PRODUCTIVITY ANALYSIS AND IMPROVEMENT OF TANNERIES IN KENYA.

A CASE STUDY OF SAGANA TANNERIES.

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Declaration~~:~~

This thesis is my original work and has not been presented in any university/institution for a degree or for consideration of any certification.

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APPROVAL

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Dedication:

This work is dedicated to my family for the immerse support during the study. To my classmates and colleagues, may God bless them for their support and criticism throughout the study.

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Abbreviations:

ALLPI	African Leather and Leather Product institute
BH	Beam House
COMESA	Common Market for East and Central Africa
CTE	Cycle Time Effectiveness
FS	Finishing Section
GDP	Gross Domestic Product
KPI	Key Performance Indicator
MS	Machining Section
OEE	Overall Equipment Effectiveness
RCA	Root Cause Analysis
SMEs	Small and Medium Enterprises
STL	Sagana Tanneries Limited
TOC	Theory of Constraints
TPM	Total Productive Maintenance
UPP	Unit Production Process
VSM	Value Stream Mapping
WIP	Work in Process

ABSTRACT

Productivity of a system is one of the key factors that affects overall competitiveness of an organisation. Productivity is the measure of the effective use of resources which is expressed as the ratio of output to inputs. Therefore productivity is the relationship between result and the time it takes to accomplish them and it is used to examine efficiency and effectiveness of any activity that is conducted in an economy,business or an individual hence it refers to the measure of the efficiency of a person,system,equipment,e.t.c in converting inputs to useful outputs. Leather processing has emerged as a very important economic activity in several developing countries that depend on Agro-economy, because of the high labour intensity of the process of converting hides and skins to leather which is a source of employment opportunity. Leather processing also promises good returns due to value addition. Kenyan leather industry was identified to be one of the promising Agro-based industries with immense potential in East Africa. In its vision 2030 to become industrialized, kenya identified the leather secctor as one of the flagship project. Leather production in kenya has not reached full potential due to a number of reasons chief among them low productivity by individual tanneries. A case study was carried out in Sagana Tanneries. Sagana Tanneries which is one of the major players in leather processing in the country, has been experiencing low productivity levels, which has hindered it from meeting its market share; hence affecting its competitiveness. The purpose of the study was to explore the factors that are affecting productivity in Sagana Tanneries and develop improvement strategies. The objectives were to analyse the productivity levels in Sagana Tanneries, to carry out Root Cause Analysis of productivity losses in Sagana Tanneries and finally develop strategies for productivity improvement.

The objectives were achieved by analysing the utilization levels of production equipment through their cycle time, throughput and OEE's. Productivity loss analysis was done by using RCA analysis tools like fish bone diagram, why-why analysis and a pareto chart. The OEE rate was analysed to be 8.97% which is below the worlds ideal OEE values of 85%. The cycle time was analysed to 19 days compared to an established standard of 15 days, labour productivity was calculated as 42 sq. ft/man-hour against a target of 96.15 sq. ft/man-hour, and equipment utilization analysis indicated that 40% of the available time is when the equipment was available. From Root Cause Analysis the factors that affected productivity in Sagana tanneries using the Pareto chart were; equipment breakdown, power failure, low speeds (process bottlenecks) and lack of raw materials were found to be the vital few causes of low productivity. Lean manufacturing and TPM principles were developed as the best strategies for productivity improvement. With the development of productivity improvement strategies which are lean manufacturing and TPM principles, the tannery in practice will be able to increase equipment utilisation by reducing the downtimes. Cost of production will also be reduced and the cycle time of the production process reduced and labour productivity increased. This in turn will increase sales which will makes the tannery competitive and able to meet the customer demands. Hence with the improvement in the production processes in the tanneries, Kenya as a country will increase its leather output and become competitive in the global market which will lead to improved living standards of its people.

Chapter 1 : CHAPTER ONE

INTRODUCTION

1.1 Background of study:

Production in an organisation can be characterised by large number of orders, rise in prices of production resources, continually shortening order times and higher demands for quality. This translates to pressure to the companies to survive and be successful hence continual search for methods that can assure its competitiveness. Productivity of a system is one of the key factors that affects overall competitive of an organisation (Jedrzejewski, 2007). According to (Levary, 1991) and (WebFinance, 2017) productivity is the measure of the efficiency of a person,system,equipment,e.t.c in converting inputs to useful outputs hence it is the average measure of the efficiency of a production system. (Stevenson, Operations Management, 2009)defined productivity as a summary measure of the quantity and quality of work performance with effective resource utilization considered, which is expressed as the ratio of output to inputs. (Teklemariam, 2004) also defined productivity as the relationship between result and the time it takes to accomplish them. (John , 1993) expressed productivity ratio as in the equation below

In any economy, productivity in the manufacturing sector leads to improved standards of living and social welfare which translates to an increase in the GDP of the nation. Productivity being the main determinant of living standards it quantifies how an economy can use its available resources.Therefore higher productivity leads to improved competitiveness and trade perfomance,higher profits,low average costs,higher wages and economic growth (Riley, 2012).For sustainability of a nations economy,manufacturing industries should be nurtured to be sustained against the global competitive market. In Manufacturing, productivity helps in:Controlling the business processes, Improving the processes continously, Understanding the processes of a business, Asssessing the performance of a business, Determining the business ability to sustain in the long run.

Therefore in the manufucturing sector productivity has a positive and significant relationship to perfomance measurement for process utilization,process output,product cost,work in process inventory and on time delivery (Mwinyihija M. , 2014).Productivity is also used to examine efficiency and effectiveness of any activity that is conducted in an economy, business or an individual. This is because productivity can is used as a measure of a manufacturing systems efficiency which leads to increased competitive advantage according to (Levary, 1991).According to (Teklemariam, 2004) productivity is linked with the utilization of resources in the company.This is the function of achieving the maximum output with minimum resource input. The resources are manpower, material, equipment, spares, building, capital and time,where the responsibility of achieving higher productivity rests on managing these resources efficiently.Productivity growth comes from working smarter,this means adopting new technonologies or new techniques for production.

One function of productivity is Time and it is a good demonstrator as it is a universal measure which is beyond human control. The system is deemed productive if it takes less time to achieve the desired results a key requirement in the manufacturing industry.other factors affecting Productivity are Quality of inputs and Utilization of resources,i.e maximum output with minimum resources.

1.1.1: Tanneries and productivity

Tanning is the conversion of raw hides and skins. A tannery is the factory where tanning takes place. In a Tannery, hides and skins are processed to leather through a series of processes. The hides and skins trade have gone through phases; witnessing positive impact on the sector. The sector changed from a purely raw material source to fairly modern industry adopting the changing technology and market trends (KLDC, 2016). The change saw the country turn into a tanning hub for the East African region through obtaining hides and skins and supply of leather in both local and regional markets. In addition, it experienced exports of semi- processed leather (wet-blue) to the international markets

Most of the tanneries in Kenya are usually small and Medium Enterprises (SMEs) and they play a very important role in a nation's economy, in terms of their contributions to the GDP and employment, and they therefore remain the core engines for productivity and economic growth of the nation (World, Bank, & Group, 2015).Tanning as a manufacturing sector, focus on productivity in terms of how to meet the customer requirements, and where they must inculcate a strong productivity mindset and embrace continuous productivity improvement. Productivity is considered as a measure of how they meet the criteria below according to (Teklemariam, 2004):

- Objectives- to what degree do they achieve the organisation objectives

- Efficiency –how efficiently are organisation resources used to generate useful output
- Effectiveness –the achieved throughput compared to what is theoritically possible

In the world today, for any organisation or company to survive in the market, it must be competitive enough, both nationally and internationally. With the rapid technology growth, production systems must be enhanced to increase efficiency in every dimension. The leather industry is very lucrative globally, compared to other Agro-business trades, hence it has a higher potential of being productive with higher earnings (Mwinyikione, 2014). This can be seen from Table 1.1 that leather and leather products have a percentage contribution of 52.8, compared to other Agro-products in the global market. From the Table one can see that the leather industry is one of the key players in the economic growth of a nation, compared to the other Agro-commodities in the international market.

Table 0.1:Comparison of major Agro-based commodities value in the international trade (Mwinyikione, 2014).

	Value in USD (billions)	% contribution of major selected commodities
Leather and leather products	52.5	51.8
Meat	12.0	11.0
Rubber	4.0	3.9
Cotton	5.9	5.8
Tea	6.9	6.8
Coffee	7.9	7.8
Rice	2.6	2.6
Sugar	10.4	10.3
Total	**53.5**	**100**

Therefore, productivity is a very important factor in enhancing the competitiveness of the tanneries. Hence productivity should be seen as how well the resources of the organisation are utilized efficiently. This may be through smart working, which means use or adoption of new techniques for production, or using equipment effectively.

1.1.2 Tanneries in Kenya

From the global context African countries like Kenya remain as marginal players in the leather industry. Despite Kenya being a leather footwear hub for East Africa two decades ago has it is only estimated at only US$ 140 million (0.14% of world export in 2013), making it significantly less competitive than global leaders (Ministry of industrialisation and enterprise development-kenya, 2015). According to a publication of Kenyan Embassy-Rome, the leather industry in Kenya mainly depends on the large livestock resource base which has an estimated population of 17.5 million cattle, 27.7 million goats, 17.1 million sheep and 3.0 million camels. The sector has a contribution to the economy of Ksh.13.6 billion and creates employment to thousands of people both directly and indirectly through the existing tanneries and other several leather goods cottages or SMEs in various part of the country (Mwinyihija M. , 2014). From the Table 1.2 it's evident that Kenya has had an improvement in the export of processed leather comparing the exports in the year 1995 and 2013. From the table it's evident that leather industry has been experiencing an upward improvement over the years which earned the country about Ksh.13.6 billion in 2013. This increase in productivity levels in the industry was as a result of the value addition process, after an imposed tax on raw hides and skins. The increase in other leather cottages led to the increase in employment levels between the study periods 1995-2013. Hence this shows there has been tremendous increase in productivity and production levels in the leather industry in the country.

Table 0.2: Operational numbers of the tanneries, export go-downs and cottage industries showing the leather sector productivity performance in Kenya (1995-2013) (Mwinyihija M. , 2014)

	1995-2000	2001-2005	2006-2010	2011-2013
Export of leather (trends in percentage)	Processed 15%	Processed 75%	Processed 90%	Processed 95%
	Raw 85%	Raw 25%	Raw 10%	Raw 5%
Prod of Hides and Skins (in sq. ft)	6.3 million	7.82million	8.25 million	10.6 million
No. Of Tanneries	17	9	13	14
Cottage units	15	17	24	30
Leather goods units	15	12	47	200

Direct employment (Nos)	1700	2500	16740	22000
Total Earnings	**2.0 billion**	**2.8 billion**	**7.86billion**	**13.6 billion**

Source: (Mwinyihija M. , 2014)

At the same time the production of the leather industry of hides/skins has been increasing in the country in the past few years this means increase in employment opportunity which leads to improved living standards hence affecting the country's GDP positively. The production performance in Kenya as analysed by Mwinyikione,2014, is illustrated in the graph in Figure 1.1.

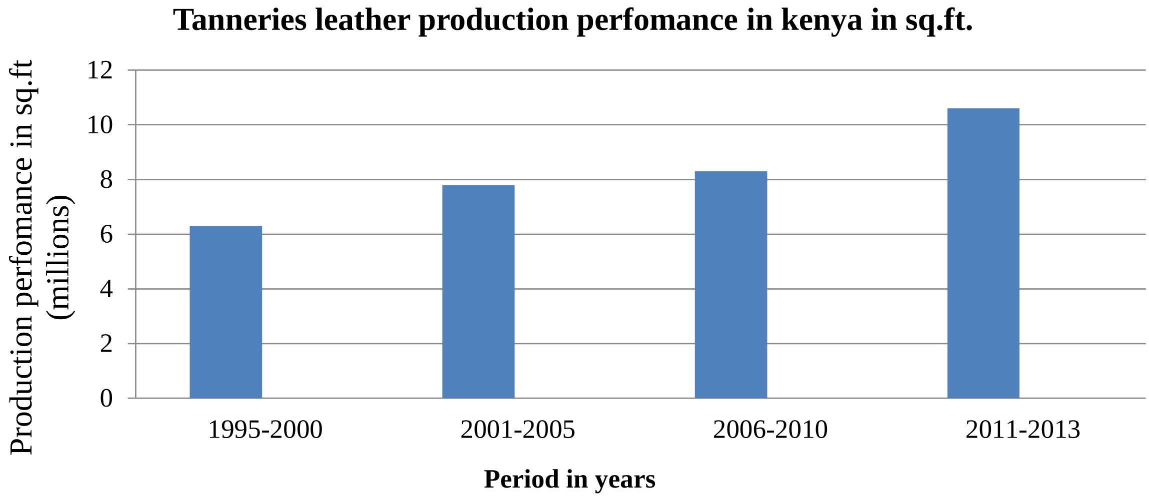


Figure 0.1:Operational numbers of the tanneries, export go-downs and cottage industries showing the leather sector productivity performance in Kenya (1995-2013) (Mwinyihija M. , 2014)

(Mudungwe, 2012) identified the Kenyan leather industry to be one of the promising Agro-based industries with immense potential where the Kenyan value chain base is very rich and is ranked third in the COMESA region from Sudan and Ethiopia. Most of the leather goods producers are the micro and small enterprise that are in the informal sector for competitiveness. According to (World, Bank, & Group, 2015) report, in Kenya only few tanneries process finished leather for domestic market as a result of high cost of raw materials and high cost of chemicals

Key players of the leather industry include the suppliers of raw hides and skins, abattoirs, tanneries and producers of products (traders).

Leather Value chains

A value chain of a product describes all the stages of a process a product undergoes from inception to the end user. The global leather value chain starts with animal husbandry/breeding and ends with the manufacture of finished leather goods (Memedovic & Mattila, 2008)). Bovine/cow hides, sheep and goatskins are the principal hides used and processed in tanneries before becoming leather footwear, garments and accessories like bags and belts and for technical products and upholstery. Leather value chain starts with the breeding of animals, slaughtering hence recovery of the hides and skins from the slaughtered animals on farms and in slaughter houses. The hides and skins are then converted to leather in the tanneries, where extensive investment in equipment is required; the leather is used to manufacture leather products in small labour-intensive workshops with less investment in equipment's, or in larger capital-intensive factories.

Value adding in agricultural commodities refers to improving the natural and conventional form, quality and appeal of a product subsequently increasing the consumer value of the product starting from the farm level to marketing of finished products. The most important livestock agro-based commodities are the hides and skins which are a derivative of the livestock sector (Mwinyikione, 2014). The development of the leather sector, considered as one of the longest value chains in the agro-based commodities, involves sustaining a dynamic raw material base, tanning, footwear, leather goods and marketing, with core stakeholders being the livestock farmers, slaughterhouse owners/butchers, traders, tanners, and footwear and leather goods strata.

The leather value chain is as shown in figure 1.2 below:

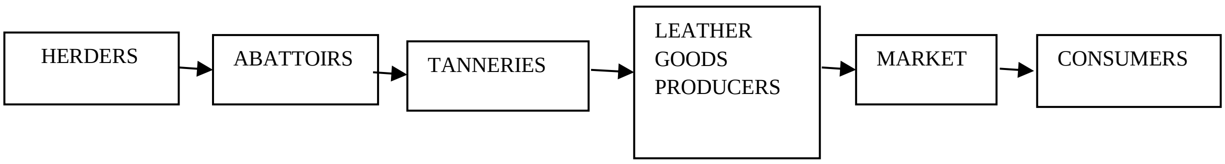


Figure 0.2:Leather value chain (Memedovic & Mattila, 2008)

From the (World, Bank, & Group, 2015)report, Kenya's, leather industry trails behind global competitors (China and India) and regional competitors (Ethiopia), in terms of productivity, quality and cost of products. Hence strategies and actions to enhance quality and standards throughout the leather value chain are vital to Kenya's ability to compete both at domestic market and globally. The strategies rest on three pillars where one of the pillars is aimed at improving the production process, technology and machinery. Maximizing the performance of machinery prolongs the life of capital equipment which eventually ensures maximum equipment utilization (Teklemariam, 2004).

1.2 Problem Environment

Leather processing has emerged as an important economic activity in several developing countries that depend on Agro-economy, because of the high labour intensity of the process involved in the conversion of the hides and skins to processed leather (Thanikaivelan, Rao, Nair, & Ramasami, 2005).In most developing economies like Kenya, leather has presumed an significant role as an opportunity segment for social development, employment creation and export realization.

Currently tanneries in Kenya have installed capacities standing at 60% for wet-blue, crust leather at 25% and finished leather taking 15% (KLDC, 2016).With improvement in the production processes Kenya can increase its leather output revenue from the current US$140 million to US$500 million. This is only possible if the current tanneries production level is improved through increasing the output or throughputs of each process and reducing their processing cycle time by eliminating equipment's down time. Generally, tanneries face the following problems:

- Low sales
- High competitiveness
- Low automation levels.

1.2.1 Case study

Sagana Tanneries is one of the tanneries and an SME, which is placed under study by the COMESA/ALLPI project, whose objective is to improve its Competitiveness through increased productivity of the tanneries. Sagana Tanneries limited was started in 1975 by eight directors, who were all Kenyans. The tannery machines were relocated from a tannery in Norway. In 2003 the management changed to a family company and the Company has a capacity to employ 50-150 people depending on the production. Currently there are about fifty employees, who are inclusive of production, security and casual staff, 80% of all employees are in the production line.

1.2.2 Market

Sagana tanneries limited performs contract tanning which takes 50% of the company's production for individual customers who then sell to Bata shoe industry.

The remaining 50% production is performed up to finishing this is more reliable and profitable, and in fact the Kenyan government advocates for this. Bata Company do their own finishing processes. Finished leathers are sold to shoe industries, and small-scale enterprises (Kariokor traders), for value addition for use in belts, wallets, bags, furniture (few). The demand is not easy to fulfil due to the different varieties of qualities demanded and the different challenges the organization faces. The company sells different leather qualities depending on the product required.

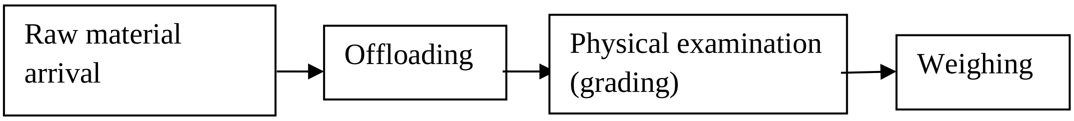


Figure 0.3: Raw material grading process. Source: (STL)

The company obtains raw materials locally especially from regions like Kirinyaga, Mt Kenya Region, Mombasa, Nakuru. Raw materials order depends on demand for a certain quality. The cost of a kilogram of skin hides keeps fluctuating with time, but the companies selling price per sq. ft. remains constant. Previously, the company selectors would be sent to the suppliers to check the raw materials for grading. Nowadays this is done on arrival of raw material to the company. The company prefers grades 1,2 and 3 Tannery Runs. This combination forms the best 'tannery run'. The company also buys grade 4 at half a price of the 'tannery run' and grade 5 at quarter the TR price. Rejects are never accepted. The grades 4 and 5, are those that have scratches, barbed wire marks, humps, ticks and identification marks etc. The grading process at Sagana tanneries is shown in Figure 1.3.

1.2.3 Production capacity and process

The tannery has a capacity to produce 400,000 sq. ft. of leather per month. The Tanning process begins at soaking where by 3.5 tonnes of skin hides are immersed in the soaking pit. At the end of finishing processes, the 3.5 tonnes yield 5600 sq. ft. of leather. The company uses a Conversion factor of 1.7 to convert kilograms to square feet, 1kg=1.7 sq. ft.

The Tanneries operation can be grouped into:

- Beam house processes

- Machinery processes
- Finishing processes

This is shown in the process flow chart in Figure 1.4

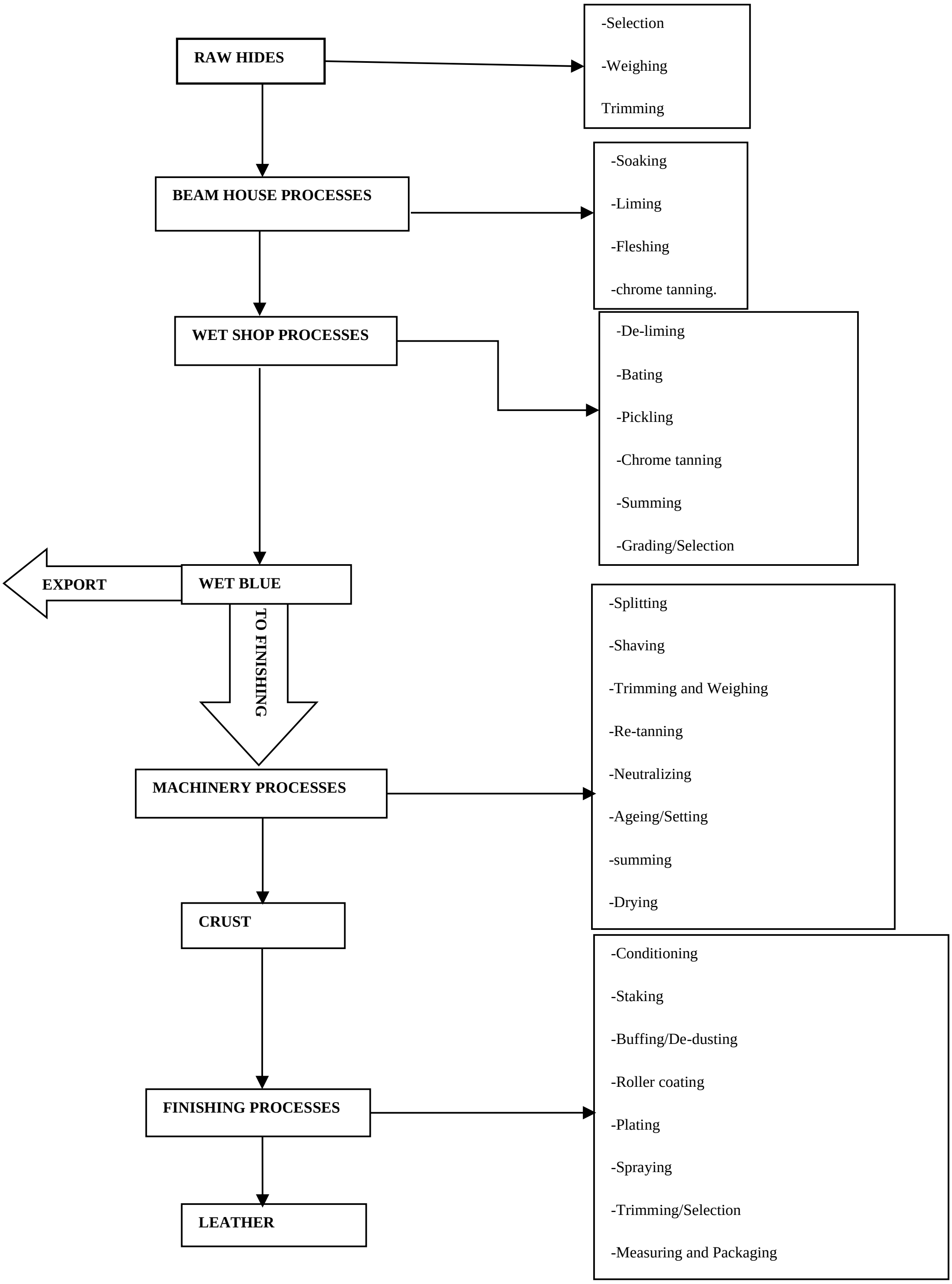


Figure 0.4: Tanneries operation flow chart. Source: STL

production data for Sagana Tanneries over a period of 12 months, was analysed to determine the actual capacity of the plant in comparison with the theoretical capacity of the plant of 400,000 square feet/month. This is further analysed on the chart below. From the Figure 1.5 below leather production in square feet in the 12 months' period was highest at 60.9% in the month of July 2017, slightly above the average production and lowest in the months of September 2016 at 25.5% below the expected factory capacity. From this also the labour productivity in sq.ft/man hour is determined.

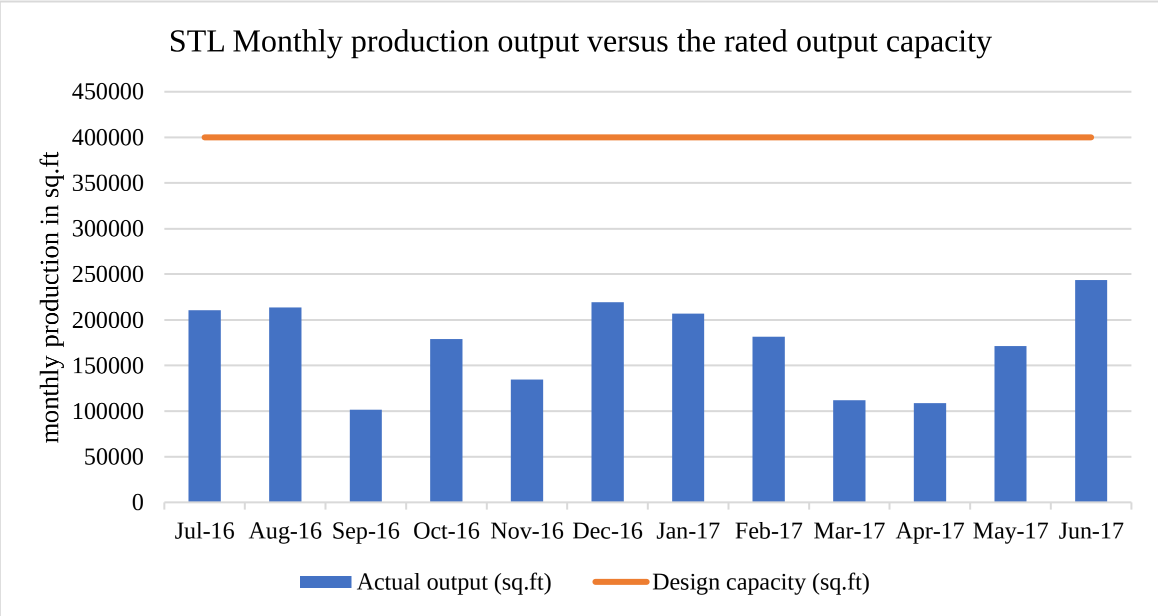


Figure 0.5: Sagana tanneries production performance. Source: STL

Some of the challenges that the tannery faced that may have contributed to the poor productivity perfomance i.e below its set capacity throughputs include:

- Mechanical breakdowns of the vacuum drying machine and the boiler

Figure 0.7:The broken-down vacuum drying machine. Source: STL

Figure 0.6: Broken down boiler unit. Source: STL

- ying sessions as they are relying on natural drying of leather. If it rains drying takes too long 3-4 days to dry a required batch of leather and other processes are also delayed

- Most of the machines are very old and cannot meet the plant capacity as they are manual, slow, High power consumers and the end product are of a lower quality as compared to the new machines. For example, the splitting machine and the buffing machine cannot give even products.

Figure 0.8: Buffing machine. Source: STL

Figure 0.9: Splitting machine. Source: STL

- Poor quality and low supply of raw materials from the suppliers
- Lack of the right chemicals for tanning,
- Material handling from one processing machine to another is manual

1.3 Problem statement

Though Sagana tanneries limited is one of the major players in leather processing in the country, the company has been experiencing low productivity levels which hinders it from meeting its market demands, hence affecting its competitiveness**.** The tannery operated at an average production of 43.4 % of its capacity during the period of preliminary study, this indicated serious problem(s) that required to be identified and solved if the tannery was to improve its productivity and remain competitive in the market.

1.4 Objectives

The purpose of the research study was to explore the factors that affected productivity in Sagana Tanneries and propose improvement strategies to be developed.

The specific objectives being:

i. To analyse the productivity levels in Sagana tanneries using OEE, and cycle time analysis.

ii. To carry out Root Cause Analysis of productivity losses in Sagana tanneries
iii. To propose strategies for productivity improvement in Sagana tanneries.

1.5 Justification

In any manufacturing set up the motivating factor is to be competitive in the market. This means the use of less input to produce maximum output within the shortest time possible and to be able to meet the specific customer demands. To remain competitive in a dynamic market environment, a company should ensure that its production process is up to the task. This calls for equipment and machineries that can operate in optimum process condition. This also requires for operators to be able to eliminate any bottle necks in the process hence ensuring the effective use of the available machine capacity. From the study a number of factors were analysed and their effect on productivity determined hence improvements strategies developed depending on the importance of each.

The study findings if implemented will benefit the company and ensure increased sales growth, reduced cost of production and increased resource utilisation reducing idle time hence leading to competitiveness in the market. The study findings will therefore help the company to be competitive in the market if the productivity is enhanced. This is because productivity can be used as a measure of a manufacturing systems efficiency which leads to increased competitive advantage.

Chapter 2 : CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1. Leather industry introduction

Tanning is one of the oldest professions for humans; this is because it began with the creation of humanity being used in making clothing and shelter. The need for better leather led to the invention of better ways of preservation such as vegetable and chemical tanning and also supporting equipment and machines to increase the quality and lifespan of the products (Hussein, 2014). The leather and its related industries is the world's largest sector based upon a by-product of the meat industry (Gupta, Gupta, & Tamra, April 2007). Trade in leather and leather products has progressively increased at the global field, this growth impacting mostly the developing world as the leather sector main producers move to Asia and projected to translate to Africa. The leather sectors relevance to the developing world is becoming conspicuous in relation to the magnitude of trading activity observed in recent years (Mwinyikione, 2014).In the developing world Asia emerged the most successful, where China and India were leading, with Brazil in tow. According to (Mwinyikione, 2014) (FAO, 2011), from a global analysis, Asia leads in both consumption of leather products and the production of footwear with 83% of a total of 13 billion pairs of shoes produced globally. Comparatively Africa is at the bottom producing only 1.3%, surpassing only Oceania at 1.2% of the global production. Kenya is at 2.40% of Africa's share and 0.09% of the global production. On Exports Kenya has a global share of 0.02% valued at US$ 78 million per annum, hence the leather sector which is a livestock agro-based sector is very important (Mwinyihija M. , 2014).

The leather industry continues to be the engine of Kenya's economic growth with an estimated contribution of over 4% of the Agricultural GDP. According to the economic survey conducted by the Kenya National Bureau of Statistics (KNBS) there was indication that the livestock sector which is a major component of the agricultural sector, contributes 12% to the GDP with a share of 40% of the agricultural GDP (KNBS, 2012). The livestock sector and associated commodity-based industries (including the leather sector) is of great importance as 80% of the country is arid and semi-arid. The socio-economic dimensions of the livestock sector in Kenya (including Africa) supports employment, wealth creation, trade, household food security, nutrition, agro-based commodity development of which to optimize on the benefits of derived commodities appropriate value addition is required (Mwinyihija M. , 2014)(Sharma, Pathania, & Lal, 2010).

2.1.1 Leather processing

On processing of the hides and skins the transformative material becomes semi-processed leather (e.g. wet-blue) or finished leather that can be used in the manufacturing of Footwear and Leather goods (Mwinyihija M. , 2010)The leather industry in Kenya has 19 tanneries with a capital investment worth Kshs. 3.8 billion (equivalent to US$ 47.5million at 2012/13 exchange rates), employs 4,000 people and operates at an average capacity utilization of 80%. With the abolishment of the 22% export compensation in 1990 a significant decline in the leather industry was observed which resulted to 10 tanneries operating at an average of 30% capacity utilization by 2004/2005. According to the Economic survey (UNIDO, 2010) report of Kenya, the quantum manufacturing index of the leather industry continued to indicate a positive trend with a 1.8% economic growth realized during 2008/09 review period, however, irrespective of the positive growth the unexplored value addition opportunities are immense with a potential of translating Kenya to huge trading hub in the East African countries and Africa at large (Mwinyihija M. , 2010). According to ((Dandira & Madanhire, 2013) Leather production uses raw material in the form of cow hides and goat and sheep skins and a number of imported chemicals. The raw material is locally collected. About 130 different types of chemicals are used in leather manufacturing which ranges from common salt (sodium chloride) to very expensive Chrome Sulphate. Leather manufacturing involves the following major steps as illustrated in process flow chart in Figure 2.1 (Chumba & W, 2017)(the process is similar to processes at Sagana tanneries):

- Pre-Process
- Pre-Tanning Process
- Tanning Processes
- Wet Finishing Process
- Dry Machining
- Finishing

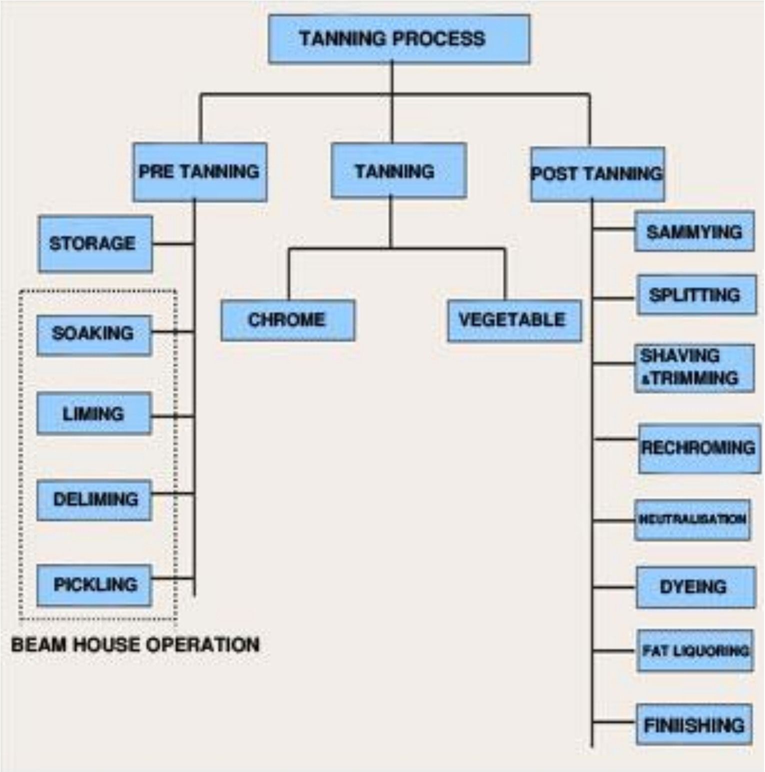


Figure 0.1: Leather processing flow chart (STL)

In Sagana tanneries leather processing is as follows: **Pre-processing** skins/hides are received and salt is applied on the flesh side of the skins/hides. Skin trimming is done to remove unwanted parts. After pre-processing, **pre-tanning process** starts with the soaking process in which skin are made flaccid by soaking them in water. After soaking hair is removed, lime is used to make hair loose. Unwanted flesh is removed using the fleshing machine after liming is done. **Deliming** is done using ammonium sulphate and then washed. **Bating** is done to purify the hides further, and then they are degreased using detergents. Tanning involves pickling of skins with acids and salts to stabilize their PH levels this helps in the preservation of the skin. Chrome Tanning is done to stabilize the collagen network of skin using tanning agents such as chromium sulphate resulting to "wet blue". Sorting is done according to the quality required at this stage or exported as wet blue. Splitting is done depending on the leather type to give the required thickness. Shaving is also done on the shaving machine to remove hairs on the skin. Wet finishing processes are carried out to impart the desired softness, colour, strength and quality. These include fat liquoring for softness, dyeing gives colour. The processed leather is taken through some drying process i.e. setting, vacuum dying, stacking/toggling, buffing, trimming, and pressing and segregation of the leather. The finishing processes are finally carried out to impart beauty and durability to the leather (Chumba & W, 2017) (Dandira & Madanhire, 2013).

The chemicals used in the leather industry can be divided into three broad categories:

- Pre-tanning Chemicals
- Tanning Chemicals
- Finishing Chemicals

Pre-tanning chemicals are used to clean and prepare skins for the tanning process and they are mostly washed away with the wastewater. Tanning chemicals react with the collagen fibres of the skin to convert them into leather. These chemicals are retained in the skin but a good amount of these is discharged into wastewater. Chrome Sulphate is the basic tanning chemical. Apart from being expensive, Chrome Sulphate is also a serious pollutant (Chumba & W, 2017).

Finishing chemicals are used to impart certain properties to the leather like softness, colour, appearance etc. Like tanning chemicals finishing chemical also get discharged into wastewater. Only the chemicals that are fully retained are applied as surface coating. A large amount of water is used in the whole manufacturing process. In tanning process water is used as carrier to facilitate different chemical reactions and after completion of the process the water leaves the system as wastewater in the same quantity as added to the system (Chumba & W, 2017). Ground water is mainly used as processing water.

Equipment's and machineries

Equipment's in an industry are usually the largest capital investment that offers opportunities for continuous improvement throughout the manufacturing operations cycle (IndustrGroup, 2015). Machines used in tanneries like Sagana tanneries include: soaking pits, liming drums, chrome tanning drums, fleshers, shavers, toggling, staking machine, buffers, plating machine, roller coater, measuring, ironing, and spraying, summing and vacuum and overhead conveyor for drying the skins (Chumba & W, 2017). In Africa, most tanning is done in tanneries using modern techniques compared to few cases where traditional techniques are used. However, most of the tanneries were established with imported reconditioned equipment and there has been little subsequent investment in modern equipment and technology (UNIDO G. , 2002). Equipment's are an example of internal factors that affect productivity and be controlled in a short run. According to

(Teklemariam, 2004), equipment productivity can be improved by good maintenance, operating the equipment in optimum process condition, reducing idle time, eliminating bottle-necks and effective use of available machines and plant capacity. The author still argues that, leather industries being a producer of perishable products that degrade unless continually processed, its productivity is highly dependent on its equipment. Productivity of equipment is usually affected by the volume, variety and period of operating the fixed capital. The age of equipment, quality and its degree of sophistication weighs heavily in any measure of manufacturing plants productivity (Hubert & Bailey, 1980). In most manufacturing industries machine utilization may be less due to poor planning and machine breakdowns (Teklemariam, 2004).To ensure equipment effectiveness, quality is used as a key measurement factor. Improving quality means minimizing waste and defective products hence increasing productivity. Production equipment begin to deteriorate as soon as they are commissioned hence leading to downtimes, quality problems, slower production rate, safety hazards, all these tend to have a negative impact on profitability, customer satisfaction, productivity among others (Muchiri P. , Pintelon, Martin, & De Meyer, 2010). (United States Patent No. US 20040148047A1/ PCT/US01/49332, 2001)Identifies productivity analysis at the equipment level to follow a Unit Production Process (UPP) concept which identifies four performance metrics that contributes to unit productivity. The metrics are: Overall Equipment Effectiveness (OEE), output of good product (throughput), Cycle Time Effectiveness (CTE) and equipment level inventory (work in process) these metrics provide a basis for conducting a root cause analysis to understand the various manufacturing productivity problems and hence help in making productivity improvements for equipment’s.

2.1.2 Productivity challenges in leather industries

(Levary, 1991) and (Stevenson, Operations Management, 2009) defined productivity as the measure of the effective use of resources which gives the average measure of the efficiency of a production system and it is a key factor for organisations to remain competitive in the market.

In the leather industry, the effective use of resources may be affected by a number of factors which may pose challenges to their achieving higher productivity levels. Obsolete equipment, low levels of training, a badly organised workflow, frequent lack of spares and tanning chemicals are factors that contribute to low levels of productivity in the leather industry (UNIDO G. , 2002).Lack of appropriate equipment maintenance management systems as cited in the Ethiopian leather industries by (Teklemariam, 2004), this means the availability of equipments is not maximized hence affect productivity of the organisation. Low operational capacity due to high, expensive and intensive capital requirement is a challenge faced by majority of the Kenyan leather industry as cited by (Mwinyihija M. , 2014). Effluent treatment facilities, supply of quality raw materials , research and development of new technologies are factors that pose a challenge in the leather industry according to a report by (UNIDO, 2010). Other than quality of local raw hides, the size of the hides have been waning over time especially in the Kenyan industry, where current average size of a hide is 25 sq.ft from an average of 30 sq.ft in 2005 This affects the competitivenes of the kenyan leather which in turn affects the productivity of the industry (World, Bank, & Group, 2015). The Kenyan leather industry lacks equipment, technology, awareness and knowledge to produce quality hides and skin as well as finished leather products which as further been curtailed by insufficient funding, investment and incentives from the industry. Other challenges that affect the leather industry especially in Kenya include: lack of policy framework to govern the leather industry,little coordination between key institutions, lack of skills, high costs of production, lack of machinery,high electricity cost and tarrif on importing inputs and lack of quality enforcemnts (World, Bank, & Group, 2015) (Botho, 2004).

2.2. Productivity concepts

Productivity refers to the effectiveness of working, not its intensity. Productivity is usually expressed as a ratio of output to input (Stevenson, Operations Management, 2009). Productivity is very vital for all business organisations that use a low-cost strategy. Therefore, productivity ratios are used to plan work force requirements, scheduling equipment’s and all the important task in a business. Hence for all profit-making organisations productivity helps determine how competitive the organisation is. Hence to determine the productivity growth, we evaluate the increase in productivity from one period to another, relative to the productivity in the preceding period.

Productivity growth = $\frac{(\text{current productivity} - \text{previous productivity})}{(\text{previous productivity})} * 100$

Hence, productivity of an organisation represents the overall efficiency of the system, which indicates how well a system is executing against its objectives and goals (Ahuja, 2006)

Generally, productivity growth plays a key factor in a country's inflation rate and standards of living of people. For companies, higher productivity relative to their competitors gives them a competitive advantage in the market place. According to (Gupta & Vardhan, 2016) productivity is a widely used manufacturing performance measure which is essential in managing production improvements.

2.2.1Types of productivity

Productivity can be broadly classified in several ways which may include human resource or capital resource. Capital based productivity includes machinery maintenance management and technological advancement. Maintenance being a technical field, tries to maximise the performance of machinery and prolong the life of capital equipment, enabling maximum utilization of equipment and high rate of return on investment. Maintenance is related to profitability through equipment output and running cost. Hence proper maintenance should decrease sudden breakdowns and increase the revenue of the plant by increasing production output (Teklemariam, 2004)

Productivity can also be the ratio of output value to the input value, which is expressed as in the equation below (John , 1993)

$$Productivity \;=\; \frac{output\ value}{input\ value}$$

From the equation we can see that productivity rises keeping everything else constant ,when the value of output increases ,the quality of output increases and the cost of resources (input) utilized decreases.

According to (Teklemariam, 2004) productivity is linked with how the resources are utilized in the company.This is the function of achieving the maximum possible with minimum resource. The resources are manpower, material, equipment, spares and building, capital and time.Where the responsibility of achieving higher productivity rests on managing these resources efficiently. Productivity growth comes from working smarter, this means adopting new technonologies or new techniques for production.

Since one function of productivity is time, we can define productivity as the relationship between result and the time it takes to accomlpish them. Time is a good demonstrator as it is a universal measure which is beyond human control. The system is deemed productive if it takes less time to achieve the desired results.

2.2.2 Productivity measurements

Productivity is a critical issue in the long –term competitiveness and productivity of an organisation (Spring, 2011).Productivity measurements in any organisations are cumulative measures, and they serve as a score card of the effective use of resources and is basically used to judge the performance of the entire industry or track the performance over time (Stevenson, Operations Management, 2009). Hence productivity measurement is criterion for productivity improvement (Spring, 2011). According to (Ahuja, 2006)a good productivity measurement model under systems concept should:

- Reflect how well a system is doing with reference to its performance objectives
- Consider all outputs of the system
- Consider all the resources consumed in the process to achieve output
- Provide information as to deployment and reallocation of resources to obtain productivity
- Reorganise the relative importance of each objective in case of a multi-performance objectives
- Make available and comprehensible the data to be used.

To calculate productivity, ((Mark & White, 2004)), it’s vital to define and measure the inputs and the outputs of the process. Productivity can also refer to total factor productivity which is a productivity measure which involves all factors of production (Afriat, 1972). Productivity measures are based on a single input (partial productivity), on more than one input (multi factor productivity), or on all inputs (total productivity) (Stevenson W. J., 2009). The choice of productivity measure depends on primarily the purpose of the measurement. Partial measures are commonly used in operations management. Types of productivity measures are:

$$Partial\ measures\ = \frac{output}{labour}, \frac{output}{machine}, \frac{output}{capital}$$

$$Multifactor\ measures = \frac{output}{(labour + machine)}, \frac{output}{(labour + capital + energy)}$$

$$Total\ measure = \frac{total\ goods\ produced}{all\ inputs\ used\ to\ produce\ them}$$

Partial productivity measures include:

- Labour productivity- units of output per labour hour
- Machine productivity- units of output per machine hour
- Capital productivity –units of output per dollar input
- Energy productivity – units of output per kilowatt-hour

Productivity indicators includes labour productivity and capital productivity and they measure the effectiveness and efficiency of the production process i.e. input into output (Spring, 2011). In the leather industry productivity parameters are not exhaustive but may include (Buljan & Kral, 2012):

- Raw material input tonnes per day, month, week, or year
- Rate of capacity utilization in term of actual work- hours of individual machine vs. work-hours theoretically possible or target set; $\frac{tonne}{work-hour}, \frac{work-hours}{work-hours} * 100$
- Rate of capacity utilization in term of actual input/output vs. theoretically possible and or target set; $\frac{tonne}{tonne} * 100$
- Tan yard output, finished leather output – per day/week/monthly $\frac{tonne\ or (m2)}{worker\ or\ work\ hour}$

2.3 Productivity levels Key Performance Indicators

Productivity may be affected by several factors such as methods used, capital, technology and a management, equipment breakdowns, shortage of materials (raw) etc (Akrani, 2013). Key performance indicators of productivity in a manufacturing set up may include:

2.3.1 Overall Equipment Effectiveness (OEE)

OEE is a quantitative metric for measuring productivity of individual equipment in a factory under a total productive maintenance (TPM) a concept by Nakajima (1988) (Muchiri & Pintelon, 2008). The author's points out that OEE categorises the major losses or the reasons for poor performance and provides the basis for setting improvement priorities and hence the beginning of root cause analysis. OEE measures the percentage of planned production time that is truly productive (Itasca, 2016).The OEE measure is a popular method of judging the effectiveness of capacity that incorporates concept of capacity reduction (leakage) (Nigel, Stuart, Robert, & Alan, 2009). It's based on three aspects of performance: time (which equipment is available), speed (throughput rate of the equipment) and quality of the product or services it produces.

$OEE = A \times P \times Q$ where, A is the availability rate, P is the performance (speed) rate and Q is the quality rate.

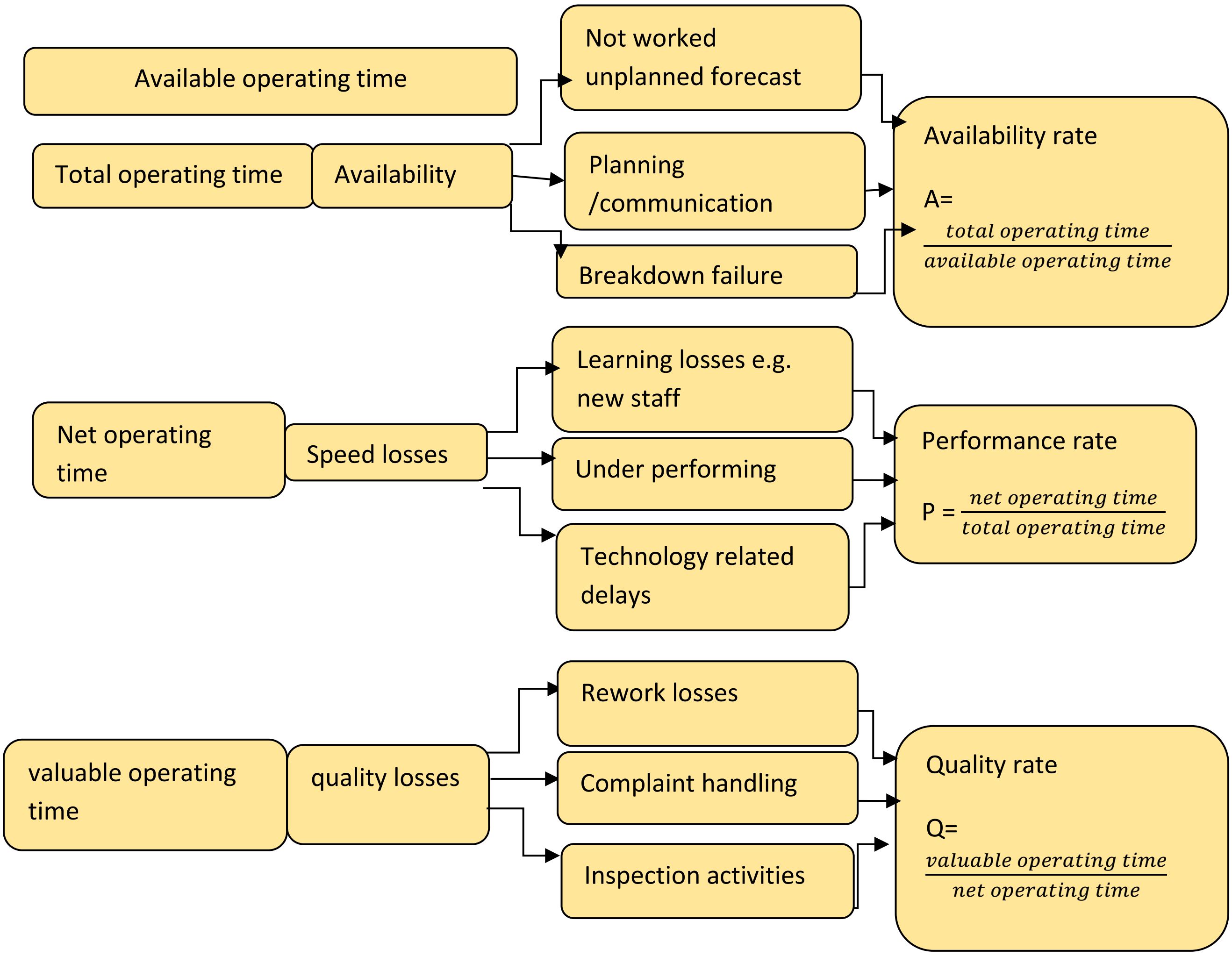


Figure 0.2:Overall Equipment Effectiveness (OEE) (Nigel, Stuart, Robert, & Alan, 2009)

OEE is useful both as a benchmark and a baseline (Itasca, 2016). Where, as a benchmark it relates the performance of a given production equipment compared to the industry standards, while as a baseline it is used to track advancement over time in eliminating waste from the production equipment. (Pomorski, 1997) describes production OEE as a measurement of equipment effectiveness as long as there is work available for production. The author also argues that, OEE measurement alone may not provide a tool which can support an improvement program, but its power is in linking the OEE data to the identification of the main equipment losses.

OEE has been identified as a safe and correct method of determining the real performance of equipment (Adriana, 2013) where the indicator of Equipment Productivity OEE is the setup time. According to (Gupta & Vardhan, 2016) OEE is an influential control tool used to overcome production insufficiencies and operational performance constraints. The use of OEE has been found to be gaining importance in computing the performance of equipment production to optimise productivity (Rohaizan, Ngadiman, Omar, & Yassin, 2015). In a study by (VivekPrabhu, Karthick, & Kumar, 2014), shows that OEE is greatly improved if the performance rate is improved.

Table 0.1: OEE major losses (Pomorski, 1997) (Exor & Data, 2017)

Major loss category	**OEE loss category**	**Example of an event**
Breakdowns	Availability	• Equipment failure • Unplanned maintenance • Unplanned maintenance
Adjustments and set up	Availability	• Equipment setup • Raw material shortage • Operator shortage
Minor stops/ Idling loss	Performance / Availability	• Equipment failure<10mins • Obstruction blockages
Speed loss-low speeds	Performance	• Machine idling • Running lower than rated speed
Production rejects/ Rejects on start up	Quality	• Rework • In process damage

According to (Sohal, Olhager, O'Neill, & Prajogo, 2010) OEE data that is collected on equipment performance is usually a major initial point for operators to comprehend there equipment losses and to be able to launch improvement strategies to eradicate them. (The & Johnston, 2017) highlights the benefits of using OEE as, providing real time target to the operators based on the input and equipment availability at the time. The author also identifies the ability to comprehend the cause of loss by identifying the type of constraint and being able to develop the improvement strategies to eliminate the loss as another benefit of employing OEE. (Sohal, Olhager, O'Neill, & Prajogo, 2010) OEE acts as a tool used to improve the effectiveness through the identification and elimination of waste in support of continuous improvement in a production.

2.3.2: Cycle time Analysis

Capacity of an equipment or system is usually measured in terms of its cycle time. Cycle time it's the average time that the process takes between completions of units (Nigel Slack, 2009). Cycle time is a vital factor in process design; it's one of the first things to be calculated as it can represent the demand placed on a process and the process capacity. (Marsudi & Shafeek, 2014) defined manufacturing cycle time to be the sum of all the processing times of every operation a product may go through from the start to the finishing. (Heizer & Render, 2014) described it as the time between arrival of raw material and the dispatching of the finished product. Cycle time is therefore the amount of time required to produce a unit and its measured in mins/pc or sec/pc (Vonderembse & Gregory, 2004) and it sets the drum beat or the pace of a process (Nigel Slack, 2009). Calculated as:

$$\text{Cycle time for the process} = \frac{\text{Time available}}{\text{Number of products to be processed in that time}}$$

A cycle time in manufacturing involves both the productive and non-productive time, where (Jovanovic, Milanovic, & Djukic, 2014) describes productive time to be when a product changes its shape or properties through a technological operation and non-productive time is the time covered during control operations and transportation or movements within the process. Too many non-value adding activities in a manufacturing process results to a prolonged cycle time, which in addition leads to accumulation of Work in Process affecting the process throughput capacity (Chen, 2013). Hence a reduction in the manufacturing cycle time will improve the production process making it lean, will improve the company's competitiveness and improve the process throughput (Dossenbach, 2017) (Chen, 2013) (Heizer & Render, 2014).from cycle time analysis the following benefiting information can be accrued: manufacturing process and capacity of a system can be identified, cost potentials in terms of input inventories, the manufacturing equipment technologies applied and causes of cycle losses (Jovanovic, Milanovic, & Djukic, 2014). Cycle time analysis is accomplished by use of time study in work measurement

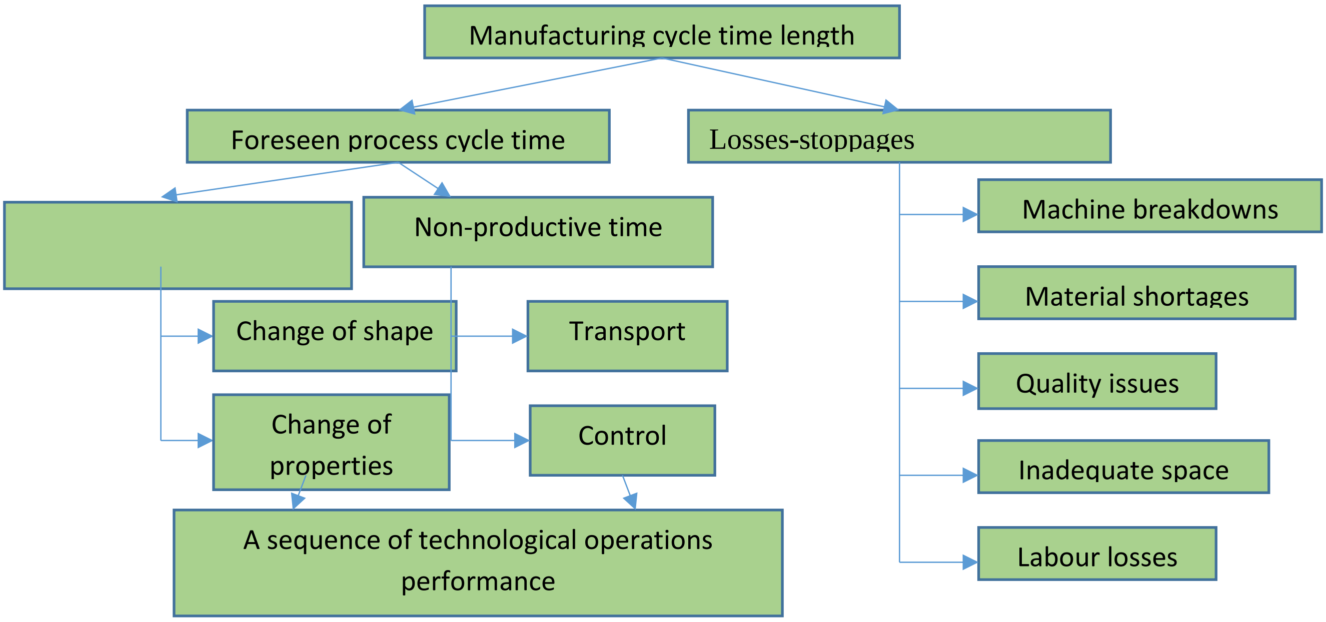


Figure 0.3 :Manufacturing cycle time length (Stevenson, Operations Management, 2009)

Cycle time analysis is done using a stopwatch to develop a standard time to accomplish a given task. Standard time is the time required by a worker, operating at a normal pace to perform a specified task using a prescribed method, with allowances for personal time, delays and fatigue (Stevenson, Operations Management, 2009) (Vonderembse & Gregory, 2004).

During observation, the time recorded is known as the Observed time and is the average of the recorded times and is given by:

$$Observed\ time\ = \frac{Sum\ of\ recorded\ times(\text{sec})}{number\ of\ observations}$$

From the Observed Time, Standard time can be computed,

$Standard\ time\ = Normal\ time\ \times Allowance\ Factor$, where Normal time is an adjustment of the observed time based on operator performance, Allowance Factor comprises of rest breaks and personal delays among others.

$$Normal\ time\ =\ Observed\ time \times Performance\ rating$$

The procedure for stopwatch time studies as given by (Stevenson W. J., 2009):

- Definition of the task to be studied
- Determination of the number off cycles to be observed
- Actual timing of the job using a stopwatch, and rating the worker's performance
- Computation of the standard time using the formula above.

2.3.3 Throughput Process design analysis

Process design analysis encompasses calculating the specifics of the process, in particular its objectives, order of activities, division of tasks and capacity and ability to integrate the effects of unpredictability (Nigel Slack, 2009). Process design defines the way units flow through an operation. Four performance objectives that are useful in the design process are: throughput (flow) rate, throughput time, the number of units in the process (work in process) and the utilization of process resources.

- Throughput rate (flow rate)- rate at which objects emerge from the process
- Throughput time- average elapsed time taken for inputs to move through the process and become outputs
- Work in process- the number of units in the process
- Utilization of process resources-proportion of available time for which the sources within the process are performing useful work.

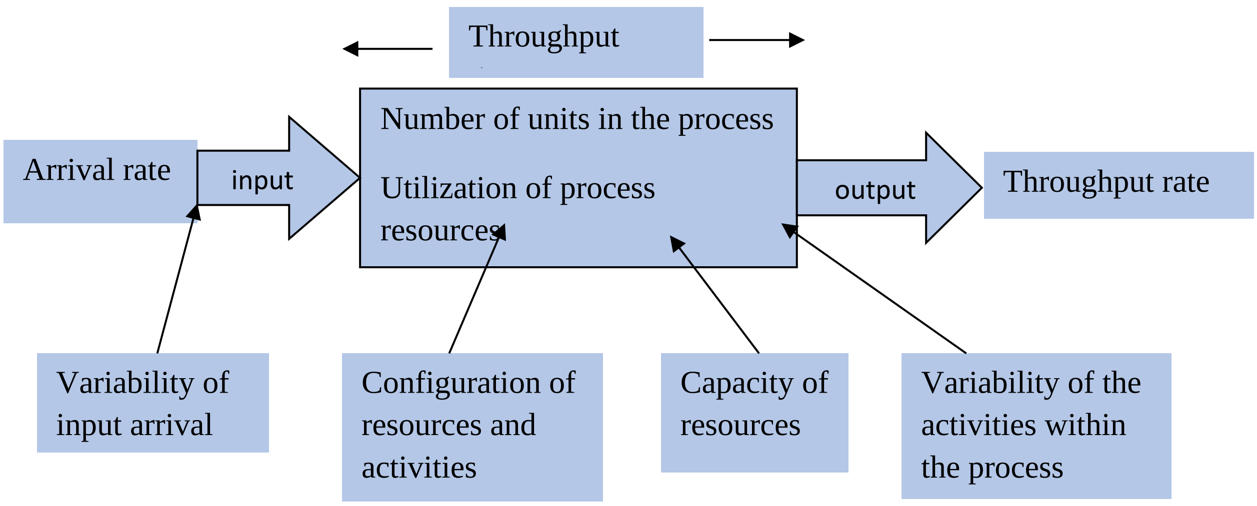


Figure 0.4:Process performance objectives and process design factors (Nigel, Stuart, Robert, & Alan, 2009)

The entire idea of a process design is to make sure that the performance of the process is suitable for whatsoever it is trying to accomplish. A process performance is adjudicated in terms of the levels of quality, speed, dependability, flexibility and cost it achieves. Throughput analysis is crucial for the design, operation and management of a production system with unreliable machineries (Li, Dennis, Huang, & Jeffrey, 2009).

Bottleneck Analysis: In production, a bottleneck is a resource or operation that limits output, essentially determining the capacity of the entire process. Even marginal changes in the capacity of a bottleneck will change the capacity of the process (Ryzin & Garrett, 2008)**.** Bottleneck analysis aims at improving the throughput by strengthening the weakest point in the production process.

Trend Analysis: It is a technique of looking at the behaviour and frequency of the performance issue and determining the bottleneck or steps in identifying the bottleneck. Performance trends can be of different types like consistent, fluctuating, increasing and even decreasing. Trend analysis can be done on both performance metrics from the end user (like response time) and also using the server metrics. (performancetestingfun).

Theory of Constraints (TOC): TOC mainly focuses on increasing through put to improve productivity (Itasca, 2016). It helps in identifying the bottleneck in a process and improves it till it is no longer the limiting factor on throughput.

2.4 Root cause analysis (RCA)

RCA is used to analyse a problem in order to get to the root cause of the problem. Its use it's supposed to eradicate, correct the cause and avert the problem from recurring by pointing the counteractive measures at the root causes (Chandrakar & Kumar, 2015). RCA refers to a collective term that describes a wide range of approaches, tools and techniques which are used to unearth the causes of problems so that the most effective solutions can be identified and executed (ReliabilityTeam, 2017). Root cause analysis involves three basic questions:

- What's the problem?
- Why did it happen?
- What will be done to prevent it from happening again.

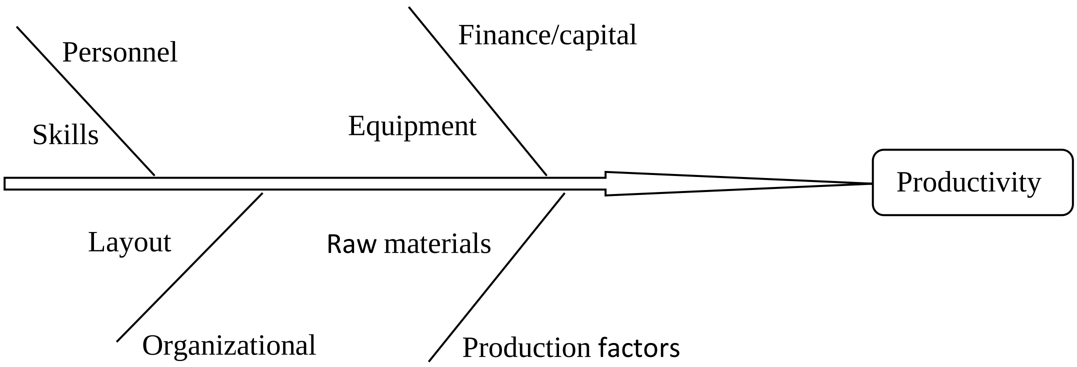
These questions are usually answered from a four-step process of RCA which is as follows

1. Data collection and analysis
2. Cause charting using Cause and Effect diagram
3. Root cause identification
4. Recommendation is given on the viable corrective measure as per the root cause.

In the use of RCA, the first step involves: establishing the objectives for the root cause analysis and selecting the necessary analysis tools (Chandrakar & Kumar, 2015).RCA identifies causal factors using structured approaches with techniques designed to give a focus for identifying and resolving the problems (Mahto & Kumar, 2008).

RCA ensures that a problem is truly eliminated by applying appropriate corrective action to the "root cause" of the problem. It involves use of tools such as:

- Cause and Effect diagrams (fishbone diagrams), shows the relationship between a given outcome and the factors that influence it (Chandrakar & Kumar, 2015), involves four major categories, Manpower, Methods, Materials and Machinery (Mahto & Kumar, 2008). This tool identifies possible causes of an effect and sorts the ideas into major categories hence it is very helpful in brainstorming effects and solutions (ASQ, 2019)
- Pareto chart which represents individual values by bars, cumulative total by line highlighting the most important among a set of factors. According to (ASQ, 2019), pareto charts are very useful when there are many causes and you want to focus on significant causes or when you need to analyse the frequency of a cause.
- 5 whys (asking why five times- each time you move close to the problem source.) (Kiran, Cijo, & Kuriakose, 2013,) (Sixsigmagroup, 2017). It's a very basic and easy to use tool. Works hand in hand with the cause and effect diagram.



2.5. Strategy for productivity improvement

To improve productivity, we must consider productivity factors. These can be classified as internal and external respectively. Internal factors are those within the organisations control which can include: product, equipment, technology, materials, energy, people, organisation and management style. While external are those not controllable by the organisation such as economic, political, and social and other infrastructure factors (Prokopenko, 1999).

According to (Hubert & Bailey, 1980), Productivity improvement is not just doing things better; it is doing the right thing better. Hence productivity can be improved by utilising the resources effectively i.e. Human and Capital resources. Human resource is an important and potential area of productivity improvement. Here productivity is achieved through high performance with a sense of satisfaction by the people doing the work. On capital resource, of most significant productivity improvement usually comes from saving material and energy. This is because, poor operator practice, bad layout and inadequate storage space aggravates problems in material handling, leading to excessive movement (Prokopenko, 1999). Improving productivity also depends on optimal choice and utilization of materials, equipment and energy resources. (Taj & Berro, 2006) demonstrated that lean manufacturing and constraint management together would improve productivity, efficiency and quality in a manufacturing plant. Lean principles focused on waste elimination and process speed while constrained management focused on increasing throughput. (Veronesi, et al., 2014) highlighted several tactics that can be considered to help improve the productivity of a plant which are, to reduce movements for efficiency optimization, reduction of bottlenecks by improving scheduling, improvement of equipment reliability, inventory levels optimization to reduce shortages and automation of the process. These tactics were achieved by use of Lean tools such Kanban system, automation, use of simulation models, TPM, redesigning plant layout.

To be competitive in the market an organisation needs to produce quality products. Therefore, quality is one of the important factors and area of productivity improvement. Productivity can also be improved through capital resource by maintaining the equipment properly to make them available whenever needed. Poor planning and lack of preventive maintenance leads to less equipment utilization, therefore, on a successful productivity improvement dive, downtime on critical production equipment should reduce considerably. This means the availability of machines increases and so the productivity (Teklemariam, 2004). A good productivity strategy calls for a system approach, which recognises the inter-relationship between the elements of the system with their environment to productivity improvement. Therefore, a productivity strategy is a pattern of decisions in an organisation that determines the procedure, objectives and principal policies and plans for achieving long-term productivity improvement goals (Prokopenko, 1999)

A good productivity improvement strategy should include the following according to (Stevenson, Operations Management, 2009):

- Develop productivity measures for all operations
- Evaluate the whole system to decide which operation are crucial to ensure effectiveness
- Develop methods for achieving productivity improvements e.g. benchmarking, team working –develop models for excellence
- Establish reasonable goals for improvement and policies
- Consider incentives to reward workers for contributions- support by management
- Measure improvements and publicize them.

Productivity improvement in an organisation may be influenced by several improvement criteria or Key Performance Indicators (KPI) such:

- Overall equipment effectiveness
- Flexible manufacturing systems optimization
- Production planning and control
- Operation analysis techniques for decision making
- Improved technology with capital investment (Ahuja, 2006)

Therefore, improvement can be in different forms such as elimination, correction of ineffective processing, process simplification, system optimization, variation reduction, throughput maximization, cost reduction quality improvement and set-up time reduction (Naveen & Ramesh, 2000).

2.5.1 Lean manufacturing concept

Lean manufacturing is a management philosophy founded by Toyota Motor Company where the main principles and practices are based and derived from Toyota Production System(TPS) (Krishnan & Parveen, 2013).Lean manufacturing refers to a set of techniques developed for a period of time that help in reducing production cost and increasing productivity using less effort, lesser space, without any new inventory, better quality and lesser defects (Dutta & Banerjee, 2014).the overall objective of Lean manufacturing is to greatly satisfy customer needs, totally eliminate wastes and use less effort with same production rate. (Taj & Berro, 2006) defined Lean manufacturing as manufacture without waste. Hence describing waste to be anything other than the minimum amount of equipment, materials, parts and the working time essential for production processes. Waste is also defined by (Itasca, 2016) as any activity that does not add value from the customers perspective. Hence the concept is used to reduce any waste in the production value stream. Lean manufacturing concept is a Japanese concept where Muda means “waste”. There are seven major waste covered in Lean manufacturing: they include overproduction waste, stock (inventory), motion, transporting, correction, waiting (delays), over processing (Taj & Berro, 2006), (Sanjay & NandKumar, 2007). The concept helps eliminate any redundant processes, delete non-value-added activities, simplify motions, minimize fatigue and reduce wait time. (Adriana, 2013) sees Lean as the set of tools that assist in the identification and steady elimination of waste which in turn improves quality while reducing production time and cost. Toyota Production System (TPS) identified the production waste to include: overproduction/push system, inventory (WIP), motion, waiting and queueing, over processing, correction, conveyance or transportation. There are practices and parameters used to maintain the Lean manufacturing system for an organization (Dutta & Banerjee, 2014)which are; Value stream Mapping, Single Minute Exchange Dies, Single piece Flow, Inventory Control via Card system, 5S concept, TPM, Production Line Optimization, Kanban (pull system) etc. Lean manufacturing becomes a success and it’s at is best when executed throughout the organization, where everyone takes an inventiveness and there is a deep-rooted culture of quality control (Krishnan & Parveen, 2013). The principles of Lean manufacturing are; Identify the Value for each product with reference to the final customer, Map the Value stream identifying all the activities and disregarding any loss generating activity, Create the Flow of all the value adding activities, Establish the Pull of each client type in the system of production flow of the value set and Seek the Perfection by moving the streamline of the process and repeating it till you reach an optimal level of the maximum values without loss (Dutta & Banerjee, 2014) (Adriana, 2013). For the successful implementation employees need to be trained to hone their latent skills and increase their awareness on latest trends and technologies. The four main indicators of Lean production are Productivity, quality, Safety and cost according to (Adriana, 2013). (Dutta & Banerjee, 2014)and (Gupta & Jain, 2013) identified waste minimization and efficiency improvement as the key objectives(benefits) of lean manufacturing system implementation, which reduces downtime, lowers lead time and inventory levels, reduces wastage and non-value adding activities hence making it possible to increase productivity and reduce cost. Some of the challenges that may be encountered while implementing Lean manufacturing according to (Gupta & Jain, 2013) may include; failure to train and educate the employees, poor attitude towards lean, lack of responsibility and financial inadequacies.

2.5.2 Total productive maintenance (TPM)

TPM is a Japanese philosophy which is unique and has been developed on the basis of productive maintenance concepts and methodologies. It was first introduced by Nippon Denso Co. Ltd of Japan, a supplier of Toyota Motor Company Japan in the year 1971. TPM is one method used to enhance productivity of a system as it maximises equipment effectiveness (Gupta & Vardhan, 2016).TPM can be described also as an inventive method that optimizes the effectiveness of equipment, eliminating breakdowns and encouraging independent maintenance which is done by the operators this is according to Nakajima (1989) who is a major contributor of TPM (Bhadury, 2000). TPM thus refers to the aspect of keeping machines in good working condition which is affected by methodical maintenance of equipment to ensure they fail less and the production process is continuous (Stevenson, Operations Management, 2009). TPM is one of the very important elements in lean manufacturing according to (Itasca, 2016) .Effective TPM approaches and programs can manage with the active needs and support organisations in realising the unexploited and under-utilized resources such as machine hours, man hours etc. this improves equipment efficiency and effectiveness which leads to improvements in the production process (Wakjira & Singh, 2012). TPM is based on eight pillars which are founded on 5S principle as highlighted by (Mendez, Morales, & Rodriguez, 2017) (Gitachu, 2017) (Venkatesh, 2015) (Wakjira & Singh, 2012) (Akrani, 2013) as follows:

1. The 5S principle foundation disregards the aspect of disorganisation, indiscipline and inadequacy in an organisation, ensuing to a clean, visually organised workplace which is self-maintaining (Gitachu, 2017). 5S basic steps are: Sorting (Seiri), Setting in Order (Seiton), Shining(cleaning)(Seiso), Standardizing (Seiketsu) and Sustaining (Self-Discipline) (Shitsuke). Hence this sets the pace for TPM introduction in an organisation.
2. Autonomous Maintenance (Jishu Hozen), this ensures that the obligation of basic maintenance is on the hands of the operators and the skilled staff can spend time on more value-added activities. This eradicates unplanned disruption of equipment.
3. Planned maintenance, this refers to scheduling maintenance activities which progressively decreases breakdowns, increasing capacity for productive activities and the cost of production is reduced as equipment are fully exploited as the pillar sets an optimum equipment performance level.
4. Quality maintenance, ensures that equipment is able to spot and avert errors or defects from moving down the value chain. This pillar also ensures the workers have the habit of determining the root causes to problems and getting a permanent solution. Special attention is paid to characteristics that are considered important by the customer. This is done through 5whys, RCA and Ishikawa diagrams.
5. Focused Improvement (Kobetsu Kaizen), this pillar focuses on small improvements on continual basis and involves all people in an organization targeting to achieve and sustain zero losses and manufacturing cost decrease by maximizing equipment effectiveness. It’s done by interdisciplinary teams that eradicates the most typical failures of waste in production processes eventually improving productivity by attaining higher levels of OEE (Mendez, Morales, & Rodriguez, 2017).
6. Training and Education this pillar brings out the initial understanding of the importance of TPM philosophy to the workers at all levels. This in turn leads to a workforce with improved knowledge, skills and techniques creating an environment of self-learning based on needs.

7. Office TPM is followed to improve productivity, efficiency and identify and eliminate losses in the administrative function and have the whole organization speak from the same page. This pillar leads to involvement of all people focusing on better plant performance, utilized work areas, reduce repetitive work, inventory levels, administrative cost, breakdowns of equipment, customer complaints and increase in productivity of people in the support functions
8. Health Safety and Environment, this pillar focuses on creation of a safe workplace and a surrounding that is not damaged by procedures and processes and plays an active role in each of the other pillars on a regular basis. This eliminates any condition deemed harmful to the well-being of the workers hence targets zero accidents, zero health damage and zero fires hence a productive workforce.

TPM pillars should be implemented in such a way as to get the full benefit of the entire system. TPM practices mostly are evidently implemented in the manufacturing industries as they tend to rely more on machines and equipment that need constant maintenance to run efficiently and effectively (Krishnan & Parveen, 2013). TPM has a number of benefits that accrues from its implementation and hence governs its choice as a strategy for productivity improvement. This benefits as captured by (Okpala & Onyekachi, 2016) and (Shanmugam, Guru, & Maran, 2015) are, TPM leads to enhanced machine and equipment efficiency and effectiveness through spot on maintenance by operators, leads to increase in process throughput, reduction in cost of manufacturing and breakdown occurrences hence leads to higher customer satisfaction levels resulting to competitiveness in the market. Other benefits identified by (Shanmugam, Guru, & Maran, 2015) are indirect such as higher employee morale levels, a neat clean organized work place and positive attitude due to their involvement in decision making and implementing the approaches of TPM. (Okpala & Onyekachi, 2016) also noted challenges that impend TPM implementation as being, lack of support from the administration management, lack of knowledge on TPM, insufficient trainings of employees, excess inventory and also some cultural orientation in an organisation.

2.5.3 Layout design

Facility layout is the arrangement of the work space: machines, workstations and logistics (Mark & White, 2004) (Naqvi, Fahad, Atir, Zubair, & Shehzad, 2016) and it is a compoent of Lean manufacturing used to eliminate or reduce waste in production. Layout planning is deciding the best physical arrangement of all resources within a facility, by ensuring efficient utilization of the resources which in turn solves issues on increased product demand, cost effective manufacturing and improved quality demands. Facility resource arrangement can significantly affect productivity by assisting in elimination of waste this leads to economic benefits achieved by reduction of overall material flow and lead time (Naqvi, Fahad, Atir, Zubair, & Shehzad, 2016). A good layout design aims at minimizing material handling in a production process, as material handling cost imparts greatly on a plants operating cost which eventually affects its productivity according to American Society of Mechanical Engineers. Where material handling is an art and science that deals with movement, packaging and storing substances in a form (Jiamruangjarus & Naenna, 2016) (Tarkesh, Atighehchian, & Nookabadi, 2009). A good layout redesign of the production system assists in reduction of transporting time and costs and all other eligible waste, hence resulting in improvements and better performance of the system (Carlo, Antonietta, Borgia, & Tucci, 2013). Challenge is coming up with the best layout design analysis tool as the best is very slow and time consuming (Naqvi, Fahad, Atir, Zubair, & Shehzad, 2016).

2.5.4: Six Sigma

Six Sigma has been defined as a methodology that improves quality by analysing data with statistics to determine the root causes of problems in quality and implement controls using the DMAIC process (define, measure, analysis, improve and control (Fursule, Bansod, & Fursule, 2012). Six sigma methodologies if well implemented has been identified to reduce machine downtime, machine setup time, inventory and in-process waste and increase in workplace safety while upgrading organizations performance and improving quality and productivity (Albliwi & Antony, 2013) (Hekmatpanah, Sadroddin, Shahbaz, Mokhtari, & Fadavinia, 2008). Where the fundamental principle of six sigma is to take an organization to an improved level of sigma capabilities through application of statistical tools and techniques, to upgrade performance, improve quality and productivity, this applies to common production problems. Six sigma has been described as a performance improvement strategy which aims at reducing defects to a low of 3.4 occasions per million opportunities, as it’s a measure of variation about the average in a process (Desai & Shrivastava, 2008). The reduction in defects leads to productivity improvement which translates to improvement of customer satisfaction and hence competitiveness in the market (Mahesh, Ette, Pierce, & Glory Cannon, 2005). According to the author the challenge Six Sigma faces in its implementation is it does not focus on the management or movement of the inventories therein but on their processes, requires also active management and employees and higher resource allocation and extensive training for the best quality control team. Though six sigma is an improvement methodology it will not be considered in the methodology as the case study has no major issue with the quality of product.

2.6: Case Studies:

Productivity growth often is an indicator of expanding output and profits as well as impending economic recovery. In most cases productivity improvements are driven by investments in technology which in turn drive economic growth (Mark & White, 2004).

A case study by (Teklemariam, 2004) which sought to improve productivity in Ethiopian, leather industries through efficient maintenance management by finding an optimum balance between high maintenance cost and low machinery downtime which would maximize the profits. This was done through analysing problems that lowered productivity in the maintenance management system and was to suggest possible solution. The tannery put under study was Ethiopia Tannery Share Company which was established in 1975 with a capacity to process 17million square feet of sheep and goat skin annually and 9 million square feet of cow hide. The tannery processes leather to finished stage with a labour force of 800 permanent employees and 100 temporary workers. From the study maintenance is done in two ways, when the machine breaks down (corrective maintenance) and when its planned (preventive maintenance). It’s evident that corrective maintenance dominated the preventive activity from the data analysed as breakdowns were more than 85% of the total maintenance activities. This in turn led to high maintenance cost in terms of wages and spare parts cost. From the analysis of both the quantitative and qualitative data the bottleneck machines were identified, and the maintenance cost of those machines was compared against the company’s profits.

From the case study the conclusion is that the major cause of breakdown is lack of skills from the operators on maintenance. The target of the maintenance programme was zero breakdown a strategy where equipment maintenance is key, Hence the TPM strategy was employed to specifically play a role in equipment availability by employing equipment, people and workplace changes and improving the equipment availability. From these a maintenance program was proposed to enable efficient maintenance of the system. This proposed programme ensured that the operators were participating and was included in the daily equipment maintenance strategies. This is TPM strategies at work.

A study on continuous improvement in safety, quality and productivity of Crystal tannery S.Co by (Bekele, 2013) showed that low productivity was as a result of wastages, non-value adding activities, delays, idle times, hence a model on continuous improvement was implemented to improve the performance based on lean tools, kaizen tools.

A study was done on a switch gear company by (Naqvi, Fahad, Atir, Zubair, & Shehzad, 2016) on productivity improvement of a manufacturing facility using SLP, with an aim of eliminating waste hence reducing the overall material flow and lead time. A procedural approach suitable for both quantitative and qualitative data was used for the study. From this study all, non-value adding activities were identified and a rearrangement of some machineries was done. With lean tools the overall material efficiency was improved significantly as with the new model productivity of the facility was increased reducing lead time and increased value addition. All these was possible since lean manufacturing principle was being implemented and hence sustain global competition from the company. From the study plant layout was able to reduce various cost of the company since the alternatives were evaluated based on an improved accessibility and material flow efficiency criteria.

2.7: Deductions from Literature

From the literature, productivity can be improved through various ways, but no specific method is best it all depends with the particular organisation and the specific problem causes. Productivity strategies cited are through TPM maintenance, layout planning, overall equipment effectiveness, manpower and raw materials management strategies, technology enhancement, lean manufacturing, effluent management, work study etc. from most of the studies productivity improvement in tanneries has not been adequately covered. On the leather tannery a case of Ethiopian leather industries on improved maintenance systems (Teklemariam, 2004),efficient production and planning control system (Hailemariam & Yoseph, 2015) and of Leather Company in Zimbabwe on effluent waste reduction by using a chiller unit as part of a framework to productivity (Dandira & Madanhire, 2013). (Singh, Garg, & Deshmukh, 2008) considered TPM to be an important strategy for equipment productivity improvement. This can be achieved by using personnel who are adequately trained and appropriate IT controlled process, this lead to an observation that TPM firms have a significantly superior business performance than non-TPM firms. All other strategies have been applied to other manufacturing industries.

2.8 Gaps in the literature

Most of the research done on the leather industries rotate around waste management (Dandira & Madanhire, 2013), value addition after tanning (Mwinyihija M. , 2014) (Hussein, 2014), efficient maintenance management a case of Ethiopian leather industries (Teklemariam, 2004). From a report by (World, Bank, & Group, 2015) the Kenyan leather industry faces challenges which affect its competitiveness, these challenges included: lack of policy framework to govern the leather industry, lack of maintenance systems, little coordination between key institutions, lack of skills, high costs of production, lack of machinery, high electricity cost and tariff on importing inputs and lack of quality enforcements.

From the literature is not evident how productivity in the leather tanneries has been addressed other than through waste management, and one case on using maintenance programs to improve an already existing PPC system. Even though there are several tools and strategies for productivity improvement, there are scanty information on their utilization in solving the productivity issues in the leather industries such as addressing the situation of the existing equipment and what is making them not meet their capacity production.

This research looks into the existing tannery equipment by analysing factors that are contributing to their low productivity rate, and eventually developing improvement strategies that can be used to solve the problem. The research will utilize productivity improvement strategies/tools like Lean manufacturing, TPM strategies, OEE analysis to address the key problems affecting Sagana tanneries and may be other tanneries on the same capacity.

Chapter 3 : CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter deals with the selection and justification of research design, methods of data collection and methods of data analysis.

3.2 Research design

The research design is the structure of any scientific work. It gives track and orders the research (Blakstad, 2008)The approach used for this study was more of quantitative than qualitative, as it involved more quantitative data generation which is analysed.

A Case study of Sagana tanneries was used to represent tanneries in Kenya. Descriptive and exploratory research methods were used. According to (Kothari, 1990) descriptive method is used to explore and describe the factors that affect productivity, while exploratory method is used to produce a posteriori hypothesis by examining a data set and identifying any potential relations between variables. In this study both primary and secondary data sources were used. The primary source contained raw, non-interpreted and unevaluated information, while secondary data involved annual reports and other production records documents that could give official information related to the study.

A case study research design was used as it was more descriptive and ensured a detailed study of a specific research problem rather than an all-encompassing statistical survey or all-inclusive comparative inquiry. It was often used to thin down a very wide field of research into one or a limited easily researchable example. The case study research design was useful for testing whether a specific theory and model actually applies to phenomena in the real world. It is a useful design when not much is known about an issue or phenomenon (university of southern carolina). The design could also be described as longitudinal as it covered 12 months period.

3.3: Data collection and analysis

The study targeted Sagana tanneries which comprises of three main section, that is, beam house section, machining(tan-yard) section and the finishing section. In the beam house section, the target population is the fleshing machine which was selected on a random selection for data collection. This reduced biasness as all the elements within the population were given an equal chance of being selected. On the machining section, the splitting machine was selected as all the work in that section must pass through the splitting machine, hence it enabled adequate collection of relevant information and data in that section. On the finishing section, the plating machine was sampled as all the work in the section must be plated before going through the various final finishing processes. The tannery operated only on one eight-hour shift daily. Data collection methods involved qualitative methods. Qualitative methods involved techniques such as scheduled interviews, physical observation, discussion techniques and company documents (archival research).

Daily data recording on equipment's operating throughput, operating cycle time, design capacity and design cycle time, number of defects per process and the available operating time was obtained for the last one year between June 2016 and June 2017. This data was used to calculate the cycle time, through-put levels and OEE for each section to determine the eventual equipment utilisation. Daily data recording on equipment availability, performance and quality was obtained for the past one year from the machine operation record. In a week only five days had full operation, hence the weekly averages were taken from the five days data for each variable. To determine the influence of the various variables on productivity of the tannery, the variables weekly averages were subjected to regression analysis. Primary data was collected through scheduled interviews and observation which involved following some processes through for five weeks, this was used to justify the secondary data that was obtained from the company records. Documentary research(desktop) which involved study of journal papers, articles, reports and other conference papers on productivity improvement strategies was used. Data presentation has been done by use of charts and tables through the help of Microsoft excel and SPSS.

3.4: Analysis of the productivity levels in Sagana tanneries

To analyse the productivity levels in Sagana tanneries, data was obtained for the last twelve months on all the operation days. The data recorded on the data sheet included, daily records on the time each operation began, downtime due to machine breakdown, power failures, blades/knifes adjustments delays, material shortage, process cycle time, available production time, number of defects, process throughput and process cycle capacity. This data was collected through observation by following some process for a period of five weeks to justify the secondary data obtained from processing records, manufacturers records and from scheduled interview with the company manager and production supervisor. The following methodologies were used in analysing the productivity levels in Sagana tanneries.

3.4.1: Equipment utilization

Equipment utilization is usually defined as the percentage of total operating time during which the equipment is in production (production time) (Hibband, et al., 2011) where production is not prevented by equipment breakdowns, set up delays or scheduled downtimes. To determine the equipment utilization, the data recorded included the production time for each batch per equipment against the total available plant operating time, the formula below was used;

$$Equipment\ utilization = \frac{Production\ time}{Total\ available\ time} x\ 100$$

Equipment utilization rate was analysed against the potential equipment utilization rate as per the plant capacity which is given as 400000 sq. ft/month. Equipment utilization was further analysed and determined through calculation of the Overall Equipment Effectiveness (OEE).

3.4.2: Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a key measure of productivity in a manufacturing/ processing plant and its used for process improvements. To determine the equipment productivity levels, the OEE of the equipment's was calculated and compared with the ideal world standards. To determine the OEE of any machine the OEE factors were calculated using the formulas:

$$Availability(A) = \frac{(Total\ Available\ time\ -\ Downtime)}{Total\ Available\ time} \times 100$$

$$Performance\ rate(P) = \frac{(ideal\ cycle\ time \times output)}{Design\ production\ time} \times 100$$

$$Quality\ rate(Q)\ = \frac{(input -\ Rejects)}{input} \times 100$$

$$OEE\ = A\ x\ P\ x\ Q$$

The data used in the analysis was obtained from company records for 12 months and from interviews from the company production manager and the production supervisor, and primary data collected through observation for five weeks. The company's working days are 5days in a week, and the operators worked on one shift of 8 hours per day and the data analysed was for a period of one-year i.e. 12 months.

The OEE analysis was done on the three key sections of the tannery i.e. the beam house, the machine (tan yard) sections and the finishing section. The key equipment's on those section was highlighted as every product in that section must pass through those machines to their subsequent processes.

3.4.3: Cycle time analysis

Cycle time analysis involved determining the total time taken by a batch of hides to go through all the processes of production. It included the processing times, waiting times and material handling times. Cycle time analysis will help get information on the manufacturing capacity and process of the system, technologies applied and manufacturing equipment used, volumes of production and causes of cycle losses. Sagana leather tannery has a combination of long-cycle processes and short-cycle processes. Time studies were performed for the processes which are highly repetitive and have relatively short cycle times. A stop watch was used to collect data for process times of each process. The observed time for each process was determined by taking the average of ten observations. From this, the normal time and standard time was obtained as follows:

$$Observed\ time\ = \frac{Sum\ of\ recorded\ times(\text{sec})}{number\ of\ observations}$$

$$Normal\ Time\ (NT) = \ Observed\ Time\ \times\ Average\ performance\ Rating$$

$$Standard\ Time = \frac{Normal\ Time}{(1 -\ allowances)}$$

Where allowances included personal needs, unavoidable delays and basic fatigue, all expressed in percentages.

The process times for long-cycle processes were obtained through interviews. The times taken for various material handling activities were obtained by timing using stop watch. The times for any other activity was estimated through observation. All these were recorded in a precedence diagram and added up to obtain the total manufacturing cycle time.

3.4.4: Throughput analysis

Throughput analysis established if the company's actual throughput rate was in line with the rated throughput rate of 400,000 sq. ft. per month. Below is the procedure that was followed during throughput analysis:

1. Production records were examined for a period of one year. The data for quantity of each product produced per month in a period of one year was collected and recorded.
2. Based on the above data, the total production per month was computed.
3. A graph was drawn to show the deviation of the actual throughput rate from the targeted capacity.
4. Productivity analysis, specifically for labour productivity was performed to determine the extent of labour utilization at Sagana tanneries. Labour productivity was calculated as follows:

$$Labour\ productivity = Leather\ produced\ (in\ sq.ft)/manhours$$

The data collected for the 12 months' period is as tabulated in the Table3.1. From the data in the table 3.1, Sagana tanneries operated far below the expected capacity of the plant during the study period of July 2016 to June 2017. The plant operated at an average of 43.4% of the expected capacity of 400,000 sq. ft./month.

From Table 3.1, it can be seen that the plant actual production capacity is below the theoretical expected capacity for the period under study with an average production of 43.4% of the theoretical capacity.

Table 0.1: Sagana tannery monthly production throughput. Source: STL

Product	Quantity (sq. ft)												
	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Total
Wet-blue	166768.3	177743.5	49662.1	113141.8	81780.2	150099.8	156326.9	125613	68601.8	90202	138971.6	203750.1	**1492593.2**
Pull-up	3774	1338.75	7172.742	9587.507	7167.99	14500.25	5965.99	10158.76	7550.24	628.252	3679.75	3974.75	**75498.981**
Silka	3758	6099.5	6442.745	2847.99	7246.76	10888.25	8738.26	11467.25	4623.25	2508.5	1354.5	5332.75	**71307.755**
Linings	1226.5	2740.76	1306.246	2140.25	1855.75	921.5	2947.75	742.75	2702.25	265.51	3240.51	1051.99	**21141.766**
Hair-on	25.5	532.75	898.501	1548.258	0	540.01	244.75	783.5	941.26	450.5	1812.74	277.75	**8055.519**
Upholstery	1072.26	116.5	935	2905.99	1199.25	625.24	0	552.76	523.01	215.75	0	659.75	**8805.51**
Suede	67.51	518.99	586.007	0	585.24	0	112.51	0	54.99	0	0	15.25	**1940.497**
Kips	24432.5	20392.76	22608.74	33918.76	21514.25	27027.99	23159.25	24577.26	16604	5923	15223.99	21417.25	**256799.75**
Gloving	6392	3865.8	8690.4	10052.1	9006.6	11391.7	7969.6	5105.1	7480	7228.4	5661	5967	**88809.7**
Splits	2892.24	274.5	3507.75	2592.5	4222.75	3279.99	1611.01	2550.26	2804.25	1350.5	1264.75	1152.5	**27503**
Total production output	**210408.8**	**213623.8**	**101810.2**	**178735.2**	**134578.8**	**219274.7**	**207076**	**181550.6**	**111885.1**	**108772.4**	**171208.8**	**243599.1**	**2052456**
Design capacity	**400,000**						**400000**					**400000**	
% production capacity	**52.6**	**53.4**	**25.5**	**44.7**	**33.6**	**54.8**	**51.8**	**45.4**	**27.9**	**27.2**	**42.8**	**60.9**	**43.4**
Productivity (sq.ft/hr)	**50.58**	**51.35**	**24.5**	**42.97**	**32.35**	**52.71**	**49.8**	**43.64**	**26.9**	**26.1**	**41.16**	**58.6**	**41.12**

3.5: Root Cause Analysis for productivity losses in STL

To determine the factors affecting productivity in Sagana tanneries, the following data was collected and recorded on the data sheets: OEE factors rate, downtime, throughput, man hours, Scheduled production attainment, WIP inventory, capacity utilization, production cycle time, number of rejects and rework. From the analysis of this data it was possible to determine the impact of equipment availability and performance on productivity or the relationship that exist between the dependent and independent variables in consideration, (the degree of variation between the variables). This was done through correlation matrix and regression analysis using SPSS software. The regression analysis helps in identifying the type of model fit that exist between the variables. From this the main causes of low productivity in Sagana tanneries was identified.

From factors such as equipment availability and equipment performance, the Root causes of equipment unavailability and poor performance were identified and recorded. These possible causal factors were tested using Cause and Effect diagram, the Pareto chart and the 5-Ws, and the root causes were finally determined. The cause and effect diagram, the pareto chart and the 5-Ws are tools in Root-cause analysis to help identify the possible root causes of a problem. According to (Chandrakar & Kumar, 2015) a root cause analysis involved: Identification of the objective, Changes to procedure, Changes to operation, Training of staff, Design modification and Verification that new equipment/solution is free from defects. There are four main steps involved:

1. Data collection
2. Cause charting
3. Root cause identification
4. Recommendation

3.5.1: Cause and Effect diagram (Cause charting)

It's a graphical illustration of the relationship between a given outcome and all its influencing factors (Chandrakar & Kumar, 2015). For Sagana tanneries, from the data obtained from the company, the causes or factors influencing equipment availability and performance was summarised and presented in a cause and effect diagram to show the relationship of the outcome which is low productivity and the factors thought to influence it.

3.5.2: Pareto chart (Root cause identification)

In RCA, after cause charting, the root cause of the given outcome was determined by constructing a pareto chart showing the frequency of occurrences of each of the causes of equipment poor performance and unavailability**.** Pareto chart helped separate the vital few from the trivial many. This was based on the 80-20 Pareto principle which states that 80% of the problems come from 20% of the causes, hence one can focus on a few vital factors in a production process.

3.5.3: Five whys (Why-Why analysis)

This is another RCA tool used mostly when the real cause of a situation is not clear (Chandrakar & Kumar, 2015). It's one of the simplest investigation tools which is easily completed with no statistical analysis, which requires a thorough understanding of what happened (Mahto & Kumar, 2008) and it's considered a brainstorming methodology of asking 'why' five times repeatedly to help arrive at root cause of a situation.

In the Sagana tanneries case study, the tool was used to help identify any unanswered question and information gap that was present and causing poor performance and unavailability of the equipment. The information gathered for this process was through interviews with those directly and indirectly involved in the production process and direct observation of the production process. This involved asking questions to the production manager, production supervisor, operators and the maintenance staff.

The Why-Why analysis was used to investigate the root cause of frequent equipment breakdown and low speeds in Sagana tanneries. It involved asking 'why' questions repeatedly till a conclusion was reached as in the following steps:

a) Why frequent equipment breakdown?
    - Some parts keep on failing almost every time

b) Why fails every time?
    - Because they are only repaired when they stop working or fail

c) Why repair only when they fail?
    - Because there is no maintenance program
    - No spare parts available

d) Why is there no maintenance programme and no spare parts?
    - Only one person is trained to repair and maintain

- Most machines are very old

e) Why only one person trained and machines too old?
    - Company policies and financial implications.

Why-Why analysis on low speeds causal factors;

a) Why low speeds of performance?
    - Slow material transfer between processes
b) Why slow material transfer between processes?
    - The material handling transfer method is manual and it takes few pieces at a time
    - Material may delay in one process, holding up other processes
c) Why delay in one process?
    - Machine breakdowns and failures which results to process bottlenecks like in the drying section
d) Why machine breakdowns and failure?
    - No maintenance programs and spare parts available

From the analysis it's evident from the two scenarios that lack of proper maintenance program, has led to the frequent machine breakdowns, which contributes to low operating speeds and continuous machine failure.

3.6. Experimental design

3.6.1: Proposed strategies for productivity improvement

To develop productivity strategies which are viable for the productivity improvement in the tannery context analysis technique was used. Context analysis is a method used to analyse the environment which an organisation operates in to ensure that any strategy being implemented is informed by all the contextual factors that might affect its implementation and sustainability (Vascellari, 2014). From the context analysis principle, the entire environment that is both external and internal was considered and this helped in analysing using SWOT analysis on the strengths and benefits of the suggested strategies to the tannery. The information used to guide on strategy development was obtained from the company records, observation, interviews with production manager and supervisor, literature review and journals.

A). LEAN

Lean manufacturing as a concept refers to a set of techniques developed for a period of time that help in reducing production cost and increasing productivity using less effort, lesser space, without any new inventory, better quality and lesser defects (Dutta & Banerjee, 2014).the overall objective of Lean manufacturing is to greatly satisfy customer needs, totally eliminate wastes and use less effort with same production rate. (Taj & Berro, 2006). There are seven major waste covered in Lean manufacturing: they include overproduction waste, stock (inventory), motion, waiting and queueing, transporting, correction, waiting (delays), over processing (Taj & Berro, 2006) (Sanjay & NandKumar, 2007).

To implement principles of Lean in manufacturing in STL the process will involve the following steps (Wright, 2017) (LeanGroup, 2018):

1. Forming a team of dedicated workers
2. Develop an open communication channel for all stakeholders
3. Train all employees on lean objectives, standard operating procedures, and the waste to be eliminated in system.
4. Analyse the current state of facility and state of lean
5. Sensitize on the foundations of lean which is workplace organization through 5-S
6. Identify and specify the Value for each product with reference to the final customer,
7. Map the Value stream identifying all the activities of each product and eliminating any loss generating activity this will involve all the steps required to take a product from raw materials to delivering the final product- determine the waste across the entire system
8. Determine the takt /cycle time on all the processes and equipment's
9. Determine the losses on all processes and equipment's by OEE
10. Line balance by levelling the load through takt time or OEE
11. Reduce cycle time by pushing set up times down can use SMED (Single minute exchange of die)
12. Create the Flow of all the value adding activities in an ordered way, without delays or interruptions.

13. Establish the Pull of each client type in the system of production flow – a customer can pull a product as needed hence no inventory by utilizing Kanban
14. Analyse quality at each source of application
15. Implement error proofing (Poka yoke) by doing it right the first time.
16. Seek the Perfection by moving the streamline of the process and repeating it till you reach an optimal level of the maximum values without loss after the value was specified, value creating activities identified, loss eliminated, flow of value set and introduced- use Kaizen (Dutta & Banerjee, 2014) (Adriana, 2013).
17. All in all, building a culture of stopping to fix problems by introducing TPM throughout the lean process.
18. For the successful implementation employees need to be trained to hone their latent skills and increase their awareness on latest trends and technologies.

The four main indicators of Lean production are Productivity, quality, Safety and cost according to (Adriana, 2013). (Dutta & Banerjee, 2014) identified waste minimization and efficiency improvement as the key objectives of lean manufacturing system implementation, which reduces downtime, wastage and non-value adding activities hence making it possible to increase productivity. With good training and positive attitude from the workers, financial support and proper communication support from the management, the lean manufacturing philosophies can be implemented.

B). TPM

TPM as a strategy will be based on its 8 pillars. According to (McKone, Schroeder, & Cua, 1999) if TPM is well established it provides dependable equipment's, while reducing the number of production losses and increasing plant capacity by providing effective maintenance of equipment's. Based on the data gathered and recorded TPM will involve the following framework in order to reduce waste and increase equipment availability hence improving the productivity in STL based on its 8 pillars.

1. Start by announcing intention to start TPM and setting a project team
2. Educate every employee on TPM benefits, activities and importance of their participation
3. Ensure the right organisation structures are in place to sustain TPM activities should be linear

4. Establish TPM policies and quantifiable goals should be SMART
5. Outline a detailed plan of resources required
6. Classify equipment according to their history and performance analysis by collecting the necessary historical data on performance rates, breakdowns, maintenance, replacements
7. Educate the team on what is OEE and how to perform Calculation
8. Measure and asses the six big losses in Equipment's and set priorities
9. Analyse the condition of each sampled equipment and document
10. Inspect and clean each component of the equipment and record the details for any disorder
11. Conduct a planned refurbishment for any disorder in step 10 above and introduce visual devices such as poka yoke and implement any set up time reduction techniques such as a quick change over through SMED
12. Developing an autonomous maintenance program for operators e.g. daily inspections, lubrications, simple repairs etc
13. Develops standard operating procedures and routines for each equipment
14. From the measured OEE, we use the 5 whys to create and develop a preventive maintenance program schedule on each equipment
15. Have smaller groups of employees to work as a team for continuous improvement

3.7: Framework of the work carried out

Table 0.2: Methodology framework

Objective	**Data collected**	**Data collection tools**	**Methodology**	**Expected Results**
Productivity analysis	-design capacity -operating capacity -design cycle time -operating cycle time -output levels -number of defects	-observation -interview schedules -company documents	-Overall Equipment Effectiveness -throughput -cycle time	-Percentage capacity level -equipment availability -quality levels -productivity levels
Root Cause Analysis	-downtime time -throughput -WIP inventory -capacity utilization -OEE -Scheduled production attainment -man hours -amount of rework -no. of rejects -production cycle time	-observation -company records	-pareto chart -Ishikawa diagram -Regression/ Correlation matrix analysis -5-Ws	- KPIs rating -
Strategies for productivity improvement.	-Safety, -inventory level - quality, -overall equipment efficiency (OEE)	- literature review -company records -interview schedules -observation -interviews	-Lean Manufacturing -TPM -layout re-design	-Relative contribution of strategies to productivity improvement

Chapter 4 : CHAPTER FOUR

RESULTS AND DISCUSSION

4.1: Introduction

In this chapter analysis was done for both quantitative and qualitative data. Cycle time, throughput rate and OEE factors has been used to determine the actual equipment utilisation and compare it with the design capacity. Correlational and regression analysis have been used to determine the impacts of the independent variables on the dependent variable to generate a conclusion. RCA tools such as Pareto charts and why-why techniques have been used to analyse the causes of low productivity and highlight the vital few causes of the major problems.

4.2: Analysis of the Productivity levels at STL:

To analyse the productivity levels at Sagana Tanneries Limited analysis was done on Equipment utilization, Production cycle time, OEE and Process throughput. The data used in the analysis was obtained from company records for 12 months and from interviews from the company production manager and the production supervisor, and primary data collected through observation for five weeks.

The company works 5days in a week, and the operators works on one shift of 8 hours per day and the data analysed is for a period of one-year i.e. 12 months. The analysis was done on the three key sections of the tannery i.e. the Beam house, the machine (tan yard) sections and the finishing section. The key equipment’s on those section was highlighted as every product in that section must pass through those machines to their subsequent processes.

4.2.1: Equipment utilization levels

To determine the equipment utilization the record on equipment’s production time in a month and the total available time were taken into consideration using the formula below:

$$Equipment\ utilization = \frac{Production\ time}{Total\ available\ time} x\ 100$$

From the data collected the equipment utilization rates for the 12 months was analysed as on the Table: 4.1. the utilization is analysed based on the factory production benchmark capacity of 400,000 sq. ft/month. From the table it’s evident that the potential equipment utilization rate(availability) from the factory benchmark is calculated at 99.9% based on the scheduled operating time and the plant operating time. However, the actual calculated equipment utilization in the 12 months is seen to average at 27%, 13% and 52% in the three tannery sections respectively.

Table 0.1: Equipment utilization

				BEAM HOUSE		MACHINE SECTION:		FINISHING SECTION:	
	Total Available time (min)	Design production time(min)	Potential equipment utilization	Prod time cycle(min)	Equipment utilization	Prod time cycle(min)	Equipment utilization	Prod time cycle(min)	Equipment utilization
June 016	8820	8880	99.90%	3650.67	41%	1141.3	13%	3593.5	41%
July 016	8820			3218.16	37%	1459.1	17%	7863	89%
Aug 016	9660			2858	30%	242.85	3%	3426	36%
Sept 016	9240			1427.04	15%	921.44	10%	7591	82%
Oct 016	7980			1973.53	25%	699.6	9%	3517.4	44%
Nov 016	9240			2247.74	24%	940.4	10%	5185	56%
Dec 016	8400			2408.3	29%	1659	20%	2849	34%
Jan 017	8820			2404	27%	2342.1	27%	3468	39%
Feb 017	8400			1969.8	24%	1355.2	16%	4698.1	56%
March 017	9660			1503.58	16%	894	9%	4792	50%
April 017	8400			1692.4	20%	970.4	12%	3836.4	46%
May 017	9240			2476.1	27%	1019.4	11%	4771	52%
June 017	8820			3462.4	39%	1233.26	14%	4768	54%
Average	8884.615	8880	99.90%	2407.055	27%	1144.465	13%	4642.954	52%

From the analysis equipment utilization in the machine section rated at 13% which is at 86.9% lower than the potential equipment utilization of 99.90%, while at beam house the rate was found to be 27% falling 72.9% below the potential equipment utilization. Compared to an estimate of average capacity utilisation in industry of between 60%- 87% in major areas of the world in 2003/2004 (Wikipedia, 2018) (James F, 1976), the calculated average utilization is low. Example a case of Ethiopian tanneries shows that they have a capacity utilization of 60% (Anon, 2004). From this analysis it is evident the time the equipment was unavailable for production was high. This is further analysed using the chart on Figure 4.1 to show the comparison between the actual production cycle time and the unavailable time of the equipment’s in Sagana Tanneries in a month.

Downtime refers to the period the machines are not producing and yet they ought to be operational. The chart Figure 4.1 below shows the total average downtime(minutes) per month in comparison to the average actual production time(minutes) for the three sections in Sagana tanneries to be 60% and 40% respectively. This is based on own business unit level benchmarking of the design capacity as a best practice, since there are no best practice KPIs for the downtime in leather industry (Paul, 2009), though in most manufacturing industries the ideal ratio of planned downtime to unplanned downtime is 19:1 and is considered world class (Hai & Dr.Jay, 2018). From the research observation in STL all of the downtime that occurred during the study period was unplanned.

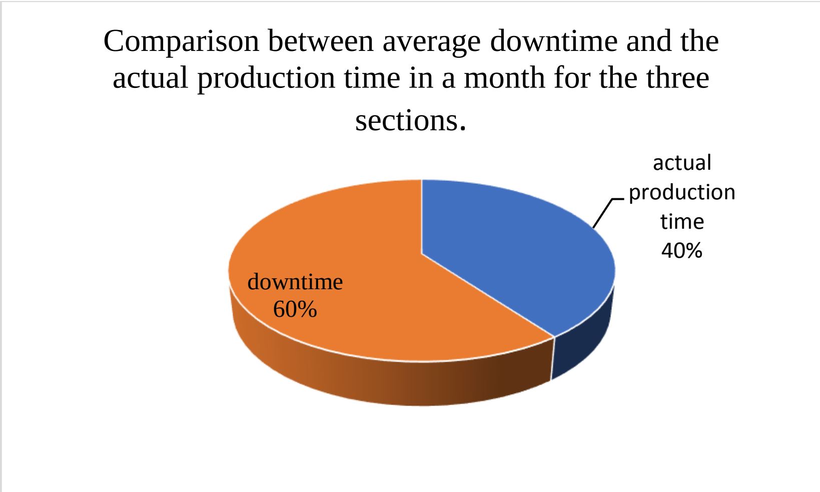


Figure 0.1: comparison between average down time and actual production time in a month

4.2.2: Overall Equipment Effectiveness

The OEE analysis was done on the three key sections of the tannery i.e. the beam house, the machine sections and the finishing section. The key equipment's on those section was highlighted as every product in that section must pass through those machines to their subsequent processes. To calculate the OEE of any machine the OEE factors were determined using the formula:

$$Availability(A) = \frac{(Total\ Available\ time\ -\ Downtime)}{Total\ Available\ time}$$

$$Performance\ rate\ (P)\ = \frac{ideal\ cycle\ time \times output}{Design\ production\ time} \times 100.$$

$$Quality\ rate(Q) = \frac{Input - Rejects}{Input} \times 100.$$

Hence, $\boldsymbol{OEE} = \boldsymbol{A} \times \boldsymbol{P} \times \boldsymbol{Q}$.

4.2.3: OEE factors rate for the three-production section

From the Table 4.2, the OEE and its factors for the three sections were analysed and recorded for a period of one year. From table, the machines availability in the beam house section was found to average at 27.2%, and the machine performance at 43.43%, while at the machining section the availability and performance factors averaged at 13% and 14% respectively. The corresponding availability and performance factors for the finishing section were calculated, and they averaged at 52.1% and 19.4% respectively. The OEE rates were calculated as 13%, 3% and 11% for the three sections respectively. These factors were compared to the ideal world OEE rate which are 90%, 95% and 85% respectively as in Table 4.3.

Table 0.2: Summary of OEE factors rates at the three sections of Sagana tanneries

	Availability	Performance	Quality	OEE	Availability	Performance	Quality	OEE	Availability	Performance	Quality	OEE
June 016	41%	66%	100%	27%	13%	14%	100%	2%	41%	15%	100%	6%
July 016	37%	58%	100%	21%	17%	18%	100%	3%	89%	33%	100%	29%
Aug 016	30%	52%	100%	15%	3%	3%	100%	0%	36%	14%	100%	5%
Sept 016	15%	26%	100%	4%	10%	11%	100%	1%	82%	32%	100%	26%
Oct 016	25%	36%	100%	9%	9%	8%	100%	1%	44%	15%	100%	7%
Nov 016	24%	41%	100%	10%	10%	11%	100%	1%	56%	22%	100%	12%
Dec 016	29%	44%	100%	13%	20%	20%	100%	4%	34%	12%	100%	4%
Jan 017	27%	43%	100%	12%	27%	28%	96%	7%	39%	14%	100%	6%
Feb 017	24%	36%	100%	8%	16%	16%	100%	3%	56%	20%	100%	12%
Mar 017	16%	27%	100%	4%	9%	11%	100%	1%	50%	20%	100%	10%
Apri017	20%	31%	100%	6%	12%	12%	100%	1%	46%	16%	100%	7%
May 017	27%	45%	100%	12%	11%	13%	100%	1%	52%	20%	100%	10%
June 017	39%	62%	100%	24%	14%	15%	100%	14%	54%	20%	100%	11%
Average	**27%**	**43%**	**100%**	**13%**	**13%**	**14%**	**100%**	**3%**	**52%**	**19%**	**100%**	**11%**
	Beam house				**Machining section**				**Finishing section**			

The factors that determine OEE, namely, Availability, Performance and Quality have values of between 0 and 1, likewise, OEE's value vary between 0-100 percent. This make OEE to be a crucial test. Table 4.3, shows comparison between the calculated OEE values and their corresponding ideal values as reported by Nakajima (1998).

Table 0.3: OEE factors comparison with the world ideal values

OEE factor	Calculated %	Ideal values	% Variation
Availability	30.78%	90%	59.22
Performance	25.56%	95%	69.44
Quality	98.86%	99%	0.14
OEE	8.97%	85%	76.03

From the Table 4.3, the percentage variation between the ideal and calculated values of OEE factors is shown, which shows a great variation in Availability, Performance and OEE values. The availability and performance rates are very low, which means further analysis to determine the exact factors causing their low rate. These shows there are various losses that are contributing to the low availability and the low performance rates of the machine.

The Figure 4.2 illustrates the comparison between the three sections equipment OEE rate for the one year in consideration.

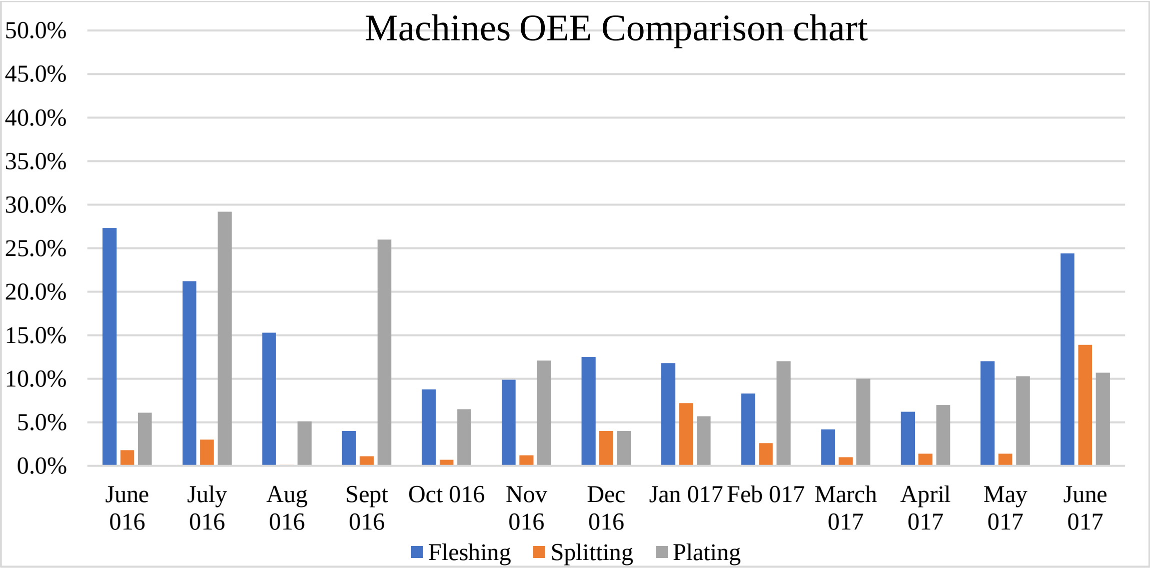


Figure 0.2: OEE comparison chart

From the Figure 4.2 it's seen that the OEE rate of the different sections is very far below that of the global standards of a manufacturing industry which is 85% as seen in Table 4.3.

The tanneries OEE is averaging below 10% which indicates there are a lot of wastes that need to be eliminated for an improved productivity.

From the equipment OEE analysis, both the performance and the availability are low compared to the world standards. But the quality rate was found to be satisfactory. Hence from the analysis the major losses which falls under the three OEE loss categories are to be identified. These losses are also contributors to the high downtime experienced. Hence there is need to identify the exact causes of low availability and performance rates of the equipment's so that we can improve the productivity of the tannery.

4.2.4: Cycle time analysis in Sagana tanneries

The cycle time analysis was made by taking into consideration the product that must pass through all the production process in the tannery to the final stage. In STL the product that has a long processing cycle time is known as Silka. It was selected so as to give an idea of the longest time a single product can take during processing in this company. The cycle time analysis was based on processing of a single batch of hides of approximately 3300kg and containing an average of 250 pieces of hides. The observation period was in the months of March and April 2017.

Table 0.4: Manufacturing Cycle time analysis

SECTION	NO	ACTIVITY	CYCLE TIME (C.T) in mins	NVA	VA
BEAMHOUSE	1	Transport hides to soak pit	30	30	
	2	Load hides into the soak pit	40	40	
	3	Soaking	960		960
	4	Offload hides from soak pit	60	60	
	5	Transport hides to liming drums	15	15	
	6	Load liming drums	45	45	
	7	Liming	960		960
	8	Offload liming drums	15	15	
	9	Transport hides to fleshing m/c	90	90	
	10	Fleshing	90		90
	11	Transport hides to chrome tanning drums	50	50	
	12	Load chrome tanning drums	45	45	
	13	Chrome tanning	720		720
	14	Offload chrome tanning drums	15	15	
	15	Pile wet blue leather to drain water	40	40	
	16	Leave wet blue to drain water	2880	2880	
TOTAL			**6055**	**3325**	**2730**

TANYARD	17	Transport wet blue to sammying m/c	45	45	
	18	Siding and sammying	135		135
	19	Pick, transport to splitting m/c, drop	10+40+10	60	
	20	Splitting	180		180
	21	Pick, transport to shaving m/c, drop	75+50+3	128	
	22	Shaving	600		600
	23	Weighing silka	15	15	
	24	Pick, transport silka to re-tannage drums, drop	5+70+5	80	
	25	Load re-tannage drums	30	30	
	26	Re-tannage	3780		3780
	27	Offload re-tannage drums	300	300	
	28	Transport to setting m/c	6	6	
	29	Setting	150		150
	30	Transport to drying sheds	24	24	
	31	Hooking leather+ movements	510+120	120	510
	32	Drying	4320		4320
	33	Unhooking leather+ movements	195+55	250	
TOTAL			**10733**	**1058**	**9675**
FINISHING SECTION	34	Transport to trimming tables, drop	30+30	60	
	35	Trimming	390	390	
	36	Pick, transport to staking m/c, drop	25+50+25	100	
	37	Staking	270		270
	38	Pick, transport to buffing m/c, drop	25+50+25	100	
	39	Buffing	270		270
	40	Pick, transport to dusting m/c, drop	30+30+30	90	
	41	Dusting	240	240	
	42	Pick, transport to impregnation area, drop	20+100+20	140	
	43	Impregnation	780		780
	44	Pick, transport to buffing m/c, drop	20+100+20	140	
	45	2nd buffing	270		270
	46	Pick, transport to dusting m/c, drop	30+30+30	90	
	47	Dusting	240	240	
	48	Pick, transport to colouring area, drop	20+120+20	160	
	49	Colouring	630		630
	50	Pick, transport to plating m/c, drop	30+30+30	90	
	51	Plating (hair cell)	240		240
	52	Pick, transport to spraying area, drop	30+30+30	90	
	53	Spraying	660		660
	54	Pick, transport to plating m/c, drop	30+30+30	90	
	55	Plating (sandblast)	240		240
	56	Pick, transport to measuring m/c, drop	20+100+20	140	
	57	Measuring	180	180	

	58	Packing	90	90	
TOTAL			**5730**	**2370**	**3360**
TOTAL MANUFACTURING CYCLE TIME			**22518**	**6753**	**15765**

The cycle time analysis presented in the Table 4.4 established that the manufacturing cycle time of an entire single batch of leather of approximately 250pc or 5610 sq.ft at Sagana tanneries is 22518 minutes, which translates to about 375.3 hours or 19 days. This was calculated using the sum of total Value adding activities and the non-value adding activities that were involved in the processing of the entire batch to completion. whereby as it is explained in section 3.4.3 the activity cycle time were obtained through observation and timing using a stop watch for short cycles and from records for the long cycles. According to the production manager under normal conditions with constant material supply and no equipment breakdowns, and according to general outline of parameters for a modern tannery (Buljan & Kral, 2012) the cycle time should be between 10 to 15 days. From BLC leather technology centre a piece of leather meant for upholstery can take 10 working days from salted hide to finishing (BLC Leather Technology, 2007).

From the observation done the process was unusually long because some equipment's were too small to accommodate the entire leather batch for one-time processing, hence the process had to be done in smaller batches like in re-tannage tanks. A process like drying took longer because it all depended on how the natural weather is like, when cold and humid it took longer to drain the moisture on the leather and also given the fact that the drying sheds had limited spaces hence there is usually a waiting duration a time. The other factor contributing to the exceptionally high cycle time is the fact that product movement was manually done hence the operators could only carry a few pieces at a time, and process like spraying, colouring and impregnation were manually done piece by piece. Sagana tanneries therefore exceeds the upper limit of the standard cycle time by 4 days.

4.2.5: Throughput analysis in Sagana tanneries

To determine the throughput of STL, a summary of production records was taken for a period of one year from July 2016 to June 2017. Throughput was taken as the total output produced per month and was compared against the expected production capacity of 400,000 sq. ft/month, as well as labour productivity per month. The summary of the data is as shown in Table 4.5.

Table 0.5: Sagana tannery monthly throughput

Product	Quantity (sq. ft) per month												
	Jul-16	**Aug-16**	**Sep-16**	**Oct-16**	**Nov-16**	**Dec-16**	**Jan-17**	**Feb-17**	**Mar-17**	**Apr-17**	**May-17**	**Jun-17**	**Total**
Wet blue	166768.3	177743.5	49662.1	113141.8	81780.2	150099.8	156326.9	125613	68601.8	90202	138971.6	203750.1	**1492593.2**
Pull-up	3774	1338.75	7172.742	9587.507	7167.99	14500.25	5965.99	10158.76	7550.24	628.252	3679.75	3974.75	**75498.981**
Silka	3758	6099.5	6442.745	2847.99	7246.76	10888.25	8738.26	11467.25	4623.25	2508.5	1354.5	5332.75	**71307.755**
Linings	1226.5	2740.76	1306.246	2140.25	1855.75	921.5	2947.75	742.75	2702.25	265.51	3240.51	1051.99	**21141.766**
Hair-on	25.5	532.75	898.501	1548.258	0	540.01	244.75	783.5	941.26	450.5	1812.74	277.75	**8055.519**
Upholstery	1072.26	116.5	935	2905.99	1199.25	625.24	0	552.76	523.01	215.75	0	659.75	**8805.51**
Suede	67.51	518.99	586.007	0	585.24	0	112.51	0	54.99	0	0	15.25	**1940.497**
Kips	24432.5	20392.76	22608.74	33918.76	21514.25	27027.99	23159.25	24577.26	16604	5923	15223.99	21417.25	**256799.75**
Glovings	6392	3865.8	8690.4	10052.1	9006.6	11391.7	7969.6	5105.1	7480	7228.4	5661	5967	**88809.7**
Splits	2892.24	274.5	3507.75	2592.5	4222.75	3279.99	1611.01	2550.26	2804.25	1350.5	1264.75	1152.5	**27503**
Total output	**210408.8**	**213623.8**	**101810.2**	**178735.2**	**134578.8**	**219274.7**	**207076**	**181550.6**	**111885.1**	**108772.4**	**171208.8**	**243599.1**	**2052456**
Design capacity	**400,000**												
Productivity (sq. ft/hr.)	**50.58**	**51.35**	**24.5**	**42.97**	**32.35**	**52.71**	**49.8**	**43.64**	**26.9**	**26.1**	**41.16**	**58.6**	**41.12**

Sagana leather tannery has a rated capacity of 400000 sq. ft of leather per month. Figure 4.3 represents a combo chart showing the actual production against the rated capacity at the tannery:

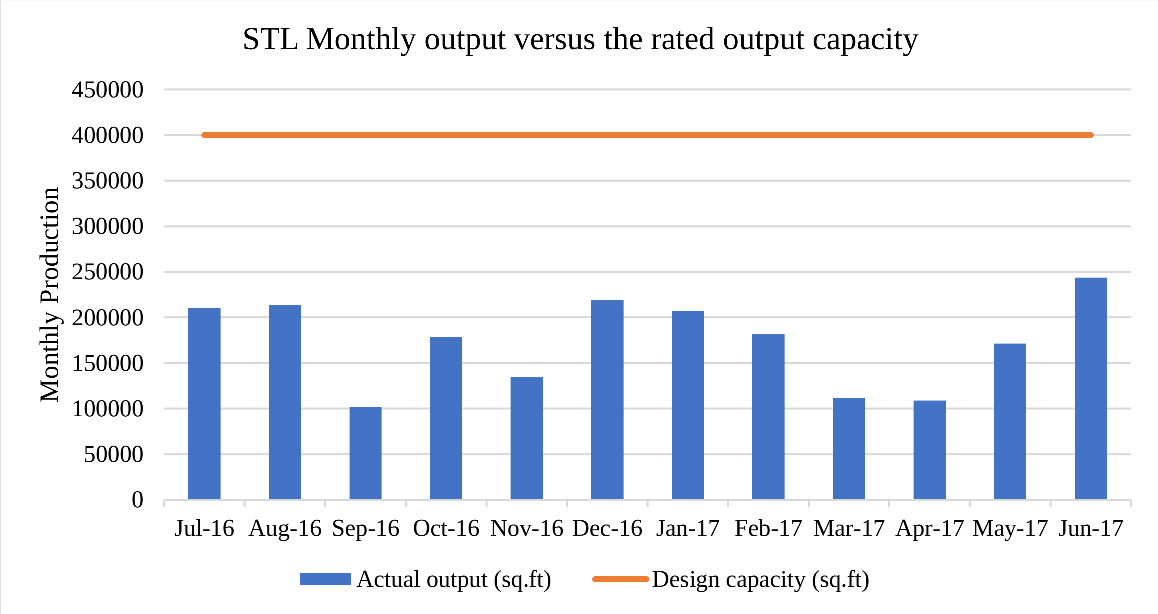


Figure 0.3: Throughput analysis

From the chart in Figure 4.3, it is clear that the company is operating way below its rated throughput of 400,000 sq. ft per month which acts as an internal benchmarking value. In most of the months, the company's' production is less than half its rated throughput. This can be seen in the months of Sept 2016, October, November, March, April and May. This low production capacity was attributed to major equipment's breakdowns, power outages, low supply of raw materials and to some extent the humid weather.

From Table 4.5, labour productivity was calculated as:

$$Labour\ productivity = outputs/inputs$$

Where the Output refers to the amount of leather produced in sq. ft in a particular month and input is the total man-hours used in production per month, given by:

$$Total\ man\ hours\ per\ month = 8hrs \times 5days \times 4weeks \times 26men = 4160hrs$$

The total number of employees directly engaged in production at Sagana leather tanneries is 26. The targeted/ design labour productivity at STL was calculated as:

$$Targeted\ Labour\ productivity = 400{,}000/4160$$

=96.15sq.fts/man/day

The Figure 4.4 shows the deviation of the actual monthly productivity from the targeted productivity:

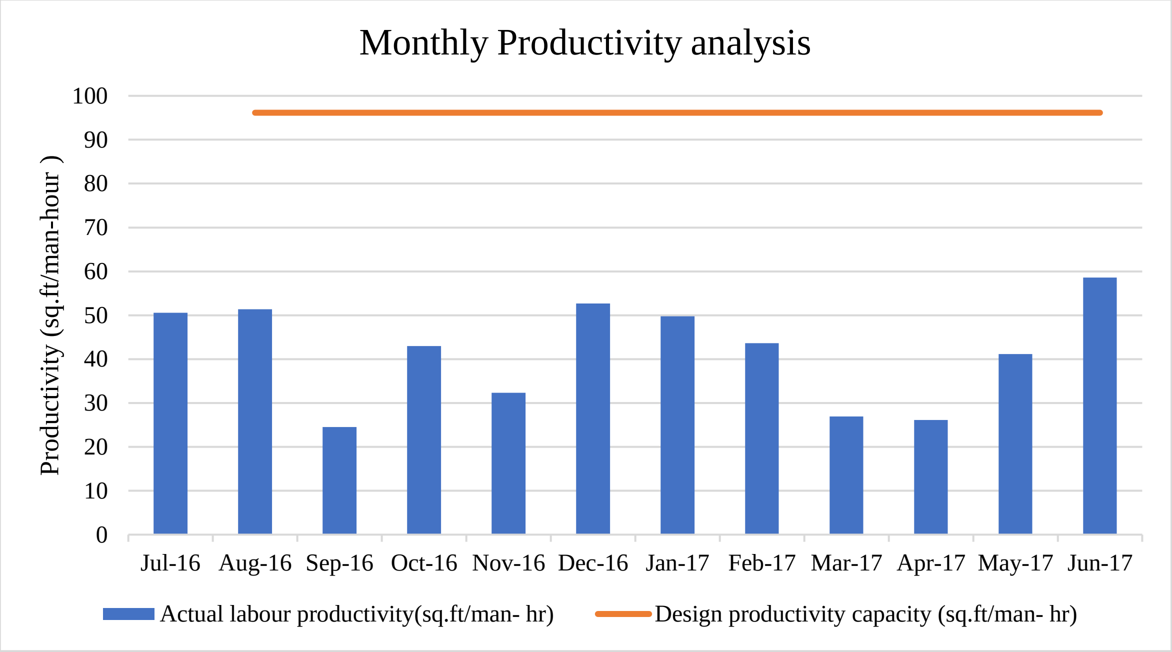


Figure 0.4: Productivity analysis

From the above analysis the actual calculated labour productivity is very low as compared to the targeted design productivity. On average, the actual labour productivity is given by:

$$Average\ actual\ labour\ productivity = 173543.6/4160$$

= 41.72 sq. ft/man/day

Comparing the calculated value to the targeted productivity of 96. 15sq.ft/man/day, and the hypothetical parameters for a model tannery which is 270 sq. ft/day/employee according to a UNIDO overview (Buljan & Kral, 2012), this means that the employees at Sagana leather tanneries are underutilized at 41.72 sq. ft/man/day. Other reasons that could be attributed to the low labour productivity could also be poor plant layout. During the industrial visits it was noted that some subsequent workstations at the finishing section are far apart thus increasing the travel distance of workers during material handling this coupled with manual movement of material within the stations makes the process slow. Hence, there is so much time wasted by workers moving between work stations as they transport materials. Such movements are non-value-adding activities that result to underutilized workmanship. The NVA also include the time wasted in setting up the machine. Some machines are old as they were reconditioned machines from a Norway tannery that were used to start -up the tannery in 1975 hence their operating speeds are very low, the waste management system also contribute to low labour productivity, as the tannery cannot manage a 24-hour production due to the small effluent management system.

4.3: Determination of root causes of low productivity in Sagana tanneries

4.3.1: Factors that affect productivity in Sagana tanneries

Table 4.6 shows the results of the relationship between availability, performance and productivity of equipment's in the beam house section. It shows that the effect of equipment availability and performance varied substantially. In July 2016, it is seen that a 10% reduction in equipment availability and a 12% decrease in equipment performance led to productivity reduction of 12%. In the month of October 2016, a 67% increase in equipment availability together with a 38% increase in equipment performance improved the productivity by 60%. Between December 2016 and March 2017, there was a notable drop in equipment availability and performance, with equipment availability dropping from 21% to -33%, and performance from 7% to -25%, which in effect led to productivity dropping from 18% to -33%. This significant drop was attributed to lack of raw materials as a result of the drought that was being experienced in the country at that time, equipment breaking down and frequent power failures also contributed to the great drop. This trend follows throughout the months with the indication that any slight change in equipment availability and performance impacts a greater change in productivity. The equipment breakdown contributed to low operating speeds, especially on the dying section. This is because the tannery relies on natural drying, it was found that when the weather conditions are not favourable especially the wet months, it took long to dry the leather, this meant holding down or delaying the subsequent process and slowing the preceding process too.

Table 0.6: Variation in availability, performance and productivity in beam house section

	Availability	Performance	Productivity in sq. ft/man hour	Change in availability	Change in performance	Change in productivity
June 016	41%	66%	4.27	100		
July 016	37%	58%	3.76	-10%	-12%	-12%
Aug 016	30%	52%	3.05	-19%	-10%	-19%
Sept 016	15%	26%	1.59	-50%	-50%	-48%
Oct 016	25%	36%	2.55	67%	38%	60%
Nov 016	24%	41%	2.51	-4%	14%	-2%
Dec 016	29%	44%	2.96	21%	7%	18%
Jan 017	27%	43%	2.81	-7%	-2%	-5%
Feb 017	24%	36%	2.42	-11%	-16%	-14%
Marc 017	16%	27%	1.61	-33%	-25%	-33%
April 017	20%	31%	2.08	25%	15%	29%
May 017	27%	45%	2.76	35%	45%	33%
June 017	39%	62%	4.03	44%	38%	46%

At the beam house section, the correlation analysis between availability and performance of the equipment with their productivity showed different relationship strengths. The correlation analysis has been done using SPSS software and employed Pearson's model for coefficient interpretation. Table 4.7 illustrates that equipment availability is strongly related to productivity with a correlation of 99.9%, while equipment performance and productivity correlates at 98.6%. Similarly, the equipment availability and performance have 98.4% correlation each with a P-value of less than 0.05 i.e. $P< 0.05$. From the analysis it's clear that the effect of availability on the productivity is very significant in the beam house section with a $R^2 = 0.998$, $p<0.001$, while that of performance is at $R^2 =0.998$ and $P<0.390$. this also explain the type of model fit for the beam house section. The model fit in this section takes this form,

$Y = X1a + X2b + c$, where,

Y=productivity

X_1 and X_2 =numerical values

a, = availability

b, = performance

C = constant

Hence the model equation, $Y = 0.096a + 0.005b\ - 0.009$..

From the model, holding all other factors constant, a unit increase in equipment availability leads to a 0.096-unit increase in productivity, while a unit increase in equipment performance leads to a 0.005-unit increase in productivity.

Table 0.7: Correlation matrix table in the beam house section

Correlations				
	Availability	Performance	Productivity	
Availability	Pearson Correlation	1	.984**	.999**
	Sig. (2-tailed)		.000	.000
Performance	Pearson Correlation	.984**	1	.986**
	Sig. (2-tailed)	.000		.000
Productivity	Pearson Correlation	.999**	.986**	1
	Sig. (2-tailed)	.000	.000	
**. Correlation is significant at the 0.01 level (2-tailed).				

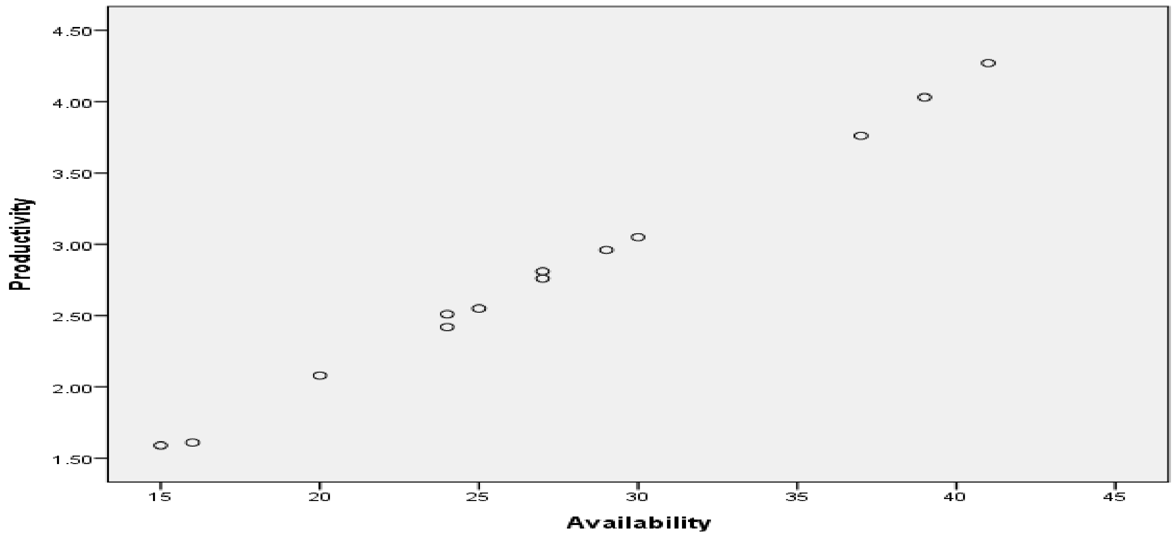


Figure 0.5: Scatter diagram showing relationship between productivity and availability in STL.

In the machining section, in July 2016, a 31% increase in equipment availability and a corresponding 29% increase in equipment performance caused a 28% increase in productivity this was calculated using the formula

$$\text{Productivity growth} = \frac{(\text{current productivity} - \text{previous productivity})}{(\text{previous productivity})} * 100$$

From Table 4.8, in the month of September 2016, there was a tremendous positive change, where availability increased with 233%, while performance increased with a 270%, and this led to a 296% increase in productivity. This high positive change was attributed to an increase in equipment availability down from 3% in august 2016 to 10% in September, has a result of reduced equipment breakdown and a reduction in power failures during the month. Similarly, a decrease of -10% and -27% in availability and equipment performance respectively led to a significant decrease in productivity of -12%, in the month of October 2016, which was attributed to an increase in equipment breakdowns.

Table 0.8: Variation in availability, performance and productivity in Machine section

	Availability	Performance	Productivity in sq. ft/man hour	Change in availability	Change in performance	Change in productivity
June 016	13%	14%	0.781	100%		
July 016	17%	18%	0.998	31%	29%	28%
Aug 016	3%	3%	0.152	-82%	-83%	-85%
Sept 016	10%	11%	0.602	233%	270%	296%
Oct 016	9%	8%	0.53	-10%	-27%	-12%
Nov 016	10%	11%	0.615	11%	38%	16%
Dec 016	20%	20%	1.193	100%	82%	94%
Jan 017	27%	28%	1.604	85%	40%	34%
Feb 017	16%	16%	0.974	-41%	-43%	-39%
Marc 017	9%	11%	0.559	-44%	-31%	-43%
April 017	12%	12%	0.697	33%	9%	25%
May 017	11%	13%	0.664	-8%	8%	-5%
June 017	14%	15%	0.844	27%	15%	27%

This significance trend in variation, explains the degree of association or correlation between the variables with correlation coefficients of 0.999 and 0.992 between productivity and availability and performance of equipment's respectively at the machining section (splitting machine), with a P-value of less than 0.0001. and R^2=0.999 from the correlation analysis in Table 4.9.

$Y = X1a + X2b + c$, where,

Y=productivity

X_1 and X_2 =numerical values

a, = availability

b, = performance

C = constant

Hence the model equation becomes, $Y = 0.051a + 0.008b - 0.005$

Table 0.9: Correlation matrix between variables in the machine section

Correlations for splitting section				
	Availability	Performance	Productivity	
Availability	Pearson Correlation	1	.990**	.999**
	Sig. (2-tailed)		.000	.000
	N	13	13	13
Performance	Pearson Correlation	.990**	1	.992**
	Sig. (2-tailed)	.000		.000
	N	13	13	13
Productivity	Pearson Correlation	.999**	.992**	1
	Sig. (2-tailed)	.000	.000	
	N	13	13	13
**. Correlation is significant at the 0.01 level (2-tailed).				

From Table 4.10, just like in other processing sections, a positive or negative change in equipment availability and performance in the finishing section causes an almost equivalent increase or decrease on productivity respectively. The correlation between availability and productivity and performance and productivity is determined as1.00 and 0.990 respectively, with a P <0.01. the regression coefficient R^2 =1.00, giving a perfect fit model on the regression line and also indicating that 100% variations in productivity can be explained by equipment performance and availability. The model takes the form of:

$Y = X1a + X2b + c$, where,

Y=productivity

X_1 and X_2 =numerical values

a, = availability

b, = performance

C = constant

$Y = 0.016a \; - 0.002b - 0.009$

Table 0.10: Variation in availability, performance and productivity in the finishing section

	Availability	Performance	Productivity in sq. ft/man hour	Change in availability	Change in performance	Change in productivity
June 16	41%	15%	0.617	100%		
July 016	89%	33%	1.351	117%	120%	119%
Aug 016	36%	14%	0.537	-60%	-58%	-60%
Sept 16	82%	32%	1.245	128%	129%	132%
Oct 016	44%	15%	0.668	-46%	-53%	-46%
Nov 016	56%	22%	0.849	27%	47%	27%
Dec 016	34%	12%	0.514	-39%	-45%	-39%
Jan 017	39%	14%	0.596	15%	17%	16%
Feb 017	56%	20%	0.847	44%	44%	42%
Mar 17	50%	20%	0.752	-11%	0%	-11%
April 17	46%	16%	0.692	-8%	-20%	-8%
May 17	52%	20%	0.782	13%	25%	13%
June 17	54%	20%	0.816	4%	0%	4%

Table 0.11: Correlation matrix in the finishing section

Correlations				
	Availability	Performance	Productivity	
Availability	Pearson Correlation	1	.991**	1.000**
	Sig. (2-tailed)		.000	.000
	N	13	13	13
Performance	Pearson Correlation	.991**	1	.990**
	Sig. (2-tailed)	.000		.000
	N	13	13	13
Productivity	Pearson Correlation	1.000**	.990**	1
	Sig. (2-tailed)	.000	.000	
	N	13	13	13
**. Correlation is significant at the 0.01 level (2-tailed).				

Table 0.12: summary of correlation matrix of Availability, Performance and Productivity of the three sections

	Productivity	Availability (BH)	Performance (BH)	Availability (MA)	Performance (MA)	Availability (FI)	Performance (FI)
Productivity	1	0.999**	0.986**	0.999**	0.992**	1.00**	0.990**
Availability (BH)		1	0.984**				
Performance (BH)			1				
Availability (MA)				1	0.990		
Performance (MA)					1		
Availability (FI)						1	0.991**
Performance (FI)							1

In determining the factors that affect productivity in STL, the correlation analysis between availability and productivity and performance and productivity is determined as1.00 and 0.990respectively, with a $P < 0.01$. the regression coefficient $R^2 = 1.00$, giving a perfect fit model on the regression line and also indicating that 100% variations in productivity can be explained by equipment performance and availability. From this analysis it's evident that the cause of low productivity are factors that are associated with equipment availability and their performance. Hence the need for a Root Cause analysis.

4.3.2: Determination of root causes of low productivity in STL:

From the results in the correlation matrix from the three sections, I.e. beam house section, machining section and the finishing section in Table 4.12, equipment availability and performance have a positive significant relationship with productivity where in the three sections the P value < 0.0001. Hence the results indicate that any improvement in the equipment's availability and performance can greatly improve productivity. Therefore, any slight change in the equipment's availability and performance have an equal impact on productivity.

From the analysis above its evident that productivity in the tannery was significantly influenced by the equipment availability and their performance, and of which also rated below the ideal values. From Root Cause Analysis method several factors that affect the availability and performance of the equipment's were identified through secondary data as discussed in chapter 3 section 3.5. In the beam house section, the factors were: power failures, machine breakdowns, lack of raw materials, set-up delays, low effluent management, lack of labour, material handling. These are illustrated in the cause and effect diagram in Figure 4.6

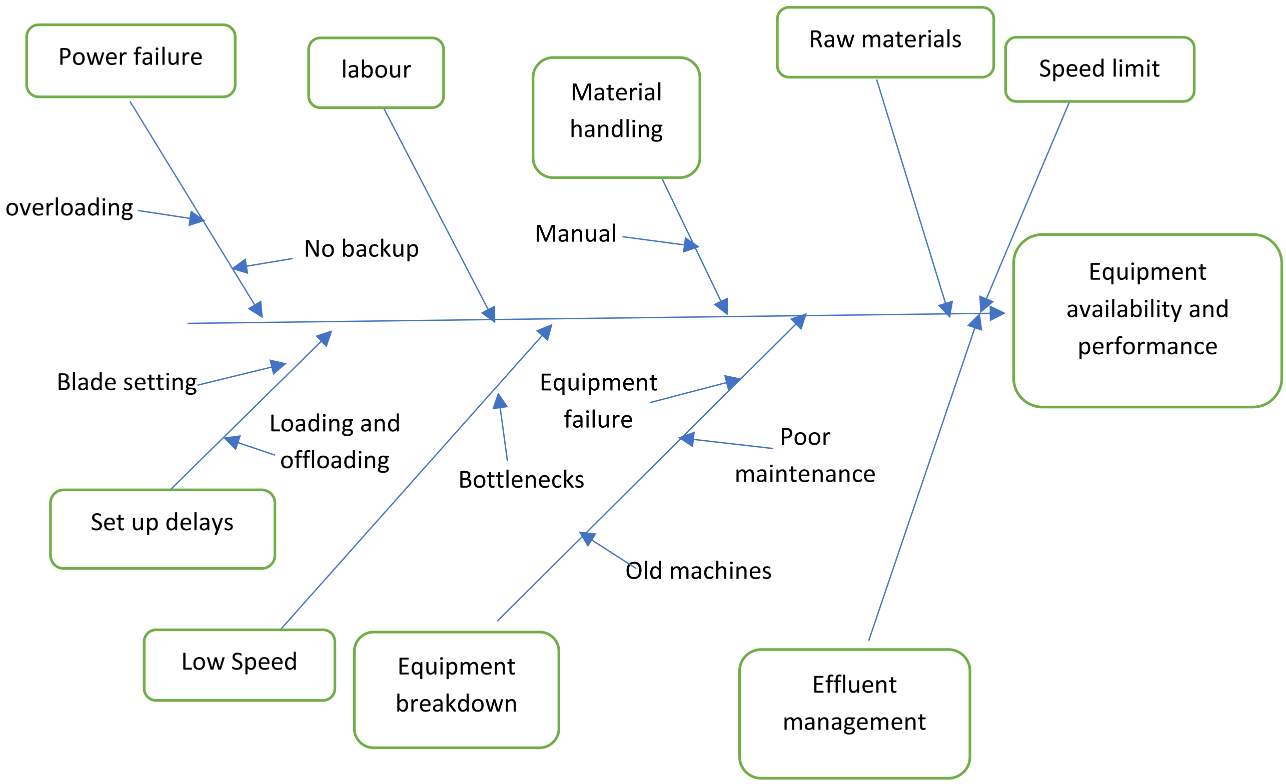


Figure 0.6: Cause and effect diagram in Sagana tannery

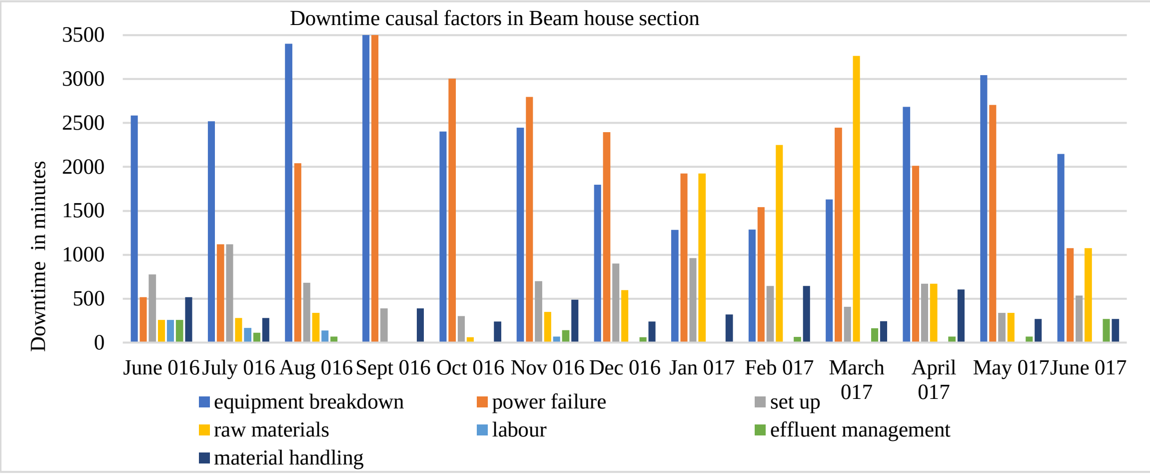


Figure 0.7: Chart on Downtime and causal factors in beam house

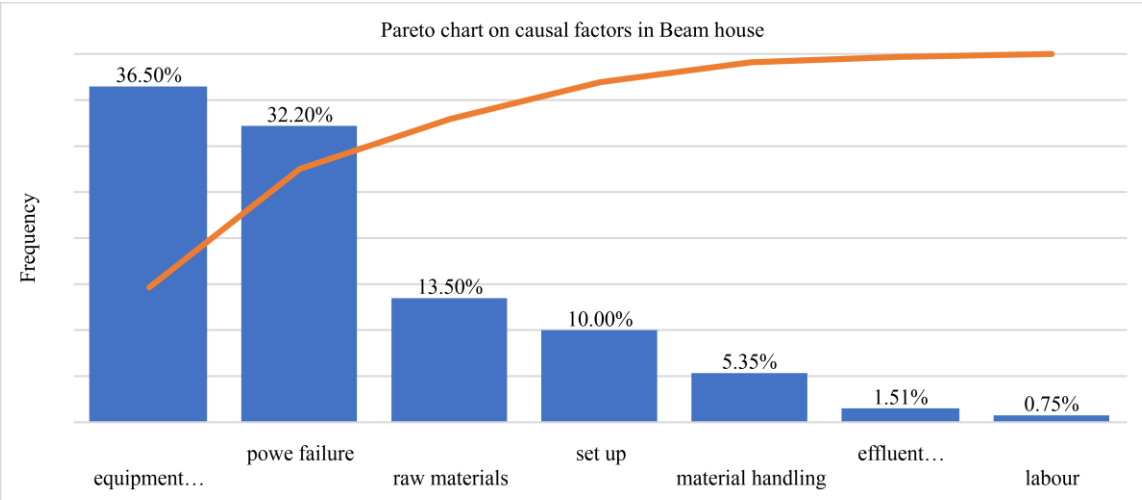


Figure 0.8: Pareto Chart on Downtime and causal factors frequency in beam house

From Figures 4.8 and 4.9, the pareto analysis indicates that equipment breakdowns contributed to 36.5% of equipment unavailability and performance, power failure contributed to 32.2% unavailability, raw material and set-up delays contributed to 13.5% and 10% respectively to equipment unavailability and performance. While material handling, effluent management and lack of labour had a 5.35%,1.5% and .75% contribution respectively. From this equipment breakdown, power failure, and lack of raw materials can be classified as the vital few while the set-up delays, material handling and lack of labour as the trivial many. From the graph on Figure 4.7, lack of raw materials contributed greatly to the downtime or equipment's unavailability especially in the months of January, February and March, as a result of the drought that had hit the country at that time which is one of the external factors that the tannery had no control of.

In the machining section, the causal factors that affect equipment availability and performance included the following; power failures, machine breakdowns, lack of raw materials, blade setting, low effluent management, lack of labour, material handling, low speed, speed limit as shown on the cause and effect Figure 4.6

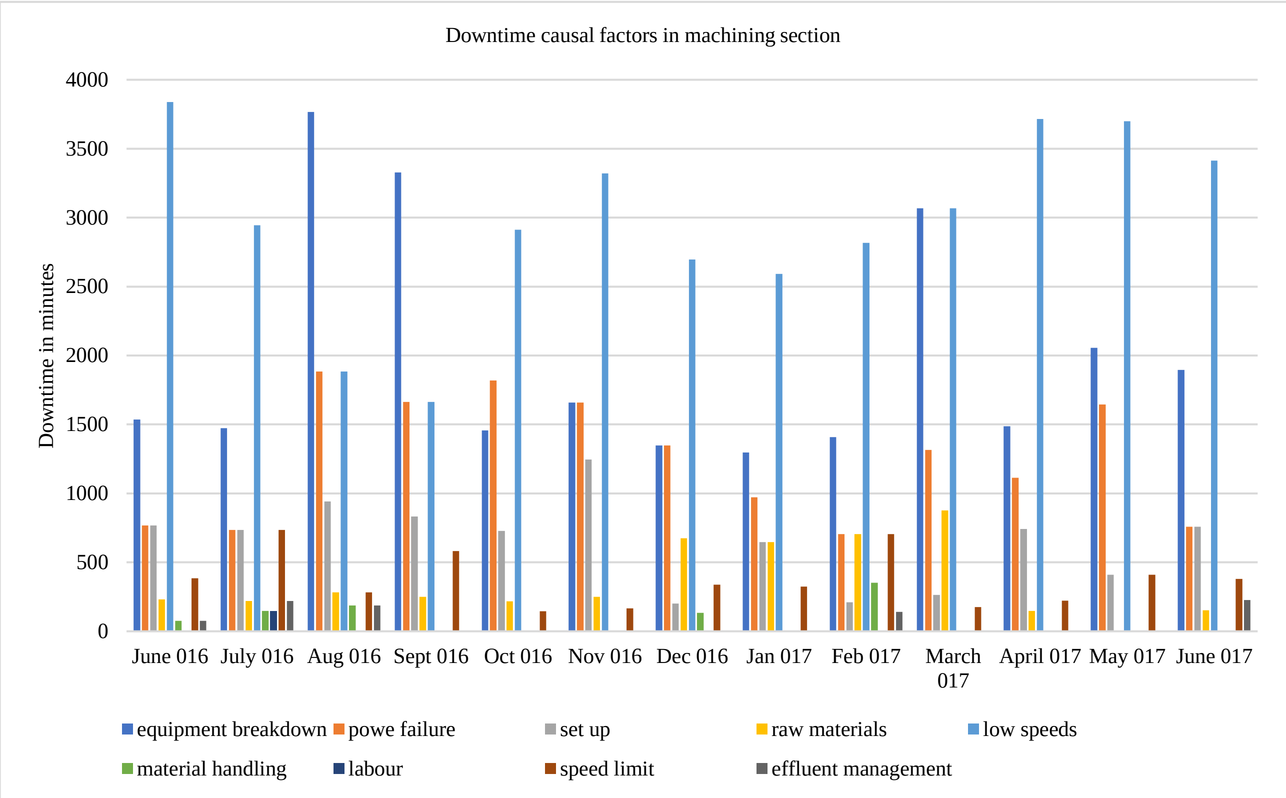
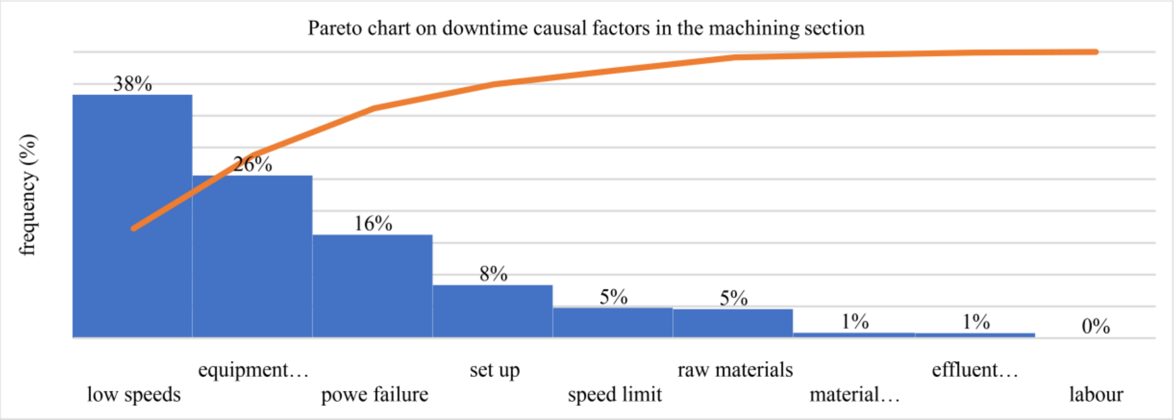


Figure 0.9: Downtime causal factors in machining section

From figure 4.9, the various downtime causal factors are presented in minutes. It's evident from the chart that low speeds in operation which were caused by bottlenecks in the process had the highest number of downtime minutes, specifically in the months that are deemed to be cold and wet in Kenya central region such as June, July, October, November, December, March, April and May, which means cumulatively it contributed to 38% of the downtimes in the section as shown on the pareto chart in figure 4.10. Equipment breakdown, power failure contributed to 26% and 16% respectively, while set-up delays, speed limit had 8% and 5% contribution each, this represented the vital few causes. The low speeds are as a result of delays caused by bottlenecks in the subsequent processes like drying. When the weather is not favourable drying takes longer since the drying area capacity is limited, leads to work in process being held. This of course affects the utilisation of the equipment hence

affecting equipment availability and performance. Equipment breakdown is also caused by the fact the main machine which is the splitting machine is old and therefore cannot keep up with work its subjected to. This affects its performance as the operating speeds are lower.

Figure 0.10: Pareto chart on causal factors in machining section



The graph in figure 4.11, represents the downtime distribution in minutes on the finishing section. While figure 4.12, represents the pareto chart on the frequency of the causal factors. From the chart low speeds contributes to 38% of equipment unavailability and low performance, while equipment breakdown contributed to 27%, power failure 13% and set-up 11% are considered the vital few causal factors. While the rest of the factors such as speed limit, raw materials, labour, material handling and effluent management are the trivial many. The low speeds of processing are as a result of delays in drying unit, which delays the subsequent finishing process. From the graph figure 4.11, it’s evident the months that the low speeds downtime is the highest are the months of June, November, December, January and April, which are deemed to be cold and wet months, hence affects the drying of the leather. This is because the company relies on the natural drying methods as their vacuum dryer is no longer operational. Frequent equipment breakdown and power outages contributes to the equipment unavailability and low performance.

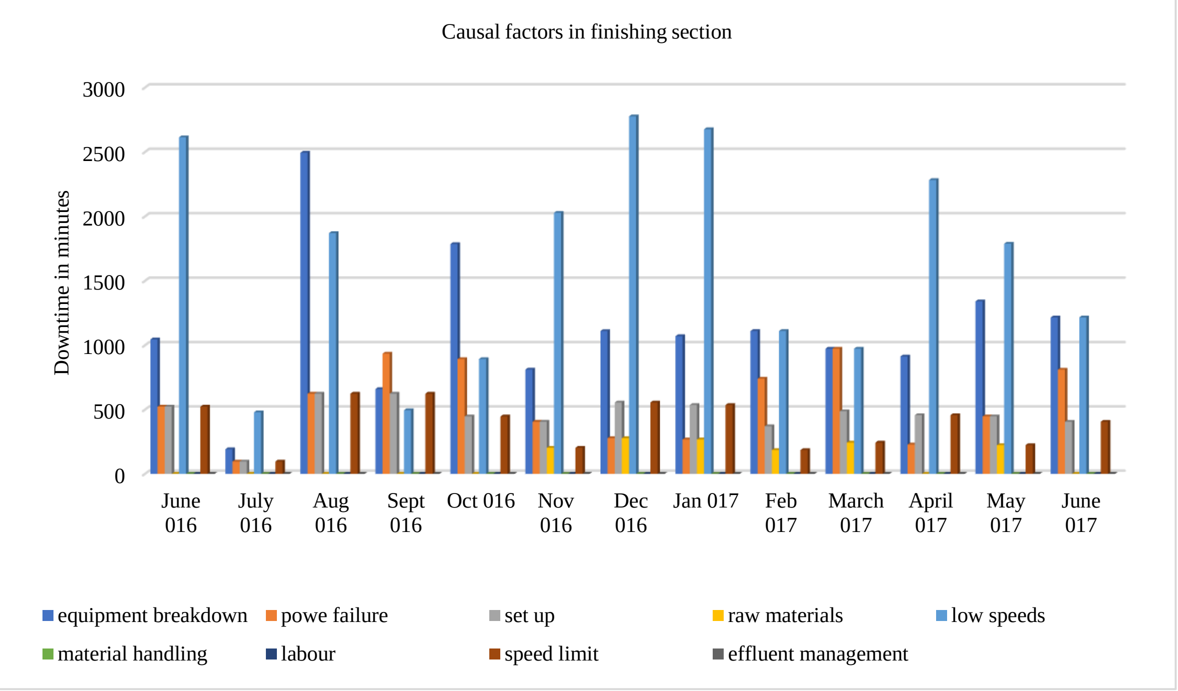


Figure 0.11: Down time in finishing section

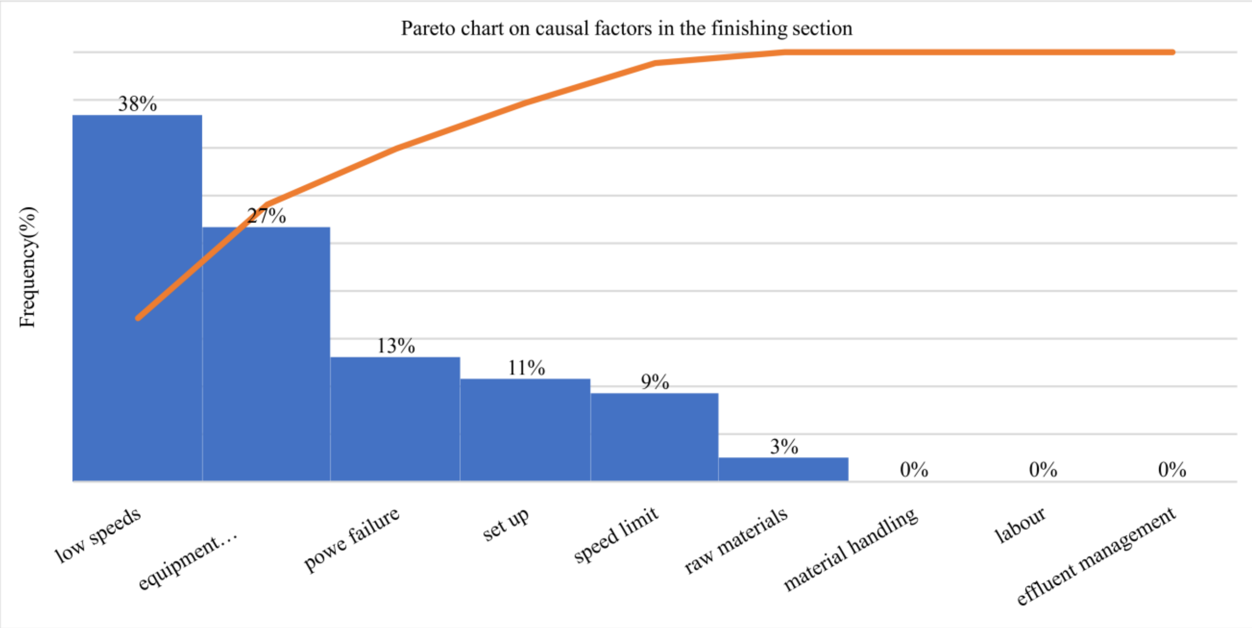


Figure 0.12: Pareto chart on causal factors in finishing section

4.3.3: Investigation of Root causes of frequent equipment breakdowns and low operation speeds in Sagana tanneries

In the Sagana tanneries case study, the Why- Why analysis tool was used to help identify any unanswered question and information gap that was present and causing poor performance and unavailability of the equipment. The information gathered for this process was through interviews with those directly and indirectly involved in the production process and direct observation of the production process. This involved asking questions to the production manager, production supervisor, operators and the maintenance staff.

The Why-Why analysis was used to investigate the root cause of frequent equipment breakdown and low speeds in Sagana tanneries. It involved asking 'why' questions repeatedly till a conclusion was reached as in the following steps:

f) Why frequent equipment breakdown?
    - Machine parts keep on failing almost every time

g) Why fail every time?
    - Because they are only repaired when they stop working or fail

h) Why repair only when they fail?
    - Because there is no maintenance program

- No spare parts available

i) Why is there no maintenance programme and no spare parts?
   - Only one person is trained to repair and maintain
   - Most machines models are very old hence no spare parts available

j) Why only one person trained and machines too old?
   - Company policies and financial implications.

Why-Why analysis on low speeds causal factors;

e) Why low speeds of performance?
   - Slow material transfer between processes

f) Why slow material transfer between processes?
   - The material handling transfer method is manual and it takes few pieces at a time
   - Material may delay in one process, holding up other processes

g) Why delay in one process?
   - Machine breakdowns and failures which results to process bottlenecks like in the drying section

h) Why machine breakdowns and failure?
   - No maintenance programs and spare parts available

From the analysis it's evident that lack of proper maintenance program, has led to the frequent machine breakdowns, which contributes to low operating speeds and continuous machine failure.

4.4: Developing Strategies for productivity improvement

4.4.1 Strategy formulation

To improve productivity in Sagana tanneries, the strategy to be selected needs to provide a solution that addresses the root causes of low productivity. Based on the root cause analysis discussed in Section 4.2, equipment unavailability and low performance which affects productivity negatively, are caused by equipment breakdown, power failures, low speeds, raw materials and set-up delays due to inefficiency and bottlenecks in the production system. From the results it's evident that equipment availability and performance can be greatly improved by reducing the breakdowns and other bottlenecks' in the production process which in turn leads to productivity improvement. Several strategies formulated for productivity improvement in Sagana tanneries include: TPM techniques, Lean manufacturing, back-up power generator, theory of constraints and Benchmarking

Table 0.13: Causal factors and appropriate solutions

Problem	**Causes**	**Root causes**	**effects**	**Viable solutions**
Low productivity	Equipment unavailability	-Breakdowns -Lack of raw material	Unachieved production and market demand	-TPM -Benchmarking
	Equipment poor performance	-Low speeds -Power failure -Bottlenecks	Unachieved production and market demand WIP leading to wastes	-Lean system -TPM -Back-up generator -layout-re-design, (Theory of constraints)

4.4.2 Evaluation of strategies

From the strategy formulation, it's evident that several strategies can be developed to solve the problem of low productivity in Sagana tanneries as in Table 4.13, but in the context analysis the strategies were evaluated so as to choose the most viable that will solve the root causes of low productivity. This is because each strategy has its strength and weakness and may be a solution to a specific situation

Table 0.14: Evaluation of strategies

Strategy	Is it cost acceptable?	Is it understood?	Is it effective?	Can it be done in practice?	
TPM	Yes	Yes	Yes	Yes	Equipment breakdown
TOC	No	Yes	yes	No	Layout design
Lean system	Yes	Yes	yes	yes	Low speed, Raw materials
Benchmarking	Yes	No	Yes	No	Enhance continuous improvement
Back-up generator	yes	yes	yes	yes	Power failure

4.4.3: Productivity Improvement Strategy Proposal

The research only gives a recommendation to the management who can either choose to implement the proposed improvement strategies or not. To implement the proposed strategy the overall objective of the tannery has to be considered. This means that the entire internal and external operations are to be involved. The strategy implementation process will involve the use of Deming's model of PDCA(Plan-Do-Check-Act). The model involves the identification of the formulated best strategy, making a plan about the strategy, check and test whether the plan works and then act on the plan by fully implementing it. To sustain the benefits of the best strategy requires formulation of standard operating procedures. The proposed strategy implementation lies with the discretion of the management and their goodwill to ensure that its implemented.

4.4.4 Summary

From the research findings, the OEE of the tannery is very low compared to the standard manufacturing equipment's OEE, the manufacturing cycle time is very high compared to the average cycle time given for a product in a model tannery, and the actual throughput of the tannery is low compared to the target throughput. From this analysis, equipment availability and performance have a significant positive relationship with productivity in Sagana tanneries. This means any significant change in either equipment availability or performance will have an equivalent change in productivity in whatever extreme. Therefore, this shows that the problem of low productivity in the tanneries is attributed to low equipment availability and low performance. From the RCA done the causal factors for low equipment availability and performance were found to be frequent equipment breakdown, low operation speeds, power failure, lack of raw materials, set-up delays, labour, material handling, waste management and other bottlenecks in the system. Where from these causal factors the main root causes that had a higher occurrence frequency overall, were, equipment breakdown, low operation speed, power failure, raw materials and set -up delays. From these root causes, an appropriate strategy that can help eliminate or solve the root cause and improve productivity was developed. The strategies that were found appropriate to solve the problem are TPM principles and Lean concept for breakdowns, low speeds and raw material supply, while a back-up power generator was proposed to sort out the issue of frequent uncontrolled power failures. Benchmarking is also proposed so that to compare with the best practises to help enhance other strategies.

Chapter 5 : CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Review of research objectives

The purpose of the research study was to explore the factors that affected productivity in Sagana Tanneries and propose improvement strategies. Where the specific objectives were: to analyse the productivity levels in Sagana tanneries, to carry out Root Cause Analysis of productivity losses in Sagana tanneries and to develop strategies for productivity improvement.

5.2 Key findings

The research findings for each objective was summarised as follows.

5.2.1 Analysis of productivity levels in Sagana tanneries

1. Equipment utilization levels

From the analysis, equipment utilization in STL, which was based on the scheduled operating time and the plant operating time for the three sections rated at 27%, 13% and

52% respectively for the 12 months of study though the estimated utilization levels of equipment's in different parts of the world range from 60%-87%. Hence it was found that 40% of the total available manufacturing time was when the equipment's were utilised, while 60% of the time the equipment's were unavailable for manufacturing. From this analysis it is evident the time the equipment was unavailable for production due to various downtimes was high considering that the ratio of unplanned downtime to planned downtime is given as 19:1. Hence most of the downtime experienced was unplanned leading to high rates of unavailability.

2. Overall Equipment Effectiveness (OEE)

At STL, the machines availability in the Beam house section was found to average at 27.2%, and the machine performance at 43.43%, while at the Machining section the availability and performance factors averaged at 13% and 14% respectively. The corresponding availability and performance factors for the Finishing section were calculated, and they averaged at 52.1% and 19.4% respectively. The average OEE factors rates were calculated as 13%, 3% and 11% for the three sections respectively. These factors were compared to the ideal world OEE factors rate which are 90%, 95% and 85% respectively. The average OEE value was calculated as 8.97% compared to 85%. The availability and performance rates are very low, which means further analysis to determine the exact factors causing their low rate. From these it was evident there were losses being experienced that need to be identified and worked on using an appropriate solution.

3. Cycle time analysis

The cycle time analysis was based on processing of a single batch of hides of approximately 5610 sq ft and containing 250 pieces of hides. The cycle time analysis established that the manufacturing cycle time of an entire single batch of leather of approximately 250pc or 5610 sq ft at, Sagana tanneries is 22518 minutes which translates to about 375.3 hours or 19 days. According to the standards for a model tannery, the cycle time should be between 10 to 15 days (Buljan & Kral, 2012). Hence from this it is clear that there are several factors that contributed to the high cycle time for a single batch. These factors included the equipment's capacity, unpredictable weather, manual material handling and movements, setup times, unplanned delays etc. Sagana tanneries therefore exceeds the upper limit of the standard cycle time by 4 days as a result of the many wastes in the process.

4. Throughput analysis

In STL, throughput was taken as the total actual output produced per month and was compared against the expected production capacity of 400,000 sq. ft/month. It is clear that the company is operating way below its rated throughput of 400,000 sq. ft per month In most of the months, the company's' production was less than half its rated throughput. This low production capacity was attributed to major equipment's breakdowns, power outages, low supply of raw materials and to some extent the humid weather.

Labour productivity was at 42 sq. fts/man-hour. and compared against the targeted labour productivity of 96.15sq.fts/man-hour and productivity of a modern tannery taken to be 270 sq. ft/day/employee. This showed that the labour force at STL was underutilised. This low throughput and labour productivity could be attributed to several factors such as poor plant layout, transportation/movement between workstations, machine set-ups delays, low operating speeds, breakdowns and power failures.

5.2.2: Root cause analysis of production losses in STL

From the analysis results a correlation was done and it was found out that the equipment availability and performance had a significant relationship to productivity and they therefore contributed to the low productivity rates. This was evident from the fact that any slight change in any of the two factors i.e. availability and performance a corresponding change in productivity was witnessed. This objective was helpful to demonstrate a serious production problem at Sagana tanneries which has made it difficult for the tannery to achieve its theoretical production design capacity of 400,000 sq. ft/month. To establish the exact factors a RCA was carried out on the three sections to determine the vital few against the trivial many so as to mitigate the problems at the tannery.

From the Root Cause Analysis carried out to determine the root causes of the various production losses, several causal factors were identified as frequent equipment breakdown, low operation speeds, power failure, lack of raw materials, set-up delays, labour, material handling, effluent management and bottlenecks in the system. The main root causes of equipment un-availability and low performance were found from the Why-Why analysis and pareto chart to be, equipment breakdown, low operation speed, power failure, raw materials and set -up delays. This are the factors that if worked on and eliminated equipment availability and performance would increase greatly, hence increasing productivity levels.

5.2.3: Proposed strategies for productivity improvement

Productivity improvement strategies were proposed after the root causes analysis. The selection of the improvement strategies was based on Context analysis of the overall environment which the tannery operated in. This gave insight to what was best suited to solve the issues at hand, this is because various techniques can be used, hence the most viable strategy to be recommended was implementation of TPM principles and Lean strategies, and provision of a power back-up generator. A further recommendation of benchmarking to enable continuous improvement to be achieved.

5.3 Conclusions

From the research findings, the situation at Sagana tanneries was analysed and the results explains why the tannery cannot meet its theoretical capacity production through-put of 400,000sq. ft./month. In conclusion to improve the productivity levels at STL the Root causes of low equipment availability and performance which are frequent breakdowns, low speeds, set-up losses, power failure, lack of raw material and material handling must be addressed. To employ both short term and long-term solutions, Lean concept and TPM principles should be employed to help minimize the waste, to ensure the equipment's are available and performing to the optimum productivity level. The frequent power failures, a cost-effective power back-up generator which can meet the power needs of the tannery its recommended, to keep the equipment in availability and in performance.

5.4 Recommendations

To solve the problem of low productivity in Sagana tanneries, there is an urgent need to implement TPM (Total Productive Maintenance) principles and Lean manufacturing system. The TPM principles should be embraced by all employees starting from the management level down to the operators and help in establishing an effective maintenance program, which will eliminate or reduce the equipment breakdowns and makes sure equipment are available for use. From the TPM principles the management at Sagana Tanneries should encourage the operators to familiarise with the machines they operate, and this should be done through trainings. Lean manufacturing will help in solving low speed problems, set-up delays which result in losses(wastes), raw material supply all which affect equipment performance. A cost-effective power back-up generator is recommended to curb power failure issues which affect both equipment availability and performance.

Other recommendations based on the study are to semi-automate the plant with new machines and equipment to facilitate material movement or handling which has an effect on set-up delays and operation speeds. The layout can also be re-designed to facilitate for the automation and ease of material flow and provide adequate space for raw material storage and work in process storage leading to a shorter lead time, hence higher productivity levels. A study is recommended in other tanneries in Kenya to find out the scenario they operate in and the applicability of the recommendations to them.

5.5 Research contribution

5.5.1 Research contribution to theory

Productivity has been identified as one of the Key indicators of competitiveness in any organisations. From the research and literature review, several factors affect productivity in the manufacturing sector, hence different strategies have been employed to solve those factors that negatively affect productivity. From the various literature reviewed, little has been done on productivity improvement in leather industries, other than on waste management and value addition. Therefore, the research has shown that productivity in leather industries can be affected by unavailability of equipment and poor performance, and that TPM principles and Lean manufacturing systems can be employed to improve productivity in a tannery just like in other manufacturing sectors.

5.5.2 Research contribution to practice

In practice if the proposed improvement strategies are implemented in the tannery, there will be an increase in productivity levels through increased equipment utilization levels, reduced lead/cycle time, increased through-put levels, hence improved productivity as the tannery will meet the customer /market demands. This in turn will lead to increase in the contribution to national GDP, translating to improved living standards of the community that is dependent on the tannery, by creation of job opportunities, reduction of poverty and increase in social welfare. At the same time the implementation of TPM and Lean principles will ensure a healthy and safe environment for the workers which will positively motivate the workers and increase their productivity levels.

5.6 Future research

Further studies can be done on effects of optimising human resource as a measure of productivity improvement in STL. Research on other tanneries in Kenya to find out the applicability of the scenario to them is recommended.

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APPENDIX

1.Appendix 1: Sales data for a period of one year:

product	June 016	July 016	Aug 016	Sept 016	Oct 016	Nov 016	Dec 016	Jan 017	Feb 017	Mar 017	Apr 017	May 017	June 017
Finished leather sq. ft	92487.76	50790	25829.08	24823.85	14750	24309.5	20382	25518	25318.27	0	14163.22	23036	15944
Crust leather sq. ft	24.50	48.25	19.75	0	367	19.75	8.55	7.5	46.25	0	146.25	0	0
Natural gloving kg	1671.1	4991.2	4474.4	2709.8	3865.8	6689.5	889.1	2500.7	1806.76	0	447.1	1091.4	2988.6

Offcuts kg	24642.35	13856.7	76.5	66.3	45.9	56.1	1798.6	97.92	125.46	0	37.06	76.67	55.25
Wet blue kg	178914.8	24323.6	403196.99	0	86810.5	117986.8	1660765.57	0	0	0	0	143155.3	27949.7
Total SQ. FT	297740.51	94009.75	433596.72	27599.95	105839.2	149061.65	189154.82	28124.12	27296.74	0	14793.63	167359.37	46937.55
Batch input sq. ft	263512.5	232293.1	206291.6	103006.4	142453.2	162246.3	173838.6	173525.8	142181.2	108531.4	122158.6	178729.5	249092.5
Diff in input and output	-34228.01	138283.35	-227305.12	100246.45	36614	13184.65	-15316.22	145401.68	114884.46		107364.97	11370.13	202154.95
% of the expected capacity (400000)	74.44%	23.5%	108.4%	6.9%	26.5%	37.3%	421%	7.03%	6.8%	0%	3.7%	42%	11.7%
COST IN K.SHS	3530749.01	3174722.42	6606265.50	1337782	2362282.00	2935371.85	3584067.6	2390591	2351633	0	1305905.15	3552610.00	1871746

2. Appendix 2: Summary of OEE factors rates

	Availability	Performance	Quality	OEE	Availability	Performance	Quality	OEE	Availability	Performance	Quality	OEE
June 016	41%	66%	100%	27%	13%	14%	100%	2%	41%	15%	100%	6%
July 016	37%	58%	100%	21%	17%	18%	100%	3%	89%	33%	100%	29%
Aug 016	30%	52%	100%	15%	3%	3%	100%	0%	36%	14%	100%	5%
Sept 016	15%	26%	100%	4%	10%	11%	100%	1%	82%	32%	100%	26%
Oct 016	25%	36%	100%	9%	9%	8%	100%	1%	44%	15%	100%	7%
Nov 016	24%	41%	100%	10%	10%	11%	100%	1%	56%	22%	100%	12%
Dec 016	29%	44%	100%	13%	20%	20%	100%	4%	34%	12%	100%	4%
Jan 017	27%	43%	100%	12%	27%	28%	96%	7%	39%	14%	100%	6%
Feb 017	24%	36%	100%	8%	16%	16%	100%	3%	56%	20%	100%	12%

Mar 017	16%	27%	100%	4%	9%	11%	100%	1%	50%	20%	100%	10%
Apri017	20%	31%	100%	6%	12%	12%	100%	1%	46%	16%	100%	7%
May 017	27%	45%	100%	12%	11%	13%	100%	1%	52%	20%	100%	10%

3. Appendix 3: Production time data

				BEAM HOUSE		MACHINE SECTION:		FINISHING SECTION:	
	Total Available time (min)	Design production time(min)	Design availability	Prod time cycle(min)	Availability	Prod time cycle(min)	Availability	Prod time cycle(min)	Availability
June 016	8820	8880	99.90%	3650.67	41%	1141.3	13%	3593.5	41%
July 016	8820			3218.16	37%	1459.1	17%	7863	89%
Aug 016	9660			2858	30%	242.85	3%	3426	36%
Sept 016	9240			1427.04	15%	921.44	10%	7591	82%
Oct 016	7980			1973.53	25%	699.6	9%	3517.4	44%
Nov 016	9240			2247.74	24%	940.4	10%	5185	56%
Dec 016	8400			2408.3	29%	1659	20%	2849	34%
Jan 017	8820			2404	27%	2342.1	27%	3468	39%
Feb 017	8400			1969.8	24%	1355.2	16%	4698.1	56%
March 017	9660			1503.58	16%	894	9%	4792	50%
April 017	8400			1692.4	20%	970.4	12%	3836.4	46%
May 017	9240			2476.1	27%	1019.4	11%	4771	52%
June 017	8820			3462.4	39%	1233.26	14%	4768	54%
Average	8884.615	8880	99.90%	2407.055	27%	1144.465	13%	4642.954	52%

4. Appendix 4: Interview schedules guiding questions:

Why-why analysis on frequency of breakdowns

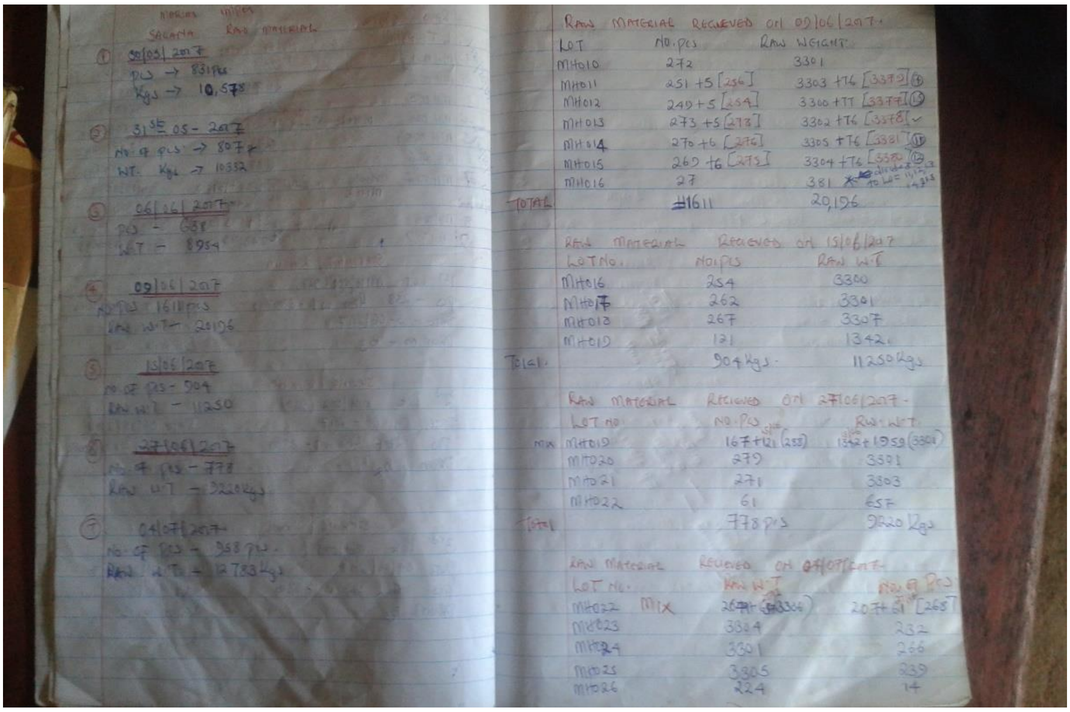
i. Why frequent equipment breakdown?
ii. Why fails every time?
iii. Why repair only when they fail?
iv. Why is there no maintenance programme and no spare parts?
v. Why only one person trained and machines too old?

Why-Why analysis on low speeds causal factors;

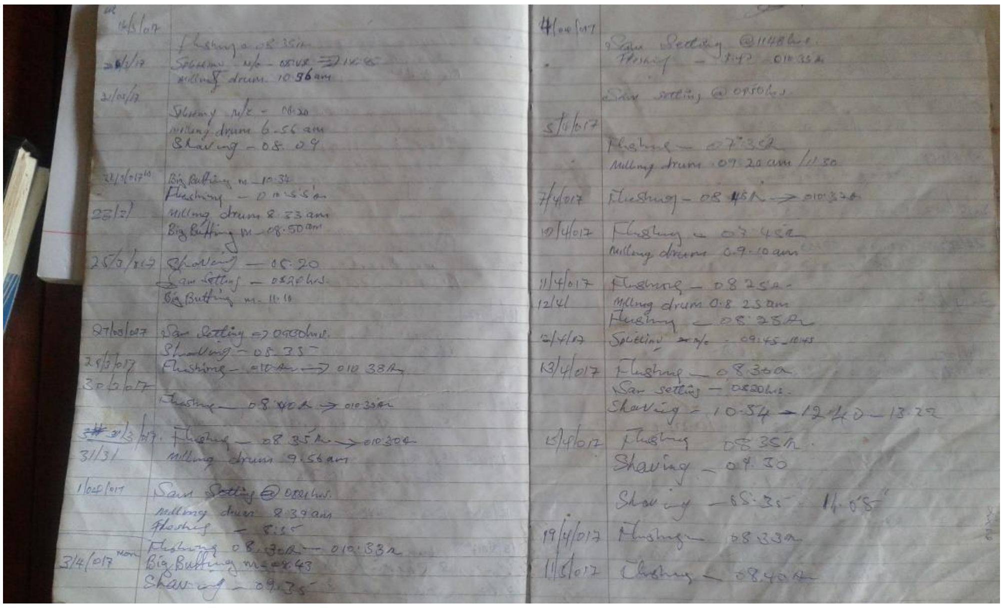
i. Why low speeds of performance?
ii. Why slow material transfer between processes?
iii. Why delay in one process?
iv. Why machine breakdowns and failure?

5. Appendix 5: Raw company document with data to be extracted

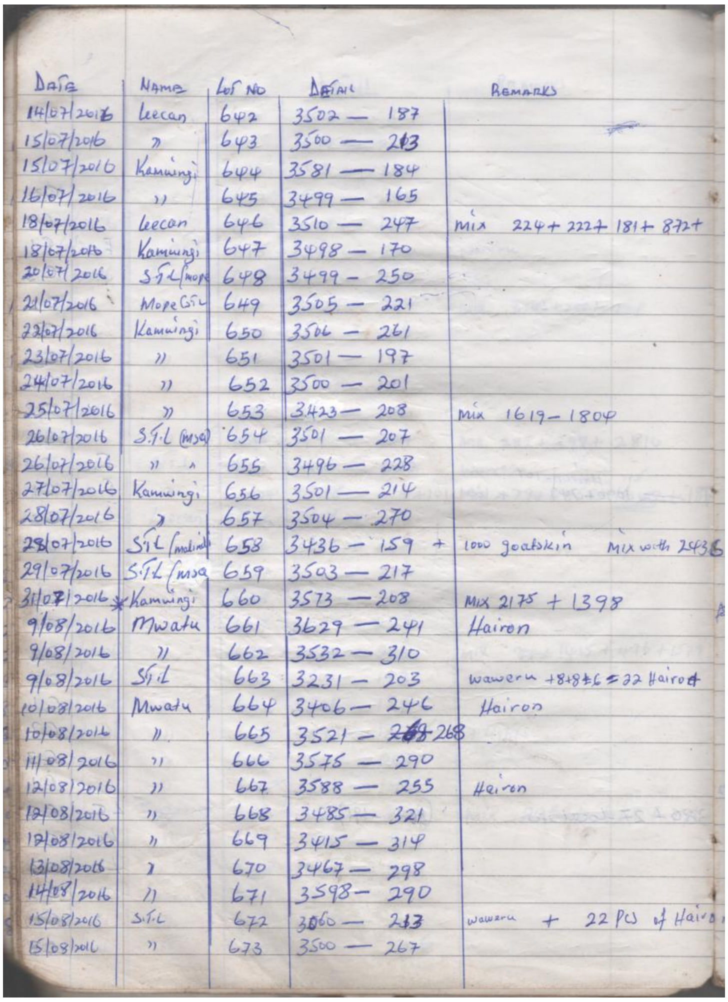
a) Raw material records sample



b) Machining operations cycle time entry sample data

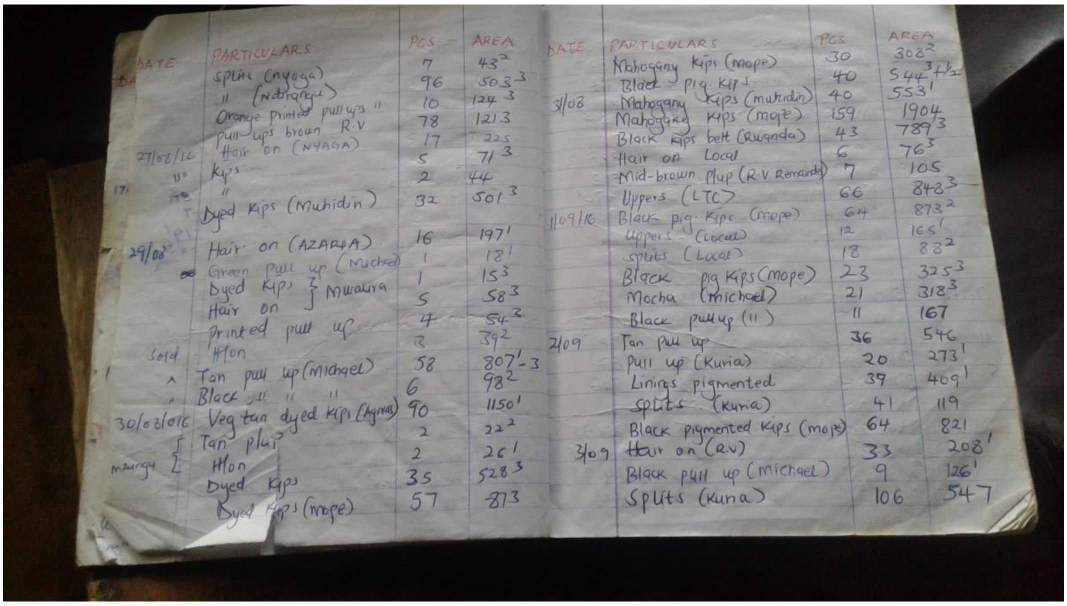


c) Beam house processing data



DATE	NAME	LOT NO	DETAIL	REMARKS
14/07/2016	Leecan	642	3502 — 187	
15/07/2016	"	643	3500 — 213	
15/07/2016	Kamwingi	644	3581 — 184	
16/07/2016	"	645	3499 — 165	
18/07/2016	Leecan	646	3510 — 247	mix 224+ 222+ 181+ 872+
18/07/2016	Kamwingi	647	3498 — 170	
20/07/2016	S.T.L (mope)	648	3499 — 250	
21/07/2016	Mope STL	649	3505 — 221	
22/07/2016	Kamwingi	650	3506 — 261	
23/07/2016	"	651	3501 — 197	
24/07/2016	"	652	3500 — 201	
25/07/2016	"	653	3423 — 208	Mix 1619 – 1804
26/07/2016	S.T.L (msa)	654	3501 — 207	
26/07/2016	" "	655	3496 — 228	
27/07/2016	Kamwingi	656	3501 — 214	
28/07/2016	"	657	3504 — 270	
28/07/2016	STL (malindi)	658	3436 — 159 +	1000 goatskin Mix with 2436
29/07/2016	STL (msa)	659	3503 — 217	
31/07/2016	Kamwingi	660	3573 — 208	Mix 2175 + 1398
9/08/2016	Mwatu	661	3629 — 241	Hairon
9/08/2016	"	662	3532 — 310	
9/08/2016	STL	663	3231 — 203	waweru +8+8+6 = 22 Hairon
10/08/2016	Mwatu	664	3406 — 246	Hairon
10/08/2016	"	665	3521 — 268	
11/08/2016	"	666	3575 — 290	
12/08/2016	"	667	3588 — 255	Hairon
12/08/2016	"	668	3485 — 321	
12/08/2016	"	669	3415 — 314	
13/08/2016	"	670	3467 — 298	
14/08/2016	"	671	3598 — 290	
15/08/2016	S.T.L	672	3060 — 213	waweru + 22 PCS of Hairon
15/08/2016	"	673	3500 — 267	

d) **Raw data finishing section data entry**



DATE	PARTICULARS	PCS	AREA
	Splits (nyaga)	7	43
	" (Ndiragu)	96	503
	Orange printed pull ups "	10	124
	pull ups brown R.V	78	1213
	Hair on (NYAGA)	17	225
27/08/16	Kips	5	71
	"	2	44
	Dyed Kips (Muhidin)	32	501
29/08	Hair on (AZARIA)	16	197
	Green pull up (Michael)	1	18
	Dyed Kips } Mwaura	1	15
	Hair on	5	58
	Printed pull up	4	54
Sold	H/on	2	39
	Tan pull up (Michael)	58	807
	Black " " "	6	98
30/08/16	Veg tan dyed Kips (Agnes)	90	1150
	Tan pl/up	2	22
Mwangi	H/on	2	26
	Dyed Kips	35	528
	Dyed Kips (mope)	57	873

DATE	PARTICULARS	PCS	AREA
	Mahogany Kips (mope)	30	308
	Black pig Kips	40	544
31/08	Mahogany Kips (muhidin)	40	553
	Mahogany Kips (mope)	159	1904
	Black Kips belt (Rwanda)	43	789
	Hair on Local	6	76
	Mid-brown Plup (R.V Remands)	7	105
	Uppers (LTC)	66	848
1/09/16	Black pig Kips (mope)	64	873
	Uppers (Local)	12	165
	Splits (Local)	18	88
	Black pig Kips (mope)	23	325
	Mocha (michael)	21	318
	Black pull up (")	11	167
2/09	Tan pull up	36	546
	Pull up (Kuria)	20	273
	Linings pigmented	39	409
	Splits (Kuria)	41	119
	Black pigmented Kips (mope)	64	821
3/09	Hair on (RV)	33	208
	Black pull up (michael)	9	126
	Splits (Kuria)	106	547