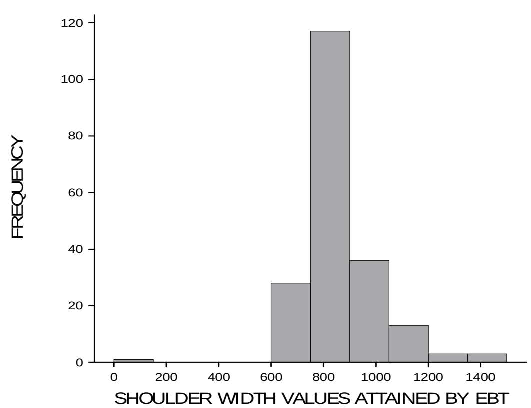

Figure 4.10(b) Shoulder Width Values Attained by Equipment-Based Technology

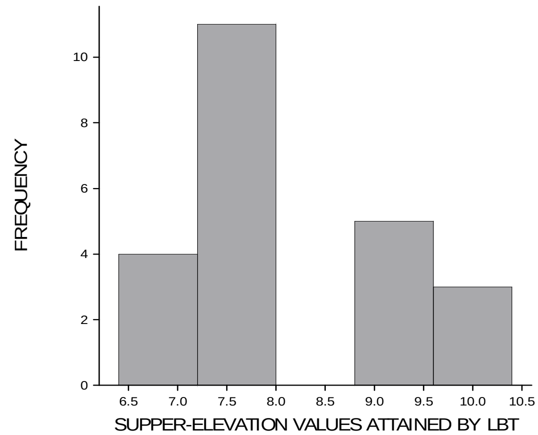

Figure 4.11(a) Super-Elevation Values Attained by Labour-Based Technology

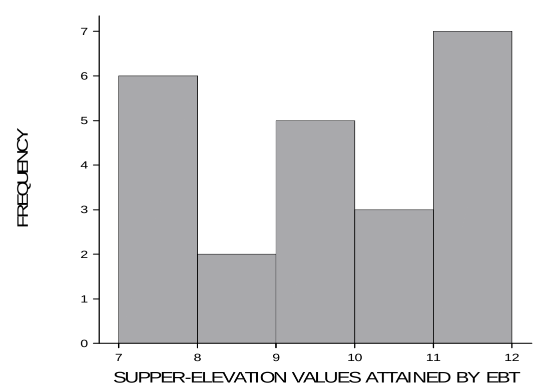

Figure 4.11(b) Super-Elevation Values Attained by Equipment-Based Technology

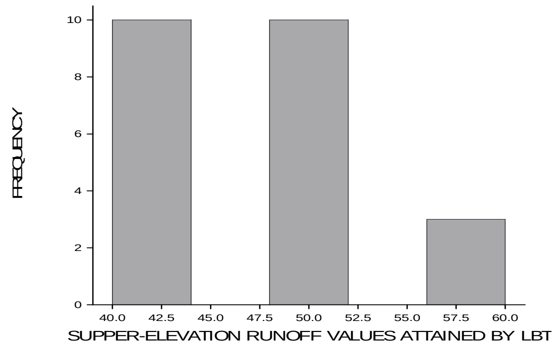

Figure 4.12(a) Super-ElevationRunoff Values Attained by Labour-Based Technology

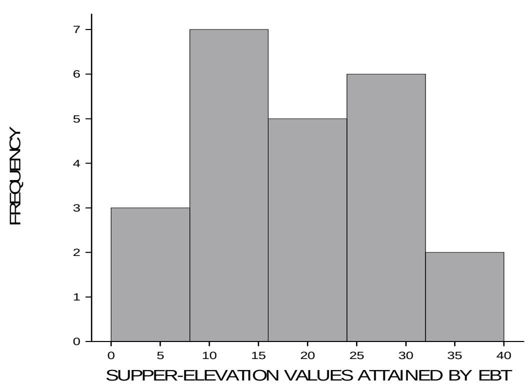

Figure 4.12(b) Super-Elevation Runoff Values Attained by Labour-Based Technology

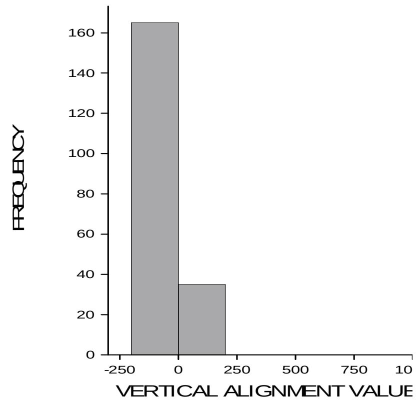

Figure 4.13(a) Vertical Alignment Values Attained by Labour-Based Technology

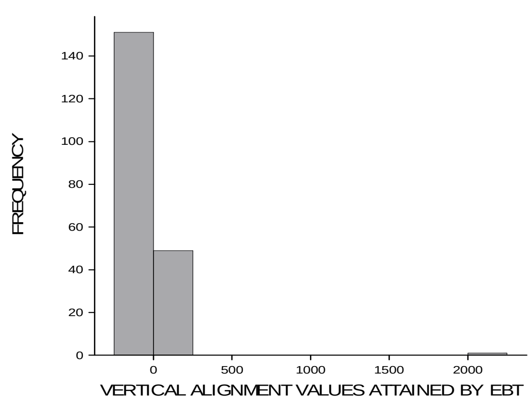

Figure 4.13(b) Vertical Alignment Values Attained by Equipment-Based Technology

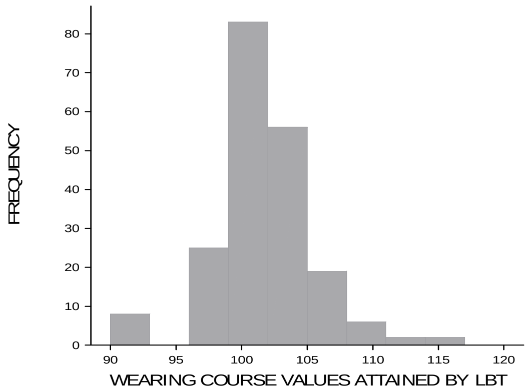

Figure 4.14(a) Limit of Agreement of Wearing Course Values Attained by Labour-Based Technology

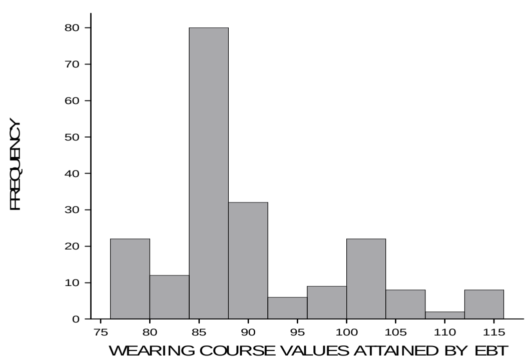

Figure 4.14(b) Limit of Agreement of Wearing Course Values Attained by Equipment-Based Technology