Simulation Modeling and Analysis of Line Length and Batch Size in Footwear Factory

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Abstract

In footwear manufacturing, factories tend to maintain production lines at a certain length. Various considerations are put into factory design, but line length is perceived more as a customary setting since it is related to order size, space availability and machine requirement. However, even when they can opt for different production length (e.g. when they plan for a facility whose order are smaller than usual, or vice versa), using different line length is not seen as a necessary or viable option. This study aims to look into the effects of production line length on the performance of a production facility. Additionally, aspects which influence the performance of footwear production facility will be investigated. These factors include the size of transfer batch among production areas, different shoes styles, and different levels of variation in the processing time. To accommodate fair comparison, we build a simulation model based on a length-switch-enabled projection of real facility. The development and validation of the model was done in cooperation with experts from Asian-based footwear factories. It was learned from simulation results that line length has impacts on production. Different manners of impact were discovered in diverse manufacturing conditions. These impacts vary among different production areas.

Keywords
Simulation, facility design, production line length, production batch size, footwear

1. Introduction

1.1 Background

Footwear is a large and rapidly growing industry. Data shows that no less than 21 billion pairs were produced in the year of 2011 (Portuguese Footwear, Components and Leather Goods Manufacturers' Association (APICCAPS), 2011). That was three times the number of people inhabiting the world throughout the year (United Nations Population Fund, 2011). Although brand owners are typically western countries, almost 90% of these productions took place in the powerhouse of footwear industry: Asia. Shoes produced in the continent are normally mass-produced by a lot of different factories. They may vary in terms of design, production policy, shoes types or styles but as the size of footwear factories and the variation of order size increase, factories still tend to order similar line-defining equipment and maintain their production lines at a certain length. Two major brands, for example, still keep their preference of production line length until today, one goes for longer lines and another works with shorter ones.

In order to obtain a general understanding of what impacts line length has on production, this research will attempt to perform an analysis on a factory-wide level. This means that the study will extend over different processes of shoes manufacturing. Koo et al. (2007) showed that the number of items or parts transferred from one area to the next affects the entire facility's capacity. Another important factor in this article is hence the production batch size. As such, we will try to set apart the effect of batch size in regards to line length. This production batch size is not to be confused with the method of estimating the variance of the sample mean of a stationary output process commonly used with the method proposed in this research (Schmeiser, 1982; Goldsman and Nelson, 1990).

1.2 Objectives

This research aims to

- Build a representative model of a footwear manufacturing facility working on identical shoes styles with different line length configurations.
- Discover which line length setting and production batch size improves the performance of the facility in terms of productivity and utilization.

2. Literature Review

2.1 Existing Works in Footwear Manufacturing Industry

Apart from the technology advances and modernization, today's process of making shoes still has its resemblance to the way it was decades ago. The industry is in fact one of some who retains a labor-intensive manufacturing. Golding (1902) comprised a complete reference for shoe making which provides a better illustration of how procedures in the factory are carried on.

Nisanci and Sury (1980) studied the characteristics of production system in an actual shoe manufacturing factory. They used simulation to experiment on scheduling rules and found that different improvements could be obtained. This, however, vary from department to department. Certain departments in the production were also found to need a larger size of operation and batch size. This study displayed the importance of distinguishing performance measurements among different departments of a footwear production. It also urges our current research to include other factors which may have impact on the overall performance of a factory. Eryilmaz et al. (2012) used simulation to analyze the performance of a footwear factory. Criteria such as production rate, duration, queues, and resource utilization are compared between different numbers of model produced in a facility. Result shows that a factory's performance is affected by the number of model it needs to work on. Not unlike other industries, the market has demanded a smaller-sized production of more diverse shoes. This requirement will also be addressed in this research. Other works with regards to production of mixed products can be found in Hasgul and Buyuksunetci (2005) and Nazarian et al. (2010). Many factors like material handling and changeover should be addressed carefully in mixed production. This research will try to build a basic construct that represents multi-product manufacturing in footwear factory, and see if different line lengths have any effect on this type of production.

3. Methodology

Aside from the research team, some experts from footwear factories are also involved to develop the case of the research. Having got the experience and familiarity with the field, they supported the process of problem formulation, data collection, and validation. This party will be referred to as the client from this point forward.

The root of the problem was production line length, but through this early step, other accompanying factors, especially batch size, were identified. The idea of the research was then used to consult with client. After the issues that need to be addressed have been finalized, the data collection process was started. Because the model-to-be needs to be an embodiment of cross-production facility (i.e. carrying out the production using two different configurations of different factories to manufacture certain style), the data collected cannot be pure observations from the clients' factory. Instead, a projection based on existing operation was constructed. This projected facility has the capability to produce certain styles and the specifications of two different production line lengths: long & short. Hence, comparable models representing different line lengths can be built. The data obtained from the client was not without limit. It took quite some repetition of collecting effort before the minimum requirement of what the research needs can be fulfilled. The rest of the data insufficiency was able to be dealt with in the experiment.

The next two phases of the research are construction and analysis. In the construction period, concepts and data from the preparation phase are used to build the simulation model. This model is then validated using several parameters, also against some data from the client. The early models are those following default configurations of the projected facility, one for long line and one for short line. Once the valid models have been obtained, they are taken into the next phase, analysis. In this concluding part of the research, the model is modified according to the variables of the experiment. The output of the experiment is then analyzed and used to develop a conclusion and recommendation for future study. Outline of the research steps can be seen in figure 1.

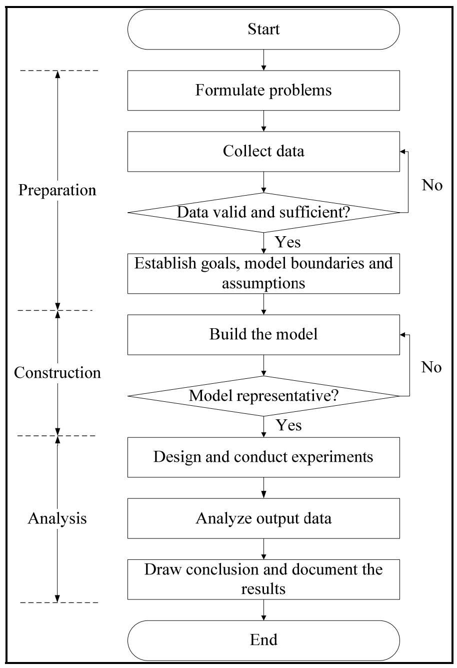

Figure 1: Flowchart of the Research Processes

4. Problem Description

4.1 The Line Length Distinction

As the primary subject of the research, it is necessary to state that there has not even been a solid definition upon the length of a production line. Companies perceive the way they arrange their production as length-less, meaning that most of them are not even aware if they actually tend to organize their production at a certain length. However, using throughput, number of workers, and length of conveyors, it is not too hard to tell if a line falls closer in the category of long or short line. Given its stringent specification, conveyor length is the strongest point to argue the line's length; number of operators and throughput of the entire line normally conform to it. In addition, longer lines' conveyors are set up to enable double process. This is done by separating each conveyor into two running halves. In this study, clients have specified that long lines are estimated to produce 2000 pairs per day, whereas short lines make 1200 pairs per day. Using this, projected units produced per man-hour (UPMH) and order size, we will have the required number of operators.

It is important to point out that the above factors should be observed in a line's assembly area, where the conveyors are mainly located. According to the clients, it is safe to say that a line can be considered long and short through its assembly area. In addition, changing line length means that the ratio of assembly line to others will change. As suggested by clients, assembly area of a long line works with two lines of short line's other areas.

4.2. Overview of Shoe Manufacturing Process

In general, there are three big groups of processes in the shoe making. The shoe itself is separated into two major parts: upper and bottom/sole. The making of these two parts are the first two groups. Another one is the process of combining the two into a complete shoe. However, making soles is almost entirely chemical. Factories working on them, called soles or chemical factory, are separated from the shoe making itself. Therefore, shoe manufacturing facilities normally work only on upper making and assembly of the two parts.

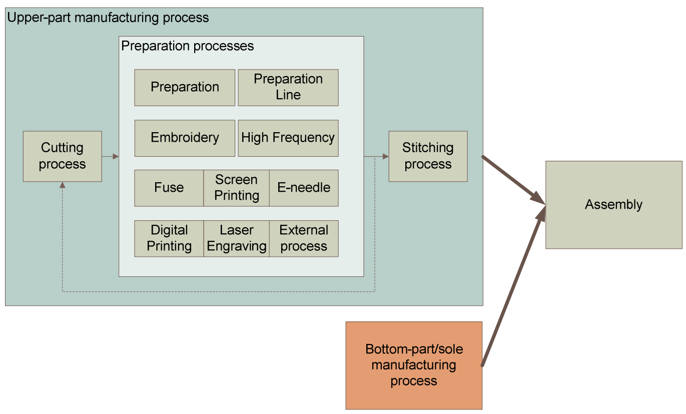

Figure 2: Complete Illustration of Shoe Manufacturing Processes

4.3 Facility Layout

The facility is a two-story building, extending to 120 meters in length and 36 meters in width. One floor hosts the fixed processes: cutting, preparation, preparation line, waiting for collection, stitching, and assembly. The other floor gives space to secondary processes: embroidery, screen printing, fuse, high frequency (HF), e-needle, digital printing, laser engraving, and representation of external processes.

4.4 Shoe Styles

Four styles of shoes implemented in this study will be referred to as style A, B, C, and D. Different shoes styles have different parts, process duration at each station, number and composition of steps, and routings. Essential differences between these four styles are presented in Table 1.

Table 1: Specification of Different Shoe Styles

	Style A	**Style B**	**Style C**	**Style D**
Parts	16	21	12	22
Steps	54	68	46	71
Production Lead Time	4043	5041	7296	7311

5. Simulation Study

We propose a discrete-event simulation (DES) model using Flexsim 6.0 which allows the model made in it to be modified using C++ code and a language of its own, flexscript. Moreover, it provides 3d visualization and ease of modeling.

5.1 Modeling Processes

There are a total of 14 working areas in the facility. Areas whose capacity are not yet specified (those aside from stitching and assembly) are first designed based on this layout. The capacity is then changed according to the simulation-based calibration. Followed by arrival, processes to completion, several specifications are included: model specification, internal specification, table-based specification, global specification, and running specification.

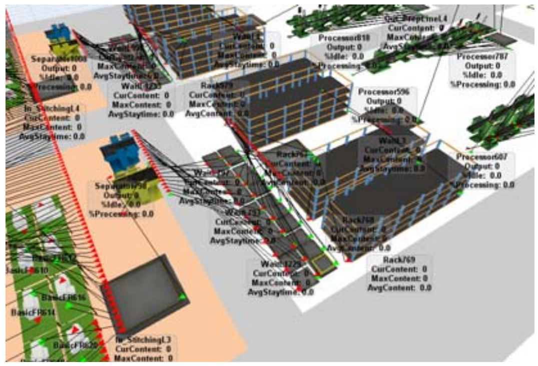

Figure 3: 3D model of real facility

5.2 Verification and Validation

In this model, verification is done by tracing the model, both manually (on the codes) and visually. Entity information can be displayed in Flexsim's 3D visualization. Hence, we can check if some anomalies happen while running the model, e.g. process happens too fast, incredibly high WIP, 100% idleness, parts not visiting certain areas, etc. Output inspection is used to validate the model. We check if the rate of output has met the requirement stated by clients in the design. By doing this analysis, we will be able to see if the level of fidelity of the model can meet the specification in the design and meet the requirements of the intended use, i.e. the real situation.

6. Output analysis

6.1. Design of Experiment

Factorial experiment was conducted to analyze all the different factors considered in this study. Since there are more than 3 factors and different number of levels, arranging the experiment in factorial design is more efficient than doing it factor-by-factor. The production lead time of style A & B shoes which is notably shorter. To exploit the difference any characteristic may have on the impact, A and B are grouped in one production, while style C and D form another one.

The main factors, also the decision variables, are line length and production batch size and there are two levels for line length, long and short, and three levels for batch size, 40, 80 and 160. The other two factors are design-related factors, variation in processing time, which has two levels: 30% and 15%, and area. Style A&B uses only 8 out of 13 areas while style C&D uses 11 areas, which do not represent any direct decision that can be made in the facility.

6.2. Results and Discussion

6.2.1. Effects on UPMH

The following test shows that all the factors are uniformly significant towards UPMH. However, it can be seen that the effect of line length in style C & D production is relatively small. This might be caused by the different complexity level of the style groups, especially production lead time. Despite its lowered difference, performance comparison is still preserved. It can still be seen that there is an increasing trend along the long-short line, with short line slightly higher (mean = 0.427340) than long line (mean = 0.424073).

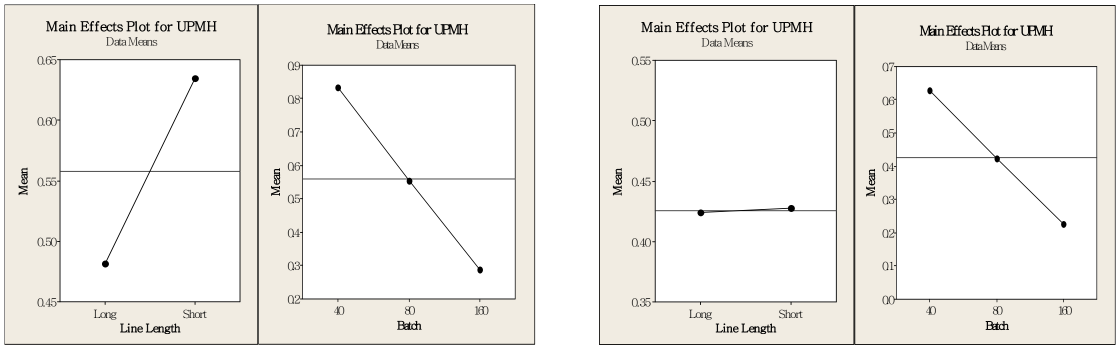

Figure4: UPMH Effect Plot of Style A and B Production (Left two) and Style C and D Production (Right two)

6.2.2. Effects on Idle Time

The second parameter for performance comparison is idle time, from which the utilization of resources can be inferred. Unlike UPMH, lower idle time means better utilization – better performance. The previous ANOVA test has shown that idle time is significantly affected by all of the main factors and in the production of any style. Figure 27 until 30 shows the plot of different idle time means at different levels of factors.

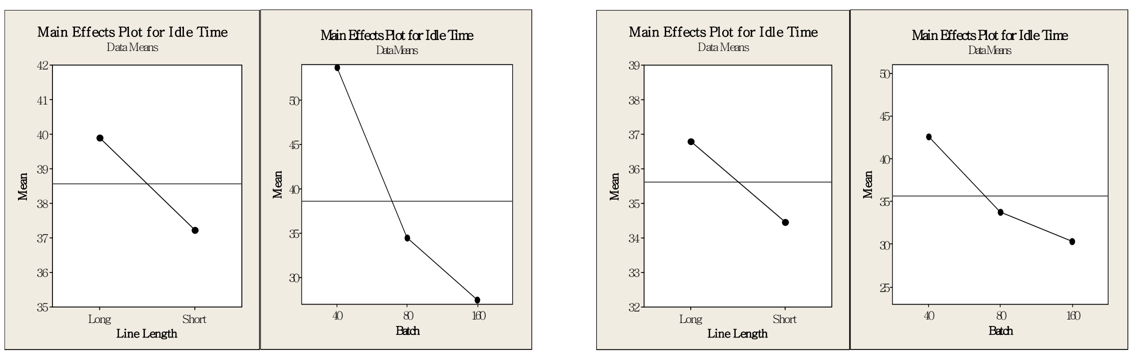

Figure5: Idle Time Effect Plot of Style A and B Production (Left two) and Style C and D Production (Right two)

7. Conclusion

The results show that lines with shorter configuration and smaller batch size give out the highest rate of UPMH. Consequently, shorter configuration results in lower level of idle time, indicating better utilization. However, with the batch size, the effects are twisted by the large proportion of workstation areas with tight capacity. Smaller batch size allows a speedier production such that majority of the areas need not much time to complete the production. Bigger batch size drags down the whole facility's performance, creating bottlenecks and keeping most of the areas busy the whole time. As a result, short line and bigger batch size deliver a lower rate of idle time. Through the experiment, it was found that this result applies generally, despite the styles worked on in the facility. However, the existence of setup time reduces the superiority of this better-performing level, particularly production batch size. The use of bigger batch size was found to be more stable when the facility runs more than one style in a production line. As indicated by the results, when the duration of setup time is big, bigger batch size may produce better performance.

During the study, simulation was also utilized to support the development of facility projection. It was used to fill in the gaps for areas whose capacity is not properly specified and find potential bottlenecks. Still, the main contribution of this study is finding the difference between long and short production line, along with factors that may affect the facility's performance, mainly production batch size and variation in processing time. The purpose of this study was not to declare a universal pattern of how line lengths and other said factors affect the production, but to investigate if there is any difference made by arranging lines using different lengths in the world of footwear industry.

Nonetheless, results have been expanded to cover different kinds of shoes styles to better address different manufacturing situations in the real footwear industry.

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Biography

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