AN Investigation OF THE PRODUCTION LINE FOR ENHANCED PRODUCTION USING HEURISTIC METHOD

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ABSTRACT

Line balancing is the phase of assembly line study that nearly equally divides the works to be done among the workers so that the total number of employees required on the assembly line can be minimized. As small improvements in the performance of the system can lead to significant monetary consequences, it is of utmost importance to develop practical solution procedures that may yield a significant enhancement in the throughputs of production. Bangladesh Machine Tool Factory (BMTF) was undertaken as a research project which had been incurring loss for a long time at their current production rate. In the course of analysis, a line balancing (LB) technique was employed to have a detail analysis of the line. This paper describes how an efficient heuristic approach was applied to solve the deterministic and single-model ALB problem. The aim of the work was sought as to minimize the number of workstations with minimum cycle time so as to maximize the efficiency of the production line. The performance level was found so low that there was no way to improve the productivity without any reduction of the idle time from the line curtailing the avoidable delays so far possible. All the required data was measured and the parameters such as elapsed times, efficiencies, number of workers, time of each of the workstations etc. was calculated from the existing line. The same production line was redesigned through rehabilitating & reshuffling the workstations as well as the workers and using the newly estimated time study data, keeping minimum possible idle time at each of the stations. A new heuristic approach, the Longest Operation Time (LOT) method was used in designing the new production line. After set up of the new production line, the cost of production and effectiveness of the new line was computed and compared with those of the existing one. How much costs could be saved and how much productivity could be increased for the newly designed production line that were estimated and the production was found to have been increased by a significant amount reducing the overall production cost per unit.

KEYWORDS: *Assembly Line Balancing (Alb), Workstation, Line Efficiency, Task Time, Cycle Time and Line Bottleneck.*

I. INTRODUCTION

An arrangement of workers, machines, and equipment in which the product being assembled passes consecutively from operation to operation until completed. Also it is called production line[1].
An assembly line[1] is a manufacturing process (sometimes called progressive assembly) in which parts (usually interchangeable parts) are added to a product in a sequential manner using optimally planned logistics to create a finished product much faster than with handcrafting-type methods. The division of labor was initially discussed by Adam Smith, regarding the manufacture of pins, in his book "The Wealth of Nations" (published in 1776). The assembly line developed by Ford Motor Company between 1908 and 1915 made assembly lines famous in the following decade through the social ramifications of mass production, such as the affordability of the Ford Model T and the introduction of high wages for Ford workers. Henry Ford was the first to master the assembly line and was able to improve other aspects of industry by doing so (such as reducing labor hours required to produce a single vehicle, and increased production numbers and parts). However, the various preconditions for the development at Ford stretched far back into the 19th century, from the gradual realization of the dream of interchangeability, to the concept of reinventing workflow and job descriptions using analytical methods (the most famous example being "Scientific Management"). Ford was the first company to build large factories around the assembly line concept. Mass production via assembly lines is widely considered to be the catalyst which initiated the modern consumer culture by making possible low unit cost for manufactured goods. It is often said that Ford's production system was ingenious because it turned Ford's own workers into new customers. Put another way,

Ford innovated its way to a lower price point and by doing so turned a huge potential market into a reality. Not only did this mean that Ford enjoyed much larger demand, but the resulting larger demand also allowed further economies of scale to be exploited, further depressing unit price, which tapped yet another portion of the demand curve. This bootstrapping quality of growth made Ford famous and set an example for other industries

For a given a set of manufacturing tasks and a specified cycle time, the classical line balancing problem consists of assigning each task to a workstation such that: (i) each workstation can complete its assigned set of tasks within the desired cycle time, (ii) the precedence constraints among the tasks are satisfied, and (iii) the number of workstations is minimized. (Krajewski and Ritzman, 2002[2], Meredith and Schafer, 2003)[3]. Scholl (1999) [6].

The precedence relations among activities in a line balancing problem present a significant challenge for researchers in formulating and implementing an optimization model for LB problem. While integer programming formulations are possible, but they quickly become unwieldy and increasingly difficult to solve when problem size increases. As a result, many researchers recommend heuristic approaches to solving the line balancing problem (Meredith and Schafer, 2003[3], Sabuncuoglu[5], Erel et al. 2000[5]; Suresh, Vivod and Sahu, (1996)[7].

An assembly line (as shown in Figure 1) is a flow-oriented production system where the productive units performing the operations, referred to as stations, are aligned in a serial manner. The work pieces visit stations successively as they are moved along the line usually by some kind of transportation system, e.g. a conveyor belt. The current market is intensively competitive and consumer-centric. For example, in the automobile industry, most of the models have a number of features, and the customer can choose a model based on their desires and financial capability. Different features mean that different, additional parts must be added on the basic model. Due to high cost to build and maintain an assembly line, the manufacturers produce one model with different features or several models on a single assembly line. Due to the complex nature of the ALB problem, there are many heuristics that was used to solve the real life problems relating to the assembly line with a view to increase the efficiency and productivity of the production line at minimum cost.

Now-a-day, in mass production, a huge number of units of the same product are produced. This is only possible with a high degree of division of labors. Since Adam Smith (1776) [8] it has been shown that division of labor will train the required skills of the workers and will increase the productivity to a maximum. The maximum degree of division of labor is obtained by organizing production as an assembly line system. Even in the early days of the industrial revolution mass production was already organized in assembly line systems. According to Salveson [9], the "First assembly line was introduced by Eli Whitney during the French Revolution [10] for the manufacturing of muskets. The most popular example is the introduction of the assembly line on 1 April 1913, in the “John R-Streeta of Henry Ford’s Highland-Parka production plant [10], where are still `up to date’ because of the principle to increase productivity by division of labor is timeless. The most known example is the final assembly in automotive industry. But nearly all goods of daily life are made by mass production which at its later stages is organized in assembly line production systems. For example the final assembly of consumer durables, like coffee machines, toasters, washing machines, refrigerators or products of the electrical industry like radio and TV or even personal computers is organized in assembly line systems.

The characteristic problem in assembly line systems is how to split up the total work to be done by the total system among the single stations of the line. This problem is called “assembly line balancing” because we have to find a “balance” of the work loads of the stations. First of all we have to determine the set of single tasks which have to be performed in the whole production system and the technological precedence relations among them. The work load of each station (also: set of task, station load, operation) is restricted by the cycle time, which depends on the fixed speed of the conveyor and the length of the stations. The cycle time is defined as the time between the entering of two consecutive product units in a station[11].

In the literature usually the objective is to minimize the number of stations in a line for a given cycle time. This is called time-oriented assembly line balancing[12]. As in recent years the industry was facing with sharp competitiveness the production cost has become more relevant. Even in such successful production systems like the assembly line system, we have to look for possibilities to cut down production cost. As final assembly is usually a labor intensive kind of production we may analyze the existent wage compensation system. Almost all collective agreements between unions and employers work with a wage differential in most developed industrial nations, e.g. in German industry which has been analyzed in detail. The higher the difficulties to perform a task, the higher the point value of the task and the wage rate. As the tasks in final assembly are similar but not of unique difficulty there exists certain different wage rates in assembly line production systems. Under this economic perspective the objective in organizing work in assembly line production systems is not to minimize the number of stations, but to minimize the total production cost per unit. Therefore we have to allocate the tasks to stations in a way that both, cost rates and number of stations are considered. This is done in cost-oriented assembly line balancing [13]. A formal description of this objective and the restrictions of this problem are given in [14, 15]. As this paper is directly related to a previous work [16] the formal descriptions needed are reduced to a minimum. Compared to existent balances which were obtained by the use of time-oriented methods neglecting wage rate differences, it is possible to realize savings in production cost up to a two-digit percentage by a cost-oriented reallocation of tasks using cost-oriented methods.

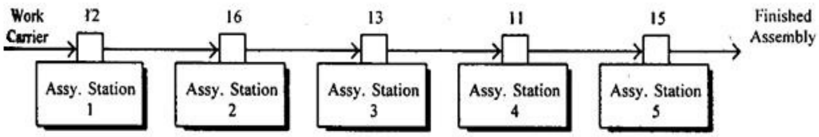

Figure 1: A typical assembly line with few work stations

II. APPROACHES TO DETERMINATION OF PERFORMANCE OF ASSEMBLY LINE BALANCING PROBLEM (ALBP)

According to M. Amen (2000)[17], there are two types of optimization problems for the line balancing problem (LBP). Assembly line balancing problems are classified into two categories. In Type-I problems with the cycle time, number of tasks, tasks times and task precedence. The objective is to find the minimum number of workstations. A line with fewer stations results in lower labor cost and reduced space requirements. Type-I problems occurs when we have to develop a new assembly line. Type-II problem occurs when the numbers of workstations or workers are fixed. Here the objective is to minimize the cycle time. This will maximize the production rate because the cycle time is expressed in time units per part (time/parts) and if we can find the minimum cycle time then we can get more production per shift. This kind of problem occurs when a factory already has a production line and the management wants to find the optimum production rate so that the number of workstations (workers) is fixed. According to Nearchou (2007), the goal of line balancing is to develop an acceptable, though not necessarily optimum but near to an optimum solution for assembly line balancing for higher production. With either type, it is always assumed that the station time, which is the sum of times of all operations assigned to that station, must not exceed the cycle time. However, it is unnecessary or even impossible (e.g. when operation times are uncertain) to set a cycle time large enough to accommodate all the operations assigned to every station for each model. Whenever the operator cannot complete the pre-assigned operations on a work piece, work overload occurs. Since, idle time at any station is the un-utilized resource, the objective of line balancing is to minimize this idle time.

Line balancing[12] is the phase of assembly line study that nearly equally divides the work to be done among the workers so that the total number of employees required on the assembly line can be minimized. The Type-II approach had been followed, where the line balancing involves selecting the appropriate combination of work tasks to be performed at each workstation so that the work is performed in a feasible sequence and proximately equal mounts of time are allocated at each of the workstations. The aim of the present study is to minimize the required labor input and facility investment for a given output. The objective of the present work was to perform either: (i) Minimizing the number of workstation (workers) required to achieve a given cycle time (i.e., given production capacity) or, minimizing the cycle time to maximize the output rate for a given number of workstations.

Assembly lines are designed for a sequential organization of workers, tools or machines, and parts. The motion of workers is minimized to the extent possible. All parts or assemblies are handled either by conveyors or motorized vehicles such as forklifts, or gravity, with no manual trucking. Heavy lifting is done by machines such as overhead cranes or forklifts. Each worker typically performs one simple operation. According to Henry Ford [19] the principles of assembly are:

(a) Placing the tools and the men in the sequence of the operation so that each component part shall travel the least possible distance while in the process of finishing.

(b) Using work slides or some other form of carrier so that when a workman completes his operation, he drops the part always in the same place--which place must always be the most convenient place to his hand--and if possible have gravity carry the part to the next workman for his operation.

(c) Using sliding assembling lines by which the parts to be assembled are delivered at convenient distances.

III. PROBLEM DESCRIPTION

First, let us make some assumptions complied with most practical mixed model assembly lines:

1. The line is connected by a conveyor belt which moves at a constant speed. Consecutive work pieces are equi-spaced on the line by launching each after a cycle time.
2. Every work piece is available at each station for a fixed time interval. During this interval, the work load (of the respective model) has to be performed by an operator while the work piece rides downstream on the conveyor belt. If the work load is not finished within the cycle time, the operator can drift to the next consecutive station f or a certain distance. If the drifting distance is reached without finishing the operations, work overload occurs. In this case, a utility worker is additionally employed to perform the remainder work so fast that the work can be completed as soon as possible.
3. The operators of different stations do not interfere with each other while simultaneously servicing a work piece (i.e. during drifting operations).
4. The operator returns to the upstream boundary of the station or the next work piece, whatever is reached first, in zero time after finishing the work load on the current unit, because the conveyor speed is much smaller than the walking speed of the operators.
5. Precedence graphs can be accumulated into a single combined precedence graph, similar operations of different models may have different operation time; zero operation time indicate that an operation is not required for a model.
6. Cycle time, number of stations, drifting distance, conveyor speed and the sequence of models to be assembled within the decision horizon must be known.

IV. SURVEY OF THEORIES

4.1 A heuristics applied for solving the cost-oriented assembly line balancing problem applied in LBP [15, 23] many heuristics exist in literature for LB problem. The heuristic provides satisfactory solution but does not guarantee the optimal one (or the best solution).

As the Line balancing problems can be solved by many ways, out of those, the Longest Operation Time (LOT)[23] approach had been used. It is the line-balancing heuristic that gives top assignment priority to the task that has the longest operation time.

The steps of LOT are:

LOT 1: To assign first the task that takes the most time to the first station.

LOT 2: After assigning a task, to determine how much time the station has left to contribute.

LOT 3: If the station can contribute more time, to assign it to a task requiring as much time as possible.

The operations in any line follow same precedence relation. For example, operation of super-finishing cannot start unless earlier operations of turning, etc., are over. While designing the line balancing problem, one has to satisfy the precedence constraint. This is also referred as technological constraint, which is due to sequencing requirement in the entire job.

V. TERMINOLOGY DEFINED IN ASSEMBLY LINE

5.1 Few Terminology of assembly line analysis [24, 25]

a. **Work Element (i) :** The job is divided into its component tasks so that the work may be spread along the line. Work element is a part of the total job content in the line. Let TV be the maximum number of work element, which is obtained by dividing the total work elements into minimum rational work elements. Minimum rational work element is the smallest practical divisible task into which a work can be divided. The time in a-work element, *i* say (T_{jN}), is assumed as constant. Also, all T_{iN} are additive in nature. This means that if "assume that if work elements, 4 and 5, are done at any one station, the station time would be ($T_{4N} + T_{5N}$). Where N is total number of work elements.

b. Work Stations (w): It is a location on the assembly line where a combination of few work elements is performed.

c. Total Work Content (T_{wc}) : This is the algebraic sum of time of all the work elements on the line. Thus;

$$T_{we} = \sum^{N}_{i=1} T_{iN}$$

d. Station Time (T_{si}) : It is the sum of all the work elements (i) on work station (s).

e. Cycle Time (c): This is the time between two successive assemblies coming out of a line. Cycle time can be greater than or equal to the maximum of all times. If, c = max {T_{si}}, then there will be ideal time at all stations having station time less than the cycle time.

f. Delay or Idle Time at Station (T_{ds}) : This is the difference between the cycle time of the line and station time.

$$T_{ds} = c - T_{si}$$

g. Precedence Diagram This is a diagram in which the work elements are shown as per their sequence relations. Any job cannot be performed unless its predecessor is completed. A graphical representation, containing arrows from predecessor to Predecessor have the *successor work element.* Every node in the diagram represents a work element.

h. Balance Delay or Balancing Less (d) : This is a measure of line-inefficiency. Therefore, the efficient is done to minimize the balance delay. Due to imperfect allocation of work along various stations, there is idle time to station. Therefore, balance delay:

$$D = nc - T_{we} / nc = nc - \sum^{N}_{i=1} T_{iN} / nc$$

Where;

c = Total cycle time;
T_{we} = Total work content;
n = Total number of stations.

i. Line Efficiency (LE) : It is expressed as the ratio of the total station time to the cycle time, multiplied by the number of work stations (n):

$$LE = \sum^{N}_{i=1} T_{iN} / (nc) \times 100\%$$

Where; T_{si} = Station time at station i, n = Total number of stations, c = Total cycle time

j. Target time : Target cycle time (which must be greater than or equal to the target task) or define the target number of workstations. If the Σt_i and n are known, then the target cycle time c_t can be found out by the formula: $c_t = \Sigma t_i / n$.

k. The Total Idle time: : The total idle time for the line is given by:

$$IT = nc - \sum_{i=1}^{k} t_i$$

A line is perfectly balanced if IT = 0 at the minimum cycle time. Sometimes the degree to which a line approaches this perfect balance is expressed as a percentage or a decimal called the balance delay. In percentage, the balance delay is found given as

$$D = \frac{100\,(IT)}{nc}$$

Where,

IT = Total idle time for the line.
n = the number of workstations, assuming one worker per workstation
c = the cycle time for the line
t_i = time for the i_{th} work task
k = the total number of work task to be performed on the production line

The total amount of work to be performed on a line broken into tasks and the tasks assigned to work stations so the work is performed in a feasible sequence within and acceptable cycle time. The cycle time for a line (time between completions of successive items on the line) is determined by the maximum amount of time required at any workstation. Work can not flow through the line any faster than it can pass through the slowest stage (the bottleneck of the line)[28]. If one workstation has a great deal of more work than others, it is desirable to assign some of this work to stations with less work so that there will exist no bottlenecks in the line.

VI. DATA PRESENTATION FOR WORK STATIONS

The following table shows the time study data at each of the work stations of the present production line[7}:

Table 1: Elapsed time at each work station

Station No.	Tasks	No. of workers	Time-1 (Minutes)	Time-2 (Minutes)	Time-3 (Minutes)
01	(a) Box opening	2	10	12	11
	(b) check	2	10	11	9
	Parts distribution	2	30	29	32
02	Frame cleaning	2	30	32	34
	Axle with wheel	2	50	54	48
	Leaf spring setting	2	30	32	30
	Engine mounting	2	20	18	21
	Axle with frame	2	40	42	45
	Harnessing	2	30	32	28
	Disc wheel setting	2	20	22	21
	Check	1	30	30	28
03	Bracket fittings	4	60	55	50
	Flexible piping	4	30	26	27
	Copper piping	4	30	28	26
	Nut tightens	4	30	25	28
	Booster + Air tank	1	170	180	190
	Check	1	30	26	25
04	Engine assembly	2	30	28	32
	Alternation	2	15	14	16
	Fan	2	15	16	17
	Self stator	2	14	15	16
	Transmission sub. Ass.	2	30	32	35
	Member assembly	2	60	60	65
05	Radiator, silencer, ass.	3	60	65	62
	Check	1	30	25	26
	Horn and hose pipe	2	20	25	25
	Air cleaner	2	20	22	26
	Fuel tank	2	30	32	35
06	Battery carrier	2	30	31	33
	Transfer line	2	30	28	35
	Propeller shaft	2	50	60	55
	Fluid Supply	2	20	25	22
	Check	1	30	35	30
07	Cabin sub assembly	3	90	100	95
	Side, signal lamp	2	30	35	40
	Cabin on Chassis	3	30	32	29
	Starting system	2	30	32	34
08	Check	2	25	26	30
	Wood pattern making	6	60	60	65
	Seat making	5	45	55	48
	Wood paining	7	47	54	51
	Load body sub assy.	8	60	58	62
09	Load body on Vehicle	12	55	58	60
	Electric wiring	4	25	30	30
	Pudding	5	52	55	55
	Rubbing the cabin	6	64	58	60
10	Primary painting	3	40	42	44
	Re-pudding	4	25	28	24
	Final painting	3	50	48	55
	Touch-up	3	32	30	34

VII. COMPARISON BETWEEN EXISTING AND MODIFIED MODELS OF THE PRODUCTION LINE

**Fig 2:Existing Model of AL :
(with ten stations)**

Station-1
Working time (modified) = 50
No. of workers (required) = 2

↓

Station-2
Working time (modified) = 60
No. Of workers (required) = 2

↓

Station-3
Working time (modified) = 192
No. Of workers (required) = 4

↓

Station-4
Working time (modified) = 156
No. Of workers (required) = 6

↓

Station-5
Working time (modified) = 229
No. Of workers (required) = 4

↓

Station-6
Working time (modified) = 174
No. Of workers (required) = 4

↓

Station-7
Working time (modified) = 199
No. Of workers (required) = 5

↓

Station-8
Working time (modified) = 205
No. Of workers (required) = 27

↓

Station-9
Working time (modified) = 234
No. Of workers (required) = 15

↓

Station-10
Working time (modified) = 192
No. Of workers (required) = 19

**Fig 3: Proposed Model of AL
(With eight Stations)**

Station-1
Working time = 60
No. of workers (working) = 2

↓

Station-2
Working time = 45
No. Of workers (working) = 2

↓

Station-3
Working time = 210
No. Of workers (working) = 6

↓

Station-4
Working time = 230
No. Of workers (working) = 8

↓

Station-5
Working time (modified) = 229
No. Of workers (required) = 4

↓

Station-6
Working time (modified) = 174
No. Of workers (required) = 4

↓

Station-7
Working time (modified) = 199
No. Of workers (required) = 5

↓

Station-8
Working time (modified) = 205
No. Of workers (required) = 27

VIII. ASSEMBLY LINE AND ANALYSIS

The present situation of the stations is shown in the following table below.

Table 2: Observed time and workers at all workstations in the existing production line

Station No.	No of Worker	Elapsed Time(Min)
Station 1	2	50
Station 2	2	60
Station 3	6	210
Station 4	8	230
Station 5	6	160
Station 6	5	198
Station 7	6	185
Station 8	33	235
Station 9	19	202
Station 10	22	210

Actual number of workers, W_A	**109**
Total Elapsed Time	**1740 mins.**

IX. Performance Analysis of the Assembly Line

Iterations for line balance efficiency at the stations:
First iteration, as a sample calculation:
Using the existing production line time data from Table 2, where the total elapsed time was 210 minutes at the workstation no.3.

9.1 Sample Calculations:

From the existing model we have[30]:

$$\text{CycleTime} = \frac{\text{Available time / Period}}{\text{Output Units required / period}}$$

$$= \frac{8 \text{ hours} \times 60 \text{ min.}}{2} = \frac{480 \text{ min.}}{2} = 240 \text{ min.}$$

$$\text{Theoretical minimum no. of workers.} = \frac{\sum T}{CT}$$

$$\text{Since, Total time, } \Sigma T = W_1T_1 + W_2T_2 + W_3T_3 + \text{-----------} + W_y T_y$$
$$= 22{,}593 \text{ minutes.}$$

$$\text{Theoretical minimum no of workers} = \frac{22593}{240} = 94.14 \cong 95 \text{ no.}$$

$$\textbf{Balance Efficiency} = \frac{\text{Theoretical minimum no. of workers}}{\text{Actual no. of worker}} = \frac{94}{109} = 86\%$$

9.2 Iterations for final balance efficiency:

Similarly, the existing assembly line had been rearranged several times many iterations had been carried out at all workstations at aim to eliminate the idle time and reducing the number of work stations to eight, keeping the precedence works logical and finally the station time have been furnished in the Table 3. Eliminating all idle time, the total elapsed time for the line has been made to 1685 minutes.

Table 3: Total elapsed time in all workstations in the new production line(for Iterations #1).

Stations	Functions	Time Consumed
Station1	Materials Handling & Distribution	223
Station2	Spot Welding Section	223
Station3	Metal Section	203
Station4	Painting Section	205
Station5	Chassis Section	205
Station6	Trimming Section.	206
Station7	Final Section.	208
Station8	Inspection Section	212
Total working time that had been reduced to		1685 minutes

9.3 Sample analysis for reducing the idle time and number of work stations to minimum as follows:

Let us consider the Work Station no. 3:

This station has five workers. Applying the line balancing technique the precedence diagram is shown in Fig 2.

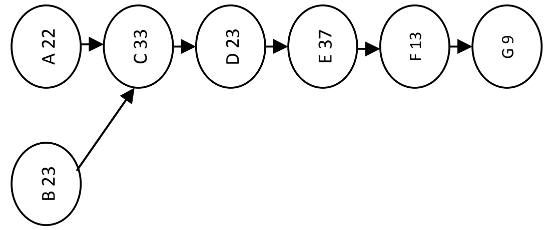

Figure 3: Precedence diagram and elapsed time of tasks operations at Station # 3 in the existing assembly line.

Table 4: Time elapsed in modified line at workstation no. 3.

Tasks /Activity	Workers	Predecessor activity	Actual time needed to finish the work (min.)
A	2	-	16
B	1	-	19
C	1	B, A	35
D	1	C	26
E	1	D	19
F	1	E	32
G	2	F	9
H	3	G	6
			$\sum = 162$

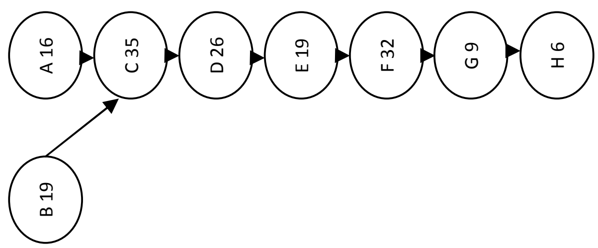

Figure 4 : Precedence diagram and elapsed time of tasks operations at Station # 3 in the proposed assembly line.

Therefore, Time can be saved at this station = (240 – 162) = 78 minutes. In this way all the idle time had been computed. This saved time could be used at another station. If all of the 5 workers work at a time, they are not fully busy with all the works. So, partly they can be utilized at other stations for maximum utilization of workers and machines and to minimize the cost of production.

Table 5: Balance Efficiency after computations of all the Iterations completed at all stations or all iterations.

Iteration no	Cycle time (CT)min.	Actual no of workers (W_A)	Theoretical minimum workers (W_T)	Balance efficiency ($eff._B$)%
01	240	107	96	86
02	240	86	72	84
03	240	109	95	86
04	240	99	96	97
05	240	101	100	99
06	240	104	100	96
07	240	104	101	98
08	240	97	97	100
09	240	103	100	97
10	240	103	99	96

In the similar way the theoretical minimum number of workers and Balance efficiency were found out and these are furnished in Table 4.

X. COST ANALYSIS AND COMPARISONS [29]

Cost Calculations and Cost savings at the present rate of production(two vehicles per day) :

Table 6: Worker reduction drive at different stations.

Station Number	No of workers that can be reduced
01	00

02	00
03	02
04	02
05	02
06	01
07	01
08	06
09	04
10	03
Total no. of workers reduced = 21	

Total no. of reduced workers = 21 Nos.
The authority pays at least Tk 200/- to every worker for each working day. Therefore, according to the previous design of the production line, cost can be saved through worker reduction policy:
Daily Savings = Tk. 200/- × 21 = Tk. 4200/-
Monthly Savings = Tk. 4200/- × 26 = Tk. 1,09,200/-
Considering one day as holiday, number of working days in a month = 26
The labor cost of existing line has been found as follows:
For one vehicle:
(a) Assembly cost Tk. 6000/-
(b) Painting Tk. 4700/-
(c) Load body fabrication Tk. 7500/-
(d) Load body Painting Tk. 6600/-

Therefore, Total Labor Cost = Tk. 24,800/-
Daily labor cost (for Production of two vehicles) = Tk.24,800/- × 2 = Tk. 4,96,00/-
Monthly labor cost =Tk. 49,600/- × 26 = Tk.12,89,600/-.
In the modified production line it could easy save: Tk. 4,200/- from every pair of automobile assembled everyday.
Therefore, Monthly money savings (for the modified model) = Tk. 4,200 /- × 26 = Tk. 1,09,200/-
Labor cost calculations if three vehicles were produced a day:
For increasing productivity in 8 hours working period (in a working day) from two to three automobiles, the number of workers on the assembly line = (0+2+3+0+2+1+2+1+1) = 12 workers more required than the existing model.
For this enhanced number of workers the labor cost will be increased too much.
Total cost increased:
Daily Increased Cost = Tk. 200/- × 12 = Tk. 2,400/-
Monthly Increased Cost = Tk. 2,400/- ×26 = Tk. 62,400/-
And Total number of vehicles assembled in a month will be = 3×26 = 78.
Total monthly labor cost for assembly of 78 vehicles = Total labor cost of two vehicles assembled + total cost increased for three vehicles assembled in a month = Tk. 12,89,600/-+ Tk.62,400/- + Tk. 13, 52,000/-

XI. RESULTS AND DISCUSSIONS

Cost Comparison if 2 and 3 nos. of automobiles could be produced in each working day:
If the top management wants to produce two automobiles each working day, the labor cost would be found for each vehicle

= Tk.12,89,600/- ÷ 52 = Tk. 24,800/-

But, if the management wants to produce three vehicles each working day, then the labor cost would be found for each vehicle = Tk.13,52,000/- ÷ 78 = Tk17,333/-.
Therefore, it would be now easy to realize that, it would be more profitable to produce three vehicles each working day, instead of two.

XII. CONCLUSIONS

The proposed line has been designed very carefully in order to keep the balance efficiency at maximum level. Through the redesigning process of the production line all the idle and avoidable delays have been eliminated and the production line has been made free of bottlenecks, as a result it is found that the production rate can be increased with a considerable amount of profit margin. Through the study of total labor costs, it had been shown that if the daily delivery rate could be kept constant, about Tk.1, 94,142.00 could be saved every month.
The gains in productivity allowed BMTF to increase worker pay from Tk. 150.00 per day to $200.00 per day and to reduce the hourly work week while continuously lowering the product price. These

goals appear altruistic; however, it has been argued that they were implemented by BMTF in order to reduce high employee turnover.

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