MODELING AND SIMULATION OF A MATTRESS PRODUCTION LINE USING PROMODEL

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ABSTRACT

Understanding the current manufacturing setup and accurately predicting the performance of a system over time makes modeling and simulation an ideal tool for systems' planning. This case study aims mainly at exploring the application of modeling and simulation (M&S) in order to evaluate and provide performance results that could help measure the capacity and the capability of an existing mattress production line, and to further investigate whether the production line could cope with the firm's expansion plan over the next five years. The simulation model was built and analyzed using the ProModel discrete-event simulation software. The analysis found that the current production setup could not cope with the demand over the next five years. Therefore, potential improvements within the production line were identified and implemented in an improved scenario model. The results indicated that the new system was able to meet the new demand and cope with the proposed expansion plan.

1   INTRODUCTION AND LITERATURE REVIEW

M&S has been a useful tool to design, analyze, evaluate and improve manufacturing systems for decades (Sona et al. 2003). "Its unique ability to accurately predict the performance of complex systems makes it ideally suitable for system planning," stated recently by Harrell et al. (2012).

Over the last couple of decades, parallel to the dramatic technological development, several business and information technology support companies have developed and delivered commercial M&S packages to the market. M&S software packages, like ProModel, ARENA, SIMUL8 and Plant Simulation, opened the new horizon for manufacturers and gave them the opportunity to use M&S in process optimization and decision support systems.

M&S is a powerful and useful tool for the manufacturing environment. Clark (1996) emphasized the importance of M&S in manufacturing by stating that "Manufacturing is one of the earliest simulation application areas and remains as one of the most popular application areas." Williams and Narayanaswamy (1997) observed that "Simulation has a long and strong track record in analysis of manufacturing systems whose complexity and interaction of components defy closed-form methods." Such statements prove the value and the importance of M&S in the manufacturing environment.

The applications of M&S in manufacturing are really vast. Abu-Taieh and Sheikh (2009) found that 14 percent of M&S packages available in the market were targeting the manufacturing sector. M&S in the manufacturing sector includes non-developed system modeling and current system development and analysis. The analysis of such systems included scheduling, sequencing, processing, material handling and resources planning. M&S is also used in the warehousing and distribution centers, which are major parts of the logistics sector. M&S can help the manufacturing sector in the Job Routing, Factory Flow,

Plant Layout, Capacity Planning, Staffing Optimization and Machine Reliability Effect (Arena Simulation Software, 2012).

Qayyum and Dalgarno (2012) used M&S to improve the capacity of a manufacturing facility, of a Small and Medium Enterprise (SME). Clark (1996) demonstrated the applications of M&S in manufacturing systems. He developed a model for a mould production cell in which he wanted to ensure that the cell met the design objectives, and to assist in specifying equipment performance capabilities. He concluded that "Simulation is a powerful approach to modeling manufacturing systems in that many complex and diverse systems can be represented." For example, if a production team in a manufacturing firm, with more than a hundred processes and resources, was required to identify problems such as bottlenecks, machine utilization and resource allocations, it would be a really difficult task to answer these questions without the use of M&S.

The concept of bottleneck management for manual automobile assembly systems through simulation was recently developed by Dewa and Chidzuu (2012). They created the required model with a focus on improving automobile assembly systems in batch mode. A complete time study was performed to collect the input data required for each workstation and operator to perform the task. After verification and validation, the model was analyzed with a special focus on the effect of vehicle sequencing, the effect of batch sizes, the individual vehicle models, the effect of a subassembly and the effect of downtime on the bottlenecks. They concluded that "the machine with the highest degree of utilization does not necessarily have to be the bottleneck. When the model is simulated, one could trace the bottleneck by finding out which machine is blocked most. The machine next to this one is the bottleneck."

Quackenbush (1968) and Silva et al. (2000) observed that it is vital to have people from the industry throughout the entire project to help the model developer and emphasized the importance of accurate information (data) in simulation projects.

Nikoukara and Paul (1999) emphasized that the selection of suitable simulation software is also of considerable importance to any simulation project. They, along with Tewoldeberhan et al. (2002), were concerned that the selection a suitable simulation package will be more difficult as the quantity and quality of those software packages increases. Thus, the need for a methodological approach for selecting an appropriate simulation package using appropriate evaluation tools and techniques was apparent.

Grant (2002) and Abu-Taieh and Sheikh (2009) provided extensive surveys in the literature showing that the ProModel software was best suited to business process re-engineering and workflows. Harrell and Price (2002) have argued that ProModel is "designed to model manufacturing systems ranging from small job shops and machining cells to large mass production, flexible manufacturing systems, and supply chain systems." Lu and Wong (2005) also described ProModel as a powerful and easy-to-use manufacturing simulation tool for modeling all types of systems and processes.

Tearwattanarattikal et al. (2008) used ProModel software to compare the performance utilization of machines, characteristics of work-in-progress (WIP) and the ability to meet due dates. They defined the expanding capacity policy as "extra shift-working hours or increasing the number of machines." The physical layout was then chosen based on the space available for the WIP flow.

Based on our literature review, the new contributions of this paper are as follows:

(1) We develop and analyze a specific simulation model for an existing mattress production line;
(2) We analyze different output analysis approaches. Greater focus is given to identify suitable methods for determining the warm-up period and the number of replications;
(3) Through analyses of results we show how potential improvements could be identified and designed into an improved model.

2 PROBLEM DESCRIPTION

The company on which this research project was based is one of the fast-growing mattress manufacturing companies in the Persian Gulf region. Since 2010, the company started to follow an aggressive expansion

strategy with an aim to expand its presence into two new countries every year. The management at the company posed 'one big question', and that is whether the current manufacturing setup could cope with the expansion plan and meet the demand of the market over the next five years, as shown in Table 1.

To answer this question, the company agreed to measure the capacity and capability of its mattress production line based on some pre-defined performance measures, such as average throughput. M&S was one possible way for measuring the capacity and capability of the production line. Since M&S is an excellent way to study the performance of manufacturing systems, the company management decided to collaborate in a research project. As a result, it became possible to investigate the capacity and capability of the mattress production line and also to explore any opportunities for improvements.

Table 1: Demand projections of mattresses during years 2012-2016.

The Demand Projections for the Years 2012-2016					
Year	2012	2013	2014	2015	2016
Quantity/year	172,693	192,948	215,371	240,259	267,857
Quantity/month	14,391	16,079	17,948	20,022	22,321

To model the production line using M&S some key issues had to be resolved. Firstly, the detail level of the proposed simulation model, the accuracy of the collected data, and the key performance measures had to be discussed and agreed upon with the company. The second issue was to determine the steady-state behavior of the simulation model. Hoad et al. (2009) suggested considering two key issues in order to ensure the accuracy of the output parameters: "first, the removal of any initialization bias; second, ensuring that enough output data are produced." Nuyens et al. (1996) went further by stating that "the typical performance measures, output parameters of interest, such as, average throughput, average response time or system utilization must also be measured in steady-state."

The output result analysis enabled the identification of the transient period, the number of replications and the length of the simulation run. As part of the scope of the study, simulation output had to be analyzed thoroughly in order to identify the methods best suited to the study parameters. There were several methods available for analysis in the literature.

3   MANUFACTURING SYSTEM DESCRIPTION

The mattress production line is composed of five major departments: Spring, Foam, Quilting, Tailoring, and Mattress Build Up, as shown in Figure 1. To better understand the production process, various steps of constructing an innerspring mattress are described below.

The construction of a mattress starts with the production of coils in the spring department. Four automatic coiling machines are utilized to produce the required coils from raw steel wire. Chassis production is the next step in the mattress construction. Four semi-automated assembly machines are used to interconnect the coils in rows by helical wire. The number of coils in each row may differ based on the chassis size. For each assembly machine an operator is responsible for using the available buffer stock to feed coils into the assembly machine.

Before transferring the chassis to the clinching section, borders and corners are produced on frame bending and corner making machines. Both borders and corners are then transferred to a separate buffer stock near the clinching section. The clinching section is composed of five clinching tables. At each table an operator is responsible to collect one chassis, two frames, and six corners from assigned buffer stocks, attach them using a pneumatic clinching gun, and transfer the finished chassis to the mattress build up department.

While the chassis is built up in the spring department, the decorative cover that serves as the exterior for the top, bottom and sides of the mattress are produced in the quilting and tailoring department. First, quilted fabrics and borders are produced on giant automated CNC quilting machines in the quilting

section. Fabric, cotton felt, threads and foam roll are the raw materials required to produce both the quilted fabric panels and borders. The outputs of the machines are then transferred to the tailoring section.
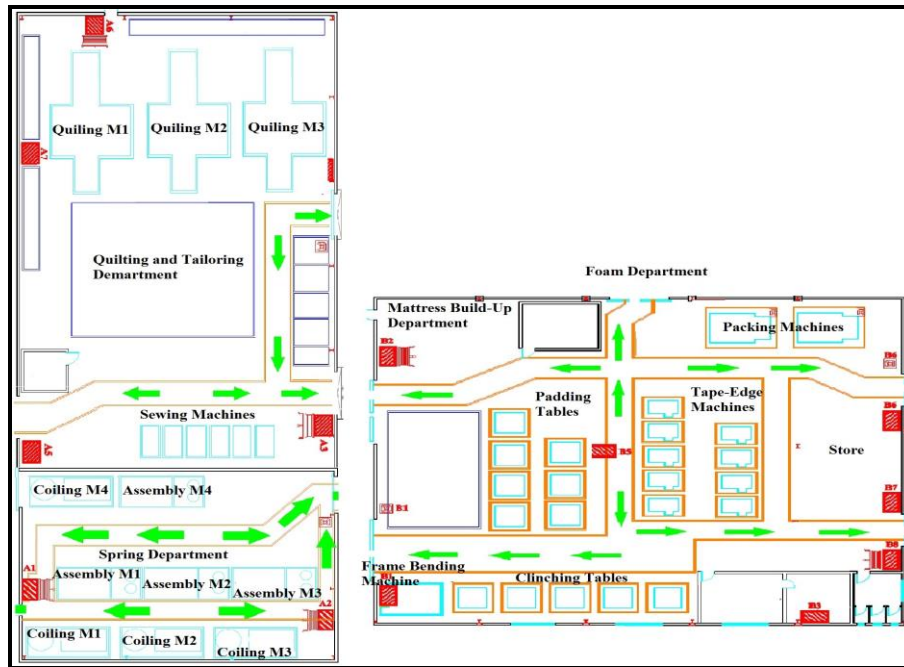

Figure 1: Production layout.

Six sewing machines, five panel sewing machines and one border sewing machine in the tailoring section are awaiting receipt of quilted fabric panels and borders. After sewing the quilted fabric panels and borders, product names change to ready panels and ready stitched borders, respectively. Attached borders and quilted fabric panels are then transferred to the mattress build up department.

The mattress build up department is the final stage of mattress construction where chassis, panels, borders and foam layers are assembled together to form a high-quality mattress. The department consists of three sections: padding, tape-edge and packing. In the padding section, seven operators work on seven padding processing tables to attach different layers of cotton felt, plastic mesh and foam sheets, which are received from the foam department, to the chassis. The produced item, called a padded mattress, is then transferred to the tape-edge section.

Nine tape-edge machines are used to manually feed the top, bottom, and side panels and a heavy-duty binding tape into the sewing machine as it moves around the padded mattress. The tape-edged mattress is then transferred to the packing section. Two semi-automated packing machines are utilized to pack the taped-edge mattresses. Once tags and labels are attached to the mattress, an operator inserts the mattress into the packing machine. Finally, the packed mattress is transferred to the finished goods store.

4   INPUT ANALYSIS

Collecting and analyzing data for specifying the corresponding inputs to a simulation model in an accurate, realistic and valid way is of paramount importance. However, it is a very laborious and time-consuming task which in some cases can take up to several months (Weiss and Piłacińska 2005).

Figure 2 illustrates a schematic diagram of material flow in each of the spring, quilting and tailoring, and mattress build up departments. The flow chart was devised in order to help the model-building process, and to identify areas of interests, such as a list of all materials, machines and processing tables required for the study.
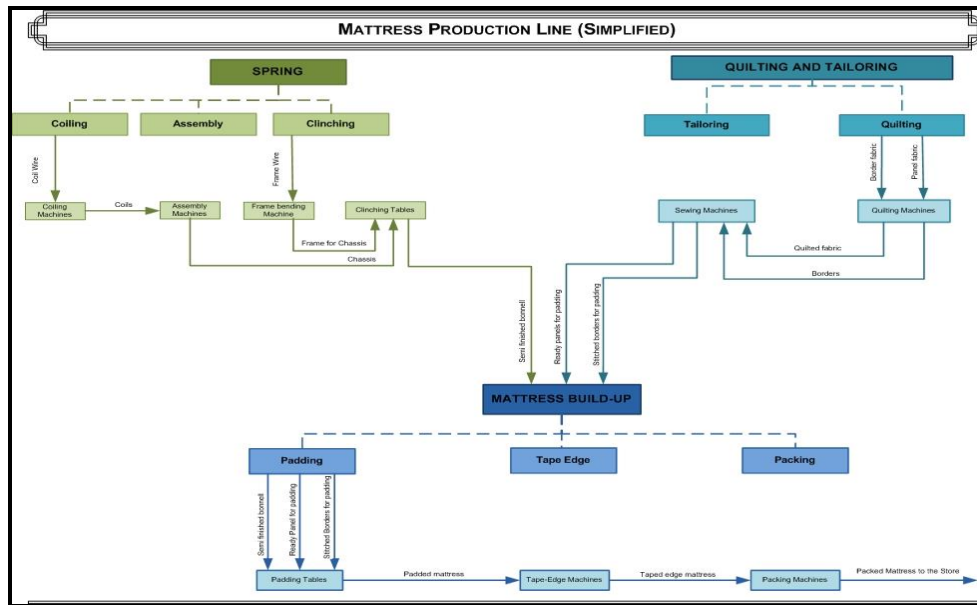
Figure 2: Revised material flow chart.

Table 2 shows that the production line consists of nine different machines and processing tables. Some are automated; others are either semi-automated or manual operations. Identifying the processing times of the automated machines such as the coiling and quilting, was a simple and straightforward task. It required finding the production capacity of each automated machine and converting it to a corresponding processing time as shown in Table 3.

Collecting data for calculating the processing times of the semi-automated machines and manual operations required special attention and a different approach. The time study technique was used to collect the required raw data for the study. Next, Stat::Fit, ProModel's input analyzer, was used to fit the data to different probability distributions.

Table 2: List of the machines and processing tables of the production line.

List of the existing machines and processing tables							
			Spring Department			Mattress Build Up Department	
#	Type	Units	Machine Name	#	Type	Units	Machine Name
1	Automated	4	Coiling	6	Manual	7	Padding
2	Semi Auto	4	Assembly	7	Manual	9	Tape Edge
3	Manual	1	Frame Bending	8	Semi Auto	2	Packing
4	Manual	5	Clinching			Tailoring Department	
			Quilting Department	9	Manual	6	Sewing
5	Automated	3	Quilting				

Processing times for each semi-automated machine and manual operation, as raw data, were inserted into the Stat::Fit input analyzer software. The software provided three goodness of fit tests, including Chi-Squared, Kolmogorov-Smirnov and Anderson-Darling, to help select the best distribution for data. However, only the Kolmogorov-Smirnov and Anderson-Darling tests were used as they are applicable over the widest range of data. Table 4 contains a summary of all probability distributions of the semi-automated and manual operations and their corresponding expressions which were deduced from both Kolmogorov-Smirnov and Anderson-Darling tests.

Table 3: List of all automated machines and their corresponding processing times.

List of automated machines and their corresponding processing times						
Spring Department						
#		Machine	Capacity	Unit	Processing time for each coil	Unit
1	Automated	Coiling 1	60	coils/min	0.016	min
2	Automated	Coiling 2	58	coils/min	0.017	min
3	Automated	Coiling 3	65	coils/min	0.015	min
4	Automated	Coiling 4	52	coils/min	0.017	min
Quilting and Tailoring Department						
#		Machine	Capacity	Unit	Processing time for each panel or border	Unit
1	Automated	Quilting 1	65	meters/hr	1.36	min
2	Automated	Quilting 2	45	meters/hr	1.46	min
3	Automated	Quilting 3	55	meters/hr	1	min

Table 4: Summary of probability distributions for semi-automated and manual operations.

Processing times for machines and processing tables							
#	Name	Distribution	Expression	#	Name	Distribution	Expression
1	Assembly M	Triangular	T(3, 4.35, 5.13)	5	Tape edge M	Weibull	4+W(2., 3.46)
2	Frame bending M	Lognormal	L(0.452, 0.11)	6	Packing M	Weibull	W(11.7, 0.338)
3	Clinching table	Beta	B(1.32, 8.4, 3, 9.07)	7	Sewing M (Panels)	Weibull	1+W(4.37, 0.564)
4	Padding table	Beta	B(1.8, 1.38, 12, 15)	8	Sewing M (Borders)	Weibull	W(6.13, 0.324)

5 SIMULATION MODEL

Building a credible and valid simulation model requires specific steps to be followed. It is well known that the starting point for creating a simulation model is the establishment of assumptions. The model-building process can get much easier when reasonable assumptions are made (Clark and Krahl 2011). Some of the key assumptions made are as follows:

- The analyzed production line is considered as a single product line. The product specifications are: a mattress of size 100 cm x 200 cm with average complexity.
- There are no maintenance activities and equipment failures, such as, machine breakdowns. Also a zero rate of defects has been assumed.
- There is a continuous and infinite supply of raw materials at the Coiling, Quilting and Frame bending machines.
- The material handling is performed manually. Operators are always available during their shifts.
- During material handling, the operators walk through assigned walkways and follow the same route every time they perform a job. They also return to their assigned locations after finishing their tasks.
- The amount of work-in-process and buffer-stock at each station is infinite.

After creating a full list of assumptions, the simulation model was built. The first step was to create the 'locations' which include machines, processing tables and WIPs. The second step was to define the 'entities' such as raw materials and other WIP products. Creating the arrival pattern of the entities was the third step. The next step was to expand the model by adding 'resources' and the corresponding 'path networks' needed to move entities from one location to another. Finally, the 'processing' logic of the entities at different locations was defined. Clark and Krahl (2011) suggested that the model-building process starts from small and manageable pieces: "start small, verify and validate, add more, verify and validate and so on." Figure 3 shows a screen capture of the model being run.
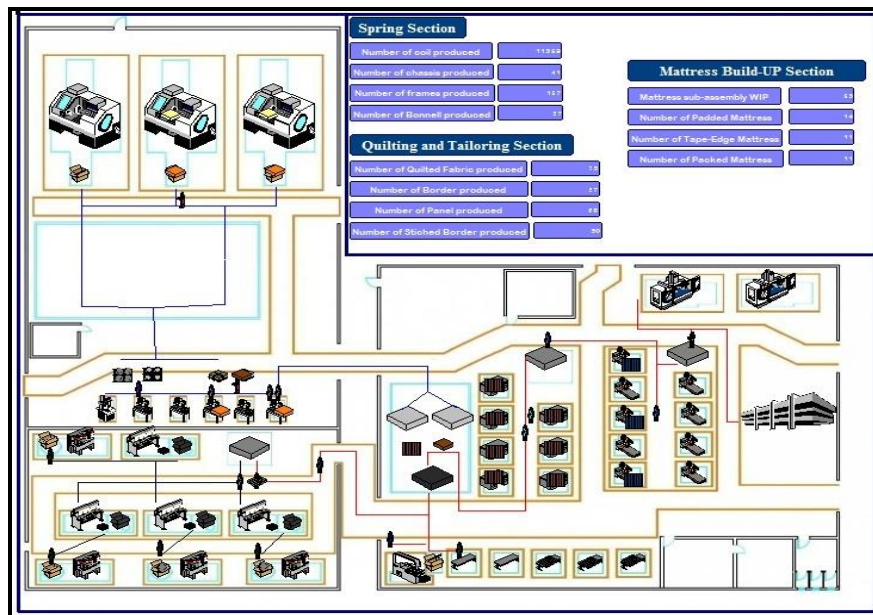
Figure 3: The production model built using ProModel.

Most of the simulation models designed for manufacturing systems are intended to provide information about the steady-state behavior of the system. Such models are known as non-terminating simulation models. And for a non-terminating simulation the output normally, but not always, reaches steady-state if the model is run long enough. In other words, steady-state behavior of a non-terminating system means that the statistical variation in the output data does not change over time (ProModel Corporation 2011, Alexopoulos 2006). To make sure the system has reached steady-state, initialization bias should be detected and removed. Moreover, it should be ensured that enough output data are produced to obtain an accurate estimate of the system's performance (Robinson 2007). Removing the initialization bias from the simulation output data is done by identifying the warm-up period. After removing the initialization bias, the accuracy of the system's performance is achieved by identifying the number of replications and the length of the simulation model run (Carrie 1988).

The starting point will be the selection of the warm-up period. Hoad et al. (2008) evaluated 44 warm-up period methods to find the best method for their automated output analyzer software, AutoSimOA. They used the following criteria in evaluating and selecting the most suitable method: accuracy and robustness of method, simplicity of the model, ease of potential automation, generality, number of parameters required, and computing time. The study results revealed that Marginal Standard Error Rule (MSER-5) using batches of 5 data points performed the best and provided the most consistent results. MSER-5, selects the warm-up period that minimizes the width of the confidence interval (CI) about the truncated sample mean. Hoad et al. (2008) concluded their study by stating that "MSER-5 does not require estimation of any parameters and can function adequately without user intervention. It is quick to run and fairly simple to understand. It is therefore an ideal candidate for automation and incorporation into an automated analyzer system."
Therefore, the same method was used to identify the warm-up period for our study. And the model's throughput was chosen as the output parameter for determining the warm-up period.

As mentioned earlier, the throughput of the model was the number of packed mattresses produced. The initial simulation run length was set to 550 hours. This number represented an equivalent number of hours of production time in one month. The number of replications was also set to five as suggested by Hoad et al. (2011). After running the simulation model for the specified period, the warm-up period was

identified as 5 hours, as shown in Figure 4. The warm-up period was added to the simulation run time for determining the number of replications required to achieve a 95% confidence level for the output results.

MSER-5 Method

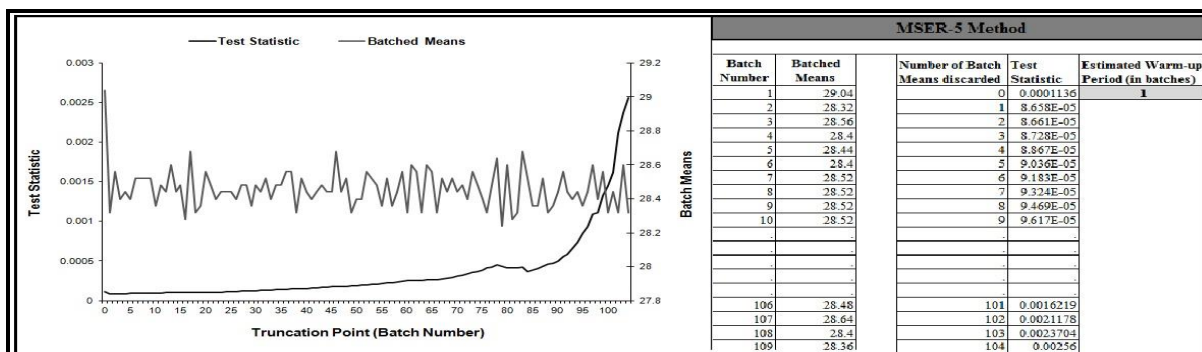| Batch Number	Batched Means	Number of Batch Means discarded	Test Statistic	Estimated Warm-up Period (in batches)
1	29.04	0	0.0001136	1
2	28.32	1	8.658E-05	
3	28.56	2	8.661E-05	
4	28.4	3	8.728E-05	
5	28.44	4	8.867E-05	
6	28.4	5	9.036E-05	
7	28.52	6	9.183E-05	
8	28.52	7	9.324E-05	
9	28.52	8	9.469E-05	
10	28.52	9	9.617E-05	
106	28.48	101	0.0016219	
107	28.64	102	0.0021178	
108	28.4	103	0.0023704	
109	28.36	104	0.00256	

Figure 4: The MSER-5 implementation to identify the warm-up period.

Hoad et al. (2007) suggested that the advantage of the Confidence Interval method is "that it relies upon statistical inference to determine the number of replications required." The method allows looking ahead by, performing a set number of five extra replications to check whether the precision of the data remains within the acceptable percentage. By analyzing the graph shown in Figure 5, the point at which the fluctuations of the data reduced to a minimum and the percentage deviation is relatively close to the significance level, was identified. The point representing the number of required replications was identified as 20.
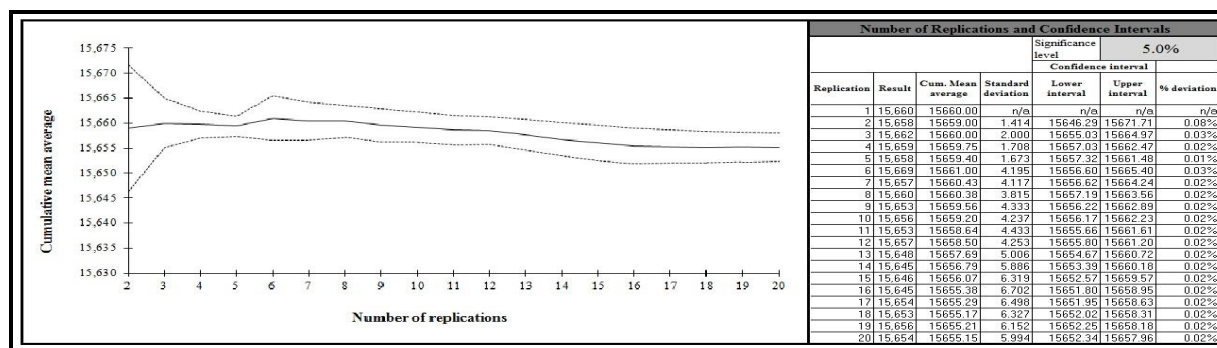
Number of Replications and Confidence Intervals

				Significance level	5.0%	
				Confidence interval		
Replication	Result	Cum. Mean average	Standard deviation	Lower interval	Upper interval	% deviation
1	15,660	15660.00	n/a	n/a	n/a	n/a
2	15,658	15659.00	1.414	15646.29	15671.71	0.08%
3	15,662	15660.00	2.000	15655.03	15664.97	0.03%
4	15,659	15659.75	1.708	15657.03	15662.47	0.02%
5	15,658	15659.40	1.673	15657.32	15661.48	0.01%
6	15,669	15661.00	4.195	15656.60	15665.40	0.03%
7	15,657	15660.43	4.117	15656.62	15664.24	0.02%
8	15,660	15660.38	3.815	15657.19	15663.56	0.02%
9	15,653	15659.56	4.333	15656.22	15662.89	0.02%
10	15,656	15659.20	4.237	15656.17	15662.23	0.02%
11	15,653	15658.64	4.433	15655.66	15661.61	0.02%
12	15,657	15658.50	4.253	15655.80	15661.20	0.02%
13	15,648	15657.69	5.006	15654.67	15660.72	0.02%
14	15,645	15656.79	5.886	15653.39	15660.18	0.02%
15	15,646	15656.07	6.319	15652.57	15659.57	0.02%
16	15,645	15655.38	6.702	15651.80	15658.95	0.02%
17	15,654	15655.29	6.498	15651.95	15658.63	0.02%
18	15,653	15655.17	6.327	15652.02	15658.31	0.02%
19	15,656	15655.21	6.152	15652.25	15658.18	0.02%
20	15,654	15655.15	5.994	15652.34	15657.96	0.02%

Figure 5: The Confidence Interval method used to determine the number of replications.

ProModel Corporation (2011) suggests that "it is usually a good idea to run the simulation enough times to let every type of event (including rare ones) happen at least a few times if not several hundred." They argue that "the longer the model is run, the more confident you can become that the results represent the steady-state behavior of the simulation model." Therefore, the simulation run length was set to 6,600 hours, equivalent to one full operational year.

6   SIMULATION RESULTS

After removing the initialization bias from the output results by identifying the warm-up period as 5 hours and running the simulation for 6,600 hours with 20 replications, the following results were obtained. The presented results were based on the data obtained from the Output Viewer of ProModel software. The most important performance measure was the total throughput (number of packed mattresses) of the system. Table 5 shows the status of some of the entities involved in the production line including the packed mattresses.

Table 5: Status summary of the entities involved in the production line.

Entity summary				
Name	Total Exits	Average Time in System (Min)	Average Time Waiting (Min)	Average Time in Operation (Min)
Coil	6,551,174	3.10	2.73	0.02
Chassis	27,993	6.69	-	4.16
Frame	72,994	0.68	0.23	0.45
Ready Panel	47,340	9.17	4.70	2.91
Packed Mattress	15,653	8,846.15	3,138.71	22.39

Comparing the number of packed mattresses with the demand for year 2012, as shown in Table 1, confirmed that the mattress production line was able to meet the demand during the first year of the expansion plan. However, the production capacity was not enough to cover the demand for the following years and a huge shortage in the production output was expected. After analyzing all the performance measures of different entities, machines, processing tables and operators many opportunities for improvements were identified. To develop an improved scenario which can help increase the throughput and also increase the efficiency of the production line in general, the utilization of several machines and operators were reviewed and considered.

Table 6: List of suggested alterations in the new simulation scenario.

Improved scenario			
#	Section	Description	Change
1	Tailoring	Remove two sewing machine (panel)	5 → 3
2	Tailoring	Reduce the number of operators in the sewing machine (panel) by two	5 → 3
3	Frame Bending	Add another operator to the frame bending machine	1 → 2
4	Padding	Increase the number of padding tables by three	7 → 10
5	Padding	Add five operators to the padding tables	7 → 12
6	Tape-Edge	Remove three tape-edge machines	9 → 6
7	Tape-Edge	Reduce the number of tape-edge operators by three	9 → 6
8	Packing	Remove one of the packing machines	2 → 1
9	Packing	Reduce the number of packing operators by one	2 → 1

A series of experiments were carried out to identify which alterations could enhance the systems' performance and increase throughput. Based on various results obtained, the above changes were finally made to the model in an improved scenario, as shown in Table 6.

As illustrated, five sections of the production line were considered; however, only alterations 3, 4 and 5 which are related to frame bending and padding sections were directly involved in increasing the throughput. Based on alteration 3, another frame bending operator was added to the frame bending machine. Alterations 4 and 5 suggest that three additional processing tables and five padding operators were needed in the padding section. The other changes; 1, 2, 6, 7, 8 and 9, were based on the fact that they can help in balancing the workload across different departments and increase the efficiency and effectiveness of the production line. In the tailoring section, two sewing machines and their operators were removed. Also three tape-edge machines and three operators were removed from the system. In the packing section, one packing machine and one packing operator were removed. After applying the suggested alterations and running the improved scenario, the following results were obtained.

In all, 23,353 units of packed mattresses were produced and exited the system, as shown in Table 7. Comparing this number with the demand levels, shown in Table 1, confirms that the mattress production line will be able to meet the demand during all of the following five years of the expansion plan. The demand level in the year 2016 is 22,321 units of packed mattresses per month, which means that the improved production line has the capacity to produce over 1,000 extra units per month.

Table 7: Status summary of the entities involved in the production line (scenario).

Entity summary				
Name	Total Exits	Average Time in System (Min)	Average Time Waiting (Min)	Average Time in Operation (Min)
Coil	6,600,672	3.10	2.70	0.02
Chassis	28,206	6.85	-	4.16
Frame	72,988	0.68	0.23	0.45
Ready Panel	46,870	11.15	5.72	2.92
Packed Mattress	23,353	4,936.01	4,849.50	22.40

7   DISCUSSION AND CONCLUSIONS

Based on the obtained results, the potential number of produced packed mattresses increased by 49.19% from 15,653 to 23,353 units per month. This quantity is enough to meet the monthly market demand until the year 2016. The main reason behind the increase in the production throughput is the improvement made in the padding section. The results of the improved scenario show that the padding section was an actual bottleneck in the system. The addition of three padding tables and five padding operators not only helped in increasing the throughput but also in having a more efficient and effective production line. As shown in Figure 6, the utilization of the padding section was improved by 4.4%, from 92.82% to 96.95% . Adding three padding processing tables could also be financially justifiable on the basis of the increase in the productivity of the production line and meeting the market demand.

Even though other improvements had no direct influence on the productivity of the production line, they helped in improving the utilization of other sections such as sewing, tape-Edge, and packing machines. Assuming those sections were overdesigned to start with, discarding two sewing and three tape-Edge and one packing machine, helped in increasing their utilizations to 71.61%, 83.42% and 22.9%, respectively.

The utilization of some of the operators was also improved as a result of the suggested alterations 1, 2, 6, 7, 8 and 9, as shown in Figure 7. The frame bending operator's utilization fell by a half and reached 50% after adding another operator. Tape-Edge operators utilization was doubled to reach 93.32% after removing three operators. And the utilization of Sewing machine operators increased to 76.57% after removing two operators. The utilization of the packing operator was more than tripled, nearly 335%, changing from 20.73% to 69.54%. And the utilization of the padding operators decreased by 15.7% and reached 84.3%. The results of the proposed changes suggest that the total number of operators remains the same; however, few operators need to be reallocated and trained to perform new tasks in different departments. This study mainly focused on the modeling of a mattress production line using the ProModel software in order to help in the production planning and decision making processes.
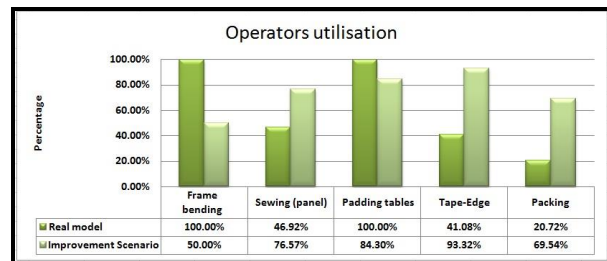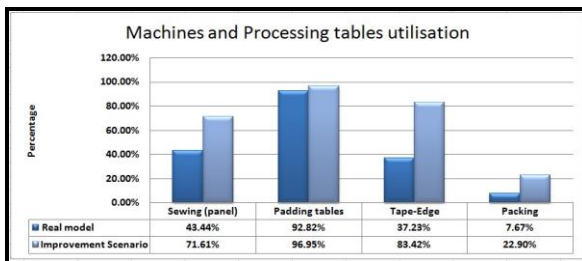

Figure 6: Machines and processing tables utilization.   Figure 7: The comparison of resources' utilization.

By using the model, the management was able to investigate whether the mattress production line could cope with the expansion plan and meet the demand of the market over the next five years. This simulation study provides strong prospects for future research in the same manufacturing environment.

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