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Garment Assembly Line Balancing Using Modeling and Simulation

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***Abstract* —** *Assembly line balancing of garment industry became an important area for research. The objective of this study is to develop a simulation model which represents real production process scenarios based on balancing U3 Shirt assembly line in Sur Military Clothing Factory that helps to decrease the waiting time, finish time, and increase the efficiency of the line in addition to generating different alternative scenarios to utilize the assembly line. The methodology adopted includes firstly calculation of cycle time of U3 Shirt assembly line process by using time study, secondly, to set up a model and simulation of the line which was achieved by using different tools and technologies: MySQL Data Base Management System (DBMS), Java language, Hyper Text Markup Language (HTML), Cascades Style Sheets (CSS) and SMARTY J. Several scenarios were created to enhance the system. Three scenarios were proposed and the best one had a result of a finish time decremented to be 24113s, the second scenario was 26603s while the third gave 26622s compared to 29616 seconds for the real scenario finish time. The efficiency of the line is increased to 19%, 10%, and 10% for the three scenarios respectively. The cost of the three alternative scenarios was increased by 9%, 15% and 3% from the real system cost consecutively. The study concluded that the real scenario case could be enhanced to be more effective by using the best scenario result that was created by using scenario 1 which saves more time, and had more efficiency.*

***Keywords*—** *Garment, Assembly Line Balancing, Time study, Simulation Model, Java..*

I. INTRODUCTION

Over the past 170 years, apparel structure has changed from the custom fitting and assembly of individual hand-sewn garments to the mechanized, automated and sometimes robotized mass production and distribution of ready-to-wear products in the world market. However, today the demand for greater product variability and shorter life cycles has caused traditional production methods to be replaced with assembly lines (1). In an assembly line each workstation repeatedly performs a set of tasks in order to produce or manufacture a specific product and a task is characterized by an operation processing time and a set of precedence relationships which specify the allowable orderings of the tasks (2). Assembly Line Balancing (LB), is the problem of assigning operations to workstations along an assembly line, in such a way that the assignment be optimal in some sense (3). Process modelling and simulation are modelling techniques available to support companies in gaining a better understanding of their manufacturing system behaviours and processes and therefore helping them in decision making. Simulation models can be developed using programming languages such as C, C++, Java, CPLEX etc. or using software packages such as ARENA, SIMIO or Witness etc. (4).

II. ASSEMBLY LINE OPERATIONS AND METHODS

In this study U3 long sleeve shirt which made by Sur Military clothing factory was selected as the case study. The fabric of the U3 is 65% polyester and 35% cotton coming from SUR Textile Mills. The colour of U3 is dark green made for land force graduation. Figure (1) shows the U3 Long Sleeve Shirt model selected for the assembly line balancing.

Fig. 1. U3 Long Sleeve Shirt model

A. Assembly of U3 Shirt:

This line consists of many operations to assemble a full U3 Shirt. The machines are kept in straight line according to the operations sequence. Processed parts movement inside the assembly line (from station to another) is made by the operator.

TABLE I. U3 Shirt Assembly Line Precedence Relations

Op No	Operation Name	Predecessor
1	Attach Back Yoke	-
2	Joint Shoulder	1
3	Attaching and Top stitch /Closing collar size label	2
4	Attach Epaulets	3
5	Attach Sleeve	4
6	Closed side seam	5
7	Attach Cuff	6
8	Top stitch Cuff 5mm	7
9	Button Hole Collar x3/Cuff	8
10	Marking Button Position x12	9
11	Attach Button (x12)	10
12	Bottom Hemming	11
13	Thread cleaning and fasten Button	12
14	Quality Control	13
15	Pressing	14

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The operator, after completing the operation forwards the semi-finished garments to the next operator. This process continues to the end of assembly line for each operation. Table I shows the U3 Shirt Assembly Line Precedence Relations

B. Time Study

10 measurements were taken for each task and operator working on assembly line of U3 shirt. Time study was conducted using a stop watch. Each operation was measured in seconds and recorded. A module was built using web application tools and techniques which characterized by ease of usage and availability to be accessible from any device which is connected to the internet.

III. Module Architecture and Design

The module is composed of three main layers; the following diagram illustrates the architecture of the module and its layers.

Fig. 2. Model Architecture and Design

A. Algorithm

A suitable algorithm is created for the model simulation. The following are the steps which were used to develop and build the simulation process.

1- Creating the simulation case.
- *Add the number of pieces to be produced.*
- *Add hypothetical simulation name to the case.*
- *Read the processes from the settings and each process timing and link them with the simulation case.*
- *Create the two scenarios for each case name them scenario 1 and scenario 2*

2- *The simulation details.*
- *Load the simulation details with the number of pieces from the database.*
- *The user will change the number of workers per process in scenario 1 and scenario 2 and then click on save.*
- *The systems save the number of workers in the database.*

- *Based on the number of process there will be loop*

Finish Time = 0
While (not end of processes)
waiting time = 0
free workers = all workers per this process.
Busy workers = empty
While (not end of pieces)
While (not end of workers per process)
If worker[i] is free
Assign piece to worker (i).
Add worker (i) to busy worker list
Else
Wait for free worker and Add time to waiting time
If time per piece < elapsed time per worker
Remove from busy worker list
Else
Wait for worker to finish
Finish Time = Finish Time + time per piece+ waiting time
End of while 3
End of while 2
End of while 1

- *At this level the elapsed time for each worker and the waiting time for each process is calculated*
- *Sum all the waiting time for all workers per each process.*
- *Calculate efficiency by dividing finish time of the last pieces of scenario 2 over finish time of the last piece of scenario 1*

- *Efficiency = ((ft2-ft1)/ft1)*100*

ft1 = scenario1 last piece finish time.
ft2 = Scenario2 Last piece finish time.

- *Calculate the change in cost by dividing number of workers in scenario 2 by the number of workers in scenario 1*

*Cost % = ((NO.W2 - NO.W1)/ NO.W1)*100*
NO.W1 = Scenario1 total workers.
NO.W2 = Scenario2 total workers

IV. Results and Discussion

With reference to SUR daily assembly line production target (1000 piece /day), simulation is considered for producing 1000 piece/day. To analyze the result of the model, three performance measures were considered: waiting time, finish time, total efficiency.

The following figure.3 is a screenshot from the simulation for 1000piece.

Fig. 3. Alternative Scenario1 screenshot

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With adding one skilled operator to the top stitch Cuff 5mm, thread cleaning and fasten Button and quality control operations the finish time on each operation was minimized to 21780, 22515 and 22573 sec respectively. The finish time of the last operation also was minimized to 24113 sec. Compared with the finish time of last operation on the real system it is found that the total efficiency was increased by 19%. So in this scenario the number of pieces production target could be obtained in less time. All these results are depicted in figures 4. On the other hand the cost on this scenario was increased by 9% but comparing to the time which saved it is acceptable. Referring to figure 5 after adding some workers it is noticed that the idle time was decreased in operations Button Hole Collar x3/Cuff, Marking Button Position x12, Attach Button (x12) and Bottom Hemming. Although some other operations idle time was increased but the total finish time was clearly minimized which matters more.

Fig. 4. Alternative Scenario1 finish time line graph

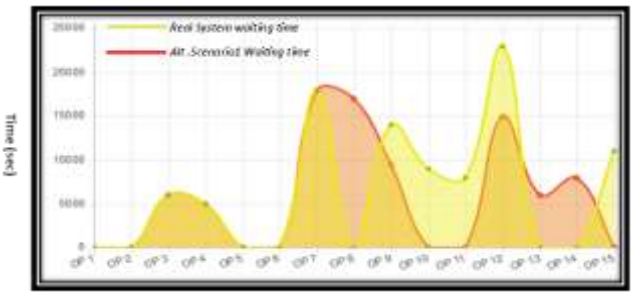

Fig. 5. Alternative Scenario1 waiting time line graph

With adding one operator to the Attach Back Yoke, Joint Shoulder, Attaching and Top stitch /Closing collar size label, top stitch Cuff 5mm and quality Control operations the finish time on each operation was minimize to 10020, 11386, 12504, 21780 and 26555 sec respectively and the finish time of last operation was minimized to 26603 sec compering with the finish time of last operation on the real system that means that the total efficiency was increased by 10%. This Alternative scenario details of the worker numbers, idle time and finish time for each operation is shown on figure 6. Alternative Scenario2 finish time line graph is shown on Figure 7.

Referring to figure 8 after adding workers it is found that the idle time was decreased in operations Attaching and Top stitch /Closing collar size label , Attach Epaulets, Button Hole Collar x3/Cuff, Marking Button Position x12, Attach Button (x12) and Bottom Hemming. Despite off the idle time increasing in some operations, but the total finish time was obviously minimized which matters more. On the other hand the cost on this scenario was increased by 15% (5 workers were added) but comparing to the saved time it is acceptable.

Fig. 6. Alternative Scenario2 screenshot

Fig. 7. Alternative Scenario2 finish time line graph

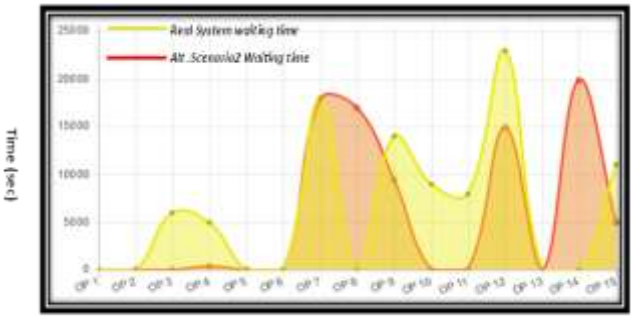

Fig. 8. Alternative Scenario2 waiting time line graph

The saved finish time in this scenario is found to be about 50.22 minutes per working day to produce the same target number of pieces (1000) which is assembled on the real scenario and that means about one working day every 8 days will approximately be spared.

By adding one skilled operator to the quality Control operation the finish time on was minimize to 26575 sec and the finish time of last operation was minimized to 26622 sec compering with the finish time of last operation on the real system. That means the total efficiency was increased by 10%. This scenario is shown on the following figures 9 and 10.

Referring to figure 11 after adding one worker it is noticed that the idle time was decreased in pressing operation. Although in the quality control operation the idle time was increased but the total finish time was clearly minimized which matters more. In this scenario the cost is less by 2/3 of

scenario2 to be 3%.

Fig. 9. Alternative Scenario3 screenshot

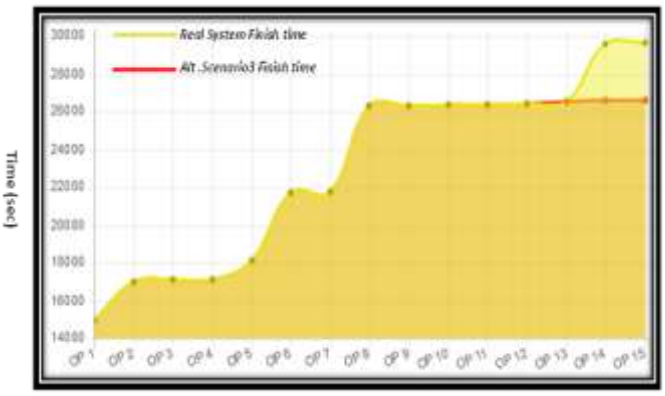

Fig. 10. Alternative Scenario3 finish time line graph

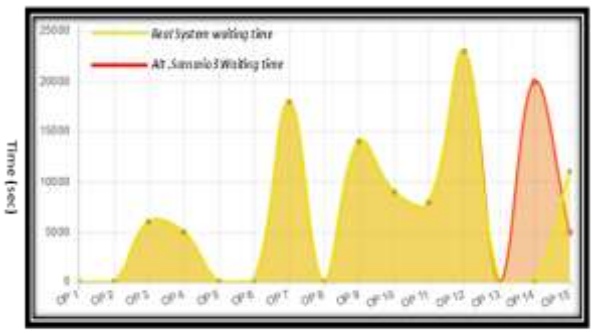

Fig. 11. Alternative Scenario3 waiting time line graph

V. CONCLUSION

The simulation model helped to decrease the finish time to assemble a 1000 pieces compared to the actual real readings as well as increasing the efficiency, beside this the simulation model system can help decision maker by affording several choices for further performance improvement, productivity increment, cost and time.

VI. RECOMMENDATIONS

Since most factories in Sudan depend on experience without the use of simulation for the product line, thus the following is recommended:

- Using of simulation tools is important to get accurate and fast results.
- Training for engineers work in these factories must be provided to develop a well-established production line model to keep the factory privacy without going to an external IT software company.
- Multi-skilled workers can improve the efficiency of the production processes and proper training of the operator is necessary to achieve improvements on productivity and efficiency.
- There is a need for back up (stand by) workers to replace any absent worker due to thickness or sudden leaving because sometimes there were workers shortage and the supervisor assistant when this happen he himself join the work to replace an absent worker.
- Increasing the workers awareness of the importance of the Time Study conducting so as not to change their working behavior to slow it down or anything else.
- In this research, only the Assembly line sewing operations of a U3 Long Sleeve shirt were studied due to availability of running style during the time of research. But this work can be extended for any new style.

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