Facility Redesign using Systematic Layout Planning

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Abstract

This paper presents facility redesign of Glazing and Metal Works using systematic layout planning. Process sequence, material flow and activity relationship were studied. The lay-out was designed and simulated. The new layout showed reduced material flow distance by 33%, waiting time by 30% and increased space utilization by 14%.

***Keywords**: Systematic Layout planning, Facility Layout design, Simulation.*

1.0 Introduction

Block layout of facility is designed considering the relationship amongst the departments. Internal layout design deals with placement of equipment, storage space, paths, etc. within the departments [1]. A methodology to redesign plant layout starts with collection of relevant data and information, performing flow analysis along with identifying the supporting services, and ending with implementation of the redesigned plant layout. Flow process charts, flow diagrams and operation process charts are commonly used for studying the existing layout. The common storage rack systems like flow rack system, single deep rack, double deep rack, push back rack can be considered while designing layout of warehouse [2]. For developing alternatives for redesigning the existing facility, factors such as ease of access, space utilization, cost of implementation and long-term viability are selected to evaluate the alternatives [3-4]. Weighted factor comparison can used to choose the best facility layout [5].

In simulation of layout using ARENA, factors such as total travelling distance, total travelling time, travelling cost, number of cross over, output over a certain time duration, average resource utilization, total average work in process, total average waiting time and total time spent in system are used as evaluation factors [6 -7]. Efficiency indices can be used to evaluate the existing and proposed layout. Direct material handling, production line flexibility and aisle space are some of the efficiency indices which can be used to indicate an improvement in efficiency of the proposed layout [8]. Material flow distance is used to compare the proposed layout with the existing [9] and adjacency score can be used for the evaluation [10]. The main objective of this paper was to redesign production floor layout of a department using Muther’s Systematic Layout Planning (SLP) methodology. Alternative layouts were simulated using ARENA simulation tool.

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2.0 Methodology

The study was undertaken in Glazing and Metal Works factory in which the process layout was followed with incidences of back tracking and unnecessary movements. Placement of machines resulted in unsmooth and discontinuous movement of parts between machines. Unused machines and empty spaces present between the lines hindered movement of workers and the parts. The space utilization was only 70% of the total available 1.3×10^5 sq. feet.

2.1 Study of Existing lay-out

Aluminum fabrication, mild steel fabrication and stainless steel fabrication were the three main fabrication units. Detailed analysis was performed on two major products from each of the three units: window and panel in aluminum fabrication, bracket and canopy in mils steel fabrication and pipe and railing in stainless steel fabrication. Operation process charts for these products are shown in Fig. 1 to 3.

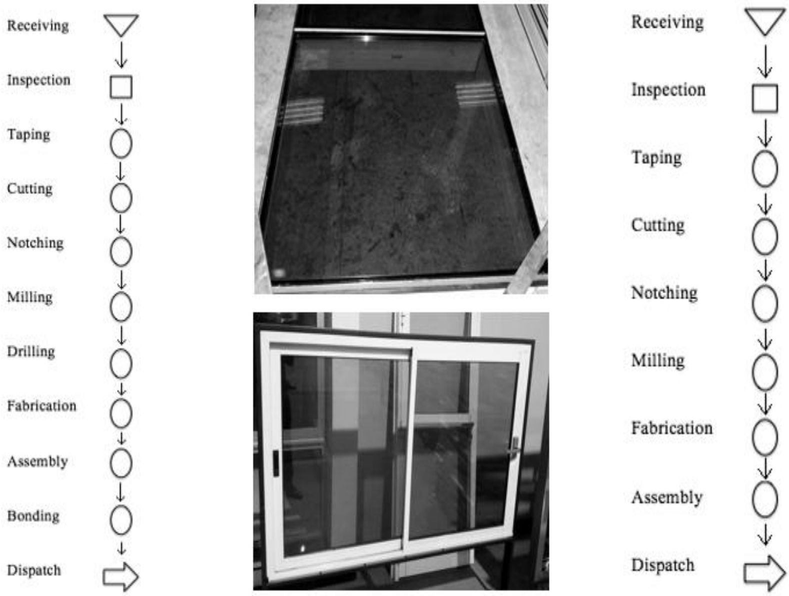

Fig. 1. Operation Process Charts for aluminium Panels and windows

Fig. 2. Operation process charts for MS brackets and canopies

Fig. 3. Operation process charts for SS pipes and railings

Existing layout is shown in Fig. 4.

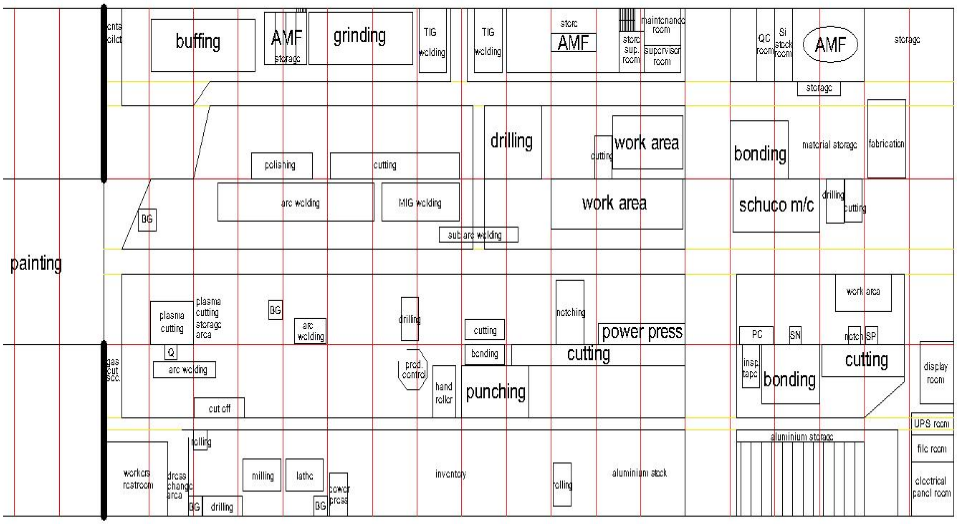

Fig. 4. Layout of existing facility - Department

2.2 Systematic Layout Planning

2.2.1 Material Flow

Flow of materials for aluminum products through the facility is mapped using AutoCAD (Fig. 5). It depicts both forward (blue) and backward (green) movements. Materials flow for other products was also studied.

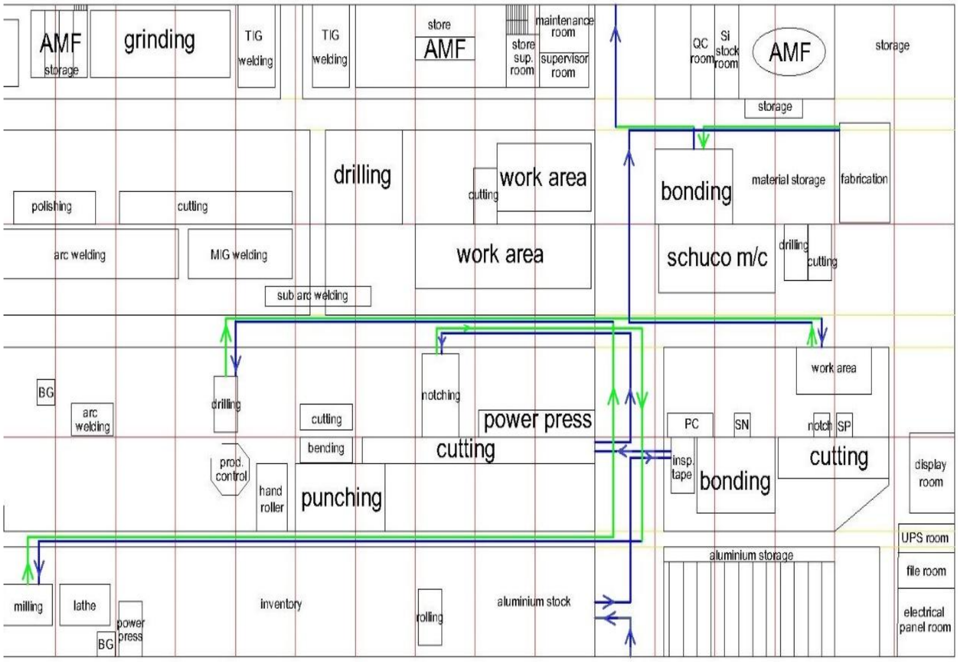

Fig. 5. Material flow process for aluminium panels

2.2.2 Mileage chart

FROM-TO chart data serves as baseline and is useful for finding the degree of closeness necessary between different departments for material interaction. Table 1 represents linear distances between different departments for each major process in aluminium fabrication. Similarly, mileage charts for the other two fabrications were studied. Departments having more material movement were placed together to minimize material handling and to ensure an optimum material flow.

Table 1. Mileage Chart - aluminum fabrication

D.	1	2	3	4	5	6	7	8	9	10	11	12	13
1	-	23.18	22.49	39.80	51.67	62.84	88.91	81.46	53.85	75.35	58.86	25.77	60.67
2	23.18	-	9.59	28.48	42.62	49.68	91.68	72.22	43.06	62.45	45.66	0.31	47.77
3	22.49	9.59	-	39.53	40.48	46.62	93.71	68.61	40.96	60.21	43.52	30.96	45.63
4	39.80	28.48	39.53	-	78.70	81.51	110.34	106.20	73.60	93.29	77.25	21.17	80.84
5	51.67	42.62	40.48	78.70	-	57.79	124.025	32.28	50.01	71.24	54.61	61.73	56.66
6	62.84	49.68	46.62	81.51	57.59	-	129.98	85.60	1.80	74.35	57.66	63.88	61.25
7	88.91	91.68	93.71	110.34	124.02	129.98	-	156.01	123.42	143.75	127.06	95.06	130.65
8	81.46	72.22	68.61	106.20	32.28	85.60	156.01	-	80.15	99.37	32.68	91.27	82.66
9	53.85	43.06	40.96	73.60	50.01	1.80	123.42	80.15	-	69.93	53.24	61.54	55.25
10	75.35	62.45	60.21	93.29	71.24	74.35	143.75	99.37	69.93	-	19.31	84.82	39.78
11	58.86	45.66	43.52	77.25	54.61	57.66	127.05	32.68	53.24	19.31	-	64.14	21.70
12	25.77	0.31	30.96	21.17	61.73	63.88	95.06	91.27	61.54	84.82	64.14	-	66.15
13	60.67	47.77	45.63	80.84	56.66	61.25	130.65	82.66	55.25	39.78	21.70	66.15	-

2.2.3 Activity Relationship Chart

Value	Closeness	Line code	Allocation
A	Absolutely necessary		5%
E	Especially Important		10%
I	Important		15%
O	Ordinary Closeness OK		20%
U	Unimportant		50%

Activity Relationship Chart between pairs of departments were derived by the From-To chart, mileage chart and material flow. The relationship chart displays which departments are related to others and it also rates the importance of the closeness between them. The relationship chart for all 3 fabrications were prepared after considering both quantitative data of distances travelled as well as the qualitative data collected from the working personnel. Fig. 6 displays the activity relationship chart of aluminum fabrication.

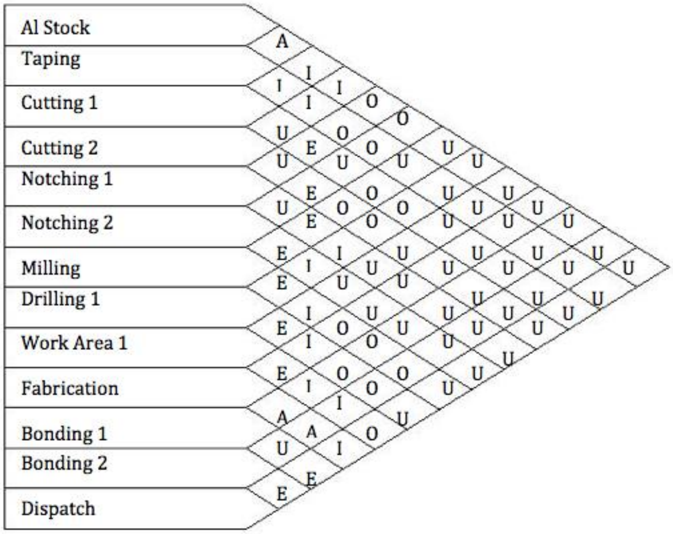

Fig. 6. Activity Relationship Chart - Al Fabrication

2.2.4. Space Relationship Diagram

This is the next crucial step in SLP. Considering the material flow and the relationship between each department, space relationship diagram for aluminum fabrication was generated (Fig. 7). It makes the proximity and relationship between two departments visually evident. The activity relationship diagrams for mild steel and stainless steel fabrication were also generated.

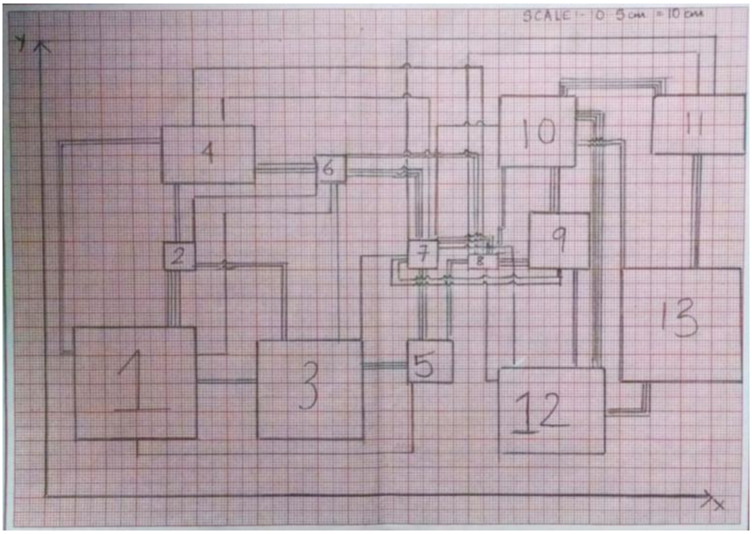

Fig. 7. Space Relationship Diagram - Al Fabrication

2.2.5. Space Requirements

The total working area of departments was collected which indicates the space required for each department. It is used in generating the alternative layouts for the facility. It is converted into the required area and the alternative block plans are derived using the areas for each department.

2.2.6 Closeness Relationship Matrix

This is the final step in SLP. A closeness relationship matrix is made using the activity relationship chart as an input. Weights are assigned to each relationship: A=10000, E=1000, I=100, O=10, U=0, X=-1000. Total closeness rating (TCR) for each department is calculated using the above weights. The department with the highest TCR is selected and located at the centre of the proposed layouts. The departments are selected from highest to lowest TCR while developing the alternative layouts, and are placed around the centre department and the dimensionless diagram is generated for aluminium fabrication as shown in table 2 and Figure 8. The TCR for the other two fabrications are also calculated.

Table 2. Total Closeness Ratings - Al Fabrication

Dept.	1	2	3	4	5	6	7	8	9	10	11	12	13	A	E	I	O	U	X	TCR	Rank
1	-	A	I	I	O	O	U	U	U	U	U	U	U	1	-	2	2	7	-	10220	10
2	A	-	I	I	O	O	U	U	U	U	U	U	U	1	-	2	2	7	-	10220	11
3	I	I	-	U	E	U	O	O	U	U	U	U	U	-	1	2	2	7	-	1220	9
4	I	I	U	-	U	E	O	O	U	U	U	U	U	-	1	2	2	7	-	1220	12
5	O	O	E	U	-	U	E	I	U	U	U	U	U	-	2	1	2	7	-	2120	8
6	O	O	U	E	U	-	E	I	U	U	U	U	U	-	2	1	2	7	-	2120	13
7	U	U	O	O	E	E	-	E	I	O	O	O	U	-	3	1	5	3	-	3150	7
8	U	U	O	O	I	I	E	-	E	I	O	O	U	-	2	3	4	3	-	2340	6
9	U	U	U	U	U	U	I	E	-	E	I	I	O	-	2	3	1	6	-	2310	5
10	U	U	U	U	U	U	O	I	E	-	A	A	I	2	1	2	1	6	-	21210	1
11	U	U	U	U	U	U	O	O	I	A	-	U	E	1	1	1	2	7	-	11120	2
12	U	U	U	U	U	U	O	O	I	A	U	-	E	1	1	1	2	7	-	11120	4
13	U	U	U	U	U	U	U	U	O	I	E	E	-	-	2	1	1	8	-	2110	3

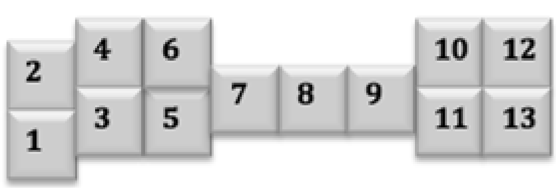

Fig. 8. Activity Relationship Diagram-Al Fabrication

2.2.7 Transportation Cost Matrix

Transportation cost matrix is a quantitative method that is used to draw a comparison between the existing and the proposed layouts. It is the product of production volume, distance and cost of the respective matrices. In the cost matrix, it is assumed that all backward moves cost $1.25/unit volume/ unit distance and all forward moves cost $1/unit volume/ unit distance.

The Formula used for total transportation cost is

$$\sum_{i=1}^{N}\sum_{j=1}^{N} \mathbf{f_{ij} * dij * cij}$$

where,

f is the production volume to and from departments

d is the distances between the departments

c is the cost for the moves between the departments

i is the department from which the material flows

j is the department to which the material flows

N is the number of departments

The sum of the resultant matrix is the facility transportation cost. The cost matrix and transportation matrix for the aluminum fabrication is shown in Table 4 and 5. The same procedure is conducted for the other two fabrications as well.

Table 3. Cost Matrix - Aluminium Fabrication

D.	1	2	3	4	5	6	7	8	9	10	11	12	13
1	-	1	1	1	1	1	1	1	1	1	1	1	1
2	1.25	-	1	1	1	1	1	1	1	1	1	1	1
3	1.25	1.25	-	1	1	1	1	1	1	1	1	1	1
4	1.25	1.25	1.25	-	1	1	1	1	1	1	1	1	1
5	1.25	1.25	1.25	1.25	-	1	1	1	1	1	1	1	1
6	1.25	1.25	1.25	1.25	1.25	-	1	1	1	1	1	1	1
7	1.25	1.25	1.25	1.25	1.25	1.25	-	1	1	1	1	1	1
8	1.25	1.25	1.25	1.25	1.25	1.25	1.25	-	1	1	1	1	1
9	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	-	1	1	1	1
10	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	-	1	1	1
11	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	-	1	1
12	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	-	1
13	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	-

Total Transportation Cost for Aluminum was Rs. 3.64 x 10^5, Mild Steel Rs. 4,841.4 and Stainless Steel Rs. 1.37 x 10^5, totaling to Rs. 5.06 x 10^5.

3.0 Redesign of Existing lay-out

The data collected from the analysis phase of the layout planning was used in proposing a new layout (Fig. 9). The dimensionless block diagrams prepared based on the relationship chart serves as a basis for the new layout. SLP technique resulted in the new plant layout after taking into consideration practical limitations and constraints and is shown in Fig. 9. When the material flow was observed in proposed method, it was seen that the backtracking was reduced significantly. From the proposed mileage chart it was observed that the distance between the departments for each of the fabrication has reduced drastically. From To chart and the cost matrix for the proposed layout is same as the existing layout.

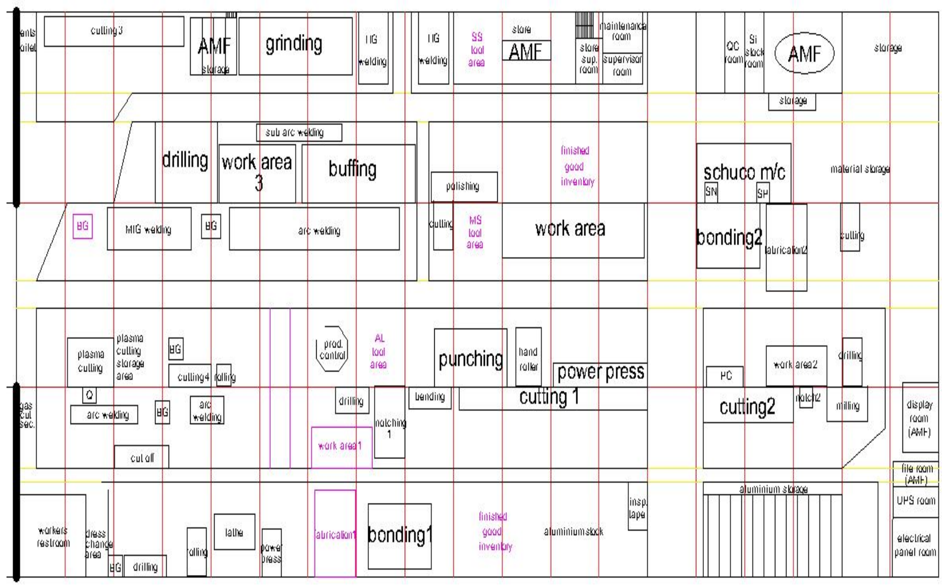

Fig. 9. Proposed Layout

3.1 Transportation Cost Matrix - Proposed

The transportation costs for the proposed layout was computed. Table 4 and 5 represent the transportation cost and summary of transportation costs for aluminum fabrication.

Table 4. Transportation Cost Matrix – Al Fabrication

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	3883	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	3140	2986.5	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	5844	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	157.5	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	32452	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	330	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	36080	12650	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	38864	0
9	0	0	0	0	0	0	0	0	0	0	0	0	9435	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	23220	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2404
15	0	0	0	0	0	0	0	0	0	0	16315	0	0	0	0

Table 5. Summary of Transportation Cost – Al Fabrication (in Rs)

Sl No	Fabrication	TC (Existing)	TC (Proposed)
1	Aluminum	2.84×10^5	1.87×10^5
2	Mild Steel	4,841.4	799.9
3	Stainless Steel	1.37×10^5	1.37×10^5
	Grand Total	4.26×10^5	3.24×10^5

3.2 Simulation

To evaluate the proposed layout, comparisons on certain key performance indices between the existing layout and proposed layout are performed. The indices used to evaluate the effectiveness of the proposed layout are waiting time, % utilization and number of products produced in the case study. Simulation was performed to evaluate the performance. First, cycle time and the waiting time of each process are collected. The distribution of data is determined using the ARENA input analyzer. Three simulation models were prepared for this study. The simulation process involves the parts arrival, processing at different stations and finally shipped. The simulation was executed for one month, eight hour and two shifts per day basis.

4.0 Results

The sample simulation model of Aluminum Fabrication department is shown in Figure 10. Simulation results are summarized in Table 6 and overall comparison of existing and proposed layouts are presented in Table 7.

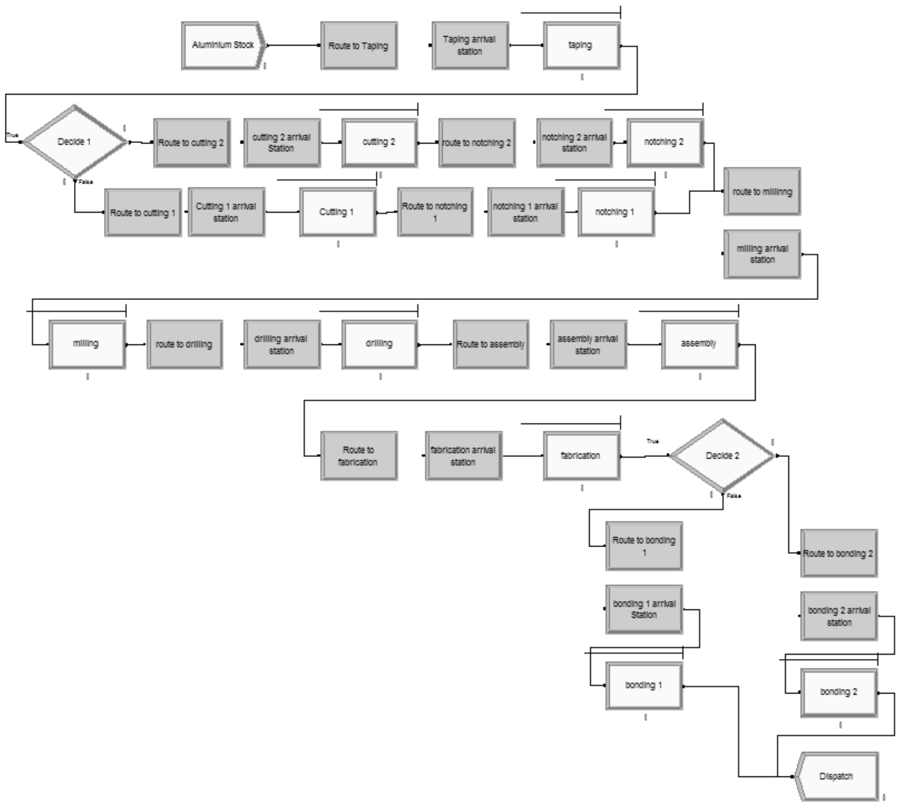

Fig. 10. Simulation model of the proposed method of aluminum fabrication unit

Table 6. Summary of simulation results

Sl. No	**Fabrication**	**No of Products produced (16 hours)**		**Waiting time (minutes per 16 hours)**		**% Utilization**	
		Existing	Proposed	Existing	Proposed	Existing	Proposed
1	Aluminum	276	279	51.16	28.9	65.82	85.56
2	Mild Steel	81	82	256.8	187.2	72.54	86.81
3.	Stainless Steel	80	81	57.13	39.04	79.83	85.62

Table 7. Results of Existing vs. Proposed Layout

Sl. No	Metric	Existing	Proposed
1.	Transportation Cost (Rs)	4.26×10^5	3.24×10^5
2	No of Products	437	442
3	Waiting Time (min)	365.09	255.14
4	Distance(m)	1364.01	914.03
5	% Utilization	72.73	85.99
6	Space utilization (%)	72.73	85.99
7	Net revenue (Rs – crore)	152	153.56

5.0 Conclusion

Facility layout of Glazing and Metal Works was redesigned using systematic layout planning. Data on the existing layout was obtained by using Process sequence, material flow and activity relationship. The lay-out was designed and simulated. The new layout showed reduced material flow distance by 33%, waiting time by 30% and increased space utilization by 14%.

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