http://dx.doi.org/10.21172/ijiet.134.08

Minimizing the In-Plant Distance Travelled by the Material in a Customized Furniture Manufacturing Company

Pavithra C[1], G.S Prakash[2], Shobha R[3]
[1,2,3]Department of Industrial Engineering and Management,
Ramaiah Institute of Technology, Bangalore, Karnataka, India

Abstract- Customized Furniture Manufacturing Company produces diversified products which have distinct process mappings based on personalization demanded by the client. Finding best optimum location for machines & workstations in order to reduce the distance travelled acts as the reserve to improve efficiency of the manufacturing system. Exploiting this reserve helps the organization to sustain global competition by increasing the production without investing on new technology & equipment's.

This paper is inclusive of frame work for the plant layout optimization in Customized Furniture Manufacturing Company through decomposition of traditional job-shop kind of facility with generic material flow pattern which reduces the distance travelled by the product inside the factory. In order to develop a new layout design with minimized travel distance, Muther's Systematic Layout Planning Methodology is followed, which is an organized way of solving facility related problems in the factory. Making use of the various tools like P-Q chart, Multi Product process flow chart, Distance matrix, Relationship diagrams the best optimum layout is designed. As a result distance travelled is reduced to 43% on an average in each product, i.e. about 1900 meter overall, which majorly contributes on reduction of lead time of the production thereby it serves the intended purpose.
Keywords – Material distance travelled, Layout optimization, Muther's SLP, Distance matrix, Relationship diagram

I. INTRODUCTION

Over the ages, the popularity of wooden traditional furniture's in India provided strength for existence of furniture industry. From past few years wood utilization has been increased since people started using wooden cupboards, furniture more. In order to meet the demands & to compete with the market players changing or optimizing the existing manufacturing system is essential. For the proper working of manufacturing system Facility plays very vital role. Facility layout design has the major influence on productivity of the Organization. The purpose of layout design is to find the most effective facility arrangement by minimizing the material handling. [1]

Systematic Layout Planning (SLP) is a prominent procedural approach and is widely used in layout design for various small and medium enterprises (Gilbert 2004). It provides the step-by-step procedure that needs to carry out in order to optimize the existing layout planning. It includes a framework of levels, a sample of strategies, and a hard and fast of conventions for figuring out, score, and visualizing the factors and areas concerned in planning a layout. According to Systematic layout planning, every layout rests on the three fundamentals: [1]

- Relationships: The relative degree of closeness favored or required amongst things
- Space: The quantity, type, and form or configuration of the things being laid out
- Adjustment: – the arrangement of things into the best fit

These three are heart of any layout planning project, regardless of products, methods, or size of project. It is therefore logical and to be predicted that pattern of layout planning procedures is based directly on these fundamentals. [1]. Systematic Layout Planning (SLP) methodology facilitates to reduce the material handling cost thereby reducing the product cost & improved the efficiency of flow [3]. The Layouts designed using SLP technique has the departments with high interrelationship are close to each other which reduced travel distance, travel time. It results into smooth efficient flow & optimal utilization of space on floor & increased the productivity [4].

Present arrangement of machines & work stations in the factory were more of Process layout, where machines were arranged based on its function. Due to which it was leading to more of material. & man movement within the factory. The main objective of the work is to make smooth flow of production for the major product categories produced, by re- organizing the machines & workstations to optimize material/man movement.

II. OPTIMIZING THE LAYOUT USING MUTHER'S SLP METHODOLOGY

2.1 Input of data & process flow analysis

Analyzing the flow of material is essential in any layout planning or optimization the existing layout. P-Q chart (Product versus Quantity produced) is the tool used determines the method of flow analysis for different types of product produced. To plot the P-Q chart 6 months production data is taken, the major business contribution is considered based on the average total quantity of the products produced.

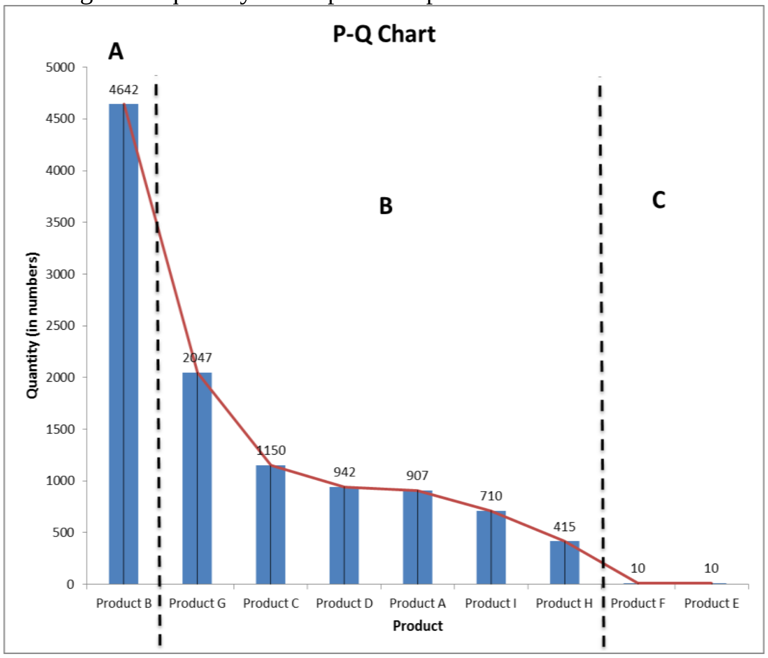


Fig 1 P-Q chart

Fig 1 is the P-Q chart plotted; the trend line signifies 3 categories of products that exist. Category 'A' items includes few high volume standardized product, which requires detailed analysis & also individual flow line needs to be created for these products. Category 'B' items, involves several high- volume products, multi- product process chart helps to analyze the flow these wide range of products. Category 'C' encloses diversified items of relatively low volume which is ignored in the study, since the production volume is less.

2.2 Identifying the relationship between activity areas

After Analyzing the flow of material to summarizing the flow, from - to chart has been potted considering all the category of items. These will helps to summarize the flow & further it helps to analyze the frequency of flow between the stations. Further distances between activity-areas are plotted in distance matrix as shown in Table 1.

Table 1 Distance matrix

From / To	RM Stack	Cutting Machine C1	Cutting Machine C2	Cutting Machine C3	Banding Machine E1, E2	Banding Machine E3, E4	Banding Machine E5, E6	Drilling Machine D1	Drilling Machine D2	Drilling Machine D3	Mnual Banding & Trimming	Product A, B Trimming & Packing	Product D,C Packing	Product G Assembly & Packing	Product I Packing	Product H Assembly & Packing	Product G Storage	FG Storage
RM Stack	0	13.95	44.75	55.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cutting Machine C1	0	0	0	0	38.61	40.26	0	0	0	0	0	0	0	0	0	0	0	0
Cutting Machine C2	0	0	0	0	17.4	19.01	26.23	0	0	56.12	0	0	0	0	0	0	0	0
Cutting Machine C3	0	0	0	0	0	0	16.16	38.92	0	0	0	0	0	64.85	0	0	0	0
Banding Machine E1, E2	0	0	0	0	0	9.94	19.91	30.79	45.68	39.3	0	54.79	0	0	0	0	0	0
Banding Machine E3, E4	0	0	0	0	0	0	0	0	0	40.73	0	0	53.24	57.78	0	0	0	0
Banding Machine E5, E6	0	0	0	0	0	0	0	73.45	0	0	0	0	0	0	3.59	74.05	0	0
Drilling Machine D1	0	0	0	0	0	0	0	0	14.7	8.41	0	0	0	0	35.89	0	0	0
Drilling Machine D2	0	0	0	0	0	0	0	0	0	0	0	0	84.47	0	0	21.68	0	0
Drilling Machine D3	0	0	0	0	0	0	0	0	0	0	0	0	0	18.17	42.65	0	0	0
Mnual Banding & Trimming	0	0	0	0	0	0	0	0	0	0	0	10.94	0	0	0	0	0	0
Product A, B Trimming & Packing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81.67
Product D,C Packing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85.87
Product G Assembly & Packing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.69	0
Product I Packing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76.5
Product H Assembly & Packing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.81
Product G Storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FG Storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The average distance travelled between the activity areas is computed, which is found 38.7 meter, this value is multiplied with the frequency of flow for each combination & intensity value matrix is drawn as shown in Table 2

Table 2 Intensity value matrix

From / To	RM Stack	Cutting Machine C1	Cutting Machine C2	Cutting Machine C3	Banding Machine E1, E2	Banding Machine E3, E4	Banding Machine E5, E6	Drilling Machine D1	Drilling Machine D2	Drilling Machine D3	Mnual Banding & Trimming	Product A, B Trimming & Packing	Product D,C Packing	Product G Assembly & Packing	Product I Packing	Product H Assembly & Packing	Product G Storage	FG Storage
RM Stack	0	13.95	44.75	55.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cutting Machine C1	0	0	0	0	38.61	40.26	0	0	0	0	0	0	0	0	0	0	0	0
Cutting Machine C2	0	0	0	0	17.4	19.01	26.23	0	0	56.12	0	0	0	0	0	0	0	0
Cutting Machine C3	0	0	0	0	0	0	16.16	38.92	0	0	0	0	0	64.85	0	0	0	0
Banding Machine E1, E2	0	0	0	0	0	9.94	19.91	30.79	45.68	39.3	0	54.79	0	0	0	0	0	0
Banding Machine E3, E4	0	0	0	0	0	0	0	0	0	40.73	0	0	53.24	57.78	0	0	0	0
Banding Machine E5, E6	0	0	0	0	0	0	0	73.45	0	0	0	0	0	0	3.59	74.05	0	0
Drilling Machine D1	0	0	0	0	0	0	0	0	14.7	8.41	0	0	0	0	35.89	0	0	0
Drilling Machine D2	0	0	0	0	0	0	0	0	0	0	0	0	84.47	0	0	21.68	0	0
Drilling Machine D3	0	0	0	0	0	0	0	0	0	0	0	0	0	18.17	42.65	0	0	0
Mnual Banding & Trimming	0	0	0	0	0	0	0	0	0	0	0	10.94	0	0	0	0	0	0
Product A, B Trimming & Packing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81.67
Product D,C Packing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	85.87
Product G Assembly & Packing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.69	0
Product I Packing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76.5
Product H Assembly & Packing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.81
Product G Storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FG Storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Vowel allocation has been done based on intensity values calculated. The rating system is designed to identify & understand the relationship, the rating conventions are as follows:

1. A : Abnormally high intensity of flow
2. E : Especially high intensity of flow
3. I: Important intensity of flow
4. O: Ordinary intensity of flow
5. U: Unimportant moves of negligible intensity

Grouping of the quantified intensity values into this vowel letter has been done in following way:

1. Identification of each route by pairing between activity-areas having the material flow has been carried out as the primary step.
2. Intensity value to each route has been assigned by referring the Intensity value matrix. (As shown in Table 4.6)
3. Arrangement in descending order of magnitude of the flow intensity for each route is done.
4. Vowel allocation has been made based on the criteria: 'A' is allotted perhaps only for the 10 % of the highest routes (but the top 40 % of the total intensity value), 'O' is allotted perhaps only for 10 % of largest in
5. Similarly 'E' & 'I' rating have been given for the remaining intensity values using the same rule.
6. Plot the intensity value of each route on bar chart or graph along with vowel allotment.

Fig 2 shows the grouping of intensity values in to vowel letter which signifies the relationship between the activity areas. Activity relationship diagram is drawn as per the vowel allocation as shown in Fig 3 which signifies the relationship between the different activity areas

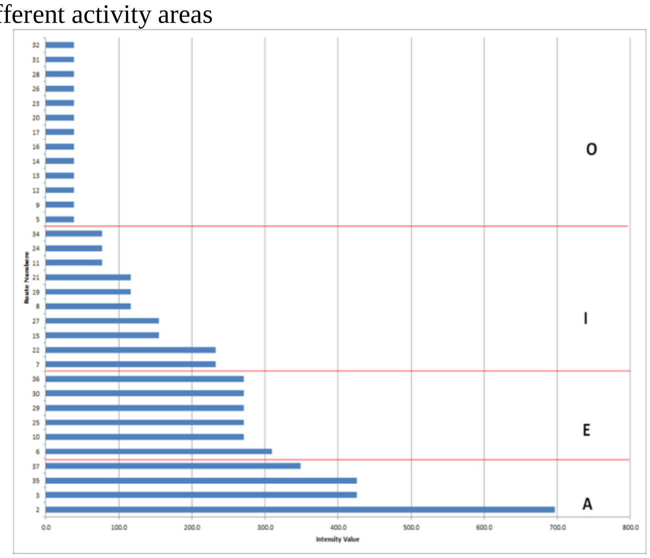


Fig 2 Graphical representation of vowel allocation

http://dx.doi.org/10.21172/ijiet.134.08

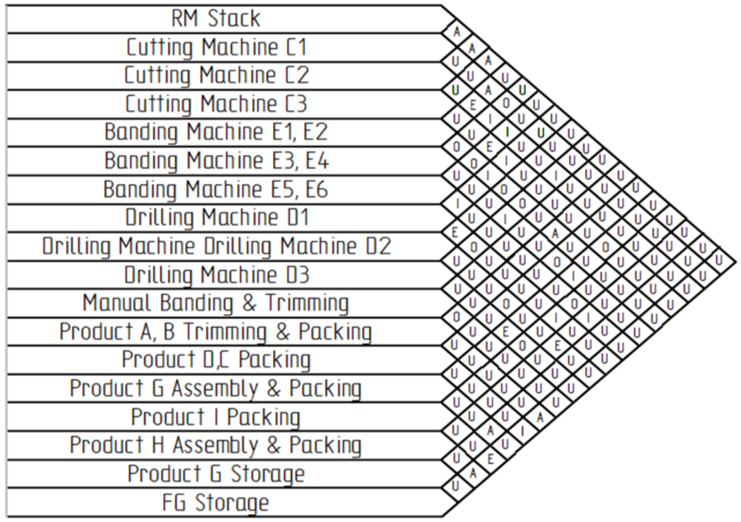


Fig 3 Activity relationship diagram

2.3 Designing the alternatives

Distance matrix & relationship diagram forms the basis for designing the alternatives, for which Total Closeness Ratio has been calculated as per the Systematic Layout Planning algorithm (SLP) [1]. The procedure involved is as follows:

1. The activity areas are considered in respective rows & columns, the relationship between the activity areas are mapped as per the relationship diagram.
2. The respective number of vowel allocation in each row is summed up & tabulated.
3. Vowel score has been defined according to Muther's SLP algorithm.
4. Total closeness ratio is calculated for each row using the formula below:

TCR (Total Closeness Ratio) = (Number of A's) x10000+ (Number of E's) x1000+ (Number of I's) x100+ (Number of O's) x10+ (Number of U's) x1+ (Number of X's) x(-1000)

Table 3 shows the computation of total closeness ratio using Muther's SLP algorithm. Based on this space relationship diagram is plotted within the actual space available in the layout. Starting with placing the activity area with highest total closeness ratio at the first, the corresponding 'A' & 'E' relationship activity area is placed nearby. After all the relationship routes starting with that activity area is completed next activity area having the highest TCR is considered. Same procedure is repeated till all the activity areas are get placed in the area available in actual layout. Fig 4 shows the space relationship diagram.

Table 3 TCR Computation

																				Vowel Score						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	10000	1000	100	10	1	-10000	
	From / To	RM Stack	Cutting Machine C1	Cutting Machine C2	Cutting Machine C3	Banding Machine E1, E2	Banding Machine E3, E4	Banding Machine E5, E6	Drilling Machine D1	Drilling Machine D2	Drilling Machine D3	Mnual Banding & Trimming	Product A, B Trimming & Packing	Product D,C Packing	Product G Assembly & Packing	Product I Packing	Product H Assembly & Packing	Product G Storage	FG Storage	A	E	I	O	U	X	TCR
1	RM Stack		A	A	A	U	U	U	U	U	U	U	U	U	U	U	U	U	U	3	0	0	0	14	0	30014
2	Cutting Machine C1	U		U	U	A	O	U	U	U	U	U	U	U	U	U	U	U	U	1	0	0	1	15	0	10025
3	Cutting Machine C2	U	U		U	E	I	I	U	U	I	U	U	U	U	U	U	U	U	0	1	3	0	13	0	1313
4	Cutting Machine C3	U	U	U		U	U	E	I	U	U	U	U	U	O	U	U	U	U	0	1	1	1	14	0	1124
5	Banding Machine E1, E2	U	U	U	U		O	O	I	O	O	U	A	U	U	U	U	U	U	1	0	1	4	11	0	10151
6	Banding Machine E3, E4	U	U	U	U	U		U	U	U	I	U	U	O	I	U	U	U	U	0	0	2	1	14	0	224
7	Banding Machine E5, E6	U	U	U	U	U	U		I	U	U	U	U	U	U	O	I	U	U	0	0	2	1	14	0	224
8	Drilling Machine D1	U	U	U	U	U	U	U		E	O	U	U	U	U	I	U	U	U	0	1	1	1	14	0	1124
9	Drilling Machine D2	U	U	U	U	U	U	U	U		U	U	U	O	U	U	E	U	U	0	1	0	1	15	0	1025
10	Drilling Machine D3	U	U	U	U	U	U	U	U	U		U	U	U	E	O	U	U	U	0	1	0	1	15	0	1025
11	Mnual Banding & Trimming	U	U	U	U	U	U	U	U	U	U		O	U	U	U	U	U	U	0	0	0	1	16	0	26
12	Product A, B Trimming & Packing	U	U	U	U	U	U	U	U	U	U	U		U	U	U	U	U	A	1	0	0	0	16	0	10016
13	Product D,C Packing	U	U	U	U	U	U	U	U	U	U	U	U		U	U	U	U	I	0	0	1	0	16	0	116
14	Product G Assembly & Packing	U	U	U	U	U	U	U	U	U	U	U	U	U		U	U	A	U	1	0	0	0	16	0	10016
15	Product I Packing	U	U	U	U	U	U	U	U	U	U	U	U	U	U		U	U	E	0	1	0	0	16	0	1016
16	Product H Assembly & Packing	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U		U	A	1	0	0	0	16	0	10016
17	Product G Storage	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U		U	0	0	0	0	17	0	17
18	FG Storage	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U		0	0	0	0	17	0	17

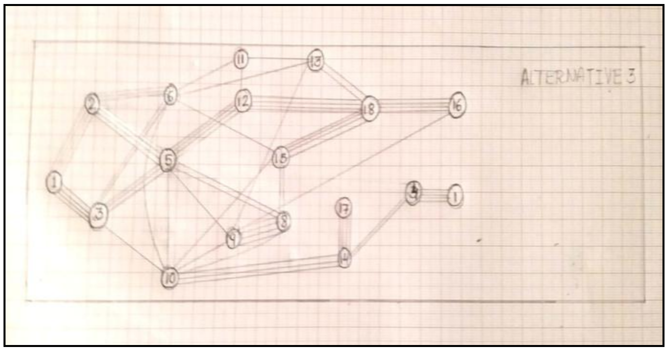


Fig 4 Space relationship diagram Alternative 3

After plotting the Space relationship diagram, actual machines are placed in layout & moved relatively to suit the best fit within the actual area available.

III. RESULTS & DISCUSSION

3.1 Evaluation of Alternatives

Three different alternative combinations of placing the activity areas have been made, using the same procedure as the above. The comparison between these alternatives has been made based on analysis of material flow by checking whether the elimination of back tracking is achieved. Fig 6, 7, 8 shows the mapping of material on the alternative layouts designed for the major business contributing product; this is compared with existing layout as shown in Fig 5. Remaining products also show considerable optimization in flow due to elimination of back tracing.

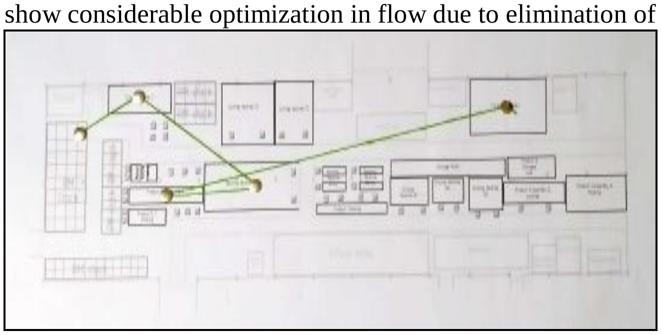


Fig 5 Existing Layout

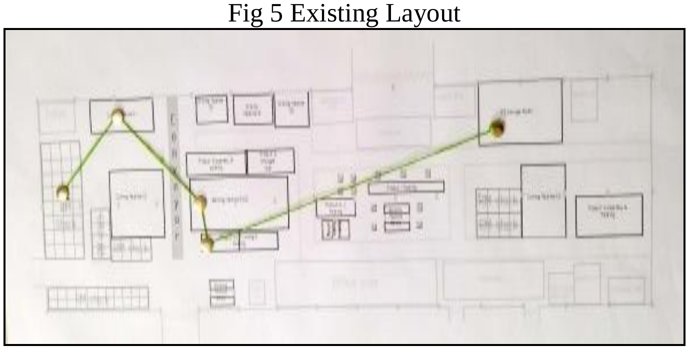


Fig 6 Alternative Layout 1

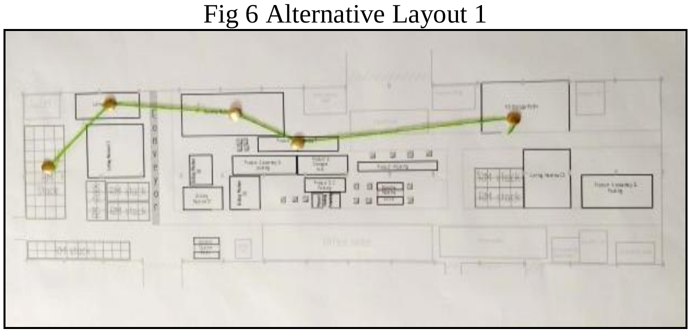


Fig 7 Alternative Layout 2

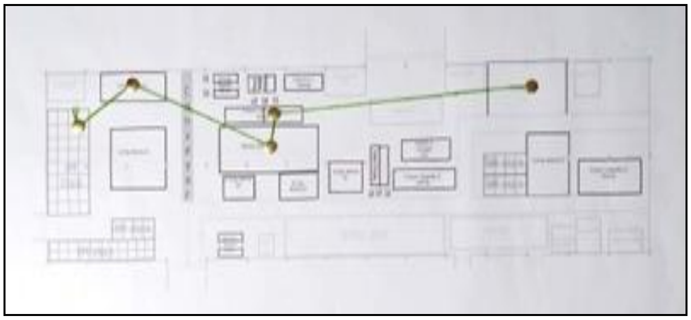
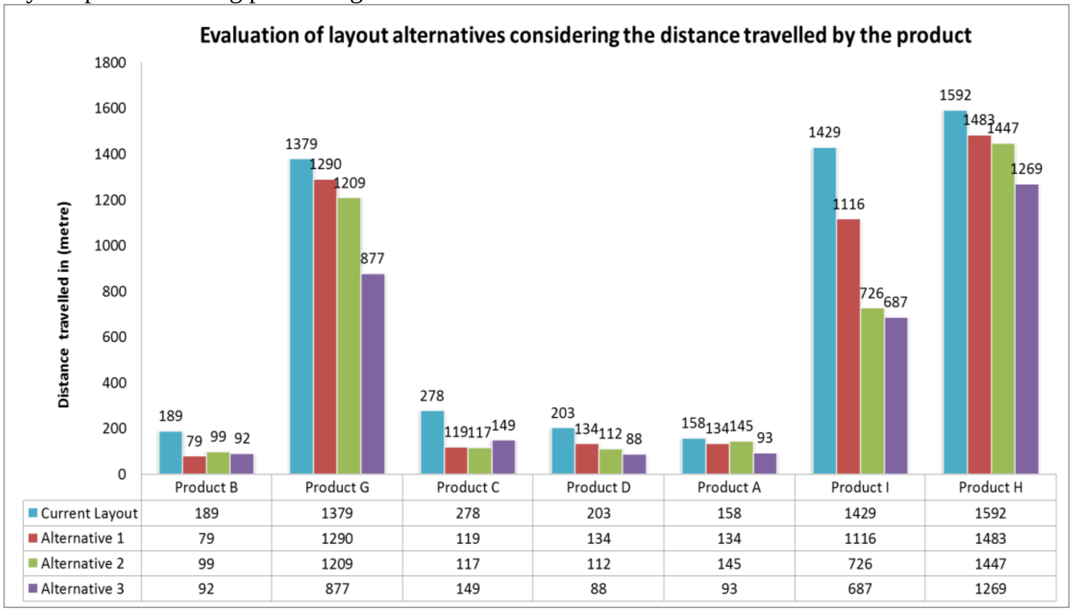


Fig 8 Alternative Layout 3

Proceeding forward evaluation is done based on minimization of distance travelled by measuring distance travelled by each product in all the alternative layouts designed. Fig 9 shows comparison of alternatives based on distance travelled by the product during processing.



	Product B	Product G	Product C	Product D	Product A	Product I	Product H
Current Layout	189	1379	278	203	158	1429	1592
Alternative 1	79	1290	119	134	134	1116	1483
Alternative 2	99	1209	117	112	145	726	1447
Alternative 3	92	877	149	88	93	687	1269

Fig 9 Distance travelled by the alternative layouts

The material flow & the percentage reduction in distance travelled clearly signify Alternative Layout 3 is the best layout.

1. It is having 52 % reduction in distance travelled for major business contributor having separate product line.
2. Beneficial for higher business contributors by having large reduction in percentage distance travelled.
3. All the manual packing stations are towards the storage unit.
4. Space availability & scope for future expansion.

3.2 Implementation

Implementation is carried out by detailing the consideration of gangways, machine actual drawing & position. Fig 14 show the detailed drawing made by placing the conveyors in the Alternative Layout 3. The gang way width of 2.5 meter has been provided wherever manual movement is necessary. Between the wall & machine width of 0.3 meter has been left for cleaning purpose. Dust suction pipes are provided to outlet the wood dust for cutting, drilling & banding machines has been relocated.

Comparison between existing layout & proposed layout in terms of distance travelled & increase in production is represented in Table 6.

Table 4 Comparison between current & proposed layout

Product name	% Contribution	Current Layout Distance travelled (meter)	Proposed Layout Distance travelled (meter)	% Decrease	Current Layout Average production (units)	Proposed Layout Average production (units)	% Increase
Product B	43%	189	92	52%	4642	6267	35%
Product G	19%	1379	877	36%	2047	2701	32%
Product C	11%	278	149	46%	1150	1392	21%
Product D	9%	203	88	57%	942	1187	26%
Product A	8%	158	93	41%	907	1242	37%
Product I	7%	1429	687	52%	710	852	20%
Product H	4%	1592	1269	20%	415	576	39%
		5228	**3255**	**43%**	**10812**	**14217**	**31%**

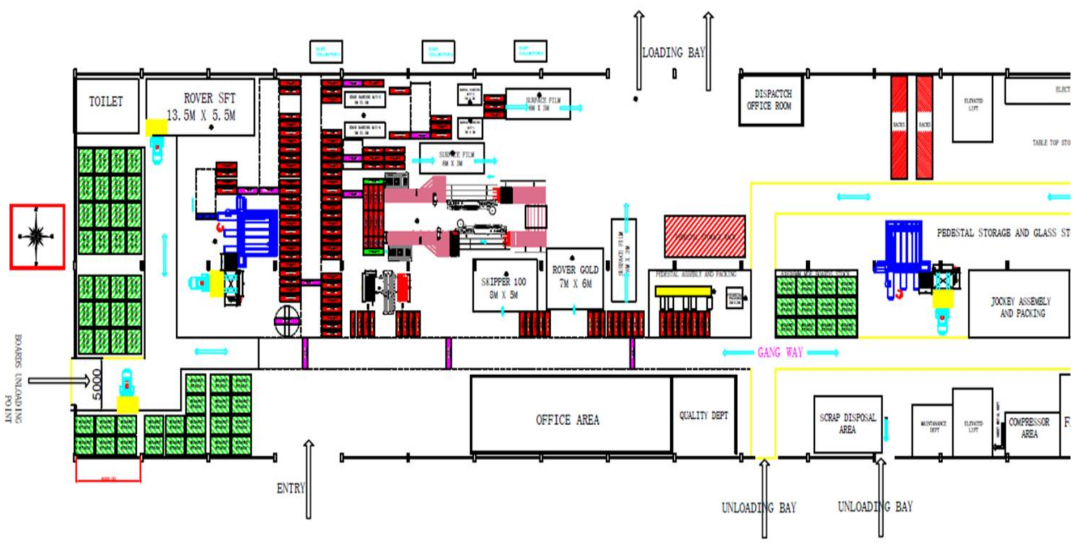


Fig 10 Detailed Layout drawing

IV. CONCLUSION

This paper is the case study of plant layout optimization by reducing the distance travelled in production of customized furniture. The goal of the optimization is to decrease the product cost, increase the production which helps to meet the arising demand in the furniture manufacturing sector. Investing in new equipment incurs more cost, hence utilizing the existing resources itself and most of the companies can't afford the equipment cost. Reducing the transportation time & cost results in considerable amount of decrease in product cost which leads the organization into profit using zero investment.

In this case study usage of Muther's SytematicLayout Planning methodology in reducing the distance travelled by the material inside the factory has been detailed. This step by step procedure facilitated to achieve required goal in a systematic manner. As a result it is found 43% reduction in distance travelled is found on an average in each product, which approximates around 1900 meters overall. One other side this reduction in travel time resulted in shortened lead time, the resulted increase in production is found to be 39% in a month after implementation which has served the purpose.

As a future scope it is beneficial to simulate the production to identify the wastes involved in the system, this further increase the efficiency of the production.

V. ACKNOWLEDGMENT

This paper was prepared by the study conducted by the First author for her Post graduation dissertation work under guidance of other co-authors. The authors wish to express their deep sense of gratitude to Dr. NVR Naidu, Principal, RIT, Bangalore for having extended their entire help throughout work and giving an opportunity to present this paper.

http://dx.doi.org/10.21172/ijiet.134.08

VI. REFERENCE

[1] Richard Muther & Associates. “Systematic Planning of Industrial Facilities (SPIF)”, Management Industrial Research Publication- Volume 1 & 2, Fourth edition, 2015

[2] Syed Asad Ali Naqvi, Muhammad Fahad, Muhammad Atir, Muhammad Zubair and Muhammad Musharaf Shehzad. “Productivity improvement of a manufacturing facility using systematic layout planning”- Cogent Engineering- Series 3: 1207296, June 2016

[3] Swati Jain, Tarun kumarYadav. “Systematic Layout Planning: A Review of Improvement in Approach to Pulse Processing Mills”, International Research Journal of Engineering & Technology, Volume:04, Issue:05, May-2017

[4] Mirza aneez Abdul Hamid, Shaikh Asif Abduljaish, Shaikh Buthanuddin Qutbuddin, Shaikh Faisal Izharul Haque. “Optimization of Plant Layout”, International Journal of Advance Research and Development, Volume 2, Issue 5, 2014

[5] Agrawal Ketan, Paharia Ashish. “Layout optimization of machining process of the side frame of cotton ginning M/C using FLP”, International Journal of Advance Research and Development, Volume 3, Issue 4, 2018

[6] Mieczyslaw S. Siemiatkowski, Maria Vargovska. “Systematic Layout Planning: A Review of Improvement in Approach to Pulse Processing Mills”, Maderas-Cienc Tecnol 21(2), DOI:10.4067/S0718, March 2019