



PRODUCTIVITY IMPROVEMENT USING TIME STUDY ANALYSIS IN A SMALL SCALE SOLAR APPLIANCES INDUSTRY- A CASE STUDY

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ABSTRACT

The pattern of economic competitiveness has changed globally now days. Many countries have joined the global economic competition to capture global market in order to remain profitable and competitive by increasing its productivity. There are many factors that influence the productivity of a manufacturing organisation. The most widely tackled issue is how to improve efficiency and productivity. Motion and time study technique is one of the productivity improvement techniques used in many manufacturing companies. Motion and time study is defined as a scientific analysis method designed to determine the best way to execute the repetitive task and to measure the time spent by an average worker to complete a given task in a fixed workplace. In manufacturing industries, assembly line is also another major area to be taken into consideration for increasing productivity. Throughout the study, the aim is to propose a new system to the related company to increase their productivity. The purpose of this paper is to discuss related issues of motion and time study implementation and assembly line balancing and its influence toward productivity improvement. Data from a study carried out on a sample of manufacturing industry small scale solar appliances shows that motion and time study implementation and assembly line balancing contributes positively towards achieving productivity.

Keywords: productivity improvement, manufacturing industries, assembly line balancing, motion and time study analysis.

INTRODUCTION

Assembly lines are production systems developed to meet the requirements of mankind, which continue to grow day by day. The demand for greater product variability and shorter life cycles has caused traditional production methods to be replaced with assembly lines. The aims of these systems are to manufacture products at production rates in the shortest time, in the most productive way, cheaply and with the quality required. Since assembly line balancing is an NP-hard problem, some heuristic methods are still needed to solve large scale assembly line balancing problems.

Paul and Rabindra (2006) used subjective assessment through questionnaire, direct observation method, and archival data to improve productivity, quality, increasing revenue and reducing rejection cost of the manual component.

Brown and Mitchell (1998) investigated operators, engineers and managers of PCA (Printed circuit assembly) factories to determine the work environment parameters that inhibited their performance and they recommended opportunities to improve production and quality.

Lim and Hoffmann (1997) found that improved layout of the workplace increased productivity of the workers, through more economical use of hand movements by conducting an experiment on hacksaws assembly.

Christopher (1998) stated that the success in any competitive context depends on having either a cost advantage or a value advantage, or, ideally both.

ImadAlsyouf (2007) illustrated how an effective maintenance policy could influence the productivity and profitability of a manufacturing process and showed how changes in the productivity affect profit, separately from the effects of changes in the uncontrollable factors, i.e. price recovery.

Browning and Heath (2009) developed a revised framework that reconceptualises the effect of lean production costs and used it to develop eleven propositions to direct further research and illuminated how operations managers might control key variables to draw greater benefits from lean implementation.

White *et al.* (1999) found that plant size had a significant effect on the implementation of lean practices. This shows that regardless of establishing what lean is, it remain important to establish how best to become lean in varied contexts.

Shah and Ward (2003) empirically validated four bundles of inter related and internally consistent practices, these are just in time (JIT), total quality management (TQM), and human resource management and investigated their effects on operational performance. Flynn *et al.* (1995) and McKone *et al.* (2001) have explored the implementation and performance relationship with two aspects of lean.

Crute *et al.* (2003) discussed the key drivers for lean in aerospace and did a lean implementation case comparison which examines how difficulties that arise may have more to do with individual plant context and management than with sector specific factors.



Womack *et al.* (1990) developed from the massively successful Toyota Production system, focusing on the removal of all forms of waste from a system.

Krafcik, (1998) describes the Japanese style manufacturing process pioneered by Toyota, which uses a range of techniques including JIT inventory systems, continuous improvement, and quality circles.

An assembly line consists of a number of workstations which are arranged along a conveyor belt, or similar material transportation equipment, in order to obtain a sequence of finished product types. The work pieces are moved from station to station and at each one certain operation are performed in view of some constraints. The first primary constraint is the cycle time. The cycle time is the time interval between finishing two units or the maximum available time for the production of any work piece at any workstation. Assembly line exists when we assemble or handle any device or product in a planned, sequential manner with two or more operators performing tasks of repetitive work at established workstation (Milas, 1990). When the products have many operations and the demand is high the process of balancing the line becomes more difficult. There are two types of optimization problems for the line-balancing problem (Ajenbit, 1998). In Type I, the cycle-time is fixed and the objective is to minimize the required number of workstations. The Type II attempts to minimize the maximum cycle-time given a fixed number of workstations. This research paper will adopt the Type I problem. The overall objective of this paper is to improve productivity through line balancing by minimizing both labor and idle times on the production line. This paper intends to investigate and evaluate the line balancing problem in a production line of Nano bright solar technologies.

The aims of the study are improving the productivity and computing the efficiency of an assembly line in small and medium industry. The objectives are to re-design the layout for the purpose of improving the line performance. Computer aided simulation is implemented in this project in order to analyze and investigate the

problems occurring in assembly line. The line balancing method is use to solve the problem. Comparison of the current system and new system are done. Simulation is done by Arena software to accomplish this study.

CASE STUDY: CURRENT LAYOUT DESIGN

The present system, the assembly line consists of 9 main activities. These 9 activities are completed in 4 workstations. Around 300 units are worked upon in a workstation. Only after all the 300 units undergo a particular operation, they are transported to the next workstation. This is how the assembling is done in the current system.

In the original assembly method, the input buffer has no pre-specified capacity. The master boxes were piled at both input and output sides of the assembly table in stacks at a workstation using storage pallets. The individual packages were then removed from the master box on to the table, all at a time, and the assembly is carried out on each package by four different operators.

The subassemblies and the headset components were pushed from one person to the next person on the table without an appropriate material handling arrangement.

Once the assembly was completed, the packages were arranged in an empty master box and placed on storage pallet.

The workstations in the present system are shown in Figure-1.

- Gooseneck gumming
- Connector insert, LED soldering
- LED PCB assembly, PCB screw fixing and battery fixing
- Battery testing, final assembly and packing

The various activities carried out at each work station are presented in following flow charts. Activities in the first workstation are given in flow charts.



Figure-1. Work stations in the factory (A: Goose neck gumming, B. Driver PCB assembly, C. Goose neck assembly, D. Final product screw fixing, E. Task light Battery mounting, F. Packing).

Sequence	Recording Symbol	Description of the activity
1		Taking the gooseneck & instant Adhesive gum apply it one side
2		Taking the Top Cap & inserting it properly so that it holds the gooseneck tight
3		Now gumming the other side of gooseneck
4		Taking the Base & inserting it properly so that it holds the gooseneck tight
5		Drying of the gooseneck
6		Transporting to the connector table

Figure-2. Activities at first work station in current assembly line.

S. No	Recording Symbol	Description of the activity
1		Take the goose neck with top cap & bottom fixed. Take the connector and Insert into the goose neck
2		After insertion of connector, take LED tested PCB from testing. Insert the connector in the holes given by checking the polarity
3		Then solder the connector to the PCB by manually
4		Then the soldered LED PCB is positioned in the grooves provided
5		Then fix the cap with screws and passed to next stage
6		Transporting to the next stage

Figure-3. Activities at second work station.



S. No	Recording Symbol	Description of the activity
1		The driver PCB which has come from testing stage is placed on the bottom and hold with using clips
2		Keeping the battery at allotted slot and connecting to the Driver PCB
3		Switch on the load to check the battery condition
4		Transporting to the next stage

Figure-4. Activities at third work station in current assembly line.

S. No	Recording Symbol	Description of the Activity
1		Check for proper LED load fixing. Whether screws are fully fixed
2		Check for proper driver PCB screw fixing, all four screws are fixed are not
3		Check for any marks or scratches on the unit
4		Switch on the unit and check if it glows properly
5		Check the solar charging by taking the adopter & inserting the pin in the DC Socket given
6		Check for working of LED if green LED glows after insertion of charging pin
7		Take the bottom cover & mount it on the base
8		Fixing the final tested product using suitable screws
9		After fixing the Screw paste the Logo stickers on the surface of the unit
10		After process is completed, pack the unit
11		Then paste the Serial no sticker on it

Figure-5. Activities at fourth work station in current assembly line.

METHODOLOGY ADOPTED FOR IMPROVEMENT IN THE CURRENT ASSEMBLY LINE

The first step in productivity improvement methodology was the present work study. For the current scenario, almost all the models produced have the similar processing steps. Hence, the product selection step has less

significance in this context. In the next step, the current process was studied and all the assembly work elements were listed. Time studies were then carried out and the data obtained was analysed to identify bottle neck situations and establish production standards.

After the completion of time study, it was observed that the fourth workstation consumes a lot of time in comparison to the other workstations. This results in the high idle times for the other workstations and a lot of accumulation of units to be processed. The challenge is to balance the assembly line by rearranging the activities in the workstations. This re-arrangement is possible because the activities which are being re-arranged are independent of the other activities in the original workstations.

We have considered adding an additional worker to the fourth workstation to reduce the cycle time. Adding an additional worker is not advisable because the activities in the fourth workstation cannot be done by both the workers simultaneously.

Flow process charts are used to identify the current methods which are used by the company. We had drawn flow process charts before and after rearranging the activities in the workstations, which can be used for comparison.

It is evident from the flow process charts that the time taken for transporting work elements from one workstation to another is eliminated. This is facilitated by the implementation of a material handling system in the form of a semi-automated conveyor belt.

Design calculations

The design calculations have been done for the following parameters of the semi-automated conveyor belt system:

The values have been calculated based on the dimensions of the conveyor belt.

Bulk density: 1.45 g/cm³ Belt width: 1 metres
Length between centres: 7.62 metres Inclination of belt: 36 degrees Belt speed: 1.2m/s

- Belt Capacity = $3.6 \times \text{belt sectional area} \times \text{belt speed} \times \text{material density} = 3.6 \times 7.62 \times 1.2 \times 1.45 = 150\text{-}200$ tonnes/hr
- Load/Metre = $B.C/3.6 \times \text{belt speed} = 39.44\text{kg}$
- Loaded Volume $L_m = B.C/\text{specific weight of material} = B.C/q(s) = 122.4\text{m}^3/\text{hour}$
- Absorbed power $P_a = (P_{dp} + R_{bd} + R_{wd}) \times v/1000\text{kw}$
Where, R_{wd} = wrap resistance for drive pulley = 230N
 R_{bd} = pulley bearing resistance for drive pulley = 100N
 $P_a = 23.028 + (230+100) \times 1.2/1000$ $P_a = 23.424\text{kw}$
- Motor Power $P_m = P_a/n$ Where n = overall efficiency by taking the power losses into account = 0.94 $P_m = 23.424/0.94 = 24.49\text{kw}$
- Motor selection: Selected motor is around 40kw and 1500 rp



- Motor gear box selection: reduction ratio= input rpm/output rpm

Output rpm is calculated by the formula $V=3.14 \times D \times N/60$
 D= diameter of driving pulley =630+12+12=664mm (according to international standards, 630mm diameter of driving pulley is suitable for the motor of power which is less than 50kw and 24mm extra diameter is provided due to lagging of the pulley)
 $1.2= 3.14 \times 0.654 \times N/60$ N= 35.043rpm

- Torque $P_a=2 \times 3.14 \times NT/60$ Where $T=60 \times P_a/2 \times 3.14 \times N$ $=60 \times 23.424/2 \times 3.14 \times 35.043$ $P_a=6.383KN$
- Tension in the belt $T_c= T/r =6.384/0.327$ $T_c=19.51KN$

DESIGN OF THE MATERIAL HANDLING SYSTEM

After the completion of tasks at each stage, the components or sub-assemblies are pushed on to a conveyor located along the centre of work table by using a material tray. The operator at the next stage pulls the tray from the conveyor and completes the assembly. Once the package reaches the end of assembly table it is placed in the master box.

Manually operated push carts are used to deliver master boxes from the storage locations to the assembly tables. Labels and other documentation to be assembled with each product do not need frequent replenishment and will be stored at the point-of-use of bins.

The conveyor belt design was simulated using CATIA software. Based on the following standard codes the belt was designed and shown in Figure-6 and Figure-7.

- IS 7155:1974 Code of practice for conveyer safety
- ISO TR: 5045-1979 continuous mechanical handling equipment – Safety code for conveyers.
- ANSI A 20.1-1976 Safety standards for conveyer and related equipment.

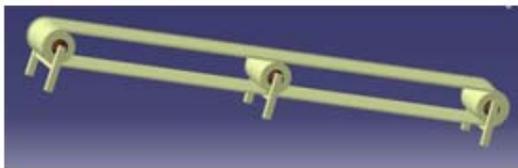


Figure-6. Side view of the conveyor belt.

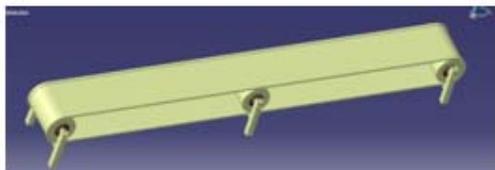


Figure-7. Top view of the conveyor belt.

These are the following changes in activities at each work station after introducing conveyor belt.

S.No	Recording Symbol	Description of the Activity
1		Taking the gooseneck & instant
2		Adhesive gum apply it one side
3		Taking the Top Cap & inserting it properly so that it holds the gooseneck tight
4		Now gumming the other side of gooseneck
5		Drying of the gooseneck
6		Taking the Base & inserting it properly so that it holds the gooseneck tight.
7		Take the goose neck with top cap & bottom fixed. Take the connector and insert into the goose neck
8		After insertion of connector, take LED tested PCB from testing. Insert the connector in the holes given by checking the polarity
		Then solder the connector to the PCB by manually

Figure-8. Activities at first work station in new assembly line.

S.No	Recording Symbol	Description of the Activity
1		The soldered LED PCB is positioned in the grooves provided
2		Take the diffuser cap and place on it
3		Then fix the cap with screws and passed to next stage
4		The driver PCB which has come from testing stage is placed on the bottom and hold with using clips
5		Keeping the battery at allotted slot and connecting to the Driver PCB.
6		Switch on the load to check the battery condition

Figure-9. Activities at second work station in new assembly line.



S. No	Recording Symbol	Description of the Activity
1		Check for proper LED load fixing. Whether screws are fully fixed
2		Check for proper driver PCB screw fixing, all four screws are fixed or not
3		Check for any marks or scratches on the unit
4		Switch on the unit and check if it glows properly
5		Check the solar charging by taking the adopter & inserting the pin in the DC Socket given
6		Check for working of LED if green LED glows after insertion of charging pin

Figure-10. Activities at third work station in new assembly line.

S. No	Recording Symbol	Description of the Activity
1		Take the bottom cover & mount it on the base
2		Fixing the final tested product using suitable screws
3		After fixing the Screw paste the Logo stickers on the surface of the unit
4		After process is completed, pack the unit
5		Then paste the serial no sticker on it

Figure-11. Activities at fourth work station in new assembly line.

RESULTS AND DISCUSSIONS

After introducing conveyor belt in the assembly line the activities sequence is changed at each work

station. The time study is performed using a stopwatch for the current layout. Following the calculations of the standard times, the cycle times and station time for each work station has been calculated for the old assembly line configuration and presented in Table-1. Then, the parameters like idle time, line efficiency, and balance efficiency among others have been calculated for new assembly line. Cost analysis has been done based on the increased production per day.

Table-1. Standard times for current assembly line.

S. No.	Basic time in minutes	Allowances		Standard time in minutes
		Fatigue 4% of basic time	Personal need 6%	
	5	0.2	0.3	5.5
	15	0.6	0.8	16.4
	5	0.2	0.4	5.6
	15	0.6	0.8	16.4
	20	0.8	1.1	21.9
	25	1	1.3	27.3
	60	2.4	2.7	65.1
	30	1.2	1.5	32.7
	15	0.6	1.8	16.4
	20	0.8	1.1	21.9
	10	0.4	0.6	11
	30	1.2	1.5	32.7
	25	1	1.3	27.3
	60	2.4	2.7	65.1
	20	0.8	1.1	21.9
	25	1	1.3	27.3
	25	1	1.3	27.3
18-28	30	1.2	1.5	32.7

Table-2. Showing tasks allotted to workstations 1 and 2.

Work station	1	2
No of workers	1	1
Work element	1,2,3,4,5,6	1,2,3,4,5,6,7
Task times	5,15,5,15,20,25	60,30,15,20,10,30,25
Time per station	93.5	209
Idle time per station	269.5	154

**Table-3.** Showing tasks allotted to workstations 3&4.

Work Station	3	4
No of workers	1	1
Work element	1,2,3,4	1,2,3,4,5,6,7,8,9,10,11
Task times	60,20,25,25	30,30,30,30,30,30,30,30,30,30,30
Time per station	143	363
Idle time per station	223	0

The last task time mentioned in each workstation is for transporting the units from the preceding workstation to the next workstation.

Transportation time = 25sec

The last task time mentioned in each workstation is for transporting the units from the preceding workstation to the next workstation.

Transportation time = 25sec Maximum daily output = $420 \times 60 / 363 = 69$ sec

CALCULATIONS FOR THE ASSEMBLY LINE

The sample calculations were done for the following parameters:

- Idle time per day = Total idle time/3600 = $643.5 / 3600 = 0.179$ hours
- Line efficiency = Total lead time/cycle time \times no of workstations = $808.5 / 330 \times 4 = 61.25\%$
- Balance delay = $100 - LE = 100 - 61.25 = 38.75$

- Balance Efficiency = Theoretical actual no. of workers/Actual no. of workers

- Theoretical no of workers = $\sum T / (\text{cycle time})$

$$\text{Since, total time } \sum T = W_1T_1 + W_2T_2 + \dots + W_nT_n$$

$$\text{Theoretical minimum no. of worker} = 808.5 / 363 = 2.2$$

$$\text{Balanced efficiency} = 2.2 / 4 = 55\%$$

- No of workstations in new configuration = (total time per cycle)/(desired number of units per day)/available time per day
= $(808.5)(140) / (420 \times 60) = 4.49$

Therefore, number of workstations in the new configuration = 4

Table-4. Showing tasks allotted to workstations 1&2 in the new system.

Work Station	1	2
No of workers	1	1
Work element	1,2,3,4,5,6,7,8	1,2,3,4,5
Task times	5,15,5,15,20,60,30,15	20,10,30,60,20,25
Time per station	181.5	181.5
Idle time per station	16.5	16.5

Table-5. Showing tasks allotted to workstation 3 and 4 in new system.

Work Station	3	4
No of workers	1	1
Work element	1,2,3,4,5,6	1,2,3,4,5
Task times	30,30,30,30,30,30	30,30,30,30,30
Time per station	198	165
Idle time per station	0	23



CALCULATIONS FOR THE NEW SYSTEM

The sample calculations of the following parameters have been calculated:

- New line efficiency = total lead time/cycle time × no of workstations = $726/198 \times 4 = 91.66\%$
- New balance delay = $100 - \text{line efficiency} = 100 - 91.66 = 8.34$
- New balance efficiency = theoretical no of workers/actual no of worker

$$\text{Theoretical no of workers} = \sum T / (\text{cycle time})$$

$$\text{Since, total time} \sum T = W_1 T_1 + W_2 T_2 + \dots + W_n T_n$$

$$\text{Total time} = 726 \text{ sec}$$

$$\begin{aligned} \text{Theoretical minimum no. of worker} &= 726/198 \\ &= 3.66 \quad \text{Actual no of workers} = 4 \quad \text{Balanced efficiency} = \\ &= 3.66/4 = 91\% \end{aligned}$$

- New idle time per day = Idle time cycle/one hour in seconds = $56/3600 = 0.016$ hours
- Maximum daily output in new system = $420 \times 60/198 = 127$ To predict and simulate the production rate per day (assume working 420 minutes), ARENA software was used. The production rate which was calculated manually was verified using this software.

The cycle time was changed from 363s in the initial situation to 198s in the new situation. It was found that the output per day in the initial situation is 69 units while the output per day in the new situation (after rearranging the activities among workstations) was 140 units. The actual output per day in the initial situation is $79 \times 5 = 345$ units. (Since the number of workers are 5 times of what we had taken for study). The actual output per day in the new situation is $127 \times 5 = 635$ units. The normal selling price of one unit is Rs 500. The revenue per day in the initial situation will be $(345 \times \text{Rs } 500 = \text{Rs } 172500)$. The revenue of station per day per lane in the new situation will be $(635 \text{ units} \times 500 = \text{Rs } 317500)$. However, the increase in output in percent will be 77.2% by using the following formula (Barnes, 1980):

$$\begin{aligned} \text{Increase in output \%} &= (\text{output, new method} - \\ &\text{output, initial method}) / (\text{output, initial method}) \% = \\ &= (317500 - 172500) / 172500 \% = 145000 / 172500 \% = 84\% \end{aligned}$$

CONCLUSIONS

On the basis of time and motion study analysis and on the calculations done for the assembly line, the following conclusions can be inferred. The results were checked by simulation using ARENA software.

- The cycle time used was based on the result of this study. Normally, it took 363 seconds for Nano bright solar technologies plant to produce one unit of study lamp. The new cycle time calculated is 198 seconds.

- The production line runs for 420 minutes and the maximum daily output is 69 units. The production line consists of 4 workstations and 20 workers. The new maximum daily output is 127 units.
- Before the production line was balanced, the line was not efficient. The line efficiency was 61.25%; the idle time was 0.179 hours, the balance efficiency was 55%.
- As a result of assembly line balancing, the line efficiency increased from 61.25% to 91.66%, the idle time decreased from 0.179 hours to 0.016 hours, the balance efficiency increased from 55% to 91%.
- Through the study of the total costs, it had been shown that additional Rs 145000 could be earned every day.

This project identified how simple methods can be used to improve work and work process in the industry. The project identified the current methods used using flow process charts and how long each component takes. By making simple changes to the process, it can reduce the time taken for each component to improve the flow and speed up the process.

Importantly, the costs and benefits of increased production rate have also been calculated which predict by making those changes that output can be increased dramatically.

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