ABSTRACT

This paper presents the use of simulation to assist the decision-making process involved in implementing lean manufacturing principles at a carton box die factory. The paper describes the application of discrete event simulation to improve and optimise the performance of the carton box die assembly line. Simulation experiments measure each system’s resource requirements and performance, quantifying benefits to be derived from applying the principles of lean manufacturing. In this study, Simio® is used to model and simulate different experimental scenarios in order to quantify the impact of selected input parameters on objective functions such as lead time. Results show that changes in the layout can reduce workers’ movements and increase productivity.

Keywords: Lean Manufacturing, Industrial Simulation, Carton Box Die Assembly Line

1 INTRODUCTION AND LITERATURE REVIEW

Simulation is one of the most valuable decision-support tools used by practitioners to solve production issues. The objective of simulation can be that of quantifying performance improvements which can be expected from effecting changes. Simulation is able to demonstrate the benefits of making some decisions throughout the entire manufacturing system. Finally, simulation through animation can provide a visual and dynamic illustration to management of how the new system would work (Ferreira et al. 2011a; Ferreira et al. 2011b). Computer simulation is particularly useful in analysing systems which incorporate randomness in their parameters or when there are no exact analytical solutions (Lucko et al. 2008). Basically, simulation constitutes a technique which allows for the transfer of reality into the computer, through the construction of a model which accurately mirrors the behaviour of a process (in existence or in its project phase) (Ferreira et al. 2010; Ferreira et al.
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2011c). By using this technique, it is possible to proof the real performance of several models, simply by varying a parameter, without unnecessary expenditure. In this manner, it is thus possible to maximise productivity in a real-life scenario.

Lean manufacturing is a philosophy for structuring, operating, controlling, managing and continuously improving industrial production systems. The key points of this philosophy include process stability, standardized work, balanced production, visual control, continuous flow production, time inventory management, etc. For additional information, readers are referred to Shingo (1989), Womack et al. (1990), Monden (1993) and (Julien and Tjahjono, 2009).

A review of the literature reveals that not much research has been explicitly undertaken with the purpose of applying simulation techniques to studies that specifically demonstrate the application of the principles of lean thinking and execution in production systems. This could be due to the lack of a comprehensive mechanism to identify the most significant lean drivers for the purpose of system processing optimisation. The works which show a narrow relationship between the production-simulation environment and the lean manufacturing philosophy can be grouped into two general categories:

- The use of simulation to establish specific parameters of a lean manufacturing system. For example, Lummus (1995) used simulation to study three production-sequencing strategies (mixed-model, minimum setup, and demand pull).
- The use of simulation to design, test and improve lean systems. For example, Carlson and Yao, 1992) used simulation to pre-test various flow layouts for a low-volume, mixed-model JIT assembly system.

In this study, one resorted to Simio®, a rather innovative simulation tool, to model and simulate two different scenarios in order to understand and quantify the impact of selected input key lean variables on objective production parameters, such as lead time. Simio® was developed in 2007 and represents a new approach in simulation object orientation. Among other characteristics, one should highlight that Simio® supports (Pegden, 2007) (www.simio.com, accessed 1 January 2011):

- Creation of 3D animation in one step, importing 3D objects from the Google 3D Warehouse.
- Importation of data from Excel worksheets.
- Its own logic function (e.g. priority rules) in many languages (C++, Visual Basic, etc.).
- Creation of its own intelligent objects and libraries.

2 METHODOLOGY

In the first phase, useful information for the study was collected in order to adequately represent the current process; a detailed analysis of the production processes was then carried out to produce the various types of carton box dies.

The data used to feed the simulation program were obtained from an existing ERP, where important variables of each production module are updated manually. After a preliminary analysis, a simulation model representing the behaviour of the entire factory process was constructed. The model was fed with the data from the ERP system. In the second step, the model was validated by comparing actual results with those obtained in the simulation model.

The application of lean manufacturing principles has led to the study of some parameters, thus allowing for improvements to be carried out. This will help the company to make the most effective decisions in order to reach its objectives. Some lean-manufacturing improvement proposals were:

- Changes in the plant layout could result in a reduction of lead times, by simplifying the product flow.
- The redistribution of workers in the factory could streamline production to meet customers’ orders.

3 DEVELOPMENT OF THE MODEL

This work comprises the analysis, modelling and simulation of a carton box die factory. The system manufactures two types of carton box dies (rotary and flat). These two forms of dies for cutting are
shown in Figure 1. The assembly line was modelled using Simio®, a discrete-event simulation tool (see Figure 2).

![Figure 1 Rotary and Flat Carton Box Die](image1)

![Figure 2 Screenshot of the Simulation Model](image2)

In the model, any manufacturing order could be represented. The orders arrive at the system with an arrival pattern that is based on an arrival table. The processing times of stations were taken from the ERP data of recent years (see Figure 3). These times, are naturally assumed to possess a tendency to follow a normal distribution in this type of manufacturing process. Therefore, statistics software was used to contrast the normal distribution considered to be intrinsic to the ERP, although this sometimes presents a very high standard deviation. This study revealed that normal distribution appears to match these data.

In the modelling process attention must be drawn to the different processing times for each type of product. Apart from these different processing times, orders must follow the predefined paths set in the model. Each order is a completely different entity and is launched into the system through a schedule provided by the ERP.
The aim of using simulation as a decision-making support tool is that of evaluating the performance of a system during a specific period of time. Most simulation models start off with an empty system and with free resources (Majan and Ingalls, 2004). In fact, the observation gathered during the initial period of simulation will affect the accuracy of the model’s performance measurements, leading to the formulation of erroneous conclusions regarding its performance (Ferreira et al. 2011b). In accordance with this, a warm-up period of 1 hour was considered for this study. During this period, the data collected were not considered for statistical purposes. The model was finally validated by comparing the simulation results of twelve orders programmed over a 24-hour period (see Table 1) and confronted with real data taken also taken from the ERP, which stores all the times for each order during that period.

### Table 1 Data for Validation

<table>
<thead>
<tr>
<th>DIE Nº</th>
<th>Time in Simio (Hours)</th>
<th>Real Time in ERP (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.1</td>
<td>11.9</td>
</tr>
<tr>
<td>2</td>
<td>15.5</td>
<td>15.0</td>
</tr>
<tr>
<td>3</td>
<td>4.3</td>
<td>3.8</td>
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<tr>
<td>4</td>
<td>3.2</td>
<td>3.1</td>
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<tr>
<td>5</td>
<td>3.1</td>
<td>2.8</td>
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<tr>
<td>6</td>
<td>15.6</td>
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<td>8</td>
<td>12.5</td>
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<tr>
<td>12</td>
<td>9.9</td>
<td>10.3</td>
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4 RESULTS

In order to apply the previously-presented methodology, one ran simulation experiments to test some of the proposals of the lean manufacturing concepts. One of these involves changing the plant layout and consists of comparing the actual layout with a new layout proposal, both using the same resources. The simulation experiments are fed with the same schedule data used for validation (see Figure 3). After running simulation, the results presented in Figures 4 and 5 show that one has managed to increase production from 9 to 11 in the carton box dies cut per day. This therefore implies an improvement of more than 20% in throughput. The simulation related with the lean manufacturing proposals of the application of reallocation, an increase or reduction of workers are, as far as tests seem to reveal to this date, not conclusive in their results.
5 CONCLUSIONS

Simulation can be used to support decision-making and to evaluate the impact of various opportunities for improvement. Ideally the simulation model can be used to evaluate the alternatives. Discrete-event simulation has proved to be robust as a tool to help quantify the benefits of lean manufacturing. The use of the simulation described in this paper can provide credible estimates for the savings in shop-floor resources and the improvements in the time-based performance statistics to be attained with lean manufacturing. In the case study presented in this paper, the simulation model demonstrated the impact of lean principles in terms of reducing transportation time and floor space, which results in significant savings in the company’s running costs.

Future work in this project would include the use of real-time data and the development of more realistic 3D animations in the model. Another line of investigation is that of obtaining a more realistic simulation model and more helpful decision-making elements by analysing the input data through fuzzy logic, as well as the application of new lean manufacturing concepts as rearrangements in workstations based on 6S techniques so as to generate different processing times in any workstation where these approaches could be applied.

REFERENCES


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