Layout improvement at a wheel barrow manufacturing company in Kenya using Systematic Layout Planning (SLP)

B.N Njiraini, S.M Maranga and B.W Ikua

***Abstract*— A good plant layout creates an efficient process flow of products, materials, tools, equipment and workers. This results in saving on material handling costs and movement time between work centers, in addition to reducing operator's fatigue. Most companies start small and grow into big establishments, expanding and adjusting plant layout to accommodate new lines or work stations. The flow of work becomes disrupted and non-value motions are created. This paper report on a re-organization of a section in a small and medium industry manufacturing wheel barrows. Systematic Layout Procedure (SLP) proposed by Muther is used. Time study is used to show the effect of the re-organized layout. The improved layout reduced the travel distances by 52% and cycle time effectively reduced by 12%.

***Keywords*— Plant layout, work study, method study, time study,

I. Introduction

PLANT layout can be defined as a plan of an optimum arrangement of facilities including personnel, operating equipment, storage space, material handling equipment and all other supporting services along with the design of the best structure to contain all these facilities [1]. The placement of the facilities in the plant area, is known to have a significant impact upon manufacturing costs, work in process, lead times and productivity [2]. Previous studies have shown tremendous improvement of operations efficiency contributing to saving of operational cost up to 50% [3]. The layout design generally depends on the products variety, space availability and the production volumes [4]. Generally, plant layout fall under four types of organization namely fixed product layout, process layout, product layout and cellular layout or group technology (5). A process layout is a format in which similar equipment or functions are grouped together, such as all lathes in one area and all stamping machines in another. A product layout is one in which equipment or work processes are arranged according to the progressive steps by which the product is made. The path for each part is, in effect, a straight line. A group technology (cellular) layout groups dissimilar machines into work centers (or cells) to work on products that have similar shapes and processing requirements. A group technology (GT) layout is similar to a process layout in that cells are designed to perform a specific set of processes, and it is similar to a product layout in that the cells are dedicated to a limited range of products. In a fixed-position layout, the product (by virtue of its bulk or weight) remains at one location. Manufacturing equipment is moved to the product rather than vice versa. Many manufacturing facilities present a combination of two layout types.

B. N Njiraini, Department of Mechanical Engineering, JKUAT (phone: +2540720707340; e-mail: bnjinu@yahoo.com).
S. M. Maranga, Department of Mechanical Engineering, JKUAT (e-mail: marangar@eng. jkuat.ac.ke).
B. W. Ikua, School of Mechanical, Manufacturing and Material Engineering - mail: ikua_bwr@eng. jkuat.ac.ke).

II. Techniques used for layout planning

There are three major techniques used for facility planning. The first involves optimization of a single criterion function and aims at minimizing costs associated with communication or flow of materials between activities. The layout problem are formulated as either discrete or continuous. When layout is considered discrete, the associated optimization problem is addressed as Quadratic Assignment Problem (QAP). A typical formulation to minimize the total material handling cost was proposed as follows [6]

$$\min \sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k=1}^{N}\sum_{l=1}^{N} f_{ik} d_{jl} X_{ij} X_{kl} \quad (1)$$

s.t

$$\sum_{i=1}^{N} X_{ij} = 1, \quad j = 1,\ldots,N \quad (2)$$

$$\sum_{j=1}^{N} X_{ij} = 1, \quad i = 1,\ldots,N \quad (3)$$

where N is the number of facilities in the layout, f_{ik} the flow cost from facility i to k, d_{jl} the distance from location j to l and X_{ij} the 0, 1 variable for locating facility i at location j. The objective function (1) represents the sum of the flow costs over every pair of facilities. Equation. (2) ensures that each location contains only one facility and equation (3) guarantees that each facility is placed only in one location. With emerging computer simulations that is able to process high volume data bases, other associated techniques such as Computerized Relative Allocation of Facilities Technique (CRAFT) are widely used. The plant layout problem is to find an arrangement of departments that minimizes the total distance traveled. Rather than attempt to obtain the optimum, we use a heuristic approach that tries to better a given solution by switching pairs of departments. At each iteration, every pair of departments is considered for switching locations. The pair that gives the greatest savings in cost will be interchanged and the process will continue by looking for another pair to switch. If no pair results in a positive savings the process stops.

Graph theoretical approach is the second technique. It is concerned primarily with generating a layout that meets adjacency requirements between activities. Many approaches which follow this technique are based on Systematic Layout Planning (SLP) methodology [7]. Muther's methodology results in the generation of an initial space relationship diagram from which a layout can be generated. The third technique tries to find an arrangement that satisfies several constraints or relations. The design allocate facilities to satisfy a set of constraints which involve such factors as position, orientation, adjacency, path, view, or distance. The distances between these departments do not change. The cost savings associated with switching two departments is determined by calculating the effect of interchanging the centroids of the two departments.

III. METHODOLOGY

The process of manufacturing a wheel barrow was broken down into three major parts. Figure 1 shows the major parts which include, a bucket, frame and wheel assembly. The process of making the bucket involves four major tasks namely; Marking out the plate, cutting, bending and welding which formed four work centers. Figure 1 shows the flow chart for the major steps and processes during fabrication. SLP method was used in evaluating and re adjusting the layout of the work centers to reduce travel distances and cycle time in fabricating the bucket as shown in Figure 2 dotted area. In order to evaluate time savings for the proposed layout, a time study was conducted for the existing layout and the proposed layout.

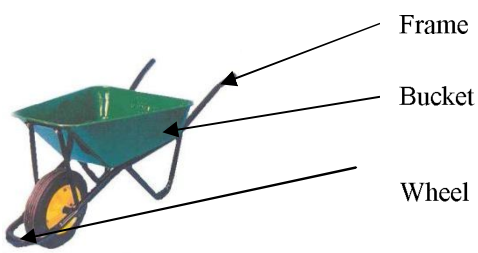

Figure 2: Wheelbarrow parts

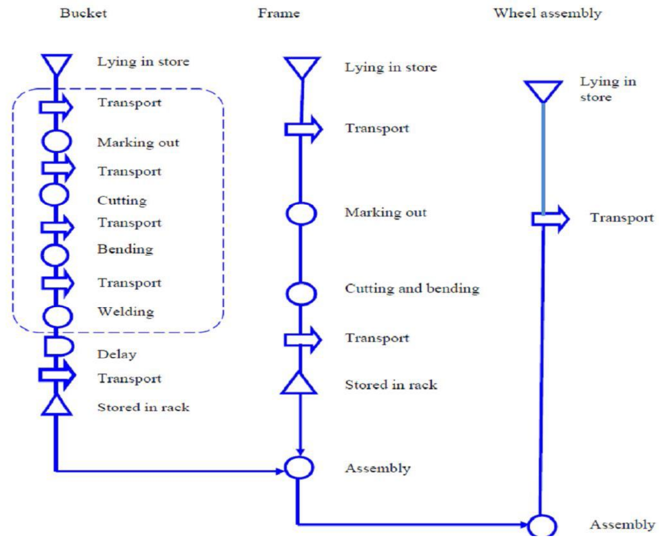

Figure 2: Process chart for wheel barrow manufacture

IV. RESULTS AND DISCUSSIONS

Figure 3 shows the existing plant layout which showed the movement involved backtracking. A string diagram was used to measure the path of the workers. To simplify the study, Euclidean distance is used to measure from the objects midpoint to another. Midpoints of Workstation A to E was measured, A(5,15), B(2,7), C(5,-2), D(9,10), E(5,-2). Using Pythagoras theorem equation 4

$$\sqrt{\sum_{i=1}^{n}(a_i - b_i)^2} \quad (4)$$

Euclidean distance from A-B-C-D-E= 43.33 Meters

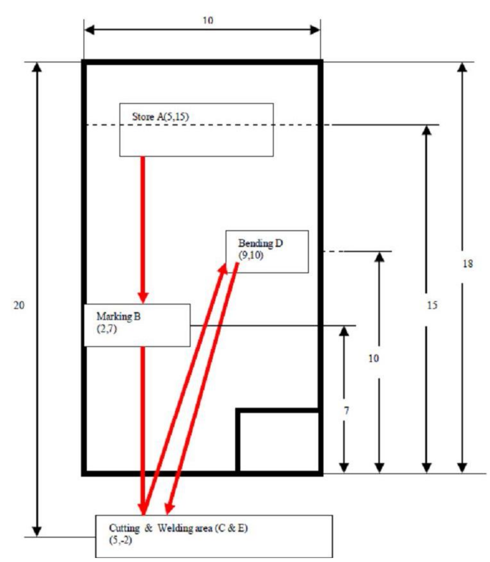

Figure 3: Workshop layout showing relative location of work centers

a. Proposed layout

Using SLP method, various alternatives were proposed and discussed with the workshop foreman. Figure 4. shows the re-organized layout that was implemented. The average distance from each work station to the other was recorded. Figure 5 shows a relationship chart showing the relative importance of the four departments

	A	B	C	D	E
A					
B	3.6				
C		4			
D			5		
E				7.3	

Figure 4: Travel chart

Workstations were located as follows; A(5,15), B (7,12), C(7,8) ,D(3,5), E (5,-2). To obtain travel distance savings; the equation (4) was used. Travel distance from A-B-C-D-E = 20.85 meters. The travel distance saving was;

$$Percentage\ cycle\ time\ saving = \frac{43.33 - 20.85}{43.33} * 100 = 52\%$$

which is 52 % saving on distance covered.

Cycle time improvement using proposed layout

Gilbreth direct time study [8] was used to determine the cycle time for each work-station for both existing and the re-organized layout. Westing House System of rating was used to rate the performance of the operator as shown in Table 1. The calculated performance rating = 1.0-0.09 = 0.91= 91%, however, on interviewing the foreman,

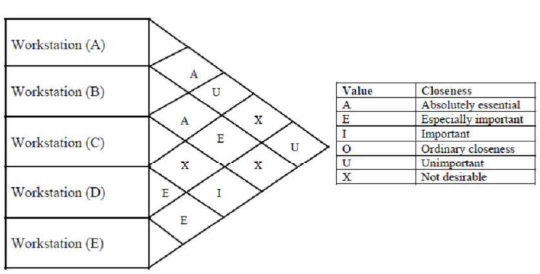

Figure 5.12: Relationship Chart

Figure 5: Relationship chart

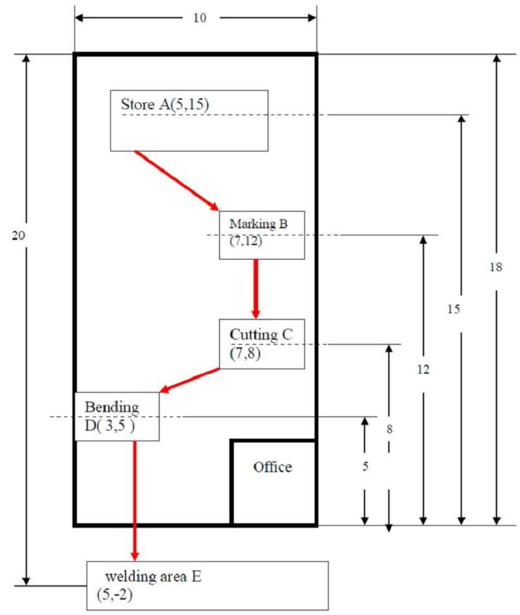

Figure 4: Proposed layout without backtracking movement

Table 1: Calculated ratings of the operator based on Westing house system

Criteria	Rating	Numerical Value
Skill	E1	0.00
Effort	C1	+0.05
Condition	F	-0.07
Consistency	F	-0.07
Total		-0.09

the average rating for the station was between 70% to 80% in real situation. To get a compromise between the West House rating and the Foreman's rating,

$$Performance\ rating = \frac{75 + 91}{2} = 83$$

Allowance was attributed to relaxation, interference, contingency and variable allowance. Due to the poor working condition, the variable allowances were based on fatigue allowances suggested by International Labor Organization (ILO) [9, 10]. The work condition was assumed to be normal as follows;

1. Atmospheric condition = normal
2. Noise = normal
3. Light = normal

Table 2 shows the allowances that were included in calculating the total cycle time.

Table 2: Calculated allowances

Allowance	Rating
Personal	5%
Fatigue	6%
Interference	3%
Contingency	3%
Tediousness	2%
Total	19%

Table 3 shows the total cycle time for various processes for existing layout. The cycle time for each work station and the total time of the entire process was calculated. With the improved rearrangement of work stations the transport time from marking to welding is reduced by 5 minutes. The overall cycle time is reduced by 12%.

Table 3: Summary of work measurement analysis of wheel barrow bucket

Description	Station	Recorded number of runs										Rating %	Normal time	Allowance %	Standard time(min)
		1 (min)	2 "	3 "	4 "	5 "	6 "	7 "	8 "	9 "	Mean				
Transport material	1	4.2	3.8	3.8	3.9	4.0	3.5	4.1	4.0	4.1	3.90	83	3.24	19	3.85
Marking out	2	3.0	2.9	3.0	2.9	2.7	3.0	2.7	3.3	3.5	3.00	83	2.49	19	2.96
Transport material	3	1.8	2.1	2.0	1.7	2.1	1.7	1.7	2.0	2.1	1.91	83	1.58	19	1.88
Cutting	4	10.3	10.2	9.9	10	10.4	9.6	10	11	10.5	10.20	83	8.47	19	10.08
Transport material	5	1.2	1.0	1.3	1.2	1.1	1.2	1.0	1.1	1.2	1.14	83	0.95	19	1.13
Bending	6	10.6	9.5	9.8	11	11.4	9.9	10	10.4	11.5	10.50	83	8.72	19	10.38
Transport material	7	0.8	1.2	1.2	1.0	1.3	0.9	1.0	1.1	1.0	1.06	83	0.88	19	1.05
Welding	8	20.2	19.8	19.7	20.6	20.5	19.3	22	26	20.4	20.90	83	17.35	19	20.65
TOTAL															51.98

V CONCLUSION

Although there has been perception that layout problems are only for big establishments, evaluation of layout in this study revealed that small firms also require continuous improvements of their layout for efficient operations. The proposed layout reduced the travel distances by 52 % which translate into cost reduction. The cycle time for fabricating the wheel barrow bucket was also reduced by 12 %. The benefit of the proposed layout outweighs the cost of relocating the facilities. Backtracking creates unnecessary movements that contribute to tardiness and operators fatigue.

REFERENCES

[1] Moore, J.M., Plant Layout and Design, Macmillan, New York (1962)

[2] Amine D. A.B., Henri P. A., Sonia, H. G., "Facility layout problems," A survey, Annual Reviews in Control 31 (2007) 255–267

[3] Tompkins, J. A., White, J. A., Bozer, Y. A., Frazelle, E. H., Tanchoco, J. M., & Trevino, J. (1996). Facilities planning. New York: Wiley.

[4] Martand, T., Industrial Engineering and Production Management, Chand, S., new Delhi (2009)

[5] Chwif, L., Pereira B. M. R., & Moscato, L. A., A solution to the facility layout problem using simulated annealing. Computers in Industry, (1998)36 (1–2), 125–132.

[6] Muther, R., Systematic Layout Planning, Cahners Books, Boston, 1973.

[7] Gilbreth, J. F., Carey, E. G., Cheaper by dozen. 1948.

[8] Sumanth, D. J., Total Productivity Management: A systemic and quantitative approach to compete in quality, price, and time. St. Lucie Press, 1998.

[9] Gavriel,S., Handbook of industrial engineering: technology and operations management. New York, NY: Wiley, 2001.

[10] Kanger, B., Engineering Work Measurement. USA: Industrial Press, 1977.