IMPROVEMENT OF PLANT FACILITY LAYOUT FOR BETTER LABOUR UTILISATION: CASE STUDY OF A CONFECTIONERY COMPANY IN THE WESTERN CAPE

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ABSTRACT

South African companies are generally labour intensive, especially confectionery companies specialising in handmade products. Labour resources are not effectively and efficiently utilised because of inappropriate facility layout and lack of Lean, JIT and OPT principles, in some cases. This study highlights how a facility layout can be improved for a confectionery company so as to improve labour utilisation. Optimised Production Techniques (OPT), Lean and other production management methods are used to improve the facility layout by improving product flow and eliminating common waste that occur in manufacturing plants. Enterprise Resource Planning (ERP) system, time studies, observations on the facility floor, interviews with Subject Matter Experts (SME), production managers, shop-floor personnel and historic data in company reports were used to generate the information required in measuring the labour utilisation for an existing facility. A labour performance standard is identified and evaluations are made with respect to the degree of this performance standard. Line balancing is applied on product line(s) contributing most to revenue in alignment with marketing strategies. Using a Western Cape Province confectionery company as a case study, the current facility layout and its labour utilisation are compared to an improved-alternative plant layout. Line balancing alternatives are modelled with discrete event simulation software to effectively evaluate them, and present recommendations.

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1 INTRODUCTION

In South Africa, where labour cost are constantly rising and accounting for a substantial percentage of the total cost of production [1], the manufacturing industry continuously strives to improve labour utilisation and reduce labour cost. The measurement of labour utilisation is a key performance indicator relevant to almost all industries. Various factors influence productivity in the manufacturing industry, especially regarding labour. Environmental, ergonomic and facility layout principles all have an effect on labour utilisation. In some cases labour is underutilised emanating from poor facility layout which might include environmental and ergonomic factors. Facility planning and design related to Lean, Optimised Production Techniques and other production management philosophies can provide a practical solution to a South African company with an inefficient workforce. The study addresses how labour can optimally be utilised in a chosen confectionery company by employing an improved-alternative plant layout. In coming up with a viable solution the paper attempts, as its sub-objectives, to: identify bottlenecks, reduce wastes, balance workloads between workstations, minimise processing time, and finally improve labour utilisation. The proposed optimal solution is presented taking into consideration spatial constraints at the facility under consideration.

2 LITERATURE REVIEW

Many researches have been done in facility planning area. Effective facility planning can reduce significantly the operational costs of a company by 10-30% [2]. Proper analysis of facility layout design could result in the improvement of the performance of production line. This can be realised by optimising the capacity of a bottleneck; minimising material handling costs; reducing idle time; maximising the utilization of labour, equipment and space [2].

Facility planning is an overall approach concerned with the design, layout and incorporation of people, machines and activities of a system [3]. Huang [4] emphasises that facility layout design defines how to organise, locate, and distribute the equipment and support activities in a manufacturing facility to accomplish minimization of overall production time, maximization of operational efficiency, growth of revenue and maximization of factory output in conformance with production and strategic goals.

In as much facility redesign and implementation may be considered imperative; however relocating equipment can be an expensive and time-consuming endeavour. In addition, determining whether a potential new layout or staffing scenario would perform better than the current configuration is difficult to determine until the new setup is complete. If the new layout fails to produce the anticipated positive results, then a lot of time and money would have been wasted. Therefore, ability to test the proposed layout before relocating equipment or even purchasing new equipment is desirable. Simulation models provide an alternative of evaluating the proposed layouts so as to obtain the near-optimal solution. Simulation software has the capability to determine factory conditions which include the determination of plant capacity, balancing manufacturing and assembly lines, managing bottlenecks and solving inventory and work-in-process problems [5] [6]. Simulation also enables the ability to model “what-if” scenarios to test changes in labour levels. In this research Simio® simulation modelling software is used to identify and optimise the bottleneck and perform line balancing by comparing different scenarios and selecting the near-optimal solution.

3 COMPANY INFORMATION & METHODOLOGY

The confectionary company studied has a product range of over a 100 products of handcrafted rusks, cookies, biscuits and snacks. Most product families have different packaging and labelling requirements. Owing to their variableness in processing
requirements, automation is rarely used; instead highly intensive manual labour is utilised. With the objectives of the study in mind, the case study would be limited to the labour intensive packaging department of the confectionery company. The packing department has three shifts of 8 hours each from Monday to Friday, and a workforce of 30 labourers. On Saturdays a 12-hour shift is scheduled. The packaging area consists of 8 permanent packaging lines of which two are dedicated to the rusk product family.

The approach followed to address the problem of a poor facility layout was by employing production philosophies to improve labour utilisation. The following steps were followed to solve the poor facility layout at the confectionary:

- Collection of data from Enterprise Resource Planning; time studies; and from Subject Matter Experts, line and production managers through interviews.
- Conducting of floor observations.
- Employment of Pareto profit-volume analysis of product range.
- Analysing of single model packaging line and facility layout.
- Employing facility layout and lean principles.
- Developing the base simulation model.
- Verifying and validating the base simulation model.
- Simulating and comparing different scenarios.
- Measuring improvements and making recommendations.

4 PARETO PROFIT-VOLUME ANALYSIS OF PRODUCTS

For the confectionery company being considered as a case study, a Pareto analysis was executed. The production data of the previous year was processed to analyse the products packed by the company. The approach taken was to identify the distribution of the production volume multiplied by the gross profit contribution of each item. The reason for analysing the profit-volume as a combination instead of only the profit contribution is as follow: certain products have high profit margins but contribute to less than 1% of the turnover of the company. An example of such a product is the Shop Rusk Tins with a 140% profit contribution but 0.59% contribution to the total revenue. On the other hand if only the volume figure of products were considered for the Pareto analysis, it would not be aligned with the financial and marketing strategies to increase turnover while decreasing cost. The distribution is depicted in Figure 1. Out of the 75 products packed at the specific factory, 16 products or 21,6% of the products make up 79% of the profit-volume, indicating the 80/20 spread. For illustrative purposes only the first twenty products (instead of all 75 products) are included in the Pareto chart in Figure 1.
Figure 1: Profit-volume contribution to product variety in which a Pareto distribution is observed

The 80/20 spread was further categorized by product family. Figure 2 illustrate the family categorization of the first 16 products by the profit-volume contribution. It is seen that rusks make up 55.5% of the profit-volume of all the products.

Figure 2: Pareto distribution by product family of first sixteen products.

The packaging area has 2 packaging lines dedicated for processing rusks. Thirteen types of rusks are produced and these can be sub grouped into 7 categories with respect to their packaging requirements. When further application of the Pareto analysis was executed, it was established that Bran and Buttermilk rusks make up 60% of the profit-volume contribution of the Rusk product family which translates into 60% of the 55.5% of the total...
profit-volume analysis. This equates into a 33% contribution of the total profit-volume by a single product. Figure 3 depicts the 80/20 distribution of the Rusk categories.

![Pareto Profit-Volume](image)

**Figure 3: Profit-volume distribution of the rusk product family**

Packaging data from the company Enterprise Resource Planning system and interviews with line managers confirmed that one of the two rusk lines was dedicated to pack class A rusks. After consulting the marketing team about the findings they indicated that the Bran and Buttermilk rusks are the flagship products and since new labelling was released on these products in February 2013, they aim to increase sales in the coming winter months for the Bran and Buttermilk rusks. With the above factors in mind, the decision was made to start with class A rusks as a single model packing line to improve facility layout and labour utilisation and then continue with the next product category of the Pareto profit-volume analysis. The line packs on average 535 batches of the Bran and Buttermilk (Class A) rusks per month.

5  **LAYOUT AND PROCESS ANALYSIS:**

The following section is an overview of the approach followed to analyse the current layout and packaging processes.

5.1  **System Description**

Products flow through production to packaging in batches, where it is packed and boxed. For class A rusks, a batch consists of twelve pans with loose rusks in the pan. On average, 4 workers operate the line of which one worker is the roaming line manager. The entire packaging process is conducted in 3 stages. Rusks are packed and weighed at the first station, sealed at the second, labelled and boxed at the third. Figure 4 shows the entire flow from arrival to dispatch.
Figure 4: Packaging Process Flow

Rusk batches arrive from the drying area and are staged in the staging lanes. Before being packed, moisture and taste test are done to meet product quality specifications. After the rusks are packed in boxes they are moved as a batch to the metal detector before being sent to the outbound loading docks.

5.2 System Analysis

The current packaging line is setup on tables placed in a straight line. The floor layout of the Rusk A packaging setup is illustrated in Appendix A. With the current configuration the Pack & Weigh station is operated by two workers each equipped with a portable scale to weigh the packets. The Sealer station is manned by one operator using a sealing machine next to the packaging table. The fourth worker labels the packets by hand and places them into a box.

The red path indicates the current flow of batches on trollies from the drying area to the staging lanes and then to the packaging line. After leaving the packaging line, all the boxes of a batch are moved to the metal detector.

Observations on the packaging floor revealed some of the most common wastes that occur in a facility. These were identified as wastes arising from poor transportation, waiting time and unnecessary motion. Inventory waste was also identified as evidenced by the generally untidy appearance of the packaging area with: congestion of batch trolleys in staging lanes, product trolleys not grouped and staged orderly. Time was wasted through unnecessary back-and-forth movements of checking arrival times on batch traceability sheets; unnecessary long travel distances of batch trolleys from drying area to staging lanes; double handling of rusks’ boxes as they were transported to metal detector.

Tompkins [7] emphasises that labour time is reduced by reducing waste and according to Ohno [8] reducing man-hours is a means of improving efficiency in lean manufacturing. The company currently measures the utilisation of labour as the time taken to pack a batch multiplied by the number of workers on the line to indicate the effective man-hours spent on a batch.

5.3 Improvements and Proposed layout

Appendix B illustrates the improved proposed layout. The blue lines and arrows indicate the flow of batches through the system. The total transport distance has been significantly decreased from 89m to 43.7m by the opening of a blocked door and the elimination of double movement of the box transporter from the end of the packaging line to the metal detector. The total transport reduction is depicted in the From-To chart (Figure 5).
Figure 5: From-To chart comparing actual distance travelled of batch from node A to G for unimproved and improved scenario.

The line configurations were tilted to complement the flow and create marked staging lanes that accommodate first in first out (FIFO) principle. This would decrease time wasted to look for the first arrived batches on traceability sheets.

The line balancing problem is evaluated in the following section making use of discrete event simulation.

6 SIMULATION MODEL:

This section will discuss the use of simulation to compare different staffing scenario combinations to determine the near-optimal configuration to reduce the man-hours spent to pack a batch.

6.1 Model Assumptions

During the development of the model assumptions were made:

- Line workers are trained to perform all operations at all of the workstations. No learning curves were modelled and as a result it was relatively simple to add and subtract workers to balance or rebalance the line and adapt to change configurations.
- Boxes were set up before a batch was packed, thus the time taken to setup boxes was excluded and the labeller only needed to pack a finished packet in a box.
- The portable sealer machine(s) and portable scale(s) are the resources on the line. No breakdown times were modelled for these resources.
- Quality rejects were not included in the model, i.e. no batches were sent back to the drying area and in effect upheld the packing line.
- Quality inspections were done while batches were staged and was not included in the simulation of the model.
- The line is operational 123.25 hours a week. Monday to Friday have three 8-hour shifts with a 30min break. Saturdays are scheduled as one 12-hour shift with 1h15min of break time included.
- Customer demand is 8 batches per shift of the Rusk A class.
- Transfer times from staging lanes were considered to account for repositioning losses.
6.2 Input Data

The process of collecting input data can be very time consuming. All input variables were determined from the conceptual model. Sources of input data include ERP systems, floor observations, design estimates and information from SME’s. To acquire accurate results from a simulation study, it is important obtain the right fit of a statistical distribution of processing times at each workstation [9]. However samples are often not large enough to apply goodness-of-fit tests. Banks et al. [10] recommends that for conditions with inadequate or limited data one is to assume uniform, triangular or beta distributions.

Time studies were conducted on the processing and transfer times of Rusk A line using the Android Time Study application developed by Hartman & Lambert [11]. The sample sizes were inadequate to perform theoretical goodness-of-fit tests. However with the data available the distribution fit tool, EasyFit, was used to fit and propose possible distributions. The available data was also processed in Microsoft Excel® to look at minimum, maximum and average processing values. The suggestion of Banks et al. [10] to use triangular and uniform distributions where data samples are inadequate for goodness-of-fit test were followed. For all three station processing times the assumed distribution used was ranked in the top 5 distribution fits by the EasyFit software.

A summary of the distributions used for the station processing times are illustrated in Table 1 below.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Distribution</th>
<th>Parameters [seconds]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pack &amp; Weigh</td>
<td>Triangular</td>
<td>9,25,44</td>
</tr>
<tr>
<td>Seal</td>
<td>Uniform</td>
<td>4,7</td>
</tr>
<tr>
<td>Label</td>
<td>Uniform</td>
<td>4,8</td>
</tr>
</tbody>
</table>

The inter arrival time of batches occur in bulk arrivals of 4 batches every 2 to 4 hours with a limit of 8 batches per shift arrival.

6.3 Verification and Model Validation

The current layout was modelled to be compared to historical data. A statistical analysis was performed to establish the number of replications needed to yield the valid results as proposed by Law [12]. The base processing model of 2 packers, 1 sealer and 1 labeller compared within a 95% confidence interval to the current batch average processing time of 55 minutes. Figure 6 shows the model animation in Simio®. After the verification of the base model different scenarios are compared by utilising the experiment tool combined with the Kim Nelson method to compare variability.
6.4 Analysis of Line Balancing and Labour Utilisation

Six different staffing scenarios were setup using the experiment tool in Simio®. These scenarios compared various staffing configurations at the rusk packaging line. The scenarios considered only include physical possible configurations. The Pack & Weigh station was identified as the bottleneck station with a 65% utilisation for the “As-is” configuration. This could be verified since the Pack & Weigh station has an average processing time of 25 seconds compared to an average of 5.5 seconds for the Sealer station and 6 seconds for the Labelling station. Figure 7 is a graphical representation of the Kim Nelson comparison of the different scenarios. The Kim Nelson method aims to compare scenarios and on a statistical significant level indicating process variation [13].

Scenario 3, consisting of 4 packers, 1 sealer and 1 labeller, operated the line under the least process variation and brought the average batch packing time down to 27 minutes. This scenario overlapped with scenario 6 where 4 packers, 2 sealers and 2 labellers were involved in the line. Table 2 is a comparison of the scenario’s station utilisations, average batch packing times and man-hour per batch indications.

It can easily be seen that scenario 3 offers the most viable improved solution. The line is better balanced and the average batch packing time is the least without any significant investment in an additional sealing machine.
Scenario 3 also accomplishes to complete the batch in the shortest man-hour time of 162 minutes. This scenario was implemented on the packaging floor. The outcome was that it is possible to pack a batch within 25 to 30 minutes with 4 packers, 1 sealer and 1 labeller.
7 CONCLUSION

The study demonstrates the application of Lean and Optimised Production Techniques incorporated to facilities design and how the employment of these techniques can improve labour utilisation.

The distance of batches travelled was reduced by routing the flow of batches along a shorter path. At the same time unnecessary motion and waiting was reduced by dedicating staging lanes to products and orderly grouping products together in a first in first out manner. The reduction of such wastes ultimately increases labour efficiency.

The study further integrated lean line balancing techniques and utilised simulation modelling to compare and balance the rusk packing line. Bottlenecks were identified; processing times minimised to finally improve labour utilisation in terms of man-hours per batch. The proposed optimal solution was presented and tested successfully to validate the simulation model as a representation of the real world.

With the near-optimal number of workers determined to pack batches, the limit exists that, when it comes to practical implementation, staff scheduling is a problem to allocate the amount of workers to pack a batch as effectively (least man-hours) as possible.

With the Pareto Profit-Volume approach followed it is recommended that the next product or family lines be analysed in a similar manner, staff scheduling be done in accordance with demand and production to allocate the amount of workers to a packaging line to pack a batch as effectively as possible.

8 REFERENCES:


APPENDIX A: "AS IS" FLOOR LAYOUT OF RUSK A PRODUCT FAMILY
APPENDIX B: PROPOSED FLOOR LAYOUT FOR THE RUSK PACKAGING AREA