Simulation Modeling for Productivity Improvement of a Production Line: A Case Study

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Abstract

Now a days most production lines of the industries are designed and equipped with necessary machineries initially which cannot meet the rising demand though their capability increase. The aim of this research was to find solutions towards solving the bottleneck and rectifying the line to improve productivity. This study is based on analyzing an existing production line in Meghna Group of Industry bottle production line which product has a rising demand. The processing time of different workstations with their capacity were collected as necessary data. Simulation was chosen as a tool to analyze the line as it is a frequent technique towards solving problems. The statistical analysis was done through Microsoft Excel software. The existing simulation model was developed using process oriented simulation software Arena to find out the bottleneck of the production line. Also a modified model was proposed which reduces 14.11% waiting time and increases 4% productivity along with increment in profit to cope with rising demand.

Keywords
Simulation, Production Line, Bottleneck, Productivity.

1. Introduction

Manufacturing sector has a great incremental return to scale which provides unique benefits in different sectors. Three types of goods are included in manufacturing production, such as the capital goods, all intermediate goods and most of the consumer goods. It is the most resonant force of development (Nath, 2012). This huge manufacturing sector play a vital role in building up a nation's economy of least developed countries in today's competitive market (Fowler & Rose, 2004; Rahman & Sabuj, 2015).
Production line is one of the main part of manufacturing industries as almost everything goes through a production line at one point (Fowler & Rose, 2004). It can be defined as a set of sequential operations where the end product is produced from raw material through a refining process that becomes suitable for consumption (Manivel & Sandeep, 2014; Watanapa, Kajondecha, Duangpitakwong, & Wiyaratn, 2011; Wiyaratn, Watanapa & Kajondecha, 2013). Assembly line is a part of production line where flow oriented production is seen which are tremendously used in both

high and low quantity production (Manivel & Sandeep, 2014; Wiyaratn et al., 2013). In accordance with the increasing huge role of manufacturing sector many engineering techniques along with some analytical methods and software tools are being developed spontaneously to increase the productivity (Fowler & Rose, 2004; ; Rahman & Sabuj, 2015). Some of the mathematical methods are Asynchronous Model, Synchronous Model, Continuous Model and so on. One of the widely used engineering tool for the analysis and improvement of a production line in a manufacturing system is simulation (Ahmadi, Dasu & Tang, 1992; Eneyo & Pannirselvam, 1998; John & E., 2013).
Simulation is a process of model creation of an existing or proposed system which can identify the system controlling factor. A greater awareness and use of simulation has been created by the recent advanced simulating technology in industries. The manager of the industries have also became concerned about the enormous benefits of simulation (Altiok & Ranjan, 1989; Dallery & Gershwin, 1992). Simulation paves the way to realize the change made by local system along with measuring the impact of the change on whole system which is difficult to identify. The measurable impacts are- parts produced per unit time, time spent in system by parts, time spent by parts in queue, time spent during transportation from one place to another, in time deliveries made, buildup of the inventory, inventory in process and percent utilization of machines and workers (Altiok & Ranjan, 1989; Hammann & N., 1995).
The main aim of this work is to simulate the existing production line of water bottle, analyze the bottleneck in the production line and develop alternative model to improve productivity by minimizing the bottleneck. The previous works in the relevant field are analyzed in literature review section. After the analysis, the shortcomings of the former research were found and some of them were overcome which is described in research gap section in brief. Then the step by step procedure followed in this research is presented in the methodology section. The analysis of existing model and the necessary modification is described in the analysis section and then the outcome of the research discussed in the result and discussion part. At last in the conclusion part, the limitations and some suggested future works are shown.

2. Literature Review

In any industrial production line simulation can be used as a very potential and subsidiary working tool. And accordingly Arena a famous simulation tool which provides all the opportunity to make a simulated model including input data analysis, model building, model verification, output analysis and so on. Following works were done in this track shown in table 1:

Table 1: Reference details

SL. No	References	Details
1	John & Jenson Joseph (2013)	They calculated the utilization and efficiency of the machines. By conducting a work flow study of 4.5Kw shafts, they simulated a model using Arena and found lathe machine containing the highest utilization rate of 26%.
2	Manivel & Sandeep (2014)	They simulated the arrangement of the material flow in the shop along with the cycle time and number of operators and analyzing their efficiency. They found out that the queue length and waiting time is more for lathe and winding machine. According to that they gave suggestion towards the most efficient arrangement by minimizing them.
3	Rahman & Sabuj (2015)	They worked to build a simulated model for a UPS manufacturing system and found three improvement area; transformer section, washing plant and overall floor layout. From them, the highest bottleneck was seen in transformer for which the proposed a new model where total waiting and transfer time was reduced.

2.1 Research Gap

From the literature review, it can be seen that a few works has already done regarding simulation. In those cases, analysis was done on the shop or small manufacturing company regarding some machines. Then they simulated and found the respective problem in each case and gave some suggestions to remove it. In one of them a new model was also suggested to improve the system. But analysis on a full production line of an industry is not done yet which has been introduced here. Along with that cost estimation regarding the change of the existing layout was also calculated to verify the profitability of the proposed line.

2.2 Problem statement

In serving full package of water supply in the visited industry, first of all, the water is refined in seven stages of purification process as De-Iron, Pre-Ozone, De-Odor, Softening, Reverse Osmosis, Ultraviolet Treatment and Ozonation. Following that PF6-2B machine is used to produce the main bottle where total cycle time needed is 21 minutes 56 seconds. The output bottle comes out with labeling through injection cavity molding and blow molding where PET resin is used as the raw material. The cap of the bottle is produced in the same way as the bottle production flow. And finally all the substances are ready for the filling and packaging section. It is the conclusive part of water supply section which is the main concern area. A combination of automated and manual system is seen where the output comes as a full ready package to be delivered.
The entry of the bottle is done manually swiftly to the washing treatment section where the bottle is supplied from the bottle production line. Inventory is kept always in the safety stock so there is approximately no chance of scarcity of bottle supply in this line. Then the remaining process runs through automatic machine flow in the sequence of washing treatment, filling process, capping, date putting up to manual cap sealing section. Two workers are employed in this section for the sealing operation of the bottle cap. Rest of the operation; feeding process and final sealing; are held through automated machine again. As cap sealing operation is manual some extra allowance of time has to be kept here. Regarding this situation a queue is also seen to form in front of this line.

3. Methodology

By collecting the information from Meghna Group of Industries about different processing time of the workstations observing five days, the existing model was analyzed by designing and simulating in Arena. From the analysis the problem areas were found which has to be mitigated. Then a new modified line was proposed to rectify it in increasing productivity. The methodology that was followed is summarized in figure 1.

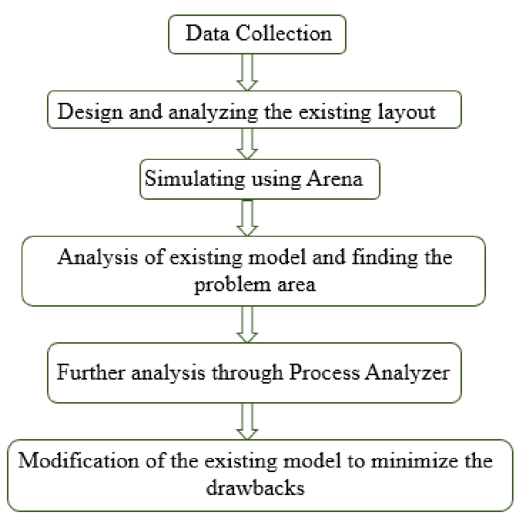

Figure 1: Steps of the research study

4. Analysis and modification

Arena Simulation software was used to draw the existing line. Each workstation was shown by Process module and exit and entrance were shown by Create and Dispose module respectively. In figure 2 the simulation of existing line is conferred here.

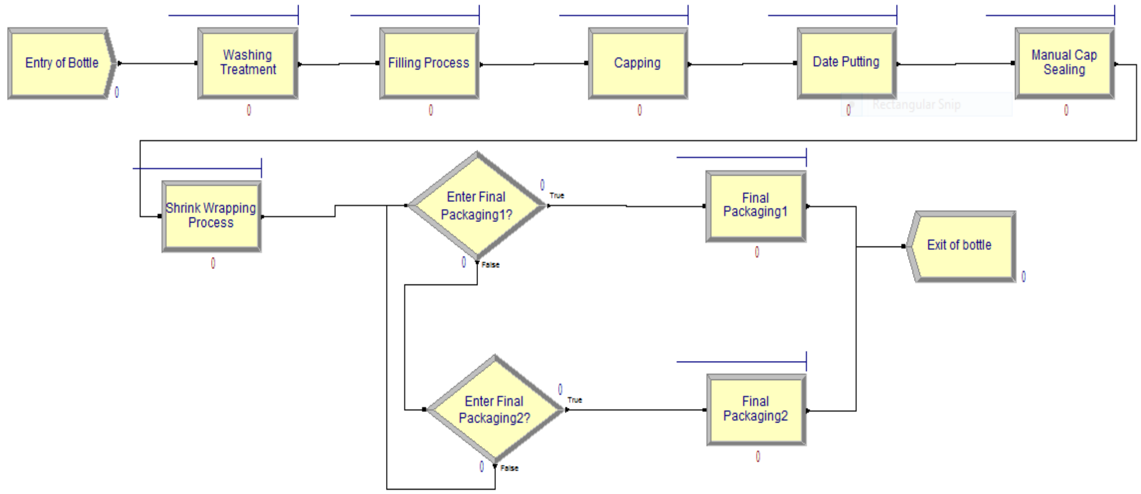

Figure 2: Existing line

In Arena, *Category Overview* and *Queue* are the two parts which contain the necessary result required for the work. The *Number Out* is 7,565 which indicates that in 4 hours the existing line can produce 7,565 number of complete bottles of water with full packaging. The Schedule utilization is another concern which is clearly seen in the model report. In table 2 schedule utilization rate of existing line obtained from the software is tabulated which shows that Date Putting Machine and Laborer shows higher utilization rate than others.

Table 2: Tabulated data of schedule utilization rate (existing line) obtained from the software

Name of the workstation	**Schedule Utilization Rate**
Capping slot	72.5
Date Putting Machine	99.3
Filling Slot	79.5
Heating Machine	38.2
Laborer	98.5
Packaging Machine	77.8
Washing slot	80.9

This data is graphically represented in figure 3 for more clarification. Date Putting Machine and Laborer these two resources are most utilized which is seen in the figure 3 by the most uprising bar showing that those two resources have the highest utilization rate so queue is seen to form in this workstations.

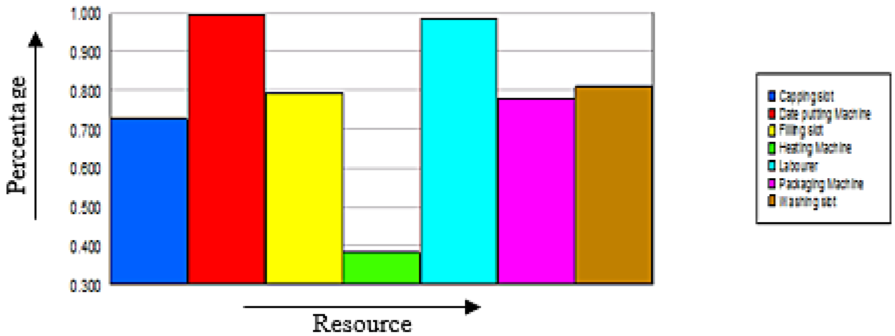

Figure 3: Resource utilization (graphical representation) of existing mode

This concept can be also defined by the amount of waiting time presented in table 3 from which it's clear that Date Putting and Manual Cap Sealing workstations utilizing Date Putting Machine and Laborer as resources respectively have the highest waiting time in the whole flow. Other stations are not facing any queue as much as these two. All these information indicates that Date Putting and Manual Cap Sealing workstations are the process bottlenecks which has be minimized to attain the aim of this research.

Table 3: Tabulated data of waiting time (existing line) obtained from the software

Name of the workstation	**Waiting Time in Second**
Washing Treatment	0.81
Filling Process	0.53
Capping	0.66
Date Putting	1273.11
Manual Cap Sealing	180.19
Shrink Wrapping Process	0.46
Final Packaging1	5.22
Final Packaging2	41.82

Again sensitivity analysis was done through Process analyzer to find out the effect of different workstations on the final output of the existing model. It shows in the chart given below in figure 4 that scenario 6 which is affecting the output most is the scene controlled by manual capping. Further analysis was done to check the effect of scenario 6 in the reduction of waiting time. From figure 5 it's clear that scenario 6 that means change in manual capping contributes the most in this regard.

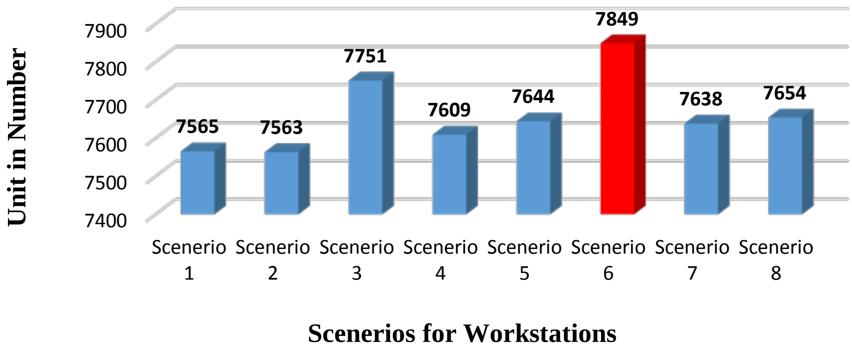

Figure 4: Bottle number output response of Process Analyzer

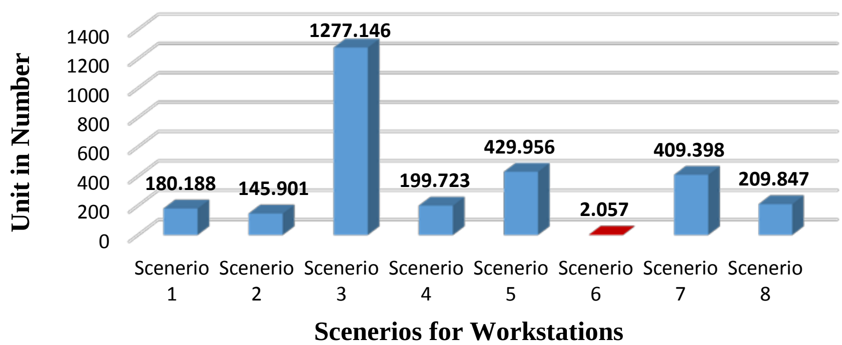

Figure 5: Manual cap sealing waiting time response of Process Analyzer

From the above discussion it is clear that manual cap sealing should be the main focus to rectify the line in increasing productivity. In respect of this a new line is proposed suggesting a semi-automated cap sealing machine in lieu of the manual operation in the workstation shown in figure 6 which will increase the capacity from 16 bpm (bottle per minute) to 40 bpm. All the other processes remain same only manual cap sealing part is transformed from manual to automated operation.

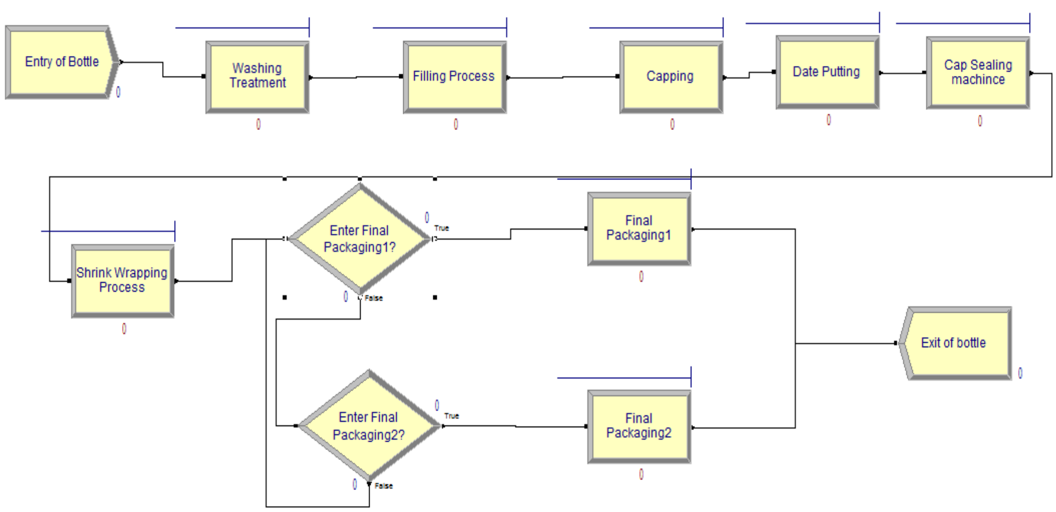

Figure 6: Proposed line

After adding the new machine to the existing line and giving necessary input regarding that the output stands to 7,843 units in a shift. Regarding this result, the schedule utilization rate has decreased for that individual workstation from 98.52% to 83.41% showed in table 4 which has come to a label with others.

Table 4: Tabulated data of schedule utilization rate (proposed line) obtained from the software

Name of the workstation	Schedule Utilization Rate
Capping slot	75.2
Date Putting Machine	99.2
Filling Slot	80.2
Heating Machine	39.9
Capping Machine	83.4
Packaging Machine	82.6
Washing slot	81.1

It has graphically shown in figure 7 where the bar of the respective resource has come to a safe percentage of utilization rate.

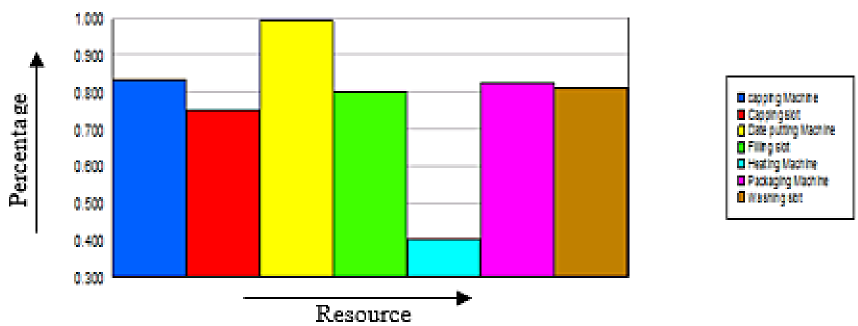

Figure 7: Resource utilization (graphical representation) of modified line

A huge change has come to the waiting line presented in table 5 for which a queue was forming before that is it has reduced from 180.19 seconds to 7.49 seconds.

Table 5: Tabulated data of waiting time (proposed line) obtained from the software

Name of the workstation	Waiting Time in Second
Washing Treatment	1.08
Filling Process	0.54
Capping	0.71
Date Putting	1237.84
Cap Sealing Machine	7.49
Shrink Wrapping Process	0.54
Final Packaging 1	6.68
Final Packaging 2	35.85

As a new machine is proposed to add in the line so it is necessary to find out time within which the industry will be able to recover their extra cost behind machine. To find out that breakeven analysis was done and it was seen that the breakeven point is shown on 90,000 units. According to the working hour the industry will be able to produce more than 8 lakhs bottle per month, so in the first month of adding the machine they will be easily able to cope up the loss and earn profit too. The analysis is shown in figure 8.

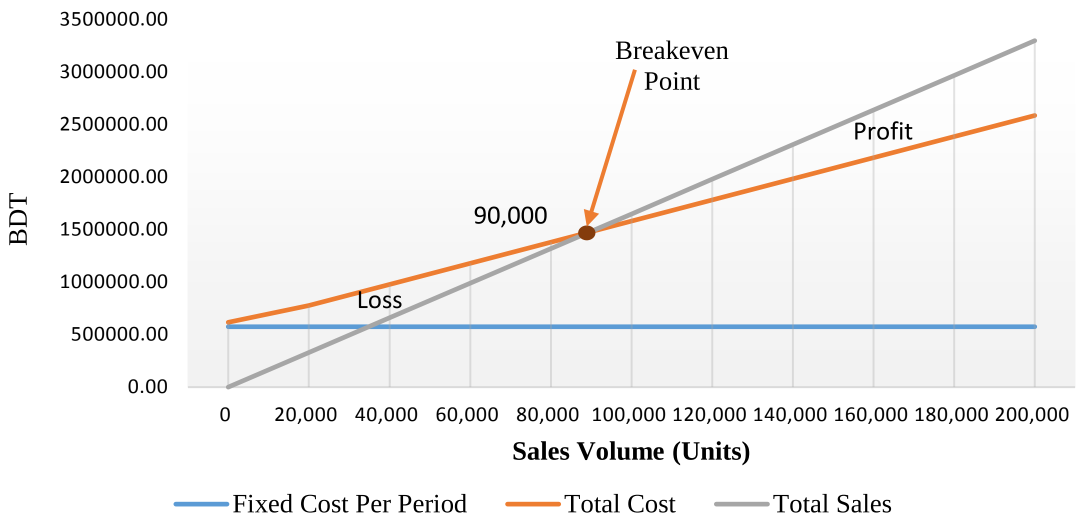

Figure 8: Breakeven analysis

5. Result and Discussion

Comparing the existing and proposed modified model, it has been noticed that 4 workers have no need to stay in the line for setting the machine but production cost per unit will increase as productivity is increasing. A comparison between the performance of both line towards productivity, waiting time and schedule utilization rate along with profit have been shown below by bar chart in figure 09-12 respectively. From charts below, it is clear that in the proposed line, with the reduction in waiting time, schedule utilization and a little bit increase in cost, a tremendous increasing profit is seen for a small percentage of productivity improvement.

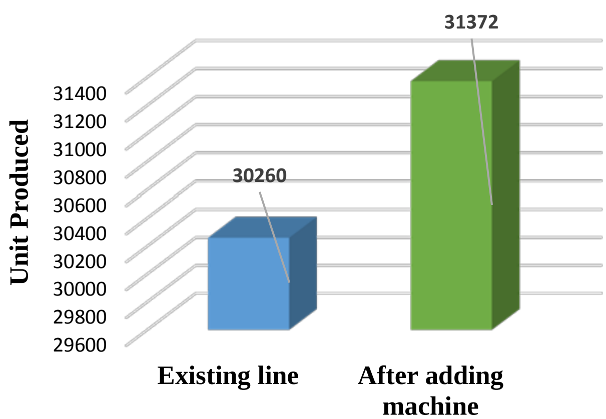

Figure 9: Comparison of production rate per day

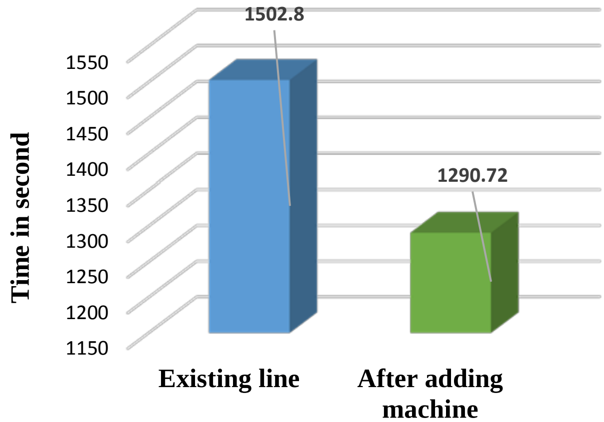

Figure 10: Comparison of average total waiting time

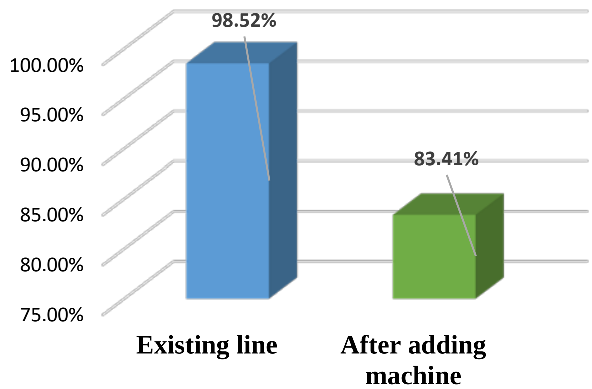

Figure 11: Comparison of schedule utilization rate

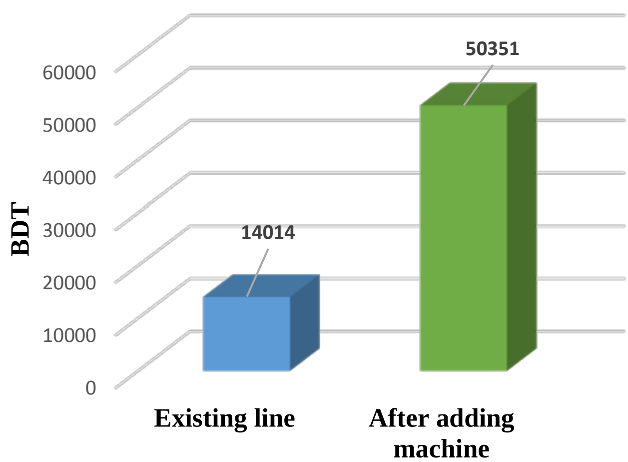

Figure 12: Comparison of profit

The remarkable changes in comparison with previous line are summarized below in table 6.

Table 6: Output summary

Sl. No.	Sector of Differentiation	Remarks
1	Productivity	4% increased
2	Average Waiting Time	14.11% reduced
3	Schedule Utilization Rate	15.11% reduced
4	Profit	36,337 BDT increased after one month

6. Conclusion

In this research, bottleneck areas of existing production line were found out to pave a way to rectify the model to increase its productivity with the application of simulation. The developed model was an ARENA simulation model of a Bottle production line in a selected industry.

Through the simulation of the existing line a large bottleneck area was seen in the Manual Cap Sealing workstation which was later replace by an automated Bottle Cap Sealing machine which reduced the average waiting time and increased the productivity. Along with that cost and revenue were calculated from the collected data which denote that with the reduction of cost in the line, the profit has also increased at a huge amount.

Despite all this works, some limitations still exists in the line. Simulation study was conducted with an assumption of not considering worker fatigue and machine breakdown and there was no practical application of the proposed model. Besides, for the terms and conditions applicable for the industry it was not possible to get the exact cost and revenue related data so an average value was collected and used. Justification of proposed model by applying it in a practical manner can be further approach of future research in this field.

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Biographies

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