J. Appl. Res. Ind. Eng. Vol. 6, No. 2 (2019) 97–107

Journal of Applied Research on Industrial Engineering

www.journal-aprie.com

Identification, Mitigation of Bottleneck by Capacity Addition and Economic Analysis for Copper Cable Production Process: A Case Study

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P A P E R   I N F O

Chronicle:
Received: 23 February 2019
Revised: 10 May 2019
Accepted: 17 June 2019

Keywords:
Bottleneck.
Capacity Addition.
Arena Simulation.
Cost-Benefit Analysis.

A B S T R A C T

A bottleneck machine in a production line will reduce the productivity of the whole. The results of having a bottleneck are stalls in production, supply overstock, pressure from customers, and low employee morale. This paper focuses on the identification of the bottleneck in the production process of “Bangladesh cable silpa limited” and after the identification, tries to mitigate the bottleneck. A bottleneck machine or process causes starving or blocking of parts in the system, thus, therefore, increases the non-value added time and reduces the system performance. In this work, the bottleneck process is identified by using ARENA simulation based on the highest utilization rate and longest queue length matrices. Then, the bottleneck is reduced by increasing the capacity or the number of the machine in the bottleneck process. We can see the effect of changing the capacity of the process without changing the actual production line. Calculating it in a conventional way is very time consuming too. The last step of the thesis is to do an economic analysis. Because when the capacity of the process is increased, the production rate increases but the additional capacity increases the cost of the production.

1. Introduction

Generally, bottleneck refers to the top narrow part of a bottle. The term bottleneck is derived from the neck of a bottle where the speed flow is limited by its neck. In engineering section the bottleneck is an experience by which the performance of an entire apparatus is severely limited by a single component. So, after engineering section in production and project management a bottleneck is a chain processes where its limited capacity reduces the capacity of the whole chain.

A production system consists of set of machines in which the raw materials are processed into a finished product. The products in any system will either be in value added activity such as processing or non-value added state such as waiting in a buffer or machine for processing. Process improvement activities attempt to reduce non-value added time. One of the reasons for increased non-value added time in a production system is due to the bottleneck machines. The production flow in any system is disrupted due to the machine failure and operator failure in the system. If these failures occur repetitively, then the machines cause bottlenecks. The failure in a single machine is able to disrupt the whole production system. Such a failure in a single machine would disrupt the whole production system. So, the major

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DOI: 10.22105/jarie.2019.182889.1088

consideration is that to mitigate the bottleneck. There are many researches for identifying bottleneck machine such as longest queue length [1, 2], lowest production rate [3], buffer with high work in process [3], highest ratio of sensitivity [3], lowest blockage and starvation time [4], highest utilization [5], and longest active duration [6]. But in this research the identification of bottlenecks is obtained through ARENA simulation software to reduce the calculation time and to improve the efficiency and performance of bottleneck identification.

The main objectives of this research is given below:

- To identify the bottleneck machine by using ARENA simulation based on the largest queue length and highest utilization rate.
- To mitigate the bottleneck and increase the production rate.
- Develop a cost-benefit analysis.

2. Problem Statement

Cable manufacturing company in Bangladesh operates under a very competitive atmosphere. Keeping the performance of the production system as high as possible is a key factor in holding a competitive advantage against the competition and in the long run ensuring the survival of the company [7].

In a cable manufacturing industry the processing time of the each machine varies largely. As a result of that, the bottleneck in the production line creates. The machines which have the high production rate become idle as there is no product prepare for processing for that machines because of the bottleneck machine’s lowest processing time. But, if we make the production line balanced or every machine has the same or close processing time, then the production rate will be increased. So in this research we first identify the bottleneck machine based on longest queue length and highest utilization rate. After identifying it, the number of machine is increased to reduce the queue length and utilization rate of the machine. In the fast part, the copper cable manufacturing process is only analyzed.

3. Literature Review

A production line in a production system processes the raw materials and then converts them into a finished product after a set of value added activities [8]. Generally, there is a need for process improvement in any industry to remain competitive in the market. The problem faced by any production industry is the disruption of the work flow by various failures. These various kinds of failures in any production machine cause machines to upstream and downstream for starving the production through the entire system. There are many researches for the bottleneck machine identification such as longest queue method, lowest production rate, lowest blocking and starving time, etc. [9]. Once the bottlenecks are identified, the methods are developed for mitigating it. By allocating buffer to bottleneck, the machine would solve blocking or starving there by mitigating bottleneck machines [10]. Then by using additional capacity and buffers the bottlenecks in production systems are mitigated [11].

Simulation of production lines is a powerful tool in obtaining the performance measures where analytical methods are either difficult or impossible to use [12]. So, the concepts of simulation use ARENA to help the modeler to reach the ability to carry out effective simulation modeling. ARENA is based on SIMAN modeling language and has an object-oriented design to any application area. A production line in the production system is simulated by using an ARENA based simulated model to select a preventive maintenance schedule and gives the best utility and performance values [13]. By using ARENA simulation software, the most appropriate probability distribution of each unreliable machine is detected. Hence, simulation is the best tool that can be used in such a study because one can search for a good feasible solution without disrupting its operation. The production capacity could be increased by 15.4 % as in the real production line [14]. Machine breakdowns and improper maintenance management cause production systems to function inefficiently. Particularly, breakdowns cause rippling effects on other machines in terms of starved and blocked states [15].

Mitigation of bottlenecks can be controlled by capacity addition strategies. To mitigate the bottlenecks, the location, source, and type of bottlenecks have to be identified in any system. Capacity addition strategies are based on highest utilization rate and longest queue length or waiting time. Based on the utilization rate, the blocking time of upstream machine and waiting time of downstream machine, and then the bottleneck machines are identified for adding resources. Capacity addition is used instead of buffer allocation because buffer allocation increases throughput. Hence, the additional capacity is required to meet the demand. Generally, the capacity addition involves installing new machines. Investing in more resources, such as new machines, more personnel, and etc. are the simplistic but more expensive solutions that often prove not to be the wisest.

4. Research Methodology

The following sections cover the steps involved in this research study.

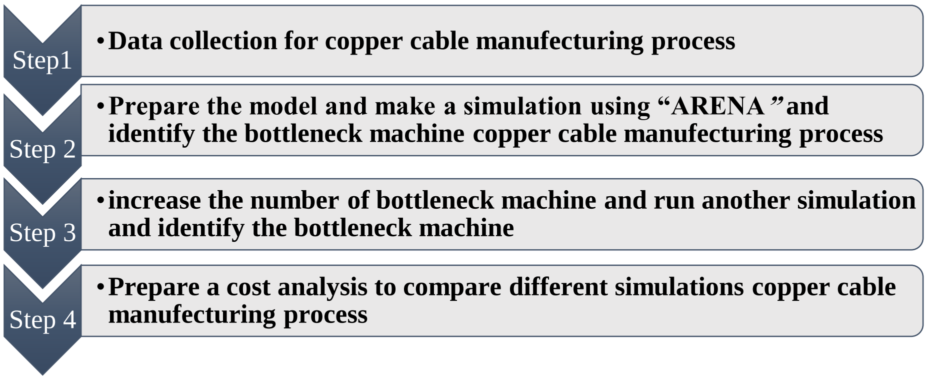

Fig. 1. *Flow diagram for research methodology.*

4.1. Data Collection for Copper Cable Manufacturing Process

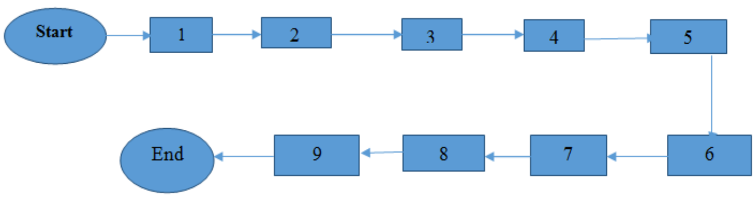

Fig. 2. *Flow chart for copper cable production process.*

Process:

- Heavy drawing.
- Medium drawing
- 60 extruder.
- Pair and quad twisting.
- Unit stranding.
- Main unit and core stranding.
- Filling, foiling and laminated sheathing.
- Steel tape Armouring.
- Final sheathing and length marking.

Table 1. *Data collection for copper cable making process.*

Process name	Minimum time (hour)	Most likely time (hour)	Maximum time (hour)	Number of machine
Heavy Drawing	*.3*	*.4*	*.5*	*1*
Medium drawing	*.15*	*.2*	*.3*	*2*
60 extruder	*.25*	*.35*	*.45*	*1*
Pair & quad twisting	*.2*	*.3*	*.4*	*5*
Unit stranding	*.25*	*.3*	*.35*	*5*
Main unit & core stranding	*.1*	*.15*	*.2*	*2*
Filling ,foiling & laminated sheathing	*.15*	*.2*	*.25*	*2*
Steel tape armouring	*.1*	*.17*	*.2*	*1*
Final sheathing & length marking	*.1*	*.2*	*.23*	*1*

4.2. Prepare the Model and Make a Simulation Using “ARENA”

Step 1. Establish a CREATE module to start the process of the copper cable. Then put the appropriate values in it.
Step 2. Put the process module according to the data taken and put respective value.
Step 3. Prepare the dispose module.
Step 4. Add the number of machines (capacity) required in each of the process.
Step 5. Adjust the run setup (Set project parameters, replication parameters, and run speed parameters).

The result of the simulation is given below:

The output of the production process (after 5 hr of production) = 5 copper cable coils; (1 copper cable coil= 3 km of copper cable).

Table 2. *Number of waiting in each process.*

Name of the machine	Minimum queue length	Maximum queue length	Average queue length
Heavy drawing machine	*0*	*4*	*.4892*
Medium drawing machine	*0*	*0*	*0*
60 Extruder Machine	*0*	*0*	*0*
Pair & quad twisting Machine	*0*	*0*	*0*
Unit Strading Machine	*0*	*0*	*0*
Main unit & core Stranding Machine	*0*	*0*	*0*
Filling , foiling & laminated Sheathing Machine	*0*	*0*	*0*
Steel tape Armouring Machine	*0*	*0*	*0*
Final sheathing & length marking Machine	*0*	*0*	*0*

Scheduled utilization rate for each machine are given below:

Table 3. *Utilization rate of each process of copper cable manufacturing process.*

Name of the machine	Utilization Rate
Heavy drawing machine	*.2503*
Medium drawing machine	*.064*
60 extruder machine	*.2083*
Pair & quad twisting Machine	*.04*
Unit strading machine	*.041*
Main unit & core stranding machine	*.045*
Filling , foiling & laminated sheathing machine	*.056*
Steel tape armouring machine	*.1062*
Final sheathing & length marking machine	*.1217*

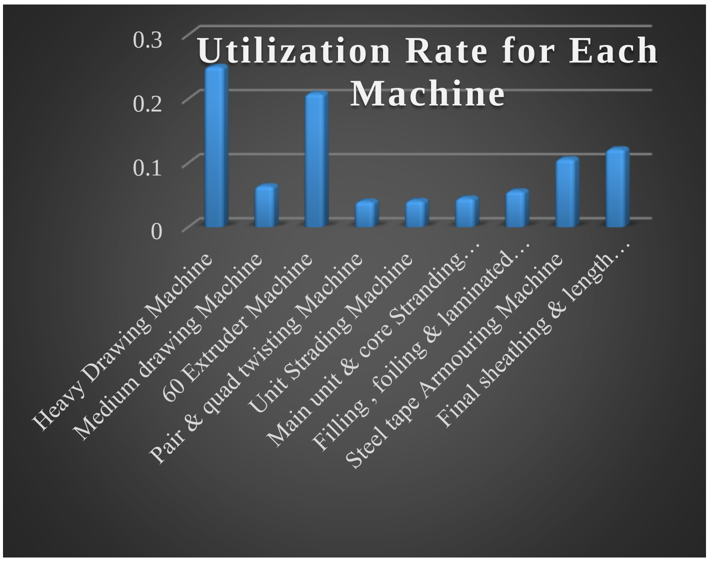

Fig. 3. *Utilization rate of each process of copper cable manufacturing process in graph.*

So from Table 2 and Table 3, it is seen that the heavy draying machine has the highest utilization rate; it has the longest queue length of 4. So it is the bottleneck machine in the copper cable making process. Other highest utilization machine is the extruder machine, so it is also the bottleneck machine in this process.

4.3. Increase the Number of Bottleneck Machine and Run another Simulation and Identify the Bottleneck Machine

The algorithm of this step:

Step 1. Start.

Step 2. Run the simulation.

Step 3. Identify the bottleneck machine based on highest utilization rate and longest queue length.

Step 4. Increase the number of bottleneck machine or increase the capacity of the machine by 1.

Step 5. Run the simulation again.

Step 6. If all the machines utilization rates are not same or there is no queue length then go back to Step 3.

Step 7. End.

The flow chart for this step is given below:

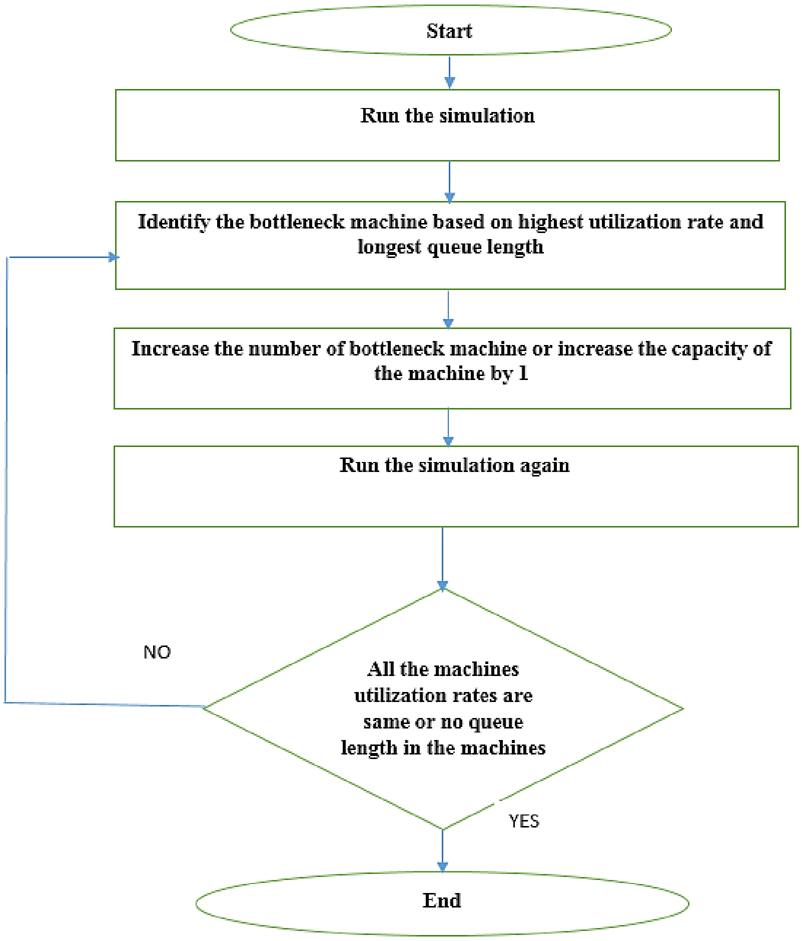

Fig. 4. *Flow chart for this line balancing step.*

To make the utilization rate same of the all machine in this copper cable manufacturing process is a tedious and almost impossible. So if the utilization rate of the machine are close or don't vary largely then we can stop the search. Or we can stop when the queue length of all machines are zero.

4.4. Prepare a Cost Analysis to Compare Different Simulations Copper Cable Manufacturing Process

In the 1st simulation, the bottleneck machine is the heavy drawing machine so we increase the number of drawing machine by 1 and run the simulation:

The output after the increase of machine = 6 copper coil. Now, fixed cost increase =2,000,000 taka, variable cost increases per year =70,000 taka, revenue per year =720,000 taka.

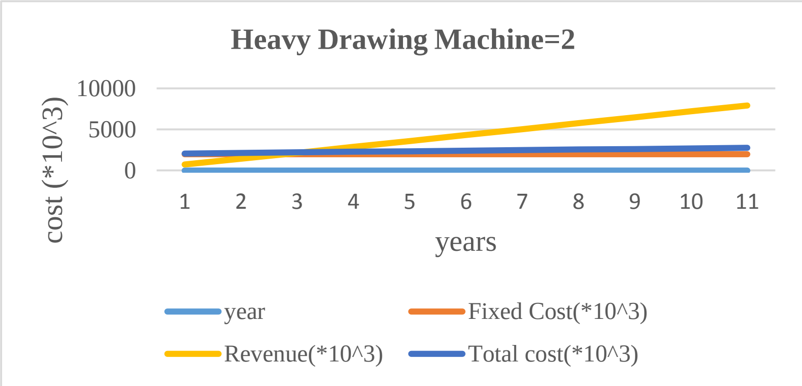

Fig. 5. *Breakeven point when increase the number of drawing machine.*

The breakeven point is 3 year. So after 3 years the company will receive the profit.

Interest rate =10% per year, present worth value of the revenue (after 11 years) =3,401,910 taka, profit present worth after 11 years of drawing machine = (3,401,910-2,000,000) taka =1,401,910 taka. Now in the new simulation, the new bottleneck machine is extruder machine. When increase the number of extruder machine, the output= 7 copper coils. Now, fixed cost increase = 2,500,000 taka, total fixed cost = 4,500,000 taka, variable cost increase per year = 120,000 taka, revenue increase per year = 1,300,000 taka.

4.4.1. Increase the extruder machine by 1 and the breakeven point

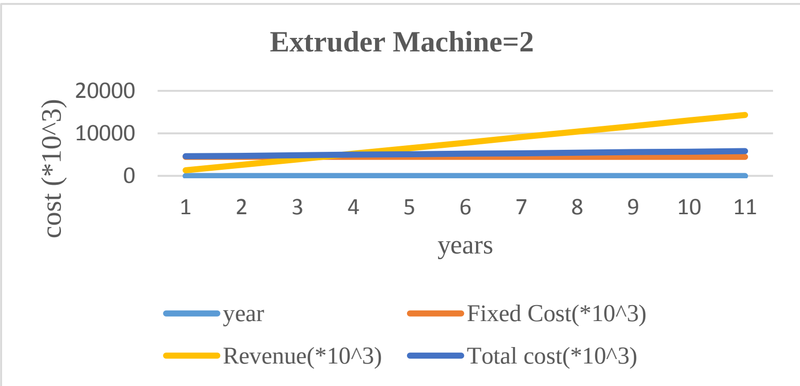

Fig. 6. *Breakeven point when increase the number of extruder machine.*

The breakeven point is 4 year (Approximately). So after 4 years, the company will receive the profit.

Interest rate = 10% per year, present worth value of the revenue after 11 years = 6,175,740 taka, profit present worth after 11 years of extruder machine = (6,175,740-4,500,000) taka =1,675,740 taka. Now, in the new simulation, the new bottleneck machine is finishing machine.

4.4.2. When increase the number of finishing machine

The output = 7 copper coils, so the output didn't change after increasing the finishing machine. Now, fixed cost increase = 6,500,000 taka, variable cost increase per year = 170,000 taka, revenue increase per year = 1,300,000 taka (no change in output).

4.4.3. Increase the finishing machine by 1 and the breakeven point

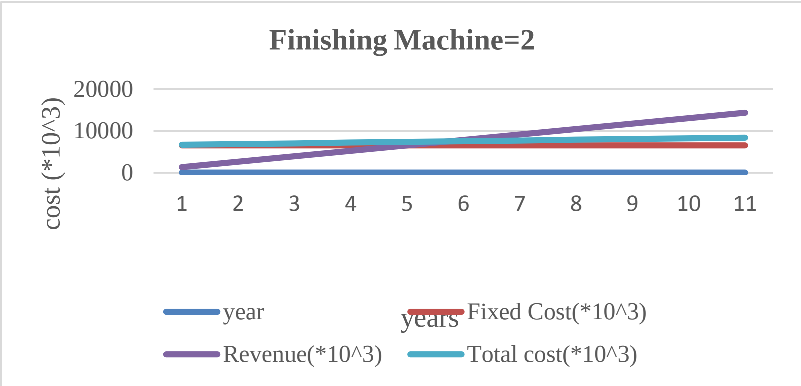

Fig. 7. *Breakeven point when the number of finishing machine increases.*

The breakeven point is 6 year (approximately). So, after 6 years the company will receive the profit.

Interest rate=10% per year, present worth value of the revenue after 11 years = 5,914,090, profit present worth after 11 years of finishing machine = (5,914,090-6,500,000) taka = -585,910 taka. Now, in the new simulation the new bottleneck machine is armouring machine.

4.4.4. Increase the number of armouring machine

The output = 8 copper coils. Now, fixed cost increase = 8,000,000 taka, variable cost increase per year = 230,000 taka, revenue increase per year = 2,100,000 taka.

4.4.5. Increase the armouring machine by 1 and the breakeven point

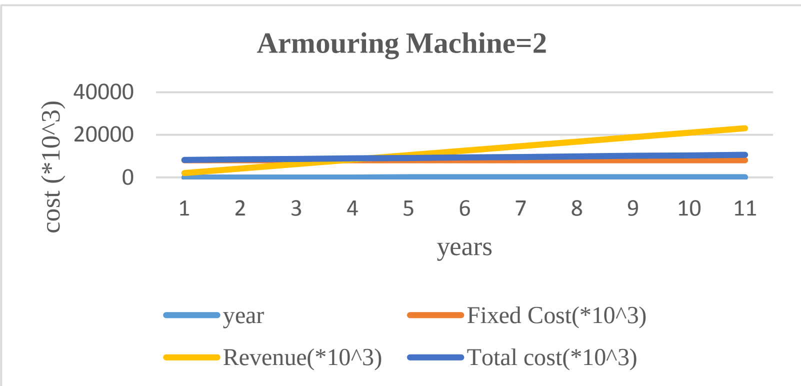

Fig. 8. *Breakeven point when the number of armouring machine increases.*

The breakeven point is 4.5 year (approximately). So after 4.5 years the company will receive the profit.

Interest rate=10% per year, present worth revenue after 11 years = 9,787,040 taka, profit present worth after 11 years of armouring machine = (9,787,040-8,500,000) taka = 1,787,040 taka.

Table 4. *Comparison of the present worth value of the profit.*

Number of Machines in Each process	Profit Present Worth After 11 Years
Heavy drawing machine=2	*1,401,910*
Extruder machine=2	*1,675,740*
Finishing machine=2	*-585,910*
Armouring machine=2	*1,787,040*

After 11 years, the increase of 4 machines (heavy drawing machine, extruder machine, finishing machine, armouring machine) seems profitable.

5. Conclusions

During this research, we tried to identify the bottleneck machine in the production process of "Bangladesh cable silpa limited". We tried to find the bottleneck machines and to mitigate it in copper cable, the production process of the company. The first step of this thesis was identifying the bottlenecks in copper cable. Bottlenecks in this project were identified using utilization metric, queue length metric. In our simulation, we found that the extruder machine has the highest utilization rate in the whole process. In that machine there are also some product which are in waiting. So it is the bottleneck in the process. The next step of our project was to mitigate the bottleneck process by capacity addition method. In this phase we changed the number machine of bottleneck process. Our main objective was to make the utilization of the all the similar process (or close so there is no queue length). The last step of our project was to do the economic analysis of each simulation. So, to examine what extent we add the new machine we have done the economic analysis, compared between the other simulations, and selected which had the largest profit after 11 year. We also considered 10% rate of interest per year and turned them into present value. Among the 4 other, the best solution was to increase heavy drawing machine, extruder machine, finishing machine, armouring machine.

6. Limitations of the Research

The constraints of this research are:

- We didn't consider the human participation or human related delays in both manufacturing process.
- We didn't consider the material handling time, we included this in the machines processing time.

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