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# Empirical Study of Productivity KPIs' In a Tannery Industry: Case Study.

NtakiraJ.Evaline[a*], Muchiri N. Peter[a], Onyancha O. Douglas[b]
[a] *School of Engineering, Dedan Kimathi University of Technology, P.O Box 657-10100, Nyeri, Kenya*
[b] *School of Science, Dedan Kimathi University of Technology, P.O Box 657-10100, Nyeri, Kenya*
**Corresponding author:NtakiraJ.Evaline*

***Abstract:****Productivity is a measure of the effective use of resources.It is the relationship between result and the time it takes to achieve the results. Leather processing is a high labour intensity process of converting hides and skins to leather which is a source of employment. However, leather production in Kenya has not reached full potentialas a result of low productivity by individual tanneries. This paper evaluated productivity level Key Performance Indicators(KPIs'), sought knowledge by analysing the OEE, throughput analysis, cycle time analysis and labour productivity analysis. The study was done through observation,assesment of company records and documents and interviews. The tannery OEE was 8.97% where the ideal value is 85%, actual throughput in a month was averaging below 250,000 $ft^{2-1}$ against a design throughput capacity of 400,000$ft^{2-1}$. Production cycle time for a single batch was 19 days compared to standard average of 15 days and the labour productivity was calculated at 41.72$ft^2$/man/day against some hypothetical parameters for a model tannery of 270 $ft^2$/man/day. From the analysis there is evidence of ineffectiveness in the performance and unavailability of the production resources. Suitable remediesproposed for the tanning plant are introduction of TPM activities and Lean manufacturing concept.*

***Key words:*** *Key performance indicators (KPIs), Leather processing, Productivity, Tannery.*

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## I. Introduction

Productivity is usually a measure of the effective use of resources. It is the ratio of output to input(Stevenson W. J., 2009)(John , 1993):

$$\boldsymbol{Productivity} = \frac{\boldsymbol{outputvalue}}{\boldsymbol{inputvalue}} \ldots\ldots\ldots (1)$$

Productivity ratios are used to plan work force requirements, scheduling equipment's and all the important task in a business. According to (Gupta & Vardhan, 2016) productivity is a widely used manufacturing performance measure essential in managing production improvements. However, productivity is affected by several factors among others such as methods used, capital, technology, management, equipment breakdowns and shortage of raw materials.

A report by(Riley, 2012) outlined that higher productivity leads; to improved competitiveness, trade perfomance,higher profits,low average costs,higher wages and economic growth. Hence for sustainability of a nations economy,manufacturing industries should be nurtured for global market competitivenes. This means 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, 2014). (Teklemariam, 2004) linked productivity with utilization of resources in a company which means one can achieve the maximum possible with minimum resource. A system is deemed productive if it takes less time to achieve the desired results. Time is therefore, a key requirement in the manufacturing industry alongside other factors ( quality,utilization of resources).

Tanning is the conversion of raw hides and skins to leather. Leather processing is an important economic activity in developing countries that depend on Agro-economy (Thanikaivelan, Rao, Nair, & Ramasami, 2005). Leather plays an important role in social development, employment creation and foreign exchange earning.Most of the tanneries in Kenya are usually small and Medium Enterprises (SMEs) playing a very important role in the nation's economy, by their contributions to the GDP and employment (WorldBankGroup, 2015). Currently tanneries in Kenya have installed equipment capacities of 60% for wet-blue, 25% crust leather and 15%finished leather (KLDC, 2016). Leather production in kenya has not reached full potential due to low productivity by individual tanneries among other reasons. 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 throughputs of each process and reducing their processing cycle time.

This paper evaluates the effect of KPIs on productivity levels. It further identifies methodologies of usingKPIs on productivity improvement. Finally, the paper conceptualizes selection methods of the strategies. To do this a survey methodology was done in a case study industry, through interviewsand documented data on influence of each KPI on productivity was obtained.

## II. Literature Review

2.1 Productivity level KPI's

Productivity levels in a manufacturing system may depend on optimal choice and utilization of equipment's, raw materials and energy resources which increases the throughput (Taj & Berro, 2006). (Veronesi, Kuban, Manenti, Parker, Holmes, & Doorly, 2014) and (Teklemariam, 2004) identified reduction of movements, equipment's downtime, bottlenecks by improving scheduling and equipment reliability to affect cycle time. The KPI's influencing productivity in a tannery include, Overall Equipment Effectiveness, Process Cycle time, Process throughput and utilization of process resources (Naveen & Ramesh, 2000),(Ahuja, 2006),(Nigel, Stuart, Robert, & Alan, 2009).

2.2 Process Cycle time

It's the average time that the process takes between completions of units(Nigel, Stuart, Robert, & Alan, 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. Its measured in mins/pc or sec/pc(Vonderembse & Gregory, 2004) . Cycle time sets the drum beat or the pace of a process(Nigel, Stuart, Robert, & Alan, 2009).

A cycle time in manufacturing involves both the productive and non-productive time.(Jovanovic, Milanovic, & Djukic, 2014) describes productive time to be time taken for product to changes its shape or properties through a technological operation. Non-productive time on the other hand 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 throughput capacity(Chen, 2013). Hence a reduction in the manufacturing cycle time will improve the production process, the company's competitiveness and the process throughput(Dossenbach, 2017),(Chen, 2013),(Heizer & Render, 2014). Cycle time analysis is accomplished by use of time study in work measurement. Cycle time analysis is done using a stopwatch to develop a standard time to accomplish a given task.

2.3 Process throughput

Throughput refers to the total amount of items processed/produced by the system over the defined period of time(Prenscia, 1992). For production systems design, operation and management throughput analysis is very crucial(Li, Blumenfeld, Huang, & Alden, 2009).

2.4 Equipment utilization

Equipment utilization is defined as the percentage of total operating time during which the equipment is in production (Hibband, et al., 2011):

$$\boldsymbol{Equipmentutilization} = \frac{\boldsymbol{Productiontime}}{\boldsymbol{Totalavailabletime}} \boldsymbol{x100} \text{ …….. (2)}$$

2.5 Overall Equipment Effectiveness,

OEE is a quantitative metric for measuring productivity of individual equipment in a factory under a total productive maintenance (TPM) (Muchiri & Pintelon, 2008). These 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 (Nigel, Stuart, Robert, & Alan, 2009). It is based on three aspects of performance: time (which equipment is available) **A**, speed (throughput rate of the equipment) **P** and quality of the product or services it produces **Q**.

Where,

$$\boldsymbol{Availability(A)} = \frac{(\boldsymbol{TotalAvailabletime} - \boldsymbol{Downtime})}{\boldsymbol{TotalAvailabletime}} \text{….. (3)}$$

$$\boldsymbol{Performancerate(P)} = \frac{\boldsymbol{idealcycletime \times output}}{\boldsymbol{Designproductiontime}} \times \mathbf{100} \text{....... (4)}$$

$$\boldsymbol{Qualityrate(Q)} = \frac{\boldsymbol{Input - Rejects}}{\boldsymbol{Input}} \times \mathbf{100} \text{..........(5)}$$

Hence, $\boldsymbol{OEE = A \times P \times Q}$ ... ... ...(6)

OEE is useful both as a benchmark and a baseline(Itasca, 2016). As a benchmark it compares the performance of a given production equipment against the industry standards, while as baseline it is used to track progress over time in eliminating waste from the production equipment.(Pomorski, 1997) describes production OEE as a measurement of equipment effectiveness for available production work. OEE is 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 a powerful control tool used to overcome production deficiencies 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), OEE was found to be greatly improved if the performance rate is improved.

2.6 Total Productive Maintenance

TPM is a Japanese philosophy which is unique and has been developed on the basis of productive maintenance concepts and methodologies. TPM is one method used to enhance productivity of a system as it maximises equipment effectiveness(Gupta & Vardhan, 2016). It is the aspect of keeping machines in good working condition through systematic maintenance of equipment to ensure they fail less and the production process is uninterrupted(Stevenson W. J., 2009). Effective TPM strategies and programs can assist organisations in discovering the unused and under-utilized resources such as machine hours, man hours etc. this improves equipment efficiency and effectiveness leading to improvements in the production process(Wakjira & Singh, 2012). 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).

2.7 Lean manufacturing

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, better quality and lesser defects(Dutta & Banerjee, 2014). Lean manufacturing is defined as manufacture without waste (Taj & Berro, 2006). There are seven major waste covered in Lean manufacturing which include overproduction waste, stock (inventory), motion, transporting, correction, waiting (delays) and 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.

## III. Research Methodology

This paper evaluates the productivity levels in a tannery. A case study was used as it is more descriptive and gave an in-depth study of the problem. The data was collected on three key sections of the tannery i.e the Beam house, the tanyard and the finishing section through observation, interviews and from the company document. The key equipment's on those section was highlighted as every product in that section must pass through those machines to their subsequent processes. 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 a period of one year.

To evaluate the productivity levels in the case study the productivity KPIs were analysed from a data recorded over a period of 12 months.

Table 1 summarises the methodology framework in use.

Table 1 : Methodology framework

| **Objective** | **Data collected** | **Data collection tools** | **Methodology** |
|---|---|---|---|
| Productivity level analysis | -design capacity<br>-operating capacity<br>-design cycle time<br>-operating cycle time<br>-output levels<br>-number of defects | -observation<br>-interview schedules<br>-company documents | -Overall Equipment Effectiveness<br>-throughput<br>-cycle time |

## IV. Results

4.1 Equipment utilization

To determine the equipment utilization the record on equipment's production time in a month and the total available time were taken into consideration. Equation 2 was used to calculate equipment utilization. Results obtained were analysed and recorded in Fig. 1 and 2.

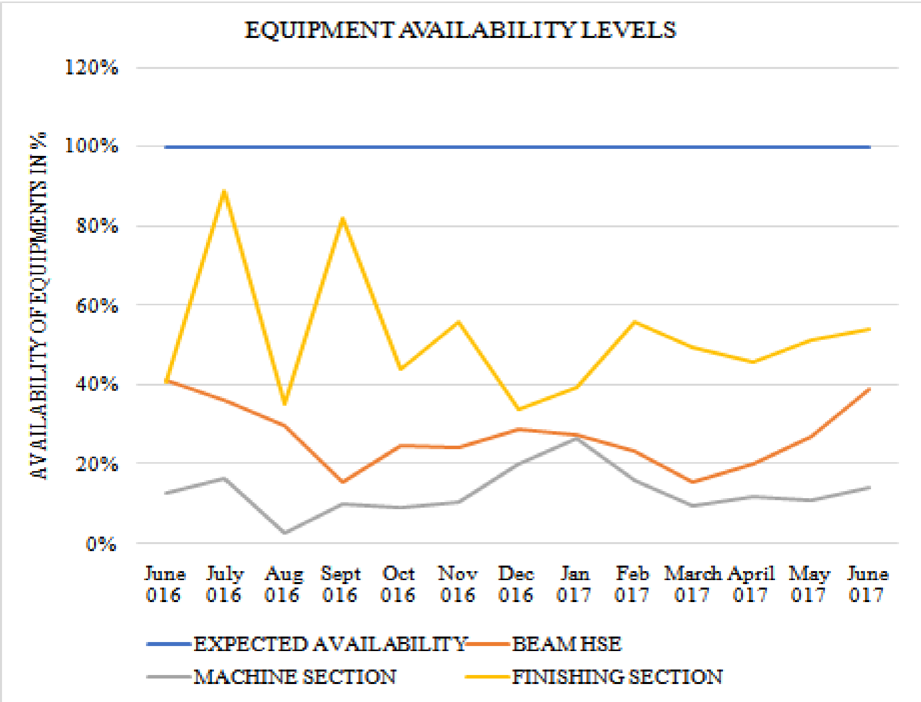


Figure 1: Equipment availability

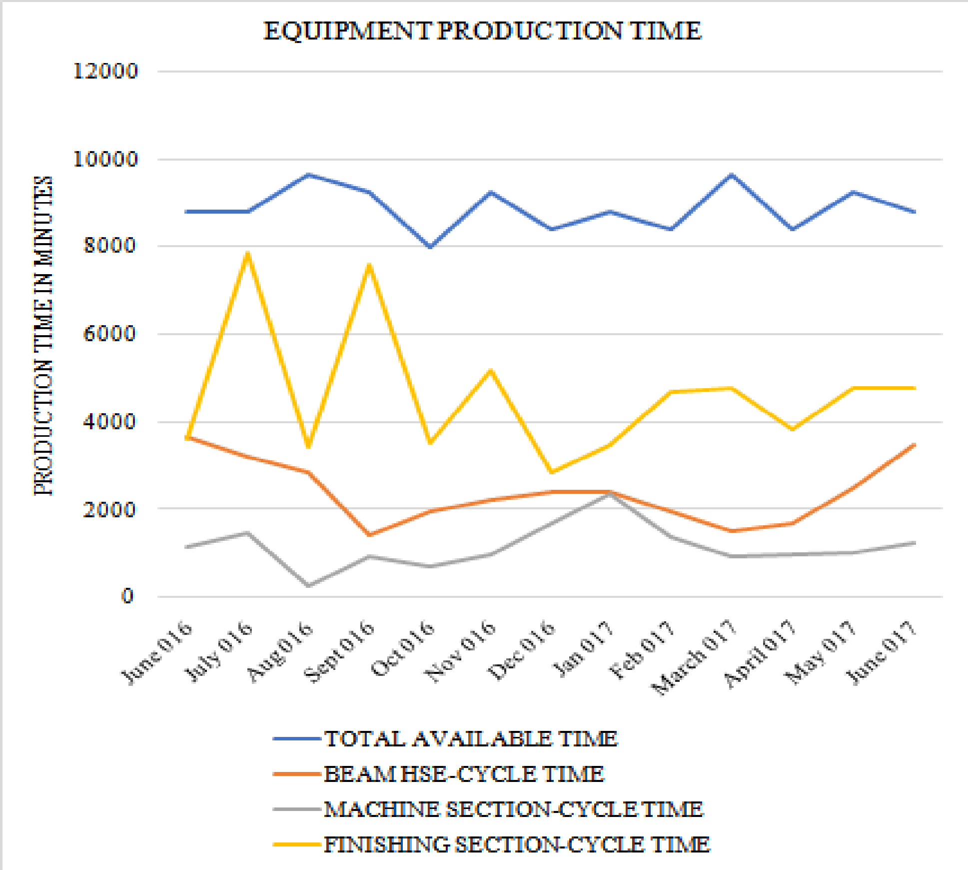


Figure 2: Equipment actual production time in minutes

From Fig. 1 and 2, equipment utilization and availability were analysed based on the factory production benchmark capacity of 400,000 $ft^{2-1}$and the total available production time per month. From the Chart the potential equipment utilization rate(availability) from the factory benchmark is 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. Analysis of 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). From this analysis the tannery has a potential for improvement on the equipment utilization and availability in order to boost its productivity levels.

**4.2 Overall Equipment Effectiveness**

To calculate the OEE of the machines, the OEE factors were first determined using the Equations 3,4 and 5. The machines availability in the beam house section was calculated 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. Fig. 3, shows the comparison of the OEE factors of the three sections of the tannery.

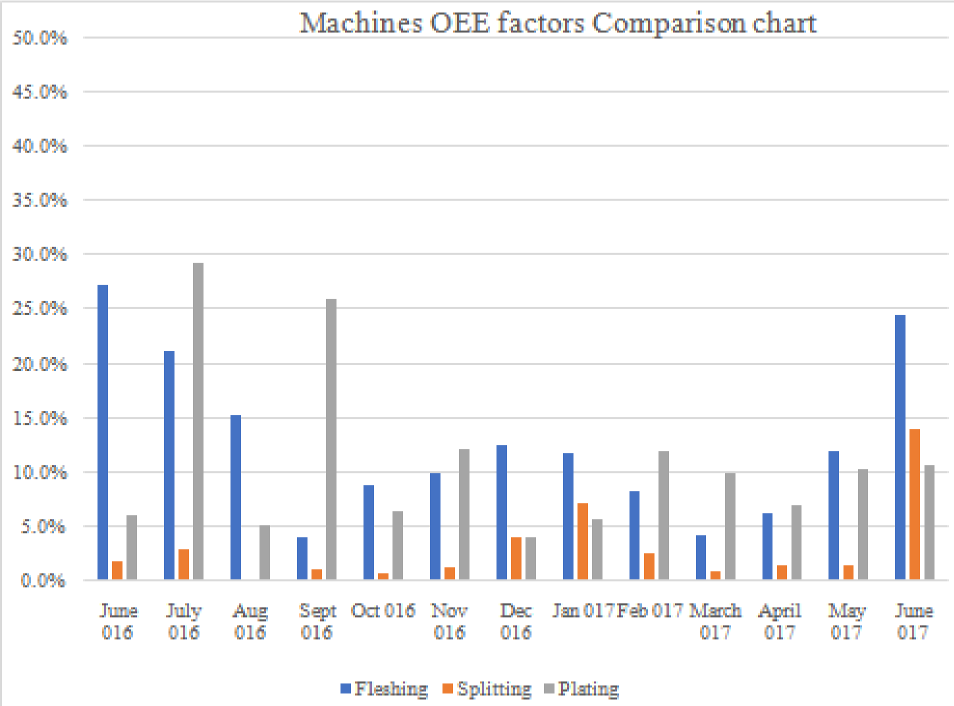


Figure 3:Machines OEE factors comparison chart

The OEE factors were averaged as 30.78%, 25.56% and 98.86% for the three sections respectively. Using Equation 6, the overall OEE rate was calculated and compared to the ideal world OEE rate which are 90%, 95% and 85% respectively as shown in Table 3.

Table 2: 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 |

Availability is a function of time the equipment is in actual operation, while performance is a function of the throughput of the equipment in a given time. This shows the type of losses in play; equipment failure/ breakdown losses, idling and minor stop losses and reduced speed losses. From this analysis an improvement strategy can be selected based on the production system environment.

**4.3 Cycle time analysis**

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 (which usually has the longest route).

Cycle time analysis established that the manufacturing cycle time of an entire single batch of leather of approximately 5610 $ft^2$in the tannery was 22518 minutes, which translates to about 375.3 hours or 19 days. 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.

**4.4 Throughput analysis**

Throughput was taken as the total output produced per month and was compared against the expected design production capacity of 400,000 $ft^{2-1}$of the leather tannery. Fig.4 represents a combo chart showing the actual production against the rated capacity at the tannery

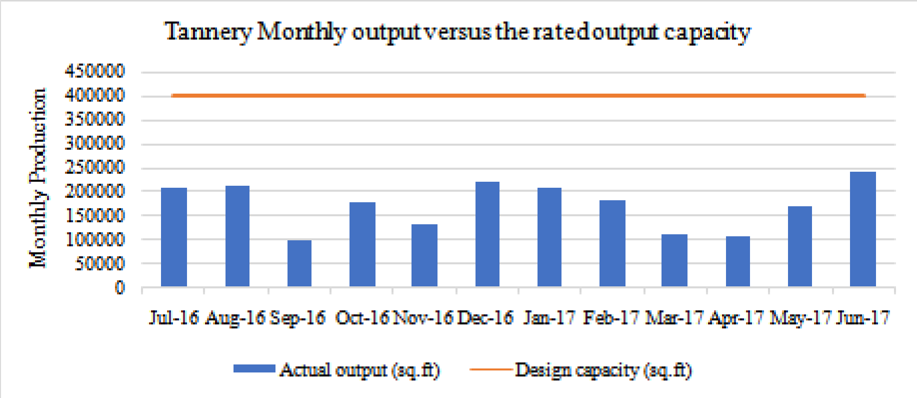


Figure 4:Monthly comparison of actual output capacity and design capacity

From Fig. 4, it is clear that the tannery is operating way below its rated throughput of 400,000 $ft^{2-1}$which acts as an internal benchmarking value. In most of the months, the tannery's production is less than half of its rated throughput.

**4.5 Labour productivity**

Labour productivity was calculated based on Equation 1 as:

$$Labourproductivity = outputs/inputs$$

Where the Output refers to the amount of leather produced in $ft^2$in a particular month and input is the total man-hours used in production per month.

The targeted/ design labour productivity at the tannery was calculated as 96.15sq.fts/man/day

Fig. 5 shows the deviation of the actual monthly productivity from the targeted productivity:

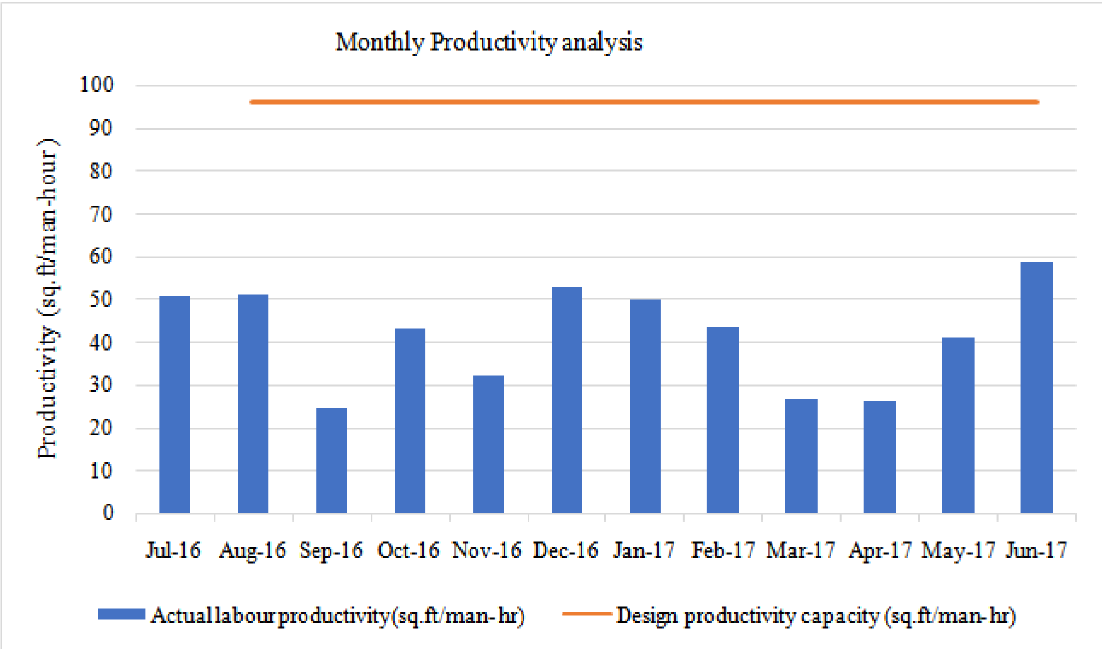


Figure 5:Monthly labour productivity analysis

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 was calculated as 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 the leather tanneries are underutilized at 41.72 sq.ft/man/day.

From the analysis of the productivity KPIs of the case study tannery, two major dimensions were considered to cut across the board. These are the performance and the availability of the equipment. The relationship between the productivity and equipment availability and performance was analysed on SPSS software and the results summarised in Table 4.

Table 4: Correlation Matrix table in the Tannery

| **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). | | | | |

The correlation analysis between availability and productivity and performance and productivity have a positive significant relationship which is determined as 1.00 and 0.990 respectively, with a P value < 0.0001. 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

$Y = 0.016a - 0.002b - 0.009$

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 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.

## V. Conclusion

The purpose of the study was to evaluate the productivity levels in a tannery which would be used as a basis for remedial actions. This was done by analysing the key performance indicators (KPI) used in productivity measurement from literature review. The data collected was analysed giving various results.

From the analysis of the productivity KPIs, the results of the productivity levels of the leather Tannery are lower than the compared standards. From this analysis there is evidence of so much non-value adding activities in the tannery, so many wastages resulting to equipment unavailability and low equipment performance. The proposal of the improvement strategies to remedy the KPI levels was through context analysis. Through this analysis all the environmental factors within which the tannery operated were scanned and based on the analysed KPI levels. This leads to the proposal of TPM principles and Lean manufacturing concept for application in the tannery to improve on its productivity levels. These strategies are linked more to improvement of equipment availability and performance in the tanning industry if well implemented.

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