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Suzhal – An alternative layout to improve productivity and worker well-being in labor demanded lean environment

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Abstract

Ergonomics continues to be relevant in work-places in which a significant amount of manual labor exists, such as in some of the Cellular manufacturing Systems (CMS). In order to distribute the workload evenly over all the workers in the line, some of the industries resorted to the practice of rotating all the workers through all workstations in the cell (Nagare cell) that prevents monotony and boredom. The presence of automated equipment in the cell will hamper this strategy for job rotation. This study aims to demonstrate the application of ergonomically designed looping layout in the assembly cell in the labor demanded lean manufacturing environment. The study was conducted in a process line in an automobile ancillary unit. The current process line which was conventional U-shaped line was simulated and the productivity has been verified and validated with the real life environment. Process map showed that the operators walked long distances, felt stress in certain workstations and that inventory piled up at the bottleneck workstation. We identify sub-cells within the cell. With the same manpower, we develop a new layout (Suzhal) and make workers rotate within each sub-cell. The proposed layout was simulated and results have been compared with the current layout. The analysis shows a reduction in the total operating cycle time, higher alertness among operators, better distribution of workloads in the group and hence higher productivity.

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1. Introduction

In the typical manufacturing companies in developed and developing countries, Lean management is part of their manufacturing philosophy which they commonly follow for productivity improvement and to run business smoothly in globally competitive world. Cellular Manufacturing Systems (CMS), Single Minute Exchange of Die (SMED), Just in Time (JIT) were part of Lean systems. As these tools help in productivity improvement, it neglects the human factors which play a vital role in sustaining productivity. The solution obtained from these tools includes layout change, workstation modification and process change but does not consider human element in it. The large number of lean manufacturing techniques has been used over different industries for productivity improvement in which Cellular Manufacturing Systems (CMS) has been playing a vital role since late 90s and still prevails in developed and developing economies.

In Cellular Manufacturing Systems (CMS), similar parts are grouped into part families and machines that produce part families are grouped to form a cell. Even though the industries were exposed to latest technologies of automation, manual assembly work cannot be eliminated due to skill demand and cost benefit analysis. Workers are assigned to one or more workstations depending on cycle time based line balancing. A large amount of literature dealt with worker assignment problems in CMS with factors such as demand, WIP inventory and different types of production systems. People working in shifts in CMS are reported to have fatigue and other symptoms such as circadian rhythms disorder [1]. Since assembly works in CMS are repetitive in nature, workers feel boredom on doing monotonous work leading to fatigue which in turn affects the productivity. Some workstations with in the cell demands more physical and cognitive load which are not ergonomically safe to the workers and there were a bias in assignment of work to workers. The possible solution recommended by ergonomic tools such as RBG Risk scale [2], RULA [3], REBA is to either look for redesigning the workstation according to human comfort or to automate the entire process. In order to remove monotony and to achieve even distribution of work load among the workers, the possible solution would be job rotation.

In shop floor management, job rotation is seen as a management technique in which operators are rotated through different workstations over a period of time in order to eliminate monotony of work and boredom. Some of the companies implement job rotation as part of lean philosophy (sometimes called as ‘Nagare cell’) in which workers do all operations within the cell and each operator cycle ends with an end product. Initially, job rotation was studied to minimize worker’s back pain problems and also to minimize heat and vibration exposure. Later, job rotation was studied on different assembly lines to alleviate boredom and was found that changing jobs at predetermined time intervals increased worker efficiency [4, 5]. The technical knowledge was found to improve among the workers which motivated them to work when they rotated through multi skill requirement jobs. As in the economically developing countries such as India, who are working on contract and temporary labors, job rotation help in increasing organization effectiveness and industrial productivity. The ergonomic studies on assembly line proved that dynamic work posture were safer than static work posture [6]. In developed countries, job rotation is common but the methodologies followed over different industries may vary. Many job rotation schedules have been developed using operations research techniques most of it is based on cycle time, only very few studies address it in ergonomic point of view. Some of the ergonomic tools like RULA have been used as a parameter for making job rotation schedules [7].

Job rotation has been applied by some employers in the manufacturing industries as a way to lower injuries and reduce workers' compensation costs. However, job rotation does not completely remove the risks and should not represent a long-term solution for combating workplace injuries. There is a challenge in implementing ergonomics in this lean manufacturing environment. The industries are looking for easy way of providing ergonomic safe workplace in lean environment. Since process of study may be complex, modifications will be costly and time consuming to capture the desired results. The desired solution was to visualize the outcome by mimicking the real system using computer simulation.

The simulation study has been widely used to get clear picture of the process before implementing the changes in real time [8]. The dynamic behavior of the system could be captured by simulating the model in computer environment. The simulation environments helped the industries in simulating and understanding the behavior of changes arise out of applying lean techniques before implementing the same in real time. Value Stream Mapping (VSM) can be used as a tool for creating a model in simulation software to mimic the real system. The bottlenecks

were generally identified by simulating the model from which line balancing and lean techniques can be applied for smooth flow of materials. The dynamic models help us to get answer to questions that could not be addressed only using the static view provided by value stream mapping[9]. The randomness behavior and what if analysis is obtained with the help of simulation software. The suggestions for improvements and changes that can be obtained through lean techniques will typically be a layout change, changing the process flow and adding/removing of resources. Simulation modeling helps us to facilitates design, layout and optimize resources with number of solution alternatives. In order to evaluate the effectiveness of each solution, the different alternatives were compared, analyzing productivity, transportation times and costs.

The layout of CMS will generally be like line/product layout in U-shape for better efficiency[10]. A number of simulation studies in CMS have been contributed to analyze the advantages of the cellular layout over functionallayout [11]. In order to provide safe ergonomic workplace to workers, smooth flow of material, balancing the line with minimum transit time, job rotation over the entire workstations were implemented. The throughput of the line is the sum of individual workstation cycle time and walking time between successive workstations. The consequence of this layout is that piling of inventory at the bottleneck workstation and more walking distance. The productivity can be increased only by deploying more workers in the cell. It is up to certain limit where workers can be deployed beyond that it will reach saturation level. We cannot deploy manpower beyond this level and we have to go back to conventional dedicated workstation assignment system to increase the production.

2. Motivation and problem statement

Automation is the part of manufacturing strategy for any industries to sustain in the global market. If automated equipment is present in the cell, then job rotation strategy which has been adopted will not work since worker will be idle during machine operating time. In order to overcome this drawback and to eliminate monotony, a new ergonomic incorporated layout has to be developed. Change in work methodologies and redesign of the layout lead to lead time reduction, lower in WIP inventory and remove non-valueadded activities.

3. Methodology

Assembly workers in CMS carry out a variety of tasks to make final products. There are many jobs in the different stages of the work process which includes fastening the components using fasteners, operating machines, testing the assembled product and dispatch to packing section.

The procedure involves capturing of process flow and current work postures and analyzing the process and the posture with the help of lean tools and ergonomics tools respectively. The procedure adopted in this study is presented in flow chart as shown in figure 1.

3.1. Observation and data collection

A process line in labor intensive lean environment in which workers were rotated through all workstations within the cell to finish the product was considered for study. The line has to be video recorded to observe the man flow and material flow. Layout details including reach of tools and parts and distance between each workstation were recorded.

3.2. Mapping the process and simulation

Process was mapped using new Process Map (P-Map) tool which depicts actual material and man flow. The current process line which was conventional U-shaped line was simulated by creating a model using discrete event simulation software Arena. The bottleneck workstation and average inventory in each workstation were recorded and represented in P-map.

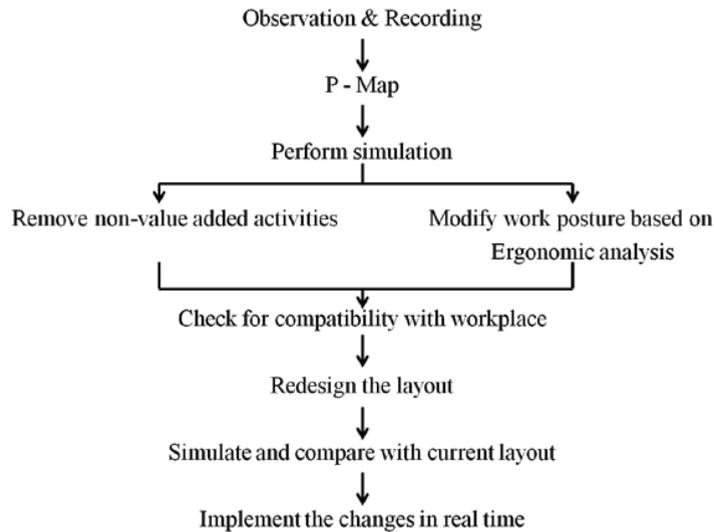


Fig. 1. Procedure for developing ergonomic layout.

3.3. Process analysis

From the P- Map and simulation analysis, number of movements, reach, distance, access to parts & tools and number of non-value added activities were recorded and analyzed. The suggestions for improvements include removal of non-value added activities and reduction of unnecessary movements.

3.4. Ergonomic analysis

Posture analysis tool (RULA) was used to find the stress intensity in workers. The important inputs could be parameters such as anthropometric data, data corresponding to postures, activity details and duration of activity/posture. It is necessary to photograph the work posture to obtain segmental joint angles which would be required for RULA analysis to understand stress intensity in different body parts. RBGPS (RBG pain score) is used to understand the perception of pain levels through Questionnaire.

3.5. Check for feasibility for implementation

The optimized work posture obtained from process analysis and ergonomics analysis is to be checked for its compatibility with the workstation. If the modified work posture does not fit to the environment, the workstation has to be redesigned.

3.6. Layout modification and simulation of modified system

Based on the suggestions, a new ergonomic incorporated lean layout is proposed to improve productivity by providing worker a safe workplace. The proposed model with reduced cycle time is simulated to find the improvement in throughput and difference in process times and waiting times. Once the simulated output data was analyzed and validated, the suggestions were implemented in real time.

4. Analysis of Nagare cell environment

A simulation study was performed on an automobile ancillary unit who are supplying parts to major automobile Original Equipment Manufacturers (OEMs). Company A has 15 identical process line setups in which some workstations were semi-automated. Based on customer demand, monthly production schedules were obtained from OEM. From the monthly schedule, based on daily capacity, weekly and daily work schedule has been made. Both company A and OEM were following Just-In-Time (JIT) system. Company A have to deliver the products on daily basis as per the commitment. Company A was maintaining minimum inventory of two days in the factory so that operating costs was lower. Based on market demand, there would be addition/removal of workers. A sample assembly line comprises of 20 workstations was considered for study in which 8 workers per shift were deployed.

4.1. Ergonomic analysis

The segmented joint angles were found out for different work postures in all 20 workstations. RULA analysis was done based on the collected data to understand the stress intensity in different body parts. From the analysis, we found that there was a significant stress in wrist, lower back and upper arm due to handling weights in awkward postures. RBGPS Questionnaire has been administered to workers to understand the perception of pain levels. From RULA and RBGPS analysis, we found that there was stress intensity in certain workstations and it can be reduced by modifying the workstations and working methodologies.

4.2. Process analysis

The assembly line consists of 20 workstations in which cycle time varies from 8 seconds to 79 seconds. The bottleneck workstation was 20th workstation which was numerically controlled testing station. The current process line was simulated using Arena simulation software and productivity has been verified with real time environment. We have observed that operator walking was more and inventory was piling up in bottleneck workstation. The non-value added activities and unnecessary movements have been identified from video capture of the process flow.

5. Results and discussions

Based on observed data and simulation results, process map was developed for current layout (Figure 2). From the process map, we could understand that WIP inventory was maximum at 20th workstation. Based on suggestions from ergonomics analysis and process analysis, workstations were modified, non-value added activities were removed which lead to development of new layout. The proposed layout with modified work postures and work methodologies were checked for compatibility with work environment. The proposed layout was simulated and

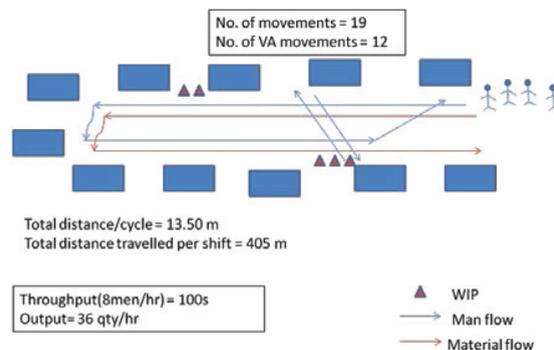


Fig. 2. Process map – Current layout.

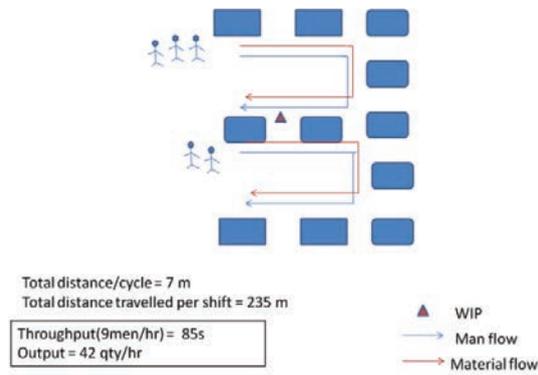


Fig. 3.Process map – Proposed new layout.

validated. The process map of new layout (Suzhal) was plotted (Figure 3) which depicts man and material flow in proposed system with the same manpower. In Suzhal layout, single cell (1-20) has been divided into two sub cells(1-16, 17-20) in which 5 operators would work in first group and remaining 3 operators work in second group.A new layout (Suzhal) was typically looking like E-shaped layout in which group of workers rotate within the sub cell.

The simulation results of current layout and proposed layout were recorded and compared. The results show that in the new layout, throughput increases, WIP inventory reduces and walking distance also substantially reduced. From the analysis, this internal looping within the cell will not only increases productivity but also reduces human stress and reduces rejections at the customer site. The advantages of Suzhal layout were that workers were scheduled without disturbing multi-skill workforce environment, eliminate monotony and reduce risk of rejections and injuries. The analysis shows that total operating cycle time has been reduced (Figure 4) in newly developed Suzhal layout, which keeps operator wakefulness higher, distributing the workloads throughout workers in the group and hence increases productivity. The validation and verification of the model were conducted for the base simulation model and new model, created in order to ensure that it does mimic the actual body shop system and is capable of generating identical throughput. With the help of simulation, the number of operators required in each shift can be determined from the study. From the results, we can infer that the throughput has been increased from 34/man-shift to 38(37.75)/man-shift with same manpower (Fig 5).

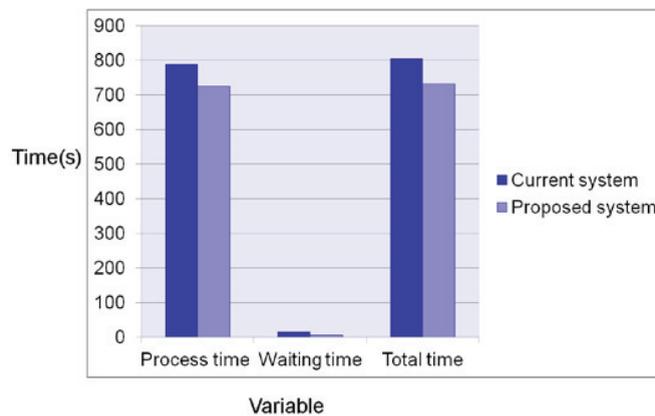


Fig. 4.Average time per entity in current and proposed system.

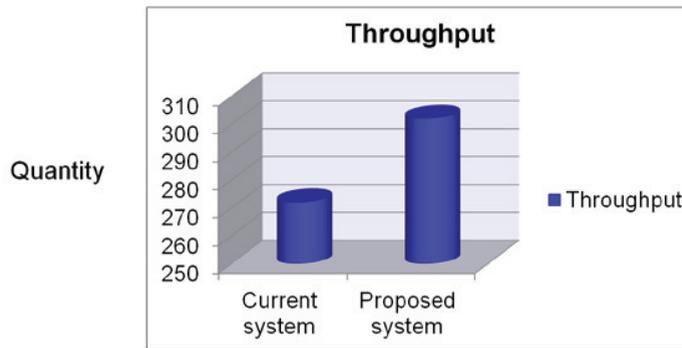


Fig. 5. Throughput in current and proposed system.

5. Conclusion

This study leads to development of methodology which incorporates ergonomics in layout design in CMS and it has been simulated and verified in assembly line. From the results, we can infer that new Suzhal layout can increase productivity by 10% with same manpower by modifying workstations and work methodologies. The Suzhal layout can be used in variety of cases where automated workstations were at different points of line subjected to simulation study and allocation of workers based on line balancing. The study can be effectively performed using easily available inexpensive and user-friendly computer-based tools. Based on market demand, alternative possibilities of worker allocation, deployment of workers, adding product varieties can be made using simulation software model. The computer simulation of various cases of scheduling gives an idea adopting different manufacturing philosophy over different period of time based on market conditions at the expense of reduced cost. Since lot of industrial management people had developed skills in lean tools, layout design, this simple easy methodology incorporating ergonomics in layout design can be easily adopted to improve the productivity by providing workers, a safe workplace.

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