Abstract—One of the most famous techniques which affect the efficiency of a production line is the assembly line balancing (ALB) technique. This paper examines the balancing effect of a whole production line of a real auto glass manufacturer in three steps. In the first step, processing time of each activity in the workstations is calculated, and finally in the third step, several improvement scenarios are generated to optimize the system throughput and the best one is proposed. The main contribution of the current research is the proposed framework which combines two famous approaches including Assembly Line Balancing and Optimization via Simulation technique (OvS). The results show that the proposed framework could be applied in practical environments, easily.

Keywords—Assembly line balancing problem, optimization via simulation, production planning.

I. INTRODUCTION

Today's market, due to the increasing of market demand and tough competitions among the auto manufacturers, the problems of quality and costs are among the most important ones in international enterprises. Balancing of a production line is one of the methods that increase the production line efficiency. This study looking to fix some of the major factors cause stopping of the production system such as rate of stopping and repairing of each workstation, the amount of temporary storage capacity of each workstation, identification of system bottlenecks, and identification of technical, financial and human resources constraints using the optimization via simulation (OvS) technique. Because of the stochastic processes in the production lines such as parts disruptions, the processing times and machine failures, the traditional mathematical programming approaches cannot handle these cases efficiently, since these techniques always assume deterministic systems. Boysen et al. [1] mentioned that simulation is a duplication of process performance of the real system with time and Sotskov [2] defines the simulation technique as a model of a real system, in order to understand the system behavior and evaluating various strategies for the optimization of the operating system. Ozbakira et al. [3] have been studied classification of assembly line balancing problems. Several methods, algorithms and different range of software are presented which each of them has advantages and disadvantages. Minor changes in the behavior of a workstation cause temporary stocks in next workstations, so the simulation technique was used as the best tool for handling such complicated systems with several stochastic events. Saberi et al. [4] have been considered simple assembly balancing line problem to minimize the number of workstations (m) including (n) processing times (V=1,...,n) in (C) periods. Amardeep et al. [5] have studied parallel assembly balancing line problem to increase flexibility of the system, reduce errors, increase efficiency and increase the rate of system throughput. The main goal of their research was to determine the optimum balancing level using the discrete event simulation in Visual Slam software. They could reduce the cycle time and minimize total transports, and decrease the investment on machines and manpower. Taghizadeh and Zeinalzadeh [6] has studied balancing of a production line and the solving the problem in an actual factory. The production line of this factory has been optimized in Witness simulation software. According to the literature review, the majority of auto manufacturers used ALB to:

- Identify the bottlenecks in the production process.
- Measure the order time/point and the effect of temporary stocks on the system performance.
- Determine the average of waiting times for each product at each workstation.
- Effect of Bottleneck stations on the time of the orders and on the waiting times.
- Effect of bottleneck stations on idle times of all non-bottleneck stations.

Tiacci [7] introduced an innovative approach to deal with the Mixed Model Assembly Line Balancing Problem (MALBP) with stochastic task times and parallel workstations. Although algorithms are potentially able to consider many features of realistic problems and to effectively explore the solution space, a lack of precision in their objective function evaluation (which usually includes a performance parameter, as the throughput) limits in fact their capability to find good solutions. Traditionally, algorithms use indirect measures of throughput (such as workload smoothness), that are easy to calculate, but whose correlation with the throughput is often poor.

II. SIMULATION MODELING

A. System Definition

The purpose of manufacturing of a product is to change raw materials (input) in order to achieve the goal (final product or output). Manufacturing process of safety glasses is highly...
complicated and delicate at the same time so that carelessness and negligence of an operator would result in wasting the product. Therefore, appropriate controls are implemented through manufacturing process to minimize the waste. Manufacturing flow process of the triangle glasses is as below: First of all, glass box is opened containing 50 panes each. The panes would be cut using Hegla CNC cutters and 50 triangle glasses would be produced out of each pane. Subsequently, the waste would be separated from the triangle glasses and sharp edge of the glass will be entirely removed in diamond tools of the glass. The glasses will be washed in the next step and they will be dried underneath the heater. The glass is sent to printing section where company’s logo is printed on them and they will be transferred to bending and shatter-proofing furnace (HTBS). Later, the triangle glasses will be checked and placed in a specific pallet. The final inspection will be done by SAIPA’s inspectors. There are two different waste materials at the production line:

- Wastes are the quantity of waste glass resulting from the operation like the difference which is considered as waste while shaping a slate of glass.
- Waste is defective and incomplete production which is considered first-class waste (second-class glass) based on Quality Control Standards. Moreover, waste contains of machine breaks which cause glass failure and security test as a destructive test of quality control which result in waste.

In 2014, the average percentage of waste materials in Miniature (a car model which has been considered in the research) triangle glass was 4.33%.

In this research, we have taken the following assumptions:

- Processing time, repairs, machine failures are all random processes.
- Location of workstations are fixed and determined.
- Flow of materials is fixed and determined.
- Annual production targets are determined in detail.
- Working hour for manufacturing triangle glass is carried out in two shifts, 7 hours a day.
- Number of machine operators is taken into account for time studies (timing).

Timing procedure uses correct methods and scientific principles in order to determine normal time of an operation which should be done by a worker qualified for optimal performance. Timing is indeed a time scale of the operations, machineries, labor force, stations and finally timing of production line. In this research, timing is measured using stopwatch device. The processing steps in Miniature triangle glass production line are as follows:

- Opening box glass
- Cutting with Hegla CNC
- Separation of triangle pane out of waste
- Hand diamond
- Hand wash
- Logo printing by hand template
- HTBS furnace, bending and shatter-proofing process
- Inspection and packing
- Final inspection of pallet and packing
- Temporary factors of workstations which contains:
  - Temporary factors of Hegla CNC cut
  - Temporary factors of hand diamond
  - Temporary factors of logo printing
  - Temporary factors of HTBS furnace

Using 250 samples of the real world model, the distribution functions are provided in Table I.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Workstation</th>
<th>Statistical distribution of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Opening box glass</td>
<td>normal (168.44, 4.8369)</td>
</tr>
<tr>
<td>2</td>
<td>Cutting with Hegla CNC</td>
<td>normal (396.19, 0.21536)</td>
</tr>
<tr>
<td>3</td>
<td>Separation of triangle pane out</td>
<td>normal (424.4, 3.0634)</td>
</tr>
<tr>
<td>4</td>
<td>Hand diamond</td>
<td>normal (12.353, 0.53834)</td>
</tr>
<tr>
<td>5</td>
<td>Hand wash</td>
<td>normal (48.367, 1.1902)</td>
</tr>
<tr>
<td>6</td>
<td>Logo printing by hand template</td>
<td>normal (424.4, 3.0634)</td>
</tr>
<tr>
<td>7</td>
<td>HTBS furnace, bending and</td>
<td>normal (10.147, 0.69165)</td>
</tr>
<tr>
<td>8</td>
<td>Inspection and packing</td>
<td>normal (168.44, 4.8369)</td>
</tr>
<tr>
<td>9</td>
<td>Final inspection of pallet and</td>
<td>normal (2429.5, 5.5555)</td>
</tr>
<tr>
<td></td>
<td>packing</td>
<td></td>
</tr>
</tbody>
</table>

Then the system was modeled in the simulation software for the desired experimentations. Since the underlying system is a non-terminating system, the warm-up period must be set. To do so, the simulation model was replicated 50 times (each time including 7 working hours) and the results depicted in Fig. 1. According to the results after 2 days, the system reaches to a stable situation. Thus, the 2-days warm-up period was set in the simulation experiments. To test the simulation model validity, 120 daily throughput samples were taken from the simulation experiments and also from the real world system and the mean were tested using non-parametric test with 5% as the significance level. The test p-value was 0.002 which shows that the simulation model is valid.

### B. System Bottlenecks

To realize the system bottlenecks, the model should be executed in longer period of time (for example 1 year). Fig. 2 indicates that at the waste separation station, the server utilization rate is 95% and in 5% of times is on standby mode for initial preparation of shift change and the system warm up. This fact proves that this workstation is the system bottleneck. Adding a new parallel workstation is one of the best solutions to remove the bottleneck (Fig. 3) according to interviews done with the system experts. There will be no improvement at this station with adding new work forces because this station is automatic without manual intervenes. Also, there is no possibility for changing the system flow. Therefore, our improving scenario will be installing a new parallel station at this bottleneck station.
III. EXPERIMENTAL RESULTS

All computations were run on a Pentium IV PC with 4 GB of RAM and Core i5 with 2.64 GHz CPU. Enterprise Dynamics Version 8.2 (ED) was used as the simulation software. According to the Fig. 4, by adding a waste separation part with two operators, we could improve the bottleneck of the system. After 35 replications, the current system and the revised system status have been reported in Fig. 3 and Fig. 4, respectively. According to these Figs 3 and 4, adding a waste separation workstation could increase the system throughput. Production rate (Sink14) -before balancing process- was 1,020 triangular glass palettes per hour while after balancing the rate is increased to 1,082 triangular glass palettes. It should be noted that the production rate has been increased to 6% compared to the current state. This increase in production is equal to 39,680 triangular glasses per year. Also, the average idle time of workstations and the average system cycle time were reduced. According to the financial statements, the production cost per unit (including the depreciation, wages, and overhead) is USD 53.27 and the margin is USD 8.55. Adding the new device will decrease the wages but the depreciation cost will be increased. The purchasing price of the new machine is USD 45,000 and so assuming 15 years as its life cycle and also considering the new production volume in each year, the new production cost per unit will be USD 53.22 and so the new margin is USD 8.50. Therefore, the company total margin average will be USD 9,197.00 in each hour, comparing this amount with the previous one (USD 8,721.00), the average margin increase is USD 476.00 in each hour or 5.45%. This fact shows the feasibility of the proposed scenario in increasing the production productivity.

IV. CONCLUSION

Utilizing the simulation technique in operational environments such as production lines could enable us to analyze the system more accurately. In this actual research, the production line of triangle glass at SAIPA auto manufacturing company was studied using ALB and simulation techniques. Applying this technique could help us to Identify and improve the system bottlenecks and reduce the inventory level at the entire production flow which prevents the accumulation of temporarily unavailable storages during the process. By adjusting the stock level at each workstation and, the reduction in the system cycle time the production managers are able to reduce the system total costs. To sum up, the simulation technique is a very useful tool to tackle the scheduling problem of complicated systems where we have several stochastic events. Regarding the research constraints, we were obliged to pick up our samples from the production line in 35 days which made several difficulties for us in the absence of enough man power sources for taking the samples. For future researches, we recommend to combine the simulation technique with meta-heuristics to provide better solutions. Also, it is highly recommended to assume the cycle time at each workstation as a stochastic decision variable to get closer to real world behaviors.

REFERENCES


