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Impact Assessment of a Facility Layout on Manufacturing Cycle Time and Throughput: A Case Study of a Tannery in Central Kenya.

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Abstract: *Facility layout design has a major impact on manufacturing cycle time hence throughput rate. Its critical objective is to minimize material handling thus decrease manufacturing cycle time and increase throughput rate resulting to improved productivity. The low productivity recorded by Kenyan leather tanneries can be attributed to poor plant layout as the major factor. This paper explores the impact of poor plant layout on manufacturing cycle time hence throughput rate based on a case study of a tannery situated in Central Kenya. Cycle time and throughput analysis are employed in this research. The manufacturing cycle time was found to be 19 days, which exceeds the standard time by 4 days. 17.42% of the manufacturing cycle time consisted of Non Value Adding time of which transportation of materials between workstations was the highest contributor as established by Pareto analysis. Throughput analysis indicated that throughput rate was way below the theoretical 235,294 kg of leather per month with the main cause being increased material handling as established by Root Cause Analysis. To address this shortcoming, re-design of an optimal layout was recommended to minimize material handling hence decrease manufacturing cycle time and increase throughput rate.*

Key words:*Facility layout, Tannery, Productivity, Throughput, Material handling*

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I. Introduction

Facility layout refers to the configuration of departments, work center, and equipment, with particular emphasis on movement of work (customers or materials) through the system (Stevenson W. J., 2009). It's the physical arrangement of the workplace, that is, assignment of departments to specific locations on the production floor (S.Heragu, 2006). According to Stevenson, the basic objective of layout design is to facilitate a smooth flow of work, material and information through the system (Stevenson W. J., 2009). S. Heragu further explains that an effective physical arrangement of departments minimizes the movement of personnel and material between departments, and thereby decreasing material handling costs, increasing a systems' efficiency and productivity (S.Heragu, 2006). It also facilitates the entry, exit, and placement of materials and products whilst eliminating bottlenecks (Gupta, Gopalakrisnan, & Turuvekere, 2004).Besides, proper layout design directly and indirectly minimizes the overall cost of products while increasing productivity and business performance. Cost reduction due to facility layout mainly is as a result of decreased material handling costs (Naqvi, Fahad, Atir, Zubair, & Shehzad, 2016). Between 20 and 50% of the total operating costs within manufacturing is attributed to material handling. Effective facilities planning can reduce these costs by at least 10% to 30% and thus increase productivity (Tompkins J. A., White, Bozer, & Tanchoco, 2010). The indirect cost reduction is as a result of effective utilization of space, workers and infrastructure, increased wellbeing and morale of the workers (Eida & Siti , 2008), attainment of product or service quality as well as increased safety of the plant (Stevenson W. J., 2009). An optimal facility layout plays a key role in reducing manufacturing cycle time and increasing throughput. Manufacturing cycle time is the sum of all the processing times of every operation a product goes through from the beginning to the end of its production, it is inclusive of all waiting and queuing times experienced at any operation (Marsudi & Shafeek, 2014). It consists of productive and non-productive time whereby productive time is when a unit changes its shape or properties through a technological operation and non-productive time occurs during transport or control operations within the process (Jovanovic, Milanovic, & Djukic, 2014).Prolonged manufacturing cycle time could be as a result of too many non-value adding activities. A process with such a cycle should be investigated to identify non-value adding activities and minimize or eliminate them completely. Toly Chen argues that long manufacturing cycle time results into accumulation of Work In Progress (WIP), which in turn makes management of the production floor a complex task (Chen, 2013). Tom Dossenbach advises companies to prioritize manufacturing cycle time reduction as it results in leaner production processes which in turn boost companies' profits (Dossenbach, 2017). Heizer also argues that minimizing manufacturing cycle time can help improve throughput a great deal (Heizer & Render, 2014). Throughput rate is the average number of units produced in a factory per unit time (Marton & Paulova, 2010). It is one of the key performance indicators for a process. The higher the throughput rate the better the process performance. Throughput rate is an inverse of cycle time as shown in equation 1. Thus, it can be increased by reducing the cycle time of a process. Some of the benefits of improving production throughput include reduced costs and increased revenues for the company.

$$\text{Throughputrate} = \frac{1}{\text{cycletime}} \qquad (1)$$

1.1 Problem Environment

It is estimated that Kenyas' leather subsector has a potential total value of Ksh.125 billion of which only Ksh.10.6 billion has been realized. Low productivity of tanneries in Kenya results from factors such as use of obsolete equipment, low level of employees training, ineffectively organized workflow (poor plant layout) and limited availability of spare parts and chemicals (UNIDO, Publications: Leather Panel, 2010) as well as high cost of hides and skins (Mwinyihija & Quiesenberry, 2013).Tanneries therefore need to increase their potentials in production to exploit their full capacity and meet the demand. One way of achieving this is byanalyzing their existing plant layouts to determine the time waste associated with poor plant layout and develop an optimal layout to reduce such waste. An optimal plant layout helps save time and costs associated with material handling, as it reduces the travel distance and time by effective and efficient sequencing of workstations. This research focused on assessing the impact of poor plant layout on manufacturing cycle time and throughput rate with the view to recommending design of an optimal layout that would result to increased productivity.

II. Related Work

In the past, researchers have used several performance measures to evaluate facility layouts. Such researchers include Back and Johansson who redesigned the facility layout of Holtab AB Sheet Metal Company and evaluated the layout alternatives obtained using performance measures such as throughput time, manual material handling, workplace environment, manual travelling distances, risk of stock out etc (Back & Johansson, 2006). W. Wiyaratn, and A. Watanapa after re-designing the layout of an iron manufacturing company evaluated the alternatives by their extent of material flow (Wiyaratn & Watanapa, 2010). Barnwal and Dharmadhikari used labour cost and production floor utilization as parameters to analyse alternatives in the redesign of engine reconditioning process section of an automobile industry (Barnwal & Dharmadhikari, 2016). In this study, they recommended the use of more parameters to analyse the layouts other than the unit cost and material travel distance. Tak and Yadav in addition to parameters mentioned above included safety and ease of supervision and control in evaluating layout alternatives obtained in the design of a layout for a steel manufacturing factory. The review of past research shows that evaluation of layouts have been mostly applied during the design phase of facilities or when there has been need to redesign the existing facilities. However, measuring the performance level of an existing layout is equally important as it helps support various decision making processes (Raman, Nagalingam, Gurd, & Lin, 2007). This should be the case since from time to time, a company experiences massive changes such as change in demand and product mix which consequently necessitatesrearrangement of the facility. Poch recommends research of more case studies as it would constitute a primary source of evidence in the task of assessing the impact of facility layout design (Poch, 2009). This study addresses this gap by evaluating the performance level of an existing layout with the view to aid in decision making.

III. Methodology

3.1 Case Study Tannery

The tannery under study is divided into three main sections namely:

1. Beam house where soaking, liming, fleshing and chrome tanning processes take place.
2. Tanyard section where sammying, splitting, shaving, retannage, setting and drying processes are carried out.
3. Finishing section where trimming, staking, buffing, impregnation, coloring, plating, spraying and measuring processes take place.

The main products at the tannery include wetblue leather which constitutes 73% of sales and finished leather which constitutes 23% of sales. Finished leather however constitutes of several products which vary in terms of quality, appearance and the routing they follow during processing. These products include: kips, pull-up, silka, upholstery, linings, suede, hair-on and split leathers.

Analysis of impact of the current layout on manufacturing cycle time and throughput
The analysis of impact of the current layout on productivity was carried out using cycle time and throughput analysis.

3.2Cycle time analysis

The total time taken by a batch of hides to go through all the processes of production was determined using time studies method. This included processing times, waiting times and material handling times. 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 and activity times. The observed time for each process and activity was determined by taking the average of ten observations. From this, the normal time and standard time was obtained as described and adopted from Stevenson (Stevenson W. J., 2009)as shown in equations 2 and 3:

$$\mathrm{NormalTime(NT)} = \mathrm{ObservedTime(OT)} * \mathrm{AverageRating} \quad (2)$$
$$\mathrm{StandardTime(ST)} = \mathrm{NT}/(1 - \mathrm{allowances}) \quad (3)$$

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

The times for long-cycle processes were obtained by recording the start time and end time of each long-cycle process and calculating the difference.The total manufacturing cycle time was calculated by adding up the times for all the activities and processes. Pareto analysis was performed to determine the vital few factors leading to high Non-Value Adding time at the finishing section of the tannery.

3.3Throughput analysis

The companys' actual throughput rate was determined using the procedure outlined below:
1. Production records were examined for a period of one year and data for quantity of each product produced per month in a period of one year collected and recorded.
2. The total production per month was computed and tabulated based on the data obtained in step one.
3. The actual monthly throughput rate was compared to the theoretical monthly throughput rate of 235,294 kg per month to indicate the deviation of the actual from the theoretical rate.
4. Root cause analysis was performed to establish the root causes of low and varying actual monthly throughput rate.

IV. Results and Discussion

4.1 Cycle time analysis

Time studies were conducted to establish the standard times for each short cycle process. Table 1 shows the summary of mean, normal and standard times for the short cycle processes:

Table 1: Times for short cycle processes

Process	Mean time (s)	Normal time (s)	Standard time (s)
Fleshing	17.28	14.69	16.32
Splitting	21.80	18.53	20.58
Shaving	45.18	38.40	42.67
Setting	12.50	10.63	11.81
Hooking (prior to drying)	162.17	137.84	153.16
Staking	24.58	20.89	23.21
Plating	16.87	14.34	15.93
Impregnation	61.65	52.40	58.22
Buffing	19.76	16.80	18.67
Dusting	19.29	16.40	18.22
Measuring	12.64	10.74	11.93

Most of the long cycle processes involve chemical treatment of batches of hides in drums, which usually takes several hours depending on the type of chemical process. Drying is also a long cycle process as it takes several hours to dry leather naturally at the drying sheds. Table 2 shows the standard times for long cycle processes.

Table 2: Standard times for long cycle processes

Process	Standard time (hr)	Standard time (mins)
Soaking	16	960
Liming	16	960
Chrome tanning	12	720
Rettanage	21	1260
Drying	72	4320

Thetotal manufacturing cycle time was obtained based on the assumption that the final product was silka, which usually has the longest product route among all the products produced at the tannery. This analysis was based on processing of a single batch of hides of approximately 3,300kg and containing 250 pieces of hides. The results obtained are as summarized in table3.

Table 3: Manufacturing cycle time

Section	VA time (min)	NVA time (min)	Total (min)
Beam house	5610	445	6055
Tanyard	9675	1058	10733
Finishing section	3360	2430	5790
Total	18645	3933	22578

The cycle time analysis presented in table 3 helped establish that the manufacturing cycle time of leather was 22578 minutes, which translates to about 376.3 hours or 19 days. The standards established for tanneries indicates that the cycle time should be between 10 to 15 days (Buljan & Kral, 2012). The tannery therefore exceeded the upper limit of the standard cycle time by four days. This revealed presence of wastages that needed to be identified and eliminated or reduced.

The total manufacturing time of 22,578 minutes constituted of 3,933 minutes or 17.42% non-value adding activities (NVA) and 18,645 minutes or 82.58% of value adding activities. The finishing section contributed the highest percentage of NVA activities, which is 10.76% of the total manufacturing cycle time, followed by the tanyard section which contributed 4.69% and the beam house contributed to 1.97%.

Pareto analysis was performed to establish the vital-few and trivial-many factors that contributed to the high NVA time at the finishing section.

Pareto analysis of factors contributing to high NVA time at the finishing section

NVA activities include those activities that are non-value adding but necessary (NVAN) and those that are non-value adding but unnecessary (NVAU). The finishing section NVA activities included transport, picking and dropping which are NVAU as well as trimming, dusting, measuring and packing which are NVAN.
Figure 1 shows a pareto analysis for factors leading to high NVA time at the finishing section:
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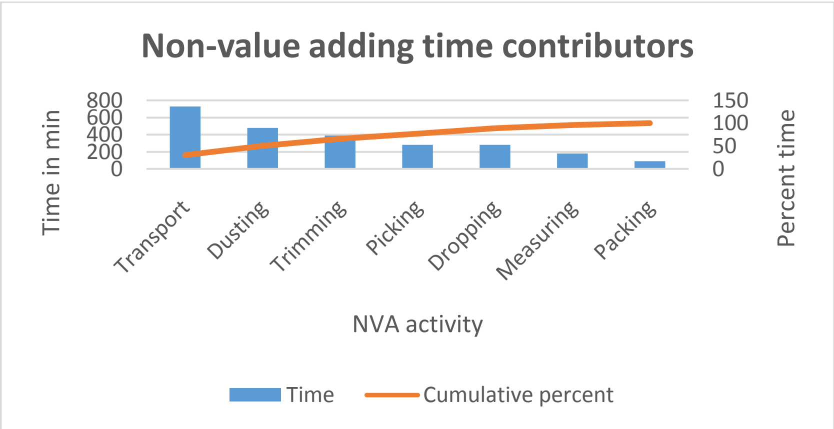

Figure 1: Pareto analysis on high NVA time at the finishing section

The Pareto analysis in figure 1 revealed that the vital few factors resulting to high NVA time at the finishing section are transportation, dusting and trimming. The most predominant cause of NVA time at the finishing section in the tannery is transportation of materials between workstations. Since dusting and trimming are necessary non-value adding activities (NVAN), this research recommended reduction of transportation time through design of an optimal layout.

4.2 Throughput analysis

Throughput analysis was conducted by examining production records for a period of one year. The data obtained is presented in figure 2, showing the actual production against the rated capacity at the Tannery.

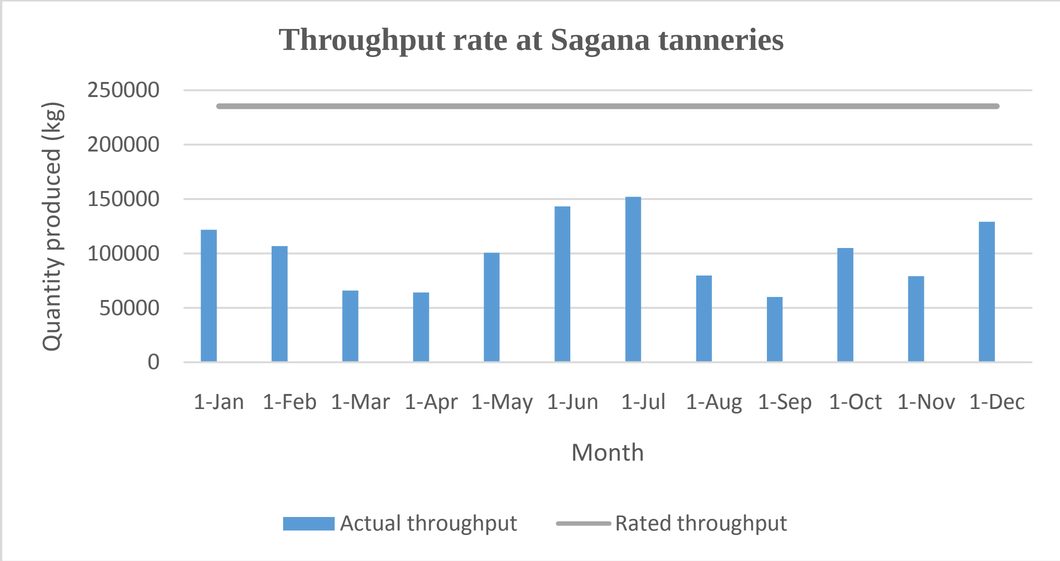

Figure 2: Monthly throughput rate at the tannery under study

From records, the tannery had a rated capacity of 235,294 kg of leather per month but according to figure 2, production at the tannery ranges from 59,888.37kg to 152,151.9kg per month. Hence, the company operates way below its rated capacity. It was also observed that the throughput rate varied significantly across the months. Root cause analysis was performed to determine the causes of low and varying throughput rate across the months.

Root cause analysis for low and varying monthly throughput rate at the tannery

The RCA for the low and varying monthly throughput rate was carried out using 5-WHYs RCA tool. The root causes recorded in the 5-WHYs worksheet were analysed. The fixable root causes were classified into broad classes; man, material, machines and methods and presented on a cause-and-effect diagram shown in figure 3:

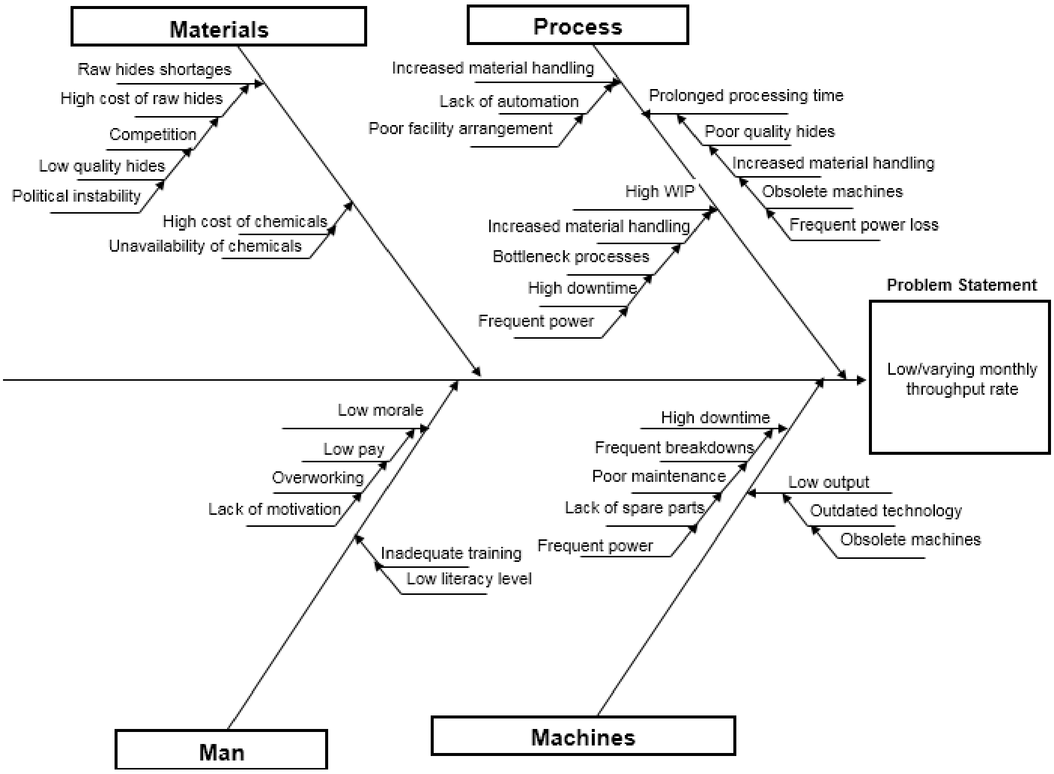

Figure 3: Cause and effect diagram for low and varying throughput rate at the company under study

From the results of RCA, it was established that the main root causes of constant low throughput were causes to do with methods, men and machines. The most predominant cause of low throughput due to methods was found to be increased material handling which resulted from lack of automation and poor facility arrangement. The main root causes of varying throughput rate were found to be related to materials. The most predominant cause was found to be shortage of raw materials as a result of factors such as competition, high cost of raw materials, political instability, poor quality of hides and prolonged drought. This research recommended design of an optimal layout to address the root cause of poor arrangement of facility so as to help decrease material handling thus shorten the manufacturing cycle time and increase the throughput rate.

V. Conclusion

This paper explores the impact of existing facility layout on productivity of a company using manufacturing cycle time and throughput rate as the performance measures. The case study at the tannery establishes that a poor facility layout necessitates increased material handling, thus prolonging the manufacturing cycle time and decreasing throughput rate. As a result, productivity is significantly lowered. In order for tanneries in Kenya to improve their productivity, there is need to analyze their existing facility layouts and design optimal ones that will minimize material handling.

References

[1]. Back, D., & Johansson, P. (2006, September 5). A model for effective development of plant layouts and material handling systems. Vaxjo: Vaxjo University, School of Technology and Design.
[2]. Barnwal, S., & Dharmadhikari, P. (2016). Optimization of Plant Layout Using SLP. International Journal of Innovative Research in Science, Engineering and Technology, 3008-3015.
[3]. Buljan, J., & Kral, I. (2012). Benchmarking in the Tanning Industry. Vienna: United Nations Industrial Development Organization (UNIDO).
[4]. Chen, T. (2013). A Systematic Cycle Time Reduction Procedure for Enhancing the Competitiveness and Sustainability of a Semiconductor Manufacturer. Sustainability, 4637-4652.
[5]. Dossenbach, T. (2017, Novemember 16). Management: Woodworking Network. Retrieved from Woodworking Network Website: http://www.woodworkingnetwork.com
[6]. Eida , R. N., & Siti , D. Z. (2008, January). A study on Facility Layout in Manufacturing Production Line using WITNESS. ResearchGate, 411-421. Retrieved November 17, 2016, from ResearchGate website: https://www.researchgate.net
[7]. Gupta, Gopalakrisnan, & Turuvekere. (2004). Computer Integrated Facilities Planning and Design. Journal of Facilities, 199-209.
[8]. Heizer, J., & Render, B. (2014). Operations Management. England: Pearson Education , Inc.
[9]. Jovanovic, J. R., Milanovic, D. D., & Djukic, R. D. (2014). Manufacturing Cycle Time Analysis & Scheduling to Optimize Its Duration. Journal of Mechanical Engineering, 512-514.
[10]. Marsudi, M., & Shafeek, H. (2014). Cycle Time Analysis of Tipping Trailer Frame: A Case Study in a Heavy Equipment Industry. South African Journal of Industrial Engineering, 176-188.
[11]. Marton, M., & Paulova, I. (2010). Applying the Theory of Constraints in the Course of Process Improvement. Research Papers. Trnava, Slovak: Slovak University of Technology.
[12]. Mwinyihija, M., & Quiesenberry, W. (2013). Review of challenges towards value addition of the leather sector in Africa. Global Advanced Research Journal of Management and Business, 518-528.
[13]. Naqvi, S. A., Fahad, M., Atir, M., Zubair, M., & Shehzad, M. M. (2016, June 29). Productivity improvement of a manufacturing facility using Systematic Layout Planning. Production and Manufacturing research article. Pakistan.
[14]. Poch, J. S. (2009). Assessing the Impact of Facility Layout Design over the Process Productivity and Costs. Nottingham: Nottingham ePrints service.
[15]. Raman, D., Nagalingam, S. V., Gurd, B. W., & Lin, G. C. (2007). Effectiveness Measurement of Facilities Layout. Proceedings of the 35th International MATADOR Conference (pp. 165-168). London: Springer, London.
[16]. S.Heragu, S. (2006). Facilities Design, 2nd edition. Louisville: iUniverse , Inc.
[17]. Stevenson, W. J. (2009). Operations Management. New York: McGraw-Hill Irwin.
[18]. Tompkins, J. A., White, J. A., Bozer, Y. A., & Tanchoco, A. J. (2010). Facilities Planning (4th edition). Riverstreet, Hoboken: John Wiley and Sons.
[19]. UNIDO. (2010, November 3). Publications: Leather Panel. Retrieved March 3, 2017, from Leather Panel website: https:// leatherpanel.org
[20]. Wiyaratn, W., & Watanapa, A. (2010). Improvement of Plant Layout Using Systematic Layout Planning (SLP) for Increased Productivity. International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:4, No:12, 1382-1386.

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