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Simulation and Analysis of Production Scheduling in Eyeglasses Industry for Productivity Improvement

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Abstract

Manufacturing systems have become progressively complex and costly. Competition and the drive for profits are forcing companies to improve productivity in their production lines through effective and proper methods of evaluating production schedules. Computer simulation is one of the reliable and well-established methods that enables companies to evaluate their line scheduling. It helps manufacturers detect and rectify the line problems and move forward with productivity improvements. The main contribution of this paper is threefold. First, it defines a computer-based framework for modeling and simulation of production schedule using real-world data collected in an eyeglasses production factory. Second, it investigates an experimental conformance verification, i.e., confirming whether the simulation carried out in the production line conforms to its intended specification or not. Therefore, the simulation results are verified by the experimental results obtained from the line. Based on the confirmed simulation study, the Generating station and Washing station are considered the line's bottlenecks. Third, it proposes some suggestions by introducing and using "what-if" analysis. Creating "What-If" scenarios is extremely beneficial for manufacturers as it allows them to conduct simulation runs based on demand forecasts and constraint modeling for generating various iterations of the production schedule. Here, different scenarios are compared and the most advantageous one is chosen. In this study, increasing 4 machines in the Generating station and 6 workers in the washing station propels the company to achieve higher system utilization and increased throughput rates by 25% and 46%, respectively.

Keywords
Productivity improvement; computer-based simulation; What-if method; bottleneck; production scheduling.

1. Introduction
One of the most important aspects of manufacturing efficiency assessment is the determination of productivity. Companies are trying to find useful methods to detect the production line problems such as bottlenecks and waiting times and concurrently, they are striving to sustain their competitiveness by decreasing the bottlenecks, total cost, total time that leads the systems to enhance productivity. Therefore, having the appropriate tools to detect, analyze and evaluate the bottlenecks for managers in a manufacturing system is essential.
To achieve this goal, different methods can be applied on manufacturing systems such as Just in Time (JIT), a range of lean manufacturing tools [1], using optimization algorithms [2], [3] machine learning methods [4], and computer simulation to deal with different industrial problems. Computer simulations have become a useful tool for the modeling of systems in many fields like Robotic [5], communication systems [6], Finite Element [7] manufacturing systems [8] and so on. In the context of manufacturing, computer simulation modeling can assist the companies to understand and evaluate bottlenecks in the production line scheduling. Since the 1950s computer simulation has been used to tackle a range of business problems leading to improvements in efficiency, reduced costs and increased profitability. This method is useful when changes to the actual system are impossible or difficult and helps the manufacturers to use "what if" scenarios. "What-If" scenarios allow the manufacturing systems to adequately analyze and visualize potential production schedules and any disruptive events that may hinder production from continuing. They can compare multiple versions of the same production schedule to find the best solution to jobs being completed late. The paper is developed as follows: in section 2 the problem is determined in which the performance of production line is described, in section 3 a literature review of conducted research is presented, section4 provides the methodology applied in this research paper including simulation of current and future line then their results are discussed and analyzed in the section 5 and finally section 6 concludes the paper.

2. Problem Description
As aforementioned, companies are trying to find the bottleneck spots in their production line. Managements need to analyze the production scheduling continuously in order to achieve the line productivity however in a manufacturing

system especially in a new production line there are various uncertainties. In this regard, the simulation of the production line based on the existing data is a desirable demand that helps the companies to understand where they are in terms of productivity. In this research paper, a complicated production line in an eyeglasses company is considered. The line comprises three main stations including more than 110 machines and resources. The main research questions are how well does the line perform? Where are the bottlenecks? How to improve productivity? To reach the appropriate responses, the production line with all details is simulated in order to calculate waiting time in each section and find the bottleneck positions. Then, the simulated model should represent the real production line truly and mimic its behavior. To this end, the model must be designed, developed, verified and validated. All "what If" scenarios can be applied to the valid model. The computer simulation is performed in the ARENA 14.0 software. The ARENA is a powerful platform that can model and analyze the process flow, packaging systems, job routing, inventory control, warehousing, distribution and staffing requirements. The valid simulation enables the companies to identify performance of the production line and scheduling problems like the bottlenecks. Based on results obtained from the valid model, some suggestions are proposed. Using "what If" scenarios can help the management to see the effect of adding some changes in the line. In this case, the simulation model can be run based on demand forecasts and constraint modeling in which various iterations are generated so that the management team can compare them and select the most advantageous one. Eventually, computer simulation and "what if "tool help us to meet production purposes.

3. Literature Review

The computer simulation is widely used in various industries. It has been carried out in most business sectors, including manufacturing and service industries that mimics reality [9]. There are many types of Simulation models that can have several dimensions [10] Static Simulation Models, Dynamic Simulation Models, Deterministic Simulation Models, Stochastic Simulation Models, Continuous Simulation Models, and Discrete Simulation Models. Zahraee et al. [8] applied computer simulation-based ARENA software to analyze and determine the bottleneck and then proposed to decrease the bottleneck and improve productivity. A classification framework helps identify the type of scheduling schemes in a flexible manufacturing system (FMS) [11] to make easier decisions to deal with production management problems. To improve the FMS system performance, a simulation method with Taguchi approach is presented [12] in which the purpose is to achieve the maximum utilization with minimum the cycle time. The Taguchi approach is used in simulation to solve decision-making problems in an integrated manufacturing system [13] in which the scheduling of manufacturing system is evaluated. In [14], writers develop a simulation optimization methodology and, a production line in a secondary manufacturing wood industry is simulated. Dogan et al [15] propose a modeling of a production line in a hardwood sawmill. In this research paper, the effect of a machine replacement is simulated and analyzed, then with further modification of the simulation model the "what if" scenarios are investigated. Zahraee et al. [16] propose the application of design of experiment and computer simulation. In this paper, a production line is simulated to analyze the bottlenecks. A production line of a bakery with ten products is simulated in [17] by using ARENA software to predict any changes to future products. A simulation of the real production line layout which is a bicarbonate beverage production line layout is developed in [18] to identify and improve the performance of the line. The key factors in the manufacturing system are evaluated by ARENA software. Kawther et al [19] use the ARENA software to simulate and analyze a production line to identify the controllability of an existing production system. Although Simulation of the production line is widely used in the research papers, most of them have focused on either a small system or a part of the production line due to some limitation in terms of software and hardware. In this paper, the production line in an eyeglasses factory is entirely simulated in which there are more than 110 operating machines in three separate sections, and then we have assessed the effect of changes in the production scheduling by using "what if" tools.

4. Methodology

This study is carried out using the ARENA 14.0 software along with a potent hardware. The procedure of production line simulation initiates by collecting the line data including the number of machines in each section, the working time, machine capacity and so on and then production scheduling is modeled and simulated in the ARENA. The next step is to validate the simulation results with respect to the real data so that this simulation becomes a reliable model to analyze and optimize the production line. The proposed scenarios using the "what if" tool can be applied to this valid model to analyze and evaluate the changes in the production line.

4.1. System Description

As mentioned above, the case study is an eyeglasses factory in which the production line is divided into three general sections. 1- Surfacing. 2- Anti-reflective (AR) coating 3- Finishing. Table 1 presents all details and data related to the production line.

Table 1: production line data

Sections	Equipment	Current Machines	Hrly Rate	Time taken for each job
Surfacing	Blocking	16	37	1.6216216
	Generating	6	30	2
		6	35	1.7142857
	Lasers	13	150	0.4
	Polishers	10	20	3
		12	20	3
	Backside Coaters	12	62	0.96774193
	De-Blockers	8	65	0.92307692
Anti-effective Coating	Wash Line	2	189	0.31746031
	AR Coaters	9	38	1.57894736
Finishing	Tracers	9	50	1.2
	Edgers	8	36	-----
		5	60	1.66666667

The process is started at the distribution center (DC) where all prescription lenses, frames, and contact lenses are stored. Based on the placed order, all required glass blanks and frames are sent off to ART Blocking station to glue the lenses to a block. Next station is Generation in which a rough shape closer to final shape, size and curvature is made. In the Laser station work order number is engraved on the lenses and in the Polishing station, they undergo multiple polish cycles and then, the lenses engage in a scratch resistant backside coating. In the De-Blocker section, the block is detached from the lenses. At the end of this section, the quality of the lenses is checked to assess the power of the lens, polish quality and coating quality. All lenses are sent to the Washing Line to make sure that they are completely clean for the next process. The lenses go either to the finishing stage or AR Coating section. Based on data obtained from the production line, 30% of the jobs skip straight to the Finishing section and 70% of the jobs go to sectoring Tracer and Edger. The shape and size of frames will be traced in the Tracer section and in the Edgers section, the lenses are cut to fit their respective frame. Finally, the glasses are inspected to make sure that they are manufactured as per customer requested. Figure 1 shows a scheme of the production line.

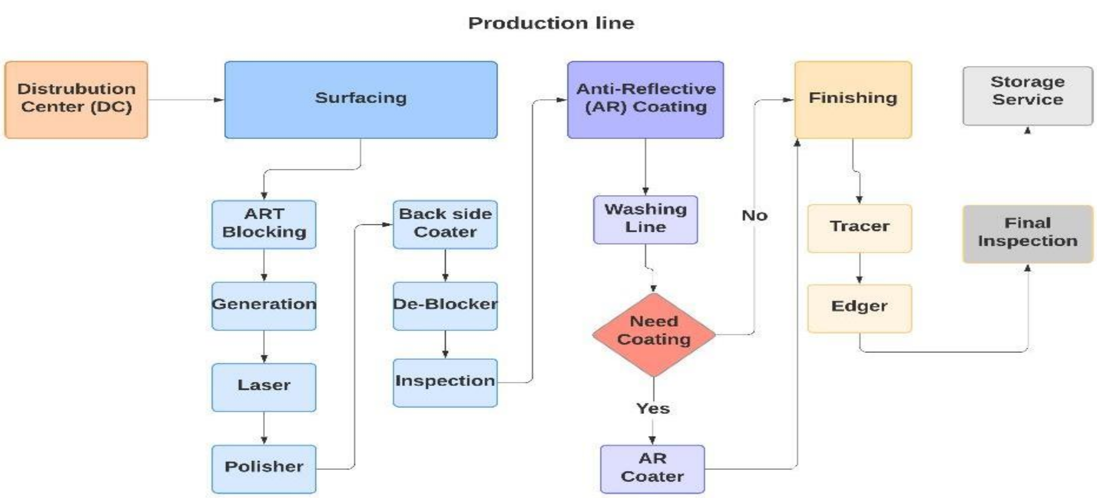
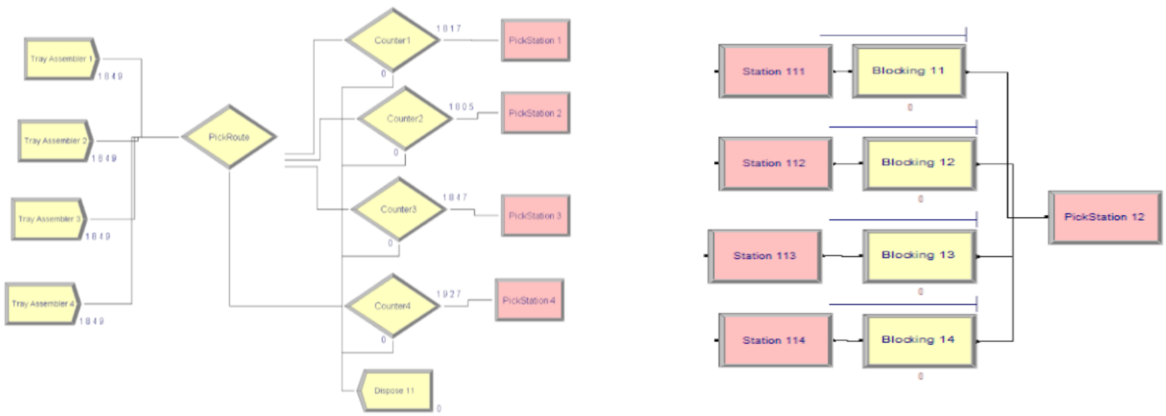


Figure 1: production line flowchart

4.2. Simulation of Current System

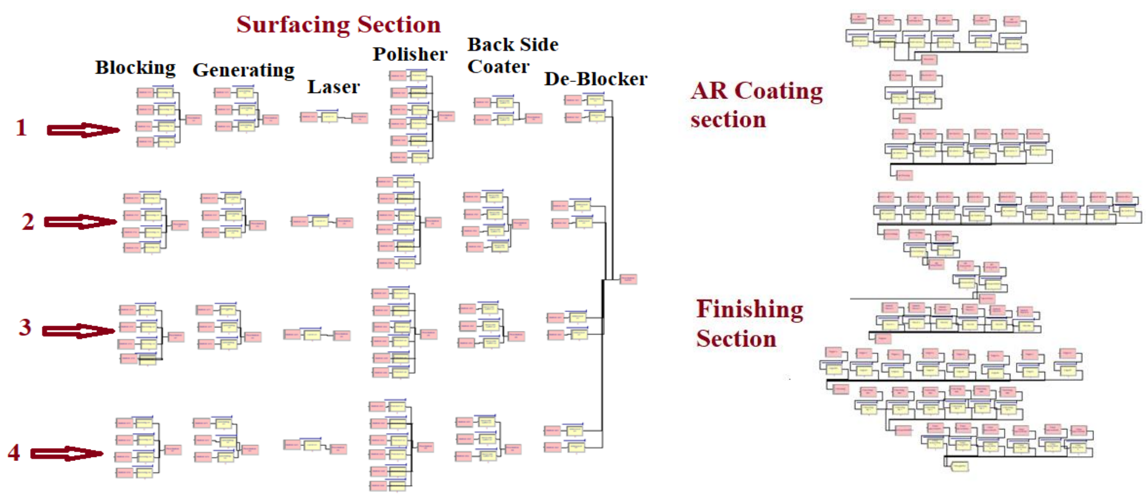
Based on the data shown in table 1, the throughput of the manufacturing system within a day is around 5000 jobs. The factory works in two shifts per a day and each shift lasts 11 hours (22 hours per day). The first stage is a simulation of the DC section. There are four workers at this station at a time and each worker on average assembles 88 jobs per hour. The lenses are transferred into a pick station unit to feed the ART blocking in the surfacing section. Figure 2 shows the simulation of Distribution Center (a) and pick station unit (b) in ARENA software.



a) Distribution Center b) Pick station unit

Figure 2: part of simulated production line

Based on the number of machines, four paths are considered in the surfacing section in which jobs are distributed based on the line scheduling. Machines are placed in series with each other, and the number and type of machines can be different. Figure 3 shows the complete production line including surfacing section (3-a) and AR Coating section and Finishing Section (3-b). In each path, selection of machines is determined by the Pick Station unit which means if a machine is busy, the pick station unit feeds the jobs into the next available machine.



a) Surfacing section b) AR Coating and Finishing Sections

Figure 3: Simulation of whole production line

validation of simulation plays a pivotal role in this research paper. In this case, the results obtained from the simulation are compared with the experimental data and result in the line. After running the simulation, the report presents that the number of entities input, and the number of output entities are 7748 and 4057 respectively which also are the main factor for the throughput of the factory. In table 2 some main factors are compared with each other in both real world and simulation model. Comparison of results shows that the simulation model is reliable, and it can be a valid simulation to analyze and evaluate the production line.

Table 2: Part of results (Real World and Simulation)

	Real	Simulation	Error%
Input	7748	7748	*
Throughput	3920	4057	3%
Utilization	50.6%	52.3%	3%
Waiting time section1	10 hr. and 15 min	11 hr.	7%
Waiting time section 2	5 hr.	5.2 hr.	4%
Waiting time section 3	8 hr.	8.2 hr.	2%

4.3. "What if" scenario simulation

The model results demonstrate that the Generating section and AR handwashing process are the bottleneck in the line. For the "what if " model, there are two general suggestions to solve this problem and improve productivity. First, the Generating section needs more Generating machines that should be provided by the company to improve the throughput of the system. Second, to solve the problem in the AR handwashing process, they can add either more washing units or more workers. Two simulations are set in order to figure out which process (Generating and AR Hand-washing) is the more critical bottleneck of the system. In the first simulation, the Generating machines are increased by one machine for each line (4 machines). This change slightly raises the throughput. On the other hand, by increasing the number of AR Handwashing workers, the throughput of the system had increased significantly (more than 1000 jobs). Therefore, the AR Hand-washing process is more critical than another one and it may be the main bottleneck of the production line. Moreover, simulation is tested again and the final recommendation for the manufacturing system is to increase 6 AR hand-washing workers, 1 more AR inspection station, 1 more Finishing up station, and 1 Final Inspection station.

5. Result

As mentioned above, a "what If" model is proposed to improve productivity of the system. Two improvements of the system are put forward in this study; however, the cost of adding machines is higher than hiring more AR Handwashing workers. Table 3 shows the number of jobs in both generating and AR hand washing sections.

Table 3: Queue Length in current model

Queue Length in Generating		**Queue Length in AR hand washing**	
Process	Jobs	Process	Jobs
Generating 11	47.78	Hand washing 1	243.53
Generating 12	47.56	Hand washing 2	243.39
Generating 21	47.18	Hand washing 3	243.21

In this model, the throughput of the system is enhanced to 5959 jobs compared with 4057 jobs in the current simulation (increase 46%). Based on the current simulation, the utilization of the line is 52.4% which is lower than what the company expected. So, in the proposed model utilization is increased by 76.9% just by hiring more workers in the AR handwashing section. Fig 4 indicates the results gained in proposed model, current model and compares them with real data.

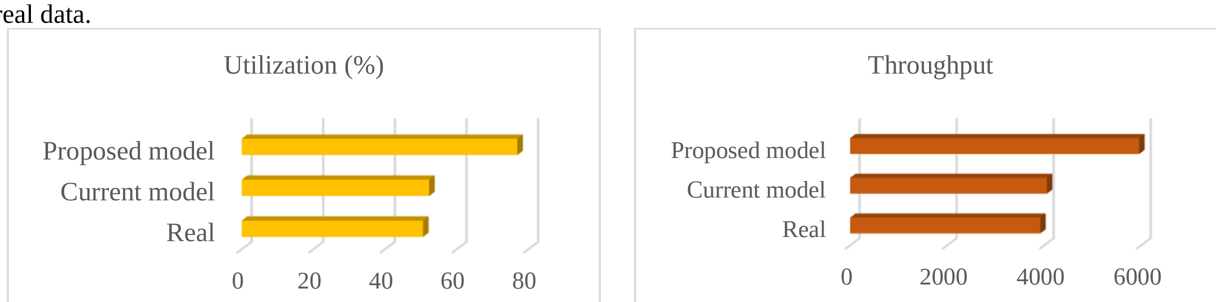


Fig 4: compare between current model and proposed model

6. Conclusion

Industry needs a manufacturing system in which products are manufactured with high quality at low cost with a priority of delivering products to customers on time. Hence, it is essential to continuously measure the performance of the manufacturing system. In this regard, this paper reports the methodology to analyze and evaluate and improve the productivity of a manufacturing system in an eyeglasses manufacturing factory. A computer simulation model is built using ARENA software to analyze the current system and then based on existing data in the production line, the results obtained from the simulation are validated. The validated model shows that the Generating process in the Surfacing section and AR handwashing process are the bottlenecks of the production line. Then two simulation models are proposed regarding the "what if" tool. The simulation study shows that the AR-handwashing process is more critical, and it may be the main bottleneck in the production line. The proposed changes based on the simulation study result in a 25% increase in system utilization rate (from 52.3% to 76.9%) and a 46% increase in the system's throughput (from 4057 to 5959 units). These results show that the computer simulation is a powerful tool to analyze and evaluate the productivity of a production line and can continuously improve it using the "what if" analysis methodology.

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