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Productivity improvement in Solar Panel Manufacturing Company through In-Process Quality Inspection: A Case Study

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Abstract

Generation of defect is detrimental for any company from several points of views. As per lean manufacturing concept, quality system is closely related to operational productivity. As such, selection of right quality inspection and audit plan are essential. Quality inspection and audit at the final stage lead to several consequences including subsequent unnecessary operations. Although intermediate inspection requires extra effort and manpower, this may save time and effort by stopping further operations on a defective item. Often, in-process inspection and audit leads to savings more than costs. This helps to increase productivity significantly. This research paper shows potential savings that may occur because of increase in productivity. The research has been conducted in a large solar manufacturing company in Bangladesh. This research demonstrates increase in productivity, as a trade-off parameter between final inspection and in-process inspection, which may lead to greater benefit.

Keywords: IPQC, productivity improvement, quality check, SLP

1. Introduction

The production process is closely related to the quality system. It's identified that the sequence of production process activities in the industry depends on the quality checking system. If the sequence of the activities is changed, the efficient layout of the production system is also changed. For different quality checking system, different efficient layout can be obtained in which the machines and other equipment are arranged differently. Arranging equipment and machines differently and discarding a few processes, the area consumed in the production floor is varied. Bottleneck can occur because of the area constraints. This paper evaluates two quality systems by the productivity of the systems. At first the process flow diagram for two different quality systems is developed. From the process flow diagram the layout of the production process is obtained by applying Systematic Layout Planning (SLP). [1] After obtaining the layout for the production process, the layout is adjusted for required WIP (work in process) inventory. If the required WIP inventory is quite large, it can block the production floor or the required WIP inventory can't be located at all, resulting in bottleneck due to area constraint. The quality systems are judged based on bottleneck generation in the system.

This study checks whether in process quality checking or final quality checking generates bottleneck in the production process. Selecting the quality inspection system that doesn't generate bottleneck, will improve the productivity.

2. Theoretical Background

Quality is the one of the most basic aspects for the survival and growth for an organization. [2] Quality is defined as "Conformance to requirements" By Phillp B. Corbosy. [3] There are four type cost associated with providing poor quality products or services.[4] These are internal failure cost, external failure cost, appraisal cost, prevention cost. Internal failure and external failure costs are the costs associated with defects found before the customer receives the product or service and after the customer receives the product or service respectively. Appraisal costs are the costs incurred due to determine the degree of conformance of quality requirement and prevention costs are costs incurred to keep failure and appraisal costs to a minimum.

Low Quality is detrimental to the business organization. Low quality can also put the consumer at risk. Low quality products may result in recall and a billion dollar of loss. The recall to replace the frontal airbags on vehicles made by 19 different automakers is "the largest and most complex safety recall in U.S history." [5] Samsung has announced an expanded voluntary recall on all original and replacement Galaxy Note7 devices sold or exchanged

in the United States in cooperation with the U.S. Consumer Product Safety Commission and in partnership with carriers and retailers. [6]

According to the American Society for Quality the definition of quality assurance is all the planned and systematic activities implemented within the quality system that can be demonstrated to provide confidence that a product or service will fulfill requirements for quality. Quality control is the operational techniques and activities used to fulfill requirements for quality. Often, however, "quality assurance" and "quality control" are used interchangeably, referring to the actions performed to ensure the quality of a product, service or process.[7]

IPQC is the abbreviation of In Process Quality Control. IPQC refers to the quality control that is performed before completing the manufacturing process during the assembly.[8] It may require more manpower but it can detect and handle problems ahead of time.

Final Quality Inspection is performed to ensure the product is manufactured according to specification, if product came out faulty, then it is scrapped or reworked. Reworking manufactured product or scrapping both are costly most of the time. Sometime it is not possible to rework on the defected products.

A bottleneck is one process in a chain of processes, such that its limited capacity reduces the capacity of the whole chain. The results of having a bottleneck are stalls in production, supply overstock, pressure from customers and low employee morale. [9]

The systematic layout planning (SLP) is a tool used to arrange a workplace in a plant by locating areas with high frequency and logical relationships close to each other. The process permits the quickest material flow in processing the product at the lowest cost and least amount of handling. [1]

An activity relationship chart (ARC) is a tabular means of displaying the closeness rating among all pairs of activities or departments. [10]

Manufacturing of solar modules requires some processes that are glass washing, cell cutting, EVA cutting, Assembly, Bussing, Back sheet and EPE placement, Lamination, Framing and Junction box attaching, curing. Then the module is inspected for defects and cleaned. Curing is not actually a desired process; it's a consequence of framing and junction box attaching process.

Glass washing is simply the washing the glasses where the EVA sheet and solar cells are need to be placed. Cell cutting is to cut the cell according to desired dimensions. EVA stands for Ethylene Vinyl Acetate. EVA is an elastomeric polymer that produces materials which are "rubber-like" in softness and flexibility. EVA cutting is the process to cut the EVA sheets in to required dimensions.

Assembly is the process in which the EVA is first placed on the glass and then the solar cells are placed. The solar cells are connected in series connection using a ribbon in the assembly process. Bussing is the process to create polarity terminals for the solar module. After bussing is performed on solar panel EPE and Back sheet are placed on the glass. A continuity test is performed by current flow in the same station.

Lamination is the process to laminate the glass with EVA, solar cells, EPE and back sheet to unite the components. After lamination excessive back sheet and EVA are cut off by trimming.

The whole solar module is framed and junction box attached with the help of sealant in the framing and junction box attaching process.

The sealant used in the framing and junction box attaching process requires to solidify before it can be evaluated in the quality inspection. The quality is inspected in sun simulator and high potential tester. The sun simulator is a very costly machine; it provides illumination approximating natural sunlight. The machine have glass layer which can be affected by sealant if it is not properly solidified. High potential tester is a safety testing instruments used to verify electrical insulation in appliances. After the quality check, module is taken outside the production floor, cleaned and packaged.

Of all of these processes the trimming process, framing and junction box attaching process, curing process are defect free processes, meaning no defects can occur from these processes.

3. Research Approach

The production of 250 Watt Peak solar modules is studied for comparison in this paper. For two different quality inspections system the process flow diagram is developed. The ARC charts are constructed from the process flow diagram. Using the process flow diagram and ARC chart; efficient layout of the system is developed by implementing SLP (Systematic Layout Planning). The layout is then adjusted for required work in process inventory. The area required for each workstation is fixed but the area of WIP depends upon the production hence on the quality inspection system. For each quality inspection system the required WIP inventory area is calculated and checked whether the area constrained production floor can accommodate the full required WIP inventory area. If the production floor can't accommodate the required WIP inventory area, the production system is bottlenecked by the area constraint. The required area of WIP inventory is compared for the two quality inspection system and checked which inspection system bottlenecks the production system.

4. Comparison between Final Quality Check and In-Process Quality Check

For final quality check the process flow diagram for solar module manufacturing is shown in the figure 1.

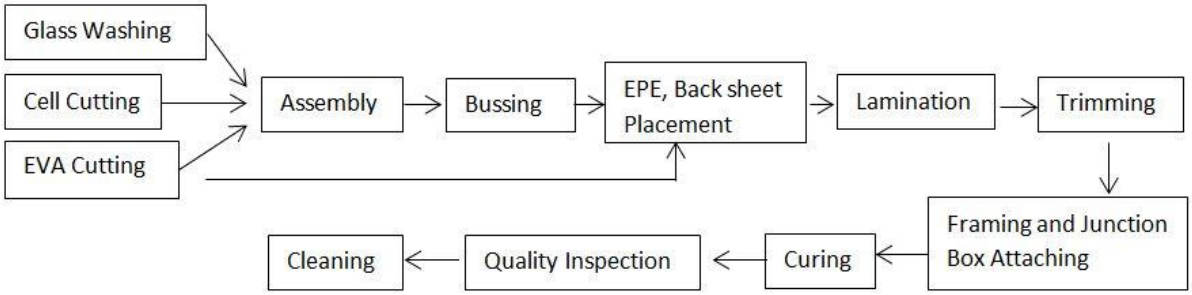


Figure 1. Process flow diagram in final quality inspection

The ARC chart is shown in figure 2 and the layout of the production floor is developed in figure 3.

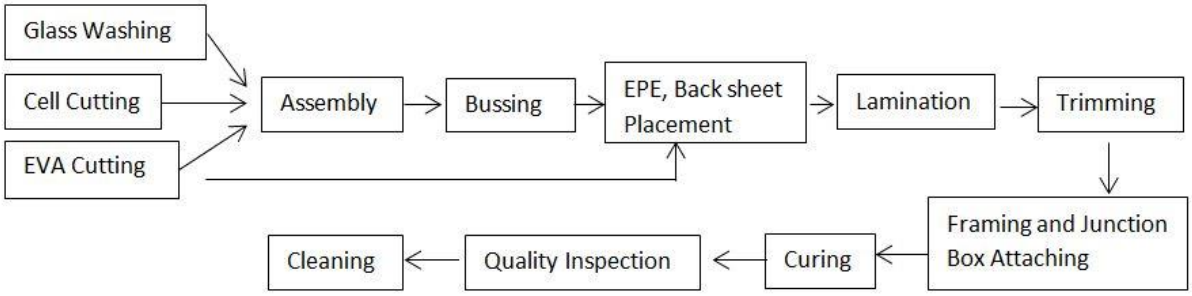


Figure 2. ARC chart for the production floor layout

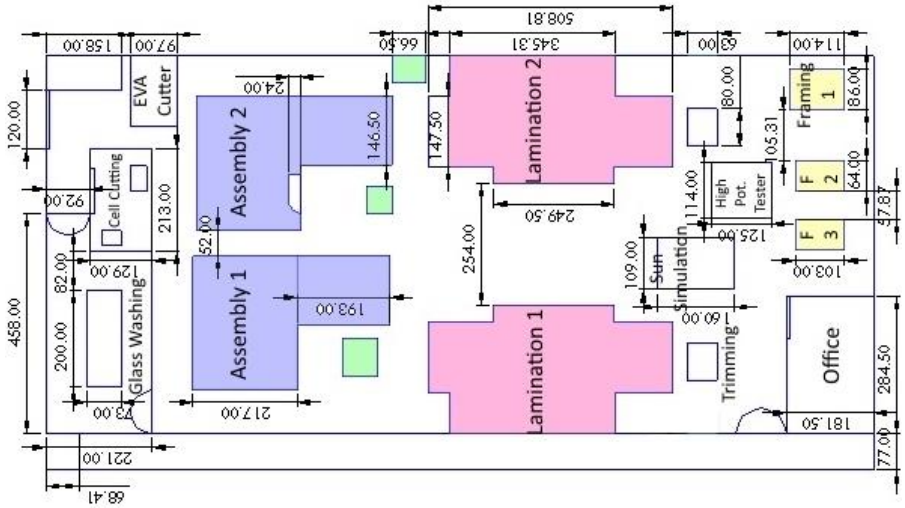


Figure 3. Production floor layout in final quality check

There is a curing time between framing and quality check (Sun simulator testing). The curing time is approximately 6 hours. It's the required time to solidify the sealant used in framing station. The production is 46 cycles of lamination machine (in 2 machines) in these 6 hours.

The required area is calculated for these 46 cycles or 138 modules (3 modules in a cycle) and shown in table 1.

Table 1. Calculation of required WIP inventory after lamination

Required Area per module (sq ft)	Required Area per stack (with 10% allowance) (sq ft)	Number of modules	Number of stacks (5 modules per stack)	Required Area in WIP inventory (sq ft)
17.33	19.06	138	28	533.68

So a maximum of 533.68 say 534 sq ft of area is needed to store the modules in WIP for curing. Due to area constraint, the production floor won't be able to hold the WIP; if however the area is managed, the whole production floor will be messed with the solar modules.

For in process quality check the process flow diagram for solar module manufacturing is shown in the figure 4.

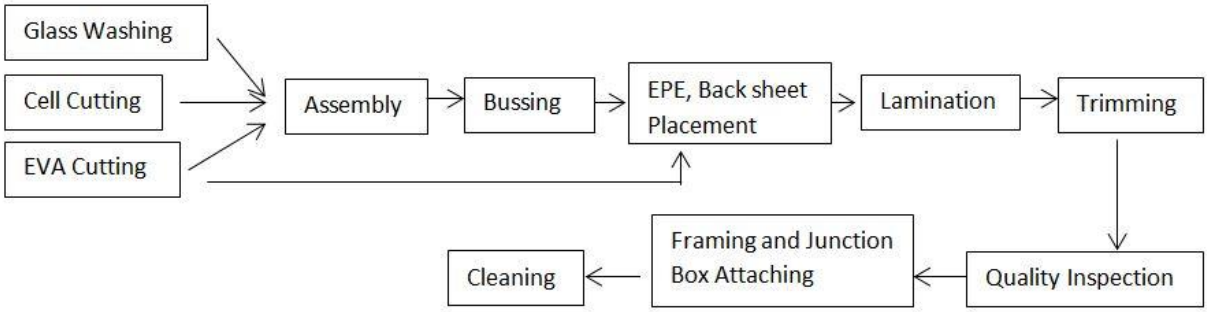
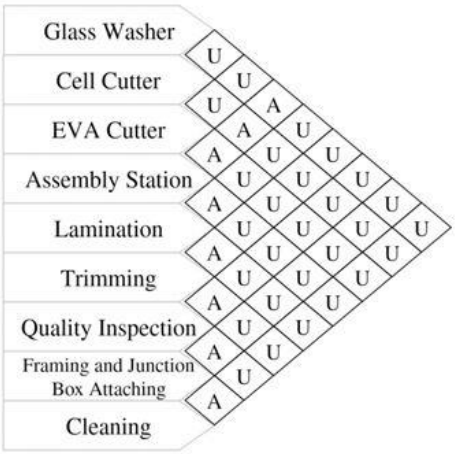


Figure 4. Process flow diagram in in-process quality inspection

The ARC chart is shown in figure 5 and the layout of the production floor is developed in figure 6.



Value	Closeness
A	Absolutely Necessary
E	Especially Important
I	Important
O	Ordinary Closeness
U	Unimportant
X	Undesirable

Figure 5. ARC chart for the production floor layout

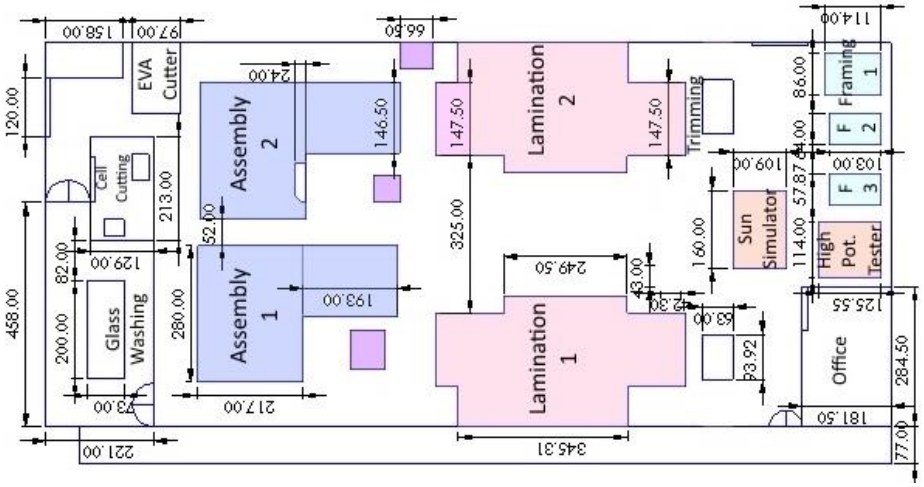


Figure 6. Production floor layout in in-process quality check

The temperature of the module needs to be at 25° Celsius before performing the quality check in sun simulator according to standard. After lamination the temperature of module is way higher and it takes 45 minutes to come down to 25° Celsius. In this 45 minutes there would be 4 cycles (2 machines) of lamination. Modules from these two cycles will be needed to keep for cooling in WIP inventory.

The required area is calculated for these 4 cycles or 12 modules (3 modules in a cycle) and shown in table 2

Table 2. Calculation of required WIP inventory after trimming

Required Area per module (sq ft)	Required Area per stack (with 10% allowance) (sq ft)	Number of modules	Number of stacks (5 modules per stack)	Required Area in WIP inventory (sq ft)
17.33	19.06	12	3	57.18

So, after trimming 57.18 say 58 sq ft is needed to store the modules for cooling which can be placed in the production floor as WIP after lamination easily.

The framing and junction box attaching process should be carried and the goods should exit production floor afterwards. The cleaning and packaging should be done subsequently at warehouse.

Based on the study, it is found that the WIP inventory after the trimming process in final quality check bottlenecks the production as a consequence, the full lamination cycle is not able to run. However, as the curing process is not required in the in process quality check; the required WIP inventory area is much less and can be provided in the production floor. The production capacity is not bottlenecked by the WIP inventory and the full lamination cycle is able to run.

So, the productivity of in process quality check system is not disrupted, whereas the productivity of final quality inspection is reduced. From this study, it can be said that the productivity can be improved by using in process quality inspection system.

5. Conclusions

This paper focuses on the productivity improvement by selecting the appropriate quality inspection system. The appropriate quality inspection system varies from industry to industry. Based on this study, it is found that the in process quality check system removes bottleneck of area constraints by altering the process activities in solar module manufacturing company. According to the study, if the quality check is performed before the defect free processes and no final quality check is performed the productivity can be improved.

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