Analysis of Ergonomics Workstation Layout Design Using Analytical Hierarchy Process

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Abstract. *Ergonomic workstation is an important component in a production line. Poor layout design of a workstation can have an adverse effect on a worker's performance. This paper presents a method for analyzing the layout design of a workstation using the Analytical Hierarchy Process (AHP). Three criterias and several sub criteria were identified. The criterions are the easiness of motion which consists of three sub criterions-working areas, position of tools, position of material; the comfort of work which consists of four sub criterions-temperature, light, working position, noise; and safety which consists of three sub criterions-safety, dust, smell. A case study was conducted on an assembly workstation of a furniture manufacturer with three alternative layout designs. The result shows that the best layout for assembly is where the worker feels comfortable in completing the task.*

Key word: *Workstation, Layout design, Ergonomics, AHP, Performance, Comfort.*

1. INTRODUCTION

An ergonomic workstation is an important component in a production line. Poor layout designs of a workstation can have an adverse effect on a worker's performance. Thus there is a need for a proper layout design of workstation that can reduce these effects.

Alternatives of the layout design can be developed based on ergonomics principles. The determination of the best design at the early design stage is a crucial decision. The selection of the most appropriate design is important because an improper design can never be compensated for by a good detailed design and will incur great expense of redesign cost (Hsu and Woon, 1998) and (Zhang et al., 2006). Therefore, selecting the best design is not an easy task and is the most critical stage in layout design development due to the many factors influencing the selection that need to be considered (Hambali et al, 2009).

There are many different methods to evaluate and select the layout of an ergonomics workstation. Each method has its strength and weakness. This study is going to focus on one method, called analytical hierarchy process (AHP).

The use of AHP for evaluating and selection has been studied by many authors. Yang and Kuo (2003) and Ertay et al. (2006) proposed a combined AHP–DEA approach to solve the facility layout design problem.

Rajhans and Ahuja (2005) suggested the use of Analytic Hierarchy Process for analyzing the parameters involved in layout and relayout decisions. The multiple criteria selected for each of the major factors, flexibility, batch size, cost and accessibility for maintenance are chosen based on the case study undertaken. Unfortunately, there are only few studies that have been done to investigate the layout design of workstation involving ergonomics aspect. They only focused on plant layout.

The objective of this study is to analyze the layout design of an ergonomic workstation using the Analytical Hierarchy Process (AHP).

2. ANALITICAL HIERACHY PROCESS

The Analytical Hierarchy Process (AHP) is a decision-aiding method developed by Saaty (1980; 1985; 1990; 1991). It aims at quantifying relative priorities for a given set of alternatives on a ratio scale, based on the judgment of the decision maker, and stresses the importance of the intuitive judgments of a decision-maker as well as the consistency of the comparison of alternatives in the decision-making process (Saaty, 1980).

Saaty (1980; 1985; 1990; 1991) developed the following steps for applying the AHP:

1. Define the problem and determine its goal.
2. Structure the hierarchy from the top (the objectives from a decision-maker's viewpoint) through the intermediate levels (criteria on which subsequent levels depend) to

the lowest level which usually contains the list of alternatives.

3. Construct a set of pair-wise comparison matrices (size *n x n)* for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement shown in Table 1. The pair-wise comparisons are done in terms of which element dominates the other.
4. There are *n(n – 1)/*judgments required to develop the set of matrices in step 3. Reciprocals are automatically assigned in each pair-wise comparison.
5. Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.
6. Having made all the pair-wise comparisons, the consistency is determined by using the eigenvalue, λ_{max}, to calculate the consistency index, CI as follows: $CI = (\lambda_{max} - n)/(n - 1)$, where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table 2. The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.
7. Steps 3 – 6 are performed for all levels in the hierarchy.

Table 1. Pair-wise comparison scale for AHP preferences (Saaty, 1980; 1985; 1990; 1991)

Numerical rating	Verbal judgments of preferences
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

Table 2. Average random consistency (RI) (Saaty, 1980; 1985; 1990; 1991)

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

3. METHOD OF RESEARCH

The study was conducted at Furniture Manufacturing Company on an assembly workstation. A survey was conducted to identify factors that affect comfort during work at the assembly workstation. Then a hierarchical structure was developed based on questionnaire distributed to the worker consisting of criteria and sub criteria. Twelve assembling male worker participated in survey. They were between 23 to 30 years old. Three alternatives for an ergonomics workstation were developed. The data was processed using AHP to determine the weight of each criterion and sub criteria.

4. RESULT

Figure 1 describes the hierarchical structure comprising of four levels. The levels are as follows:

Level 0: *Objective*. This level presents the target achieved that an ergonomics workstation.

Level 1: *Criteria*. This level describes some factors that affect achieving the target or objective. The three factors identified are easiness of motion, comfort of work, and work safety.

Level 2: *Sub criteria*. Level 2 presents factors affecting the criteria. These comprises of position of tools, position of materials, temperature, light, working position, noise, work safe, dust, and smell.

Level 3: *Decision Alternatives*. This level contain of three alternatives of the ergonomics workstation design proposed. These are workstation I, workstation II and workstation III each having different layout characteristic.

Figure 2 shows the different layout of each workstation. They contain five components which are the main materials (A), assembling area (B), bin (C), supporting material (D), and tools/equipments (E). Layout of workstation I (Figure2 (a)) is such that the main material and supporting material are located on the left of the worker. While the bin and equipments/tools are located on the right of the worker. The worker completes the task in a squat and bends position. The temperature at the workstation is 24 degrees Celsius.

Figure 2 (b) shows the layout of workstation II where the main material is located on the left of the worker. The bin, supporting material and tools/equipments are located on the right of the worker. The worker completes the task in a squatting position. The temperature at the workstation is 25 degrees Celsius. Figure 2 (c) describes the layout of workstation III. The main material, supporting material, and tools/equipment are located on the left of the worker. The bin is located on the right of the worker. The worker completes the task in bending position. The temperature at the workstation is 26 degrees Celsius. For all the workstation design, the assembly area is located in front of the worker.

Table 3 shows the final results of AHP which are the priority weights of each proposed ergonomics workstation. The weights are the results of multiplying the geometric means of the criteria, sub criteria and alternative workstation. The workstation that has the highest priority weight is the best workstation from an ergonomically point of view.

5. DISCUSSION

The priority weight of WS I, WS II, WS III based on easiness of motion criteria and working area sub criteria are 0.0686, 0.0347, 0.0175 respectively. This means that WS I has the highest priority weight. The working area of WS I is larger than the others so that it is easier for the worker to move when perform the task.

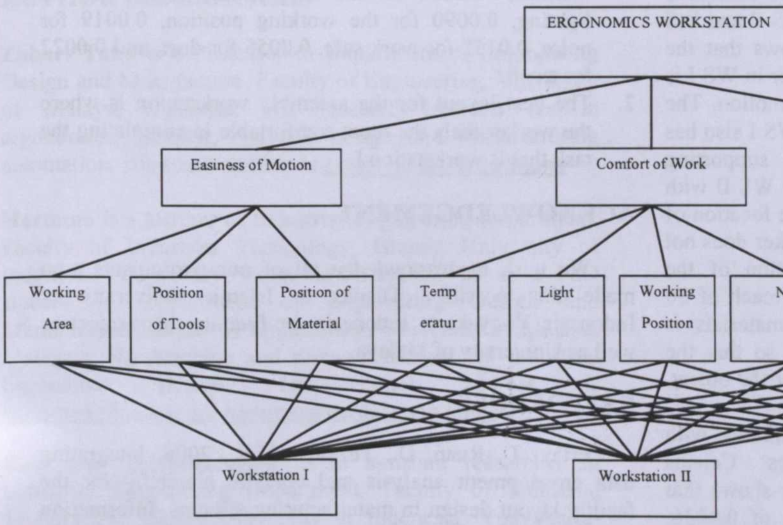

Figure 1. Structure of Hierarchy

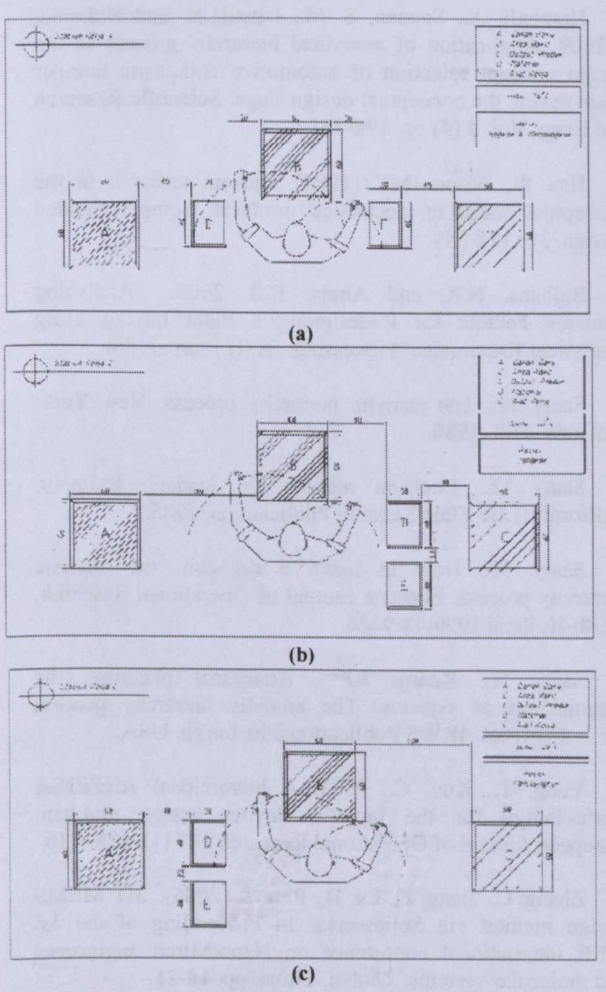

Figure 2. Ergonomics design of assembling workstation proposed; (a) Workstation I, (b) Workstation II, (c) Workstation III

Table 3. Geometric Mean and Weight of Priority in Assembling Workstation

Criteria	Sub criteria	Alternative Workstation	Geometric Mean	Weight of Priority	The highest priority of workstation
Easiness of Motion (0.4640)	Working Area 0.2982	WS I	0.4963	0.0686	Workstation I
		WS II	0.2512	0.0347	
		WSIII	0.1269	0.0175	
	Position of Tools 0.0874	WS I	0.5110	0.0207	Workstation I
		WS II	0.2102	0.0085	
		WSIII	0.1523	0.0061	
	Position of Material 0.0587	WS I	0.5792	0.0158	Workstation I
		WS II	0.0985	0.0026	
		WSIII	0.2003	0.0054	
Comfort of Work (0.193419849)	Temperature 0.03856598	WS I	0.4894	0.0036	Workstation I
		WS II	0.1989	0.0014	
		WSIII	0.1948	0.0014	
	Light 0.03879422	WS I	0.4892	0.0036	Workstation I
		WS II	0.2416	0.0018	
		WSIII	0.1625	0.0012	
	Working position 0.08068629	WS I	0.5816	0.0090	Workstation I
		WS II	0.2618	0.0040	
		WSIII	0.1089	0.0017	
	Noise 0.02882199	WS I	0.3501	0.0019	Workstation I
		WS II	0.2684	0.0014	
		WSIII	0.2074	0.0011	
Safety of Work (0.213038125)	Work safe 0.14851246	WS I	0.4982	0.0157	Workstation I
		WS II	0.1787	0.0056	
		WSIII	0.1824	0.0057	
	Dust 0.0447468	WS I	0.5816	0.0055	Workstation I
		WS II	0.2618	0.0024	
		WSIII	0.1089	0.0010	
	Smell 0.01793308	WS I	0.5867	0.0022	Workstation I
		WS II	0.2004	0.0007	
		WSIII	0.1522	0.0005	

The priority weight for position of tools sub criteria is the higest for WS I at 0.0207. The weights for WS II and WS IIII are 0.0085 and 0.0061 respectively. It shows that the location of the tools in the right side of the worker in WS I is reachable by the right hand as well as ease of motion. The tool position is in the worker's reach of 30 cm. WS I also has the highest priority weight for position of supporting materilal sub criteria, that is 0.0158, followed by WS II with 0.0026 and WS III with 0.0054. It shows that the location of the suporting material on the left side of the worker does not present a problem. This is because the position of the supporting material is still within the worker's reach of 30 cm. Both positions of tools and supporting materials is within the normal reach of the worker's hand so that the worker feels more comfortable when reaching for the object. The worker also does not need to twist the body.

It was found that worker poductivity increases with temperature between 24 to 27 degrees Celsius (Wignjosoebroto, 1995). The result of the study shows that WS I (24° C) has the highest priority weight of 0.0036, followed by WS II (25° C) and WS III (26° C) of 0.0014 respectively. It means that WS I is the most comfortable at 24° C. Increasing the temperature will make the condition become warmer causing discomfort. On the light sub criteria, WS I has the highest priority weight of 0.0036 while WS II is 0.0018 and WS III is 0.0012. This means that the lighting of WS I was identified as the most comfortable. This is beacuse the lighting did not come from the artificial sources but from natural lighting. The worker recieved the artificial light indirectly thus reducing glare. With WS II and WS III there is no natural lighting. The artificial light produces a higher glare. A higher glare can cause eye fatigue or strain.

The work position also affects the comfort at work. WS I has priority weigth of 0.0090 which the worker perform the task in a stoop and squat position. For WS II, the worker works while stooping only. And in WS III, the worker works while squating only. Both will cause increasing fatigue of the musculoskeletal system especially the back and legs because it is monotonous and repetitive for a long period.

Noise is an another factor that affects comfort at work. The result of the AHP identified WS I with the higest priority weight of 0.0019 compared with WS II (0.0014) and WS III (0.0011). This shows that WS I has a low level of noise so that it is the most comfortable for the worker. Besides comfort at work, high dosage noise for long periods will result with negative impact on the safety and health of a work espesially on the hearing.

Dust and smell come from materials being processed and also the outside component will affect the health of workers due to incresing air pollution. Table 3 shows that WS I is identified as the safest. The priority weight of each sub criteria (work safe, dust, and smell) for WS I are the highest that is 0.0157, 0.0055 and 0.0022 respectivelly compared to WS II (0.0056, 0.0024, 0.0007) and WS III (0.0057, 0.0010, 0.0005).

6. CONCLUSSION

It can be concluded that:

1. The highest priority weight for all the sub criterions is workstation I with 0.0686 for the working area, 0.0207 for the position of tools, 0.0158 for the position of material, 0.0036 for the temperature, 0.0036 for the lighting, 0.0090 for the working position, 0.0019 for noise, 0.0157 for work safe, 0.0055 for dust, and 0.0022 for smell.
2. The best layout for the assembly workstation is where the worker feels the most comfortable in completing the task that is workstation I.

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