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Enhancing Production Line Performance Using Simulation: A Case Study

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Abstract— *This paper studies the performance of a current production line at an automotive production facility. The concerned problem relates to the car seats production line. Management in the production facility are interested in increasing the productivity of the car seats production line. The current performance of the production line is well studied and represented using a discrete event simulation model. Then, recommendations to enhance the production line performance are suggested. Performance enhancement is measured in terms of processing time, waiting time, and production rate. The recommended courses of actions are evaluated through simulating the production line system before and after implementing the recommendations. Simulation results show that the suggested recommendations enhance the performance of the car seat production line.*

keywords—Utilization; processing time; waiting time; bottleneck; workstation; production rate.

1. Introduction

Organizations invest a huge amount of capital in one of the most complicated activities undertaken by man which is manufacturing. Manufacturing commonly employs assets – tangible or intangible, such as facilities, equipment, machinery, raw materials, products, services and human resources. For a given number of assets, there is an optimum combination in order to get the highest value possible in terms of quality and profit.

Today, customers around the world are starting to demand higher quality cars at lower price with fast delivery. Mass production is a common method used by most of the companies in production to gain higher production rate at the lowest cost [3]. In mass production, assembly lines are required to manage the workload, make proper arrangement of humans and machine to gain better efficiency. In line balancing application, there are two common issues. First, reducing the task time or processing time that have been assigned to all workstations to suit and not exceed the cycle time that has been given. Second, minimizing the highest workload assigned to a specific workstation when the number of workstation and line cycle time are fixed [4,6].

In this work, several feasible scenarios for line balancing are conducted using discrete event simulation.

The line balancing approach is concerned with matching the production rate to the takt time at each process in the workstations after removing all waste. Line balancing aims to maximize usage of workers, achieve high machine utilization, minimize slack and processing times, and reduce the overall production cost [14]. On the other hand, Discrete event simulation is used for systems where changes occur in discrete points of time [3]. Hence, discrete event simulation is a widely used technique for enhancing the performance of manufacturing systems, for example, as in [1, 7, 11]. Enhancing the production line balancing using discrete event simulation has been proved an efficient approach in [5].

This work focuses on balancing the assembly line of car seats in an existing manufacturing facility. The manufacturing facility under study is a key player in the automotive feeding industries since 1985. It old and has long-term relationships with most of the automotive assembly plants in Egypt. It serves the local and some global markets with high quality products meeting international standards with high level of customization and integrity.

By using modeling and simulation, saving cost can be reached easily to improve the assembly line performance compared to the actual production system. In addition, waiting time, number of operators, and the number of workstations as well can be reduced, achieving high utilization of machines and workers' pace, and as a result reaching a high productivity with minimum cost and high-quality products. The production facility, where the case study is conducted, is a car seats' huge supplier for many automotive assembly plants in Egypt.

There is a company that dominates more than 70% of Egyptian market share in terms of passenger car seats, carpets and pads with a high level of consistency [2].

2. Simulation Methodology

The represented system of the production line has to be modified and improved in various aspects. many problems are existed in such facility such as utilization, waiting times, processing times, etc. Moreover, this current production line lacks line balancing. As a result, line balancing can be achieved through the following equation:

$$\% \, LBL = \frac{nT_{max} - \sum t_i}{nT_{max}} X100 \, \%$$

Where;
LBL: $Line\ balance\ rate$

$N = number\ of\ workstations$
$Tmax = value\ of\ the\ highest\ cycle\ time$
$\sum t_i = total\ cycle\ time$

In order to solve these issues, by building a mathematical model which contains all the parameters of physical model and represent physical model in virtual form then conditions are applied which we want to experiment on physical model, then, simulation starts. It is used to examine the effect of each factor in a production system. Discrete Event Simulation is used with the advantages to simulate dynamics in the production system. [9-14]. Therefore, by simulation this production line on Excel and Arena, problems are almost solved and improved through:

- Identification of bottleneck process.
- Analyzing bottleneck process.
- Reducing cycle time.
- Reducing takt time.
- Calculating overall machine efficiency.
- Reducing tool change over time.

3. SIMULATION MODEL APPROACHES AND TRIALS

3.1. MODEL ASSUMPTIONS

- The process cycle time for every work task is based on existing records.
- For combined tasks, the new process cycle time is the average of total time of tasks.
- For tasks that are assigned to other operators, the cycle time is based on recorded measurements.
- The machine speed or production rate is constant.
- All operators are on the same level of experience and skill.
- Assuming normal distribution for all stations
- first operator spends 0.1 seconds in reaching for the next part and start working on it

3.2. APPROACHES AND TRIALS

The initial structure of the assembly line consisted of 10 workstations, 8 of which consisted of 1 worker and the rest consisted of 2 workers per station. Stations F and G had a different nature than the other 8 stations. They consisted of 2 workers per each station, the workers do the exact same job which allows the stations to finish work relatively fast.

Initial assembly line structure and efficiency

The operations of the different stations were assigned as follows:

Table 1. Station layout and operations

Station	Operation	No. of workers
Station A1	Frame Assembly 1	1
Station A2	Frame Assembly 2	1
Station B	Pad the seat back with fiber layer	1
Station C	Pad the seat back with foamed back cushion	1
Station D	Install wire rods to seat covers	1
Station E	Pad seat bottom cover with foamed cushion	1
Station F	Fasten hog rings to bottom seat	2
Station G	Install finished cushion to seat frame	2
Station H	Install the cushion to the frame bottom	1
Station I	Install head rest	1

The results for the modeled systems were as follows:

Table 2 Results of the modeled system

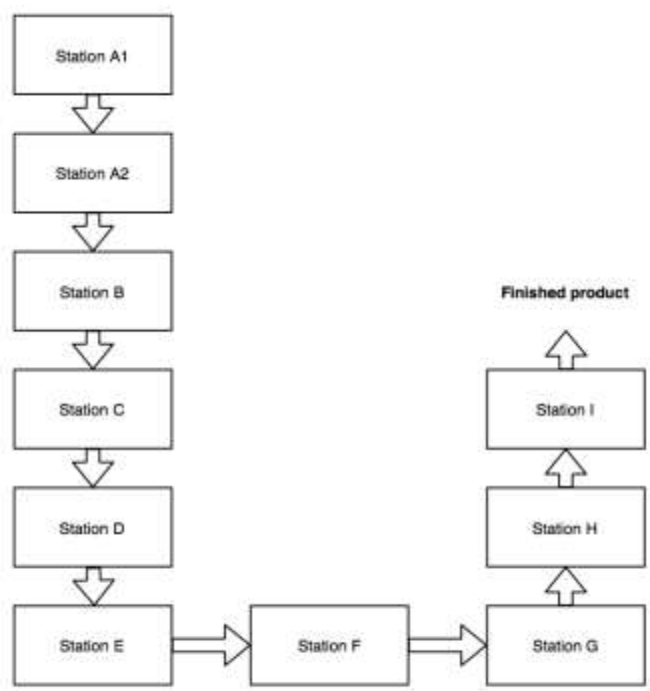

Figure 1 Diagram of the initial system

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System	Simulated
Number of operators	11
Number of stations	10
Line balance loss rate	54%
Waiting time	1.5 Minutes

Model trial 1

In this trial we tried combining stations C and D as well as stations H and I

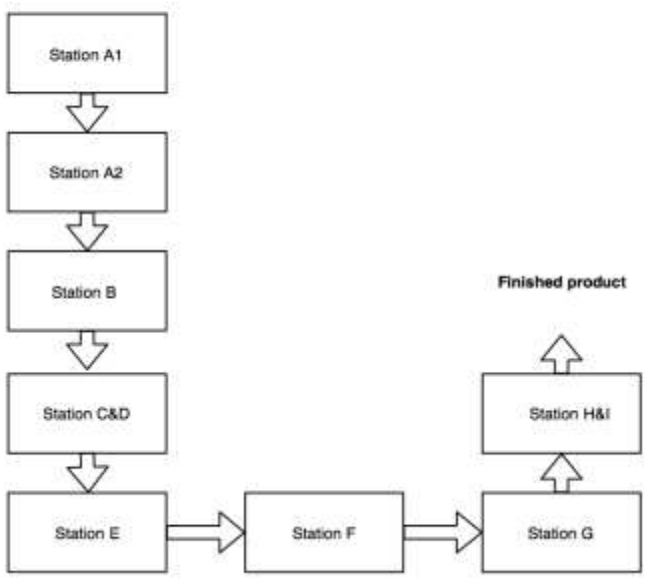

Figure 2 Diagram of first modeling trial

The operations and number of workers were assigned as follows:

Table 3 Trial 1 stations layout and operations

Station	Operation	No. of workers
Station A1	Frame Assembly 1	1
Station A2	Frame Assembly 2	1
Station B	Pad the seat back with fiber layer	1
Station C&D	Pad the seat back with foamed back cushion& Install wire rods to seat covers	2
Station E	Pad seat bottom cover with foamed cushion	1
Station F	Fasten hog rings to bottom seat	1
Station G	Install finished cushion to seat frame	1
Station H&I	Install the cushion to the frame bottom& Install head rest	1

Model trial 2

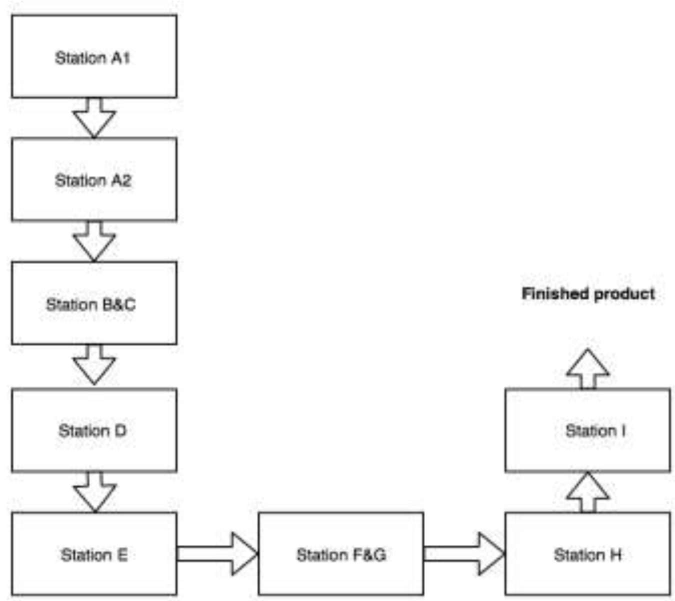

Figure 3 Diagram of first modeling trial

Table 4 results of the first model iteration

Characteristic	Simulated	Trial 1
Number of operations	12	11
Number of stations	10	8
Line balance loss rate	54%	24%
Waiting time	1.5 Minutes	8.45 Minutes

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Table 5 Trial 2 stations layout and operations

Station	Operation	No. of workers
Station A1	Frame Assembly 1	1
Station A2	Frame Assembly 2	1
Station B&C	Pad the seat back with fiber layer & foamed back cushion	
Station D	Install wire rods to seat covers	1
Station E	Pad seat bottom cover with foamed cushion	1
Station F&G	Fasten hog rings to bottom seat & install finished cushion to seat frame	1
Station H	Install the cushion to the frame bottom	1
Station I	Install head rest	1

And the results of the model were as follows:

Table 6 Results of the second modeling trial

Characteristic	Simulated	Trial 1
Number of operations	12	11
Number of stations	10	8
Line balance loss rate	54%	49%
Waiting time	1.5 Minutes	171.15 Minutes

Model trial 3

The operations of the different stations were assigned as follows:

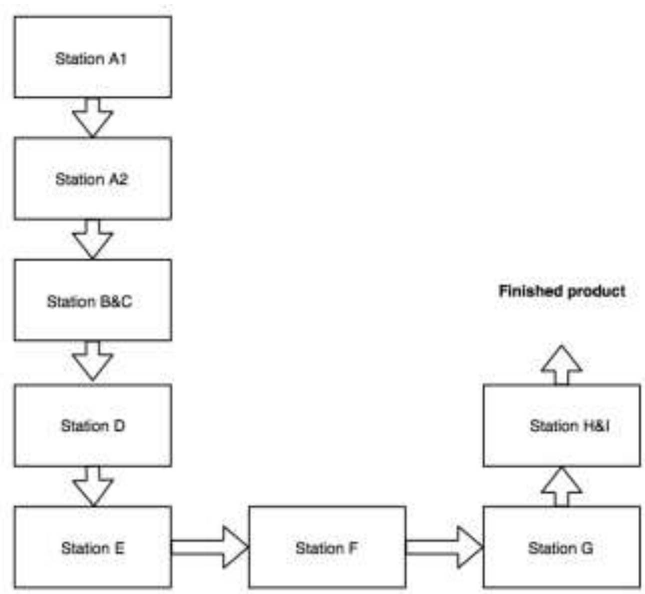

Figure 4 Diagram of third modeling trial

Table 7 Trial 3 stations layout and operations

Station	Operation	No. of workers
Station A1	Frame Assembly 1	1
Station A2	Frame Assembly 2	1
Station B&C	Pad the seat back with fiber layer & foamed back cushion	1
Station D	Install wire rods to seat covers	1
Station E	Pad seat bottom cover with foamed cushion	1
Station F	Fasten hog rings to bottom seat	1
Station G	Install finished cushion to seat frame	1
Station H&I	Install the cushion to the frame bottom& Install head rest	1

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The results of this model were as follows:

Table 8 Results of the third modeling trial

Characteristic	Simulated	Trial 1
Number of operations	12	11
Number of stations	10	8
Line balance loss rate	54%	20%
Waiting time	1.5 Minutes	9.07 Minutes

4. RESULTS

To get a proper simulation analysis, system model is reconfigured and experienced using excel. The simulation made for the current situation so it could be a bench mark for the future trials. Then, in each trial, we made the simulation runs under different settings of the input parameters, and the results for each trial were checked for their appropriateness. We run the model and checked the output with the real data we gathered from the plant. The simulation model runs for more than 2490 products.

The results are generated by modifying the current system. Modification is made based on the concept of eliminating, combining and simplifying the assembly process without any additional machine and man power. Recommended changes to the assignment of task to each operator in the line are:

- Combined B&C and H&I Tasks in two stations instead of four and 2 workers instead of 4.
- Redesign tasks in G and F
- Add another worker to A1 station.

The first trial resulted in an increase in the line balance loss rate as discussed earlier in our research paper which lead us to try another iteration presented in trial 2. Trial 2 presented a minor improvement over trial 1 and resulted a slightly better line balance loss rate. As a final iteration we tested a final workstation and production layout which presented a better result in the form a decrease in the line balance loss rate.
Comparison between the three trials are shown in the table below:

Table 9 Line balance loss rate comparison

	Original system	Simulation trial 1	Simulation trial 2	Final simulation trial
Line balance loss rate	54%	24%	49%	20%

5. CONCLUSION

Line balancing has a place in paced assembly line manufacturing, but not in flow line situations. The theory of constraints is a wholesome approach for productivity. improvement since it is concerned with the welfare of the company, not just the optimization of the manufacturing department. The key performance measurements such as throughput, line efficiency, and operational expense help us check whether we really are achieving productivity improvement. line balancing give positive impact towards the production line with a few improvements. It also shows that by using simulation time can be save in the process to simulate the line balancing. Line balancing not only can reduces the bottleneck but increased output too. As a result, costs of cars can be reduced which is ultimately the main purpose for this study.
For further work, this case study shows that workplace management is a vital element in production facilities, and the results has been shown. These results can be widely applied in manufacturing facilities to enhance productivity levels, decrease labor cost, high utilization of man power and machines capacity in an organized and efficient way.

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