Productivity and Efficiency Improvement Using Witness Simulation and Ergonomic Study in Automotive Assembly Line

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ABSTRACT

The most crucial part of manufacturing industry is the assembly line because it will determine the efficiency and the productivity of the companies. There are many aspects of improvement that can be executed to achieve optimum efficiency and productivity of production system. This paper is focusing on the 2 factor of improving the automotive assembly line. First objective is to study the ergonomic level and second objective is to improve the assembly line balancing. An ergonomic system in automotive assembly line plays a vital role to lower the risk of injury of musculoskeletal disorder (MSD) among employees. The assembly line can be improved such in many ways, for example, the arrangement of working layout, the height of the workplace and how the worker is handling the piece part. All of these are imperative to increase the efficiency of employees. The research was conducted at an ABC automotive company in Pahang, Malaysia. The existing productivity and efficiency of assembly line was studied. The study involves a total of four main stations on the assembly line. The increment percentage of labor and station efficiencies is tabulate to show the comparison before and after layout improvement was done.

Keywords: WITNESS, productivity, efficiency, musculoskeletal disorder (MSD), line balancing

1 INTRODUCTION

In current manufacturing industry, assembly lines are the basis of many production systems. An assembly line is composed of successive stages, in which work pieces are consequently assemble down the line and are transferred from one station to the other through workforce or material handling equipment. Assembly lines are of significant in the industrial production of high quantity standardized commodities and more recently even gained importance in small volume production of customized products [1]. A heuristic procedure providing a compromise between the objective function and the suggested stability measure is developed and evaluated on benchmark data sets [2]. The aim of this work was to appoint all given tasks to workstations and workplaces while reducing the line cost predicted as a weighted sum of the number of workstations and workplaces.

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The objective of this paper was to recommend a stability measure for appropriate and optimal solutions of this problem concerning possible variations of the processing time of individual tasks. In determine the existences of ergonomic risk factors correlate with awkward postures of the lower extremities, trunk and neck were developed and assess. Awkward postures of the trunk and neck were standard, occurring in more than about 70 percentage of the jobs. Results produced by the checklist were mainly in agreement with results created by the experienced ergonomists. In contrast, the checklist was found to be more sensitive in identifying the presence of awkward postures. The list discovered to be a useful rapid-screening instrument for analyzing periodic jobs that expose workers to possible harmful postures. Furthermore, the list was not used to evaluate non-cyclical jobs, for example, maintenance and skilled trades [3]. The usage of robotic devices such as exoskeletons might then be a relevant solution to reduce workers pain and prevent MSD. In general, ergonomics intervention acts as a focal driver for a healthy and successful organization in nowadays socio-economic surroundings [4].

Efficient ergonomics in workstation design shows improve interaction between man-machine systems. Productivity of worker substantially depends upon ergonomic design of workstation. A lot of research has been conducted on analyzing and enhancing ergonomics of workstation, facility layout, and tool design. Analysis regarding operator performance and comfort in repetitive assembly task has been done [5]. Analysis of work stress during production process among Indian workers has been carried in manufacturing industries of India [6]. Ergonomic research on manual component insertion line in printed circuit board assembly has been done using technique of questionnaire, direct interview and archived data [5]. For productivity improvement in manufacturing industries, efficiency of worker plays a significant role. Productivity of worker substantially depends upon ergonomic design of workstation. Efficient ergonomics in workstation design shows better interaction between man-machine systems. Many research has been done on analyzing and increase ergonomics of workstation, facility layout, and tool design. Research regarding operator performance and comfort in repetitive assembly task has been studied [5]. Impact of workstation design, assembly design, jig design and working postures on assembly line shows jig design have most important effect on assembly line. Ergonomic review on manual component insertion line in printed circuit board assembly utilizing technique of questionnaire, direct interview, and filed information [5]. Ergonomics studies have shown that workplace design already influences the performance of workers. Workbenches may be able to be used to improve the comfortableness in workplace, design of workbenches with enough assembly working surface heights for the workers must be counted. Workstation may operate with less efficiency, if anthropometry data mismatches with workstation design. Work-related musculoskeletal disorders (MSDs) include all musculoskeletal disorders that are induced or intensified by work and the conditions of its performance [7]. The most common musculoskeletal problem in the working community is low back pain (LBP), which together with a few upper extremity disorders (UED) has the positive scientific proof of all MSD. Low back pain was the most prevailing body region illness testified by men (34.8%); neck and low back pain by women 39% and 36.5% respectively [7].

The discrete-event simulation Witness software was used for the case study. Generally WITNESS is a discrete event simulation package invented by Lanner Group, founded in the United Kingdom. WITNESS is classified as visual collaborative discrete-event simulation software. Model in this simulation software are built up of “elements” which are replications of actual manufacturing subsystems [8]. It can provide vision into the performance, capacity and limitations of a factory. Thus, it allows manufacturers perform changes to a factory model until the preferred performance is accomplished, with the expectation that the new-built factory or

newly reconfigured production line is “right-first-time” by lowering the need to actually prototype the process [9]. WITNESS simulation software can provide data according to layout given and generate the statistical report [10]. Thus, the ergonomic will improve the productivity of the company when employee is in prosperous of health.

2 RESEARCH BACKGROUND

This research is to determine the productivity and efficiency of the assembly line in automotive company. The automotive company ABC is the place chosen for the study. The assembly line chosen for the study is E-class car assembly line. Four of the station were selected from total of sixteen station in the E-class car assembly line. The criterion on how the station was chosen is by selecting stations that have many problems involve in productivity and ergonomic aspects. This study will collect data of the current design layout, the number of workstation, number of operators, task assign to each operator and processing time. Besides that, ergonomic studies is also conducted to identify the injury or disease that cause by working at assembly line such as musculoskeletal health in the workplace.

The critical part is how to implement the system on the old regime, there are two involvement strategies are representations of the same overall strategy, first is the risk factor must be identified and the second is deal with the individual at risk. However, proper management of ergonomic interventions is necessary to ensure that the implementation is adequate and flexible in dealing with the problems at hand. Safety and health protection during working have become critical and also the associated specific perspective, which has significant effects on the legal position of employees and employers.

Safety and health protection during working have become critical and also the associated specific perspective, which has significant effects on the legal position of employees and employers. As for the new layout improvement will be proposed to overcome the problem. Design of the new layout is vital in order to improve the efficiency of the production line and reduce the idle time of each workstation. Then, the proposed layout is analyse using WITNESS software to ensure efficiency and productivity is proven increase then the current layout.

3 METHODOLOGY

In this study, firstly the data about current assembly line layout is collected. The four stations that were chosen are station 9, station 10, station 11 and station 12. From the observation these stations have longer cycle time than others. This station also has involvement of massive parts assembled. For each station there are workers (operators) that were assigned by the engineers. Number of workers assigned at station 9 is 2 while 4 workers is assigned at station 10. Station 11 have 2 workers and station 12 have 4 assigned to their station respectively. For each worker there are particular task must be done to avoid interference of work between workers to keep the smoothness of the assembly process.

The method of data collection in this research is by recording the cycle time of each worker doing a task assigned. In contemplation the validity and accuracy the cycle time will be registered three occasions, in the morning, before lunch break and 2 hours before the end of the day. The cycle time check sheets are used during recording the data. This research is using simulation software to do the analysis because of simulation software is proved to be faster and get accurate result. The software employed in this research is witness software. This software function is to analyse the efficiencies of the workers in the assembly line.

Once the efficiencies of the workers are acquired, then we can observe which workers are not achieving the optimum efficiencies. Hence the improvement of that assembly line can be made. Formula use in this project is the increment percentage formula, meaning that we want to observe the different of station and labor efficiencies before and after improvement. The equation (1) is stated below:

$$\text{Percentage of improvement} = \frac{improvement - current}{current} \times 100 \qquad \textbf{(1)}$$

4 RESULT AND DISCUSSION

Using the WITNESS interactive simulation software, the analysis of layout model will be generated. The result include the station and labor efficiency (percentage of idle and busy time) with buffer quantity for each station. The data was taken in the morning session before afternoon breaks. Next session in the evening, 2 hours before production stop. Take note that the unit of cycle time is in second and the travel time from station to station is 4 seconds. There are 3 sets of cycle time recorded for each worker processes. However, only one set of cycle time are need in the simulation. Hence, the average of the cycle time is taken to be compute in the simulation. Table 1 shows the average cycle time.

Table 1: Average cycle time

Station	Labor	Process	Time(seconds)
9	2	1	261
		2	267
10	4	3, 4	275
		5, 6	281
		5, 6	317
		3, 4	311
		3, 4	313
		3, 4	267
		5, 6	278
11	2	7	258
		8	249
12	4	9	276
		10	283
		11	231
		12	228

4.1 Current Layout

After obtained the raw data, raw data need to be computed in WITNESS simulation software. Firstly, the survey for the ergonomic was conducted to check the worker Musculoskeletal Disorder (MSD) problem. Check sheet is used to identify employee Musculoskeletal Disorder condition and the pain level that they experienced. This survey involved all employee in station 9, 10, 11 and 12 respectively. The result for this survey is then tabulated in Table 2. The layout of current assembly line layout will be designed as shown in Figure 1.

The type of cycle time used is a multiple cycle time because of involvement of many processes at once.

By using Witness, the simulation was ran with total time of 24990 seconds. Within this 24990 seconds include time of recesses, production start and stop preparation.

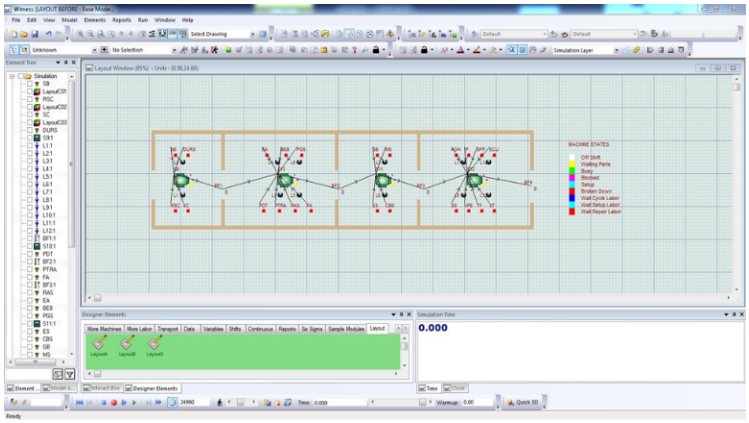

Figure 1: Layout of current assembly line in WITNESS

From the simulation result of the current layout, the number of produce units per day is 11 units. Station 9 has 35 buffer units while others station have 1 buffer unit. That is because the cycle time to finish all process in station 9 is shorter than others station. From the efficiencies point of view, station 9 is the most productive and station 11 is the least productive with too many idle times. For pre decisions, station will be considered to be eliminated or not. The labor from station 11 and 12 have more idle than busy rather than station 9 and 10. The workloads are balanced in station 9 and 10. Thus, only labor from station 11 and 12 will be considered for changing station to improve the efficiency of the workers. The overall review after the simulation for current layout is the assembly line is not productive and less efficiency. It is because of the arrangement labor or many extra labors that can lead to waste of time.

4.2 NEW LAYOUT

In the new layout, the improvement from the ergonomic perspective is taken by using moving conveyor in assembly line and supplied the employee adjustable chair. This two implementation is applied at the new layout to improve productivity of the workers. The moving conveyor is used to improve productivity and mainly to help employee from getting injury when assembly heavy part. This give massive support in new layout productivity. The type of chair supplied to the employee is adjustable chair. The adjustable chair are equipped with fully tilt chair, waterfall seat to help improve the blood flow, back height and back depth adjustment. This to reduce MSD problem for employee like lower back pain, tension neck syndrome, degenerative disc disease, radial tunnel syndrome and upper extremity disorder. The survey check list for Musculoskeletal Disorder (MSD) condition is given back to get feedback from the employee.

Table 2 show the MSD condition before and after the implementation of moving conveyor and adjustable.

Table 2: Comparison for MSD before and after implementation

Type of MSD	Before (%)	After (%)
Lower Back Pain	28.07	8.77
Tension Neck Syndrome	28.07	5.26
Degenerative Disc Disease	14.04	5.26
Radial Tunnel Syndrome	17.54	8.77
Upper Extremity Disorder	12.28	7.02

From Table 2, workers MSD pains are decrease to show that the implementation done is a success. Other solutions are stated as rearrange the labor placement. By rearrange the labor placement, the labor will be transferred to the other stations that have higher busy percentage or the station that have complicated assembly operation. The other solution is reducing labors at the stations 12 from 4 workers to 2. Hence it will increase the efficiencies of the worker hence increase the productivity also cut the operation cost. Lastly, rearrange the stations placement. The stations will be reorganized according to the cycle time, started from the lowest cycle time to the highest cycle time.

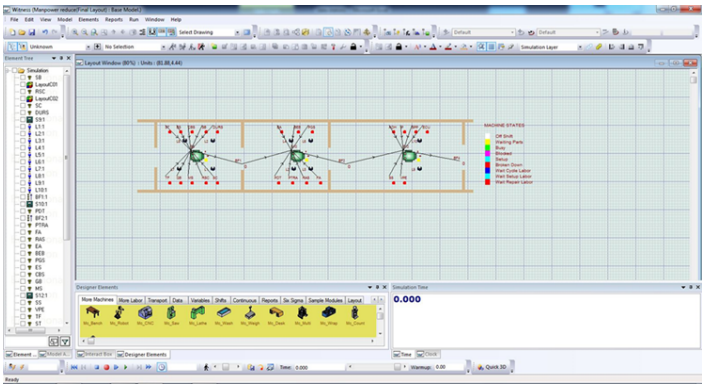

Figure 2: Improvement layout in WITNESS

Figure 2 shows the new layout for the assembly lines in WITNESS software. Station 11 is removed because productivity contributed is below company target. The percentage of idle time is more than percentage of busy time. Then, 2 labor from station 11 are transferred to station 9 in order to help reduce the buffer rate and balance back the cycle time. The assembled parts from station 11 and several parts from the station 12 also have been transferred to station 9. At station 12, 2 labor are reduce which are labor 11 and labor 12 because of lack efficiencies also the idle time percentage is higher than busy efficiencies.

This layout simulation will be run for the same period with the existing layout, which is 24990 seconds as shown in Figure 2.

The number of units produced per day is still the same with the old layout with 11 units per day. However, the number of buffer units at the station 9 is decreasing from 35 to the 7 unit's buffer.

The percentage of the improvement is calculated by using equation (1). The buffer unit percentage is decreasing with 80%. From the calculation the current layout is improving from waste aspect.

$$\text{Percentage of improvement} = \frac{35-7}{35} \times 100 = 80\% \ / \ 0.8$$

From Table 3, labor 1 and labor 2 is decreasing in efficiency. That is because station 9 receive workload from station 11 which had been removed. In contrast, efficiencies for transferred labor are increasing for labor 7, 8, 9, and 10. The increment percentage is calculated using equation 2. Labor 3, 4, 5, and 6 show same efficiency before and after improvement because station 10 is not involve in rebalancing the layout. Thus, labor from station 10 are not included in Table 3.

Table 3: Table of increment percentage

Title	Before (%)	After (%)	Percentage (%)	Trend
Labor 1	49.92	20.92	58.10	decreasing
Labor 2	50.32	21.53	57.20	decreasing
Labor 7	11.58	29.90	158.20	increasing
Labor 8	10.96	28.02	155.60	increasing
Labor 9	12.15	17.25	41.90	increasing
Labor 10	12.50	17.56	40.50	increasing

Overall review after the layout improvement is much better than the current layout. The efficiencies of some labor are increasing, and some are decreasing, it is because of the assembly line balancing balance back the effectiveness at the same level and increase the productivity also efficiency. By doing this improvement also can reduce the operation cost because of the station elimination and the labor reduction. Hence, this new improvement on the layout is ready to be implemented.

5. CONCLUSION

The result shows that rising problem of musculoskeletal disorder (MSD) diseases must be taken seriously by the manufacturing company. Thus, on this ergonomic studies proof of aided tools such as adjustable chair would reduce the MSD problem among employees.

The second objective accomplished as data collected from the current layout and cycle time is used to improve the current layout as simulated in WITNESS simulation software. By using WITNESS, the simulation analyse on productivity, efficiencies of stations, efficiencies of labor and the buffers unit.

As a summary for the current layout, the efficiencies of each station and the labor efficiency are not satisfying the company's board target. The buffer unit at station 9 is high because of the assembly line is not even balance. The buffer unit at station 9 is 35 unit compare to other station which only have 1 buffer unit respectively. Thus it will make station 9 100% busy with no idle time and leave station 11 with 77.46% of idle time percentage. This relatively large gap between the two station shows that the line is not well balance. The improvement of the current assembly line was proposed by referring these solutions which are reducing the station, reducing the labor and the reassigned the labor. The new layout did not consist of station 11 because lack of productivity. For increment percentage for each labor, labor 7 shows the highest increment with 158.20% followed by labor 8 with 155.60%. In short, decision to reduce the stations and the labor must be cautiously done because many parameters needs to be considered. Therefore use of WITNESS software are saving enormous amount of time as the software suggested areas of improvement based on the data collected.

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