Manufacturing Problem Solving in a Job Shop—Research in Layout Planning

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Abstract

For ensuring efficient operation of a job shop, it is important to minimize waste, which has no value addition to the final product. For a job shop, minimizing movement is considered as the highest priority for waste prevention. For this reason, the layout for a job shop should be designed in such a way to ensure the lowest possible cost for production by reducing non-value added activities, such as movement of work-in-process. An effective and efficient way of layout planning for a job shop is a key for solving movement inefficiencies and facilitating communication and interaction between workers and supervisors. This involves relocation of equipment and machinery to streamline materials flow. The primary objective of relocation is to avoid flow conflicts, reduce process time, and increase efficiency of labor usage. Proximity of the most frequently used machines minimizes the movement cost significantly, which eventually minimizes the cost of production. This paper describes the research done in process flow improvements in a job shop manufacturing steel components. The literature focused mainly on mathematical modeling with assumptions that are not applicable for a typical small-scale job shop operation. However, this was overcome by collecting material movement data over three months and analyzing the information using a *From-To* chart. By analyzing the chart, the actual loads between departments for the operation period were tabulated in available plant space. From this information, the inter-departmental flow was shown by a model. This provides the basic layout pattern, which was improved. A second step was to determine the cost of this layout by multiplying the material handling cost by the number of loads moved between each pair of departments. As a recommendation for solving the problem, two layout models have been developed for ensuring the lowest movement cost.

Introduction

Transportation is considered as one of the seven wastes for lean manufacturing, and effective layout planning is considered as a key to overcome this kind of waste. It is stated, “Double handling and excessive movements are likely to cause damage and deterioration with the distance of communication between processes” [1]. Therefore, layout planning has clear impact with the quality and quantity of the final products by reducing waste and improving efficiency.

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There is significant direct benefit for designing layout to improve the overall quality of production. The main advantages are to minimize workforce, inventory, and space to ensure quality of products exceeds customer needs. There is a positive relationship between the effective layout planning and total cost of waste minimization. Additionally, utilizing existing resources to produce more is the key to success for any manufacturing operation. According to Vaidya, Shende, Ansari, and Sorte, "An efficient layout may also contribute to the reduction in the production cycles, work-in-progress, idle times, number of bottlenecks or material handling times and to the increase in the production output, with obvious implications on productivity" [2].

This research examines the applicability of systematic layout planning (SLP) for job shop layout planning that results in effective lean manufacturing and reduces transportation waste to a minim. By using a *Form-To* chart, a different state of transportation cost is observed and compared to draw a distinct picture. Future layout designs can make overall reductions in transportation waste for a job shop operation. It reduces the per unit travel time, which cumulatively increases overall productivity. To maximize the overall productivity utilizing the same resources, SLP can play a critical role.

Layout Planning for Small Manufacturing

Considering increasing demand for quality production and competition in the global marketplace, it is necessary to change production processes to deliver products on time with higher production efficiencies. For facing the global economic downturn, it is critically important to minimize the overall cost of production by identifying waste and providing systematic and methodical steps to minimize it. Zhenyuan, Xiaohong, Wei, Defeng, and Lijun stated, "The changes of production planning, technological process, production organizational mode and material handling will all affect the facility distribution scheme of a production line" [3].

To ensure a lean workplace, it is necessary to have an efficient layout for the production unit. To have a clear idea regarding lean facilities, it is stated, "Lean facility layout means arranging the physical equipment within a workshop to help the facility work in a productive way [3]. As lean manufacturing is the key for overall efficiency for production, arranging the layout in such a way that ensures less waste in production is essential.

Changes of machines and workstations affect the overall production situation for every manufacturing industry. Layout planning is considered as a part of strategic planning for any organization. Abraham and Sasikumar asserted, "Plant layout planning includes decisions regarding the physical allocation of the economic activity centers in a facility, where an economic activity center is any entity occupying space" [4]. Therefore, layout planning ensures that every aspect of production and planning are synchronized. It is very costly to have an inefficient layout. According to D. R. Sule, "Plant layout is important for two reasons:

a). Material handling costs comprise 30-75% of total manufacturing costs and
b). Modifications or rearrangements are usually costly in terms of both time and money" [5].

An efficient layout can minimize the non-value added cost for production and reduce overall cost.

Other variables for production are affected due to inefficient layout planning, such as workforce organization and arrangement. Matusek indicated that, “Other objectives can be detailed as effective utilization of manpower, space and infrastructure, as well as providing for the overall wellbeing and morale of the worker” [6]. So for the maximum utilization of worker hours, effective layout planning and implementation is essential. Furthermore, there are positive correlations between safety and layout planning. The higher the movements of materials, people, and equipment, the greater the tendency for accidents on the shop floor. For job shop operations, it is imperative that these considerations be addressed.

Traditionally, there are two approaches for the facility layout problem. “The first one is the quantitative approach aiming at minimizing the total material handling cost between departments based on a distance function. The second one is the qualitative approach aiming at maximizing closeness rating scores between departments based on a closeness function” [3]. So the proximity between related machines could ensure minimum travel time and maximize the overall utilization of the resources. For designing the layout, it is necessary to study the movement of the work-in-process from one machine to another.

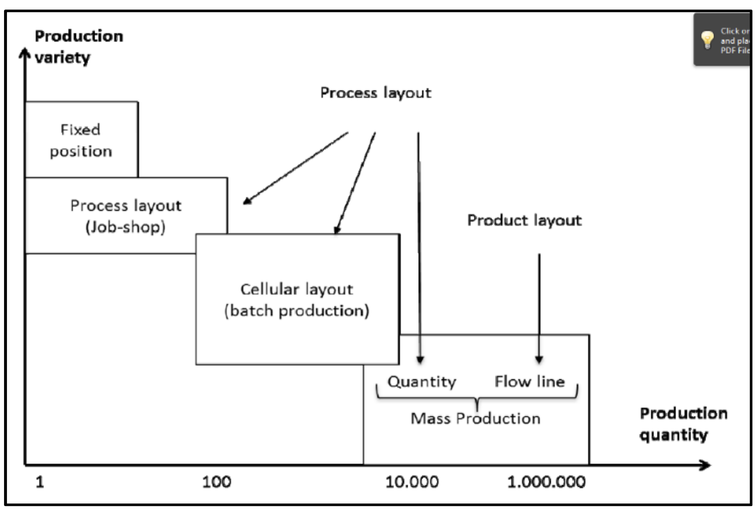

Figure 1. Types of layout for different manufacturing [7]

Layout planning type depends upon the type of production process. For typical job shop operations, process layout is applicable for the layout planning (Figure 1). Industry experts indicate that, “the generation of a plant layout is challenging, especially for the process-oriented layout” [6]. For process layout, groups of similar activities are arranged according to their functions. Each of the departments is dedicated for their different domain. For example, for a machine shop, sawing is located in one area and welding is located in another.

Improper arrangement of the machines has adverse effects to the workforce for optimizing the production in fullest extent. Flexibility of works depends on proper arrangement of machines. Failing to organize the machines efficiently leads to worker confusion, waste of

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time, and lack of standardization. According to W. Wiyaratn, and A. Watanapa, "The way to solve these problems was to improve the steps in working and the area where they worked through observation and fieldwork as well as proposing tools to facilitate the work to set balance and find the standardized time" [8]. Therefore, to best use a workforce in an organization, proper arrangement of machines is necessary.

Procedure

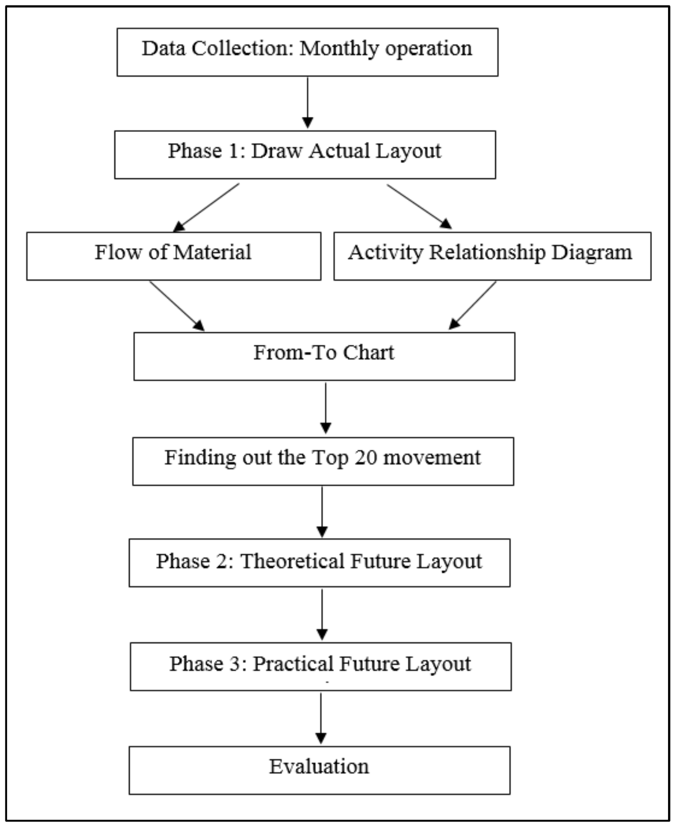

Figure 2. Different phases of conducting research

The main goal of this research is to minimize the travel distance or transportation for the XYZ job shop and measure the effectiveness of a *From-To* chart to improve travel efficiency.

Phase 1

The actual layout has been drawn and data has been collected from randomly selected total 30 days of operations during January-March, 2013. The top 20 movements have been taken under consideration to redesign the layout from the *From-To* chart.

Phase 2

A theoretical layout design has been drawn without considering the other variables such as the cost of moving large machines and workers' flexibility to minimize travel time for the operation. This theoretical layout creates the most efficient spacing and minimal travel distance.

Phase 3

All the related variables associated with moving the machines for layout designing has been considered strictly. It is very costly to change the position of big machines, for example CNC machines. So by keeping that in mind, only less costly moveable machines and workstations have been shifted to favorable positions to get the optimum result for minimizing transportation waste.

Data Collection

The initial data has been collected from the movement of the work-in-process of XYZ job-shop for three months (January to March 2013). For collecting data, particular dates were selected via a simple random sampling: 10 dates for movement for a particular month. Operation day(s) without movements were not considered, and the next randomized dates were taken. Machines are renamed in a short form according to their job function for the rest of the paper (Figure 3).

A	B	C	D	E	F	G	H	I	J
CNC 18 10	CNC 12 15	LE	CNC 14 19	CNC 16 20	CNC 22 VLT 23	GRD 28 29	WLDING	CNC 17	CNC 21
K	L	M	N	O	P	Q	R	S	T
SAW 28	SAW 25	PRS 67	FAB 40	FAB 42	LTH 15	CNC 13	ASM	CNC 11	FAB 38
U	V	W	X	Y	Z	AA	AB	AC	AD
FAB 39	FAB 41	PRS 68	MLT 30	MLT 31	PRS 71	FAB 43	SAW 29	MIL 37	PRS 70

Figure 3. Machines in a short form

Figure 4 shows the number of movements from machine to machine. For example, from F (CNC 22 and VTL 23) to E (CNC 16 and 20), the number of movements is six for January. Likewise, the same chart has been made for February and March to organize the data regarding movement from machine to machine. The main goal was to draw a *From-To* chart from the Figure 4.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
A		1						4			1																			
B								2			4																			
C											6																			
D																														
E							2																							
F					6																									
G						1																								
H		1				2	9																							
I																														
J											1																			
K					1		1																							
L	2	4					1	1				1																		
M						1	3	2			1																			
N							2	2										1												
O						2		3																						
P												1																		
Q																														
R							5	2																						
S									2	1	3																	1		
T							1														3									
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V																		1												
W						1																								
X								1			1																	2		
Y							1	1																						
Z																														
AA							1						1																	
AB													1					1												
AC																														
AD																														

Figure 4. Movement of work in process for January 2013

From-To Chart

	TO																													
FROM	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD
A		24	4				1	16	5		11	2	3																	
B			4		1		3	18	12		22	4	1					1	6	1										
C				1				4		1	4	1	1																	
D					1	1	2	3		2	1			3							2									
E						9	2							1																
F							2	6																						
G								17		1	2	1	3	3				10		5	4		2		2		5	1		1
H											16	4	4	6	4			10		3	4		1		2	1	2	1		1
I																		2	5				1							
J											4							2	2				2							
K													6	4					3	1				1		1				1
L													1										1							1
M																1				1			1							
N																		3		1							1	1		
O																														
P																														
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R																						2	2				3	5		
S																											1			
T																					3		3							
U																										2				
V																									1	1				
W																											2	3	1	
X																														
Y																														
Z																														
AA																														
AB																														
AC																														
AD																														

Figure 5. *From-To* chart for XYZ job shop for January-March 2013)

A *From-To* chart is created to demonstrate the space relationship for manufacturing layouts and to calculate the efficiency of a layout. From the movement of 30 randomly selected days during January- March 2013, a *Form- To* chart was created to observe the WIP movement (Figure 5). If the numbers were close to diagonal of the chart, the movement was less from machine to machine. Whereas, in this given diagram, all the numbers are scattered in this chart. Therefore, calculated future layout needs to be illustrated to reduce the cumulative distance covered due to movement of WIP from machine to machine.

Assessment of the cumulative distance covered can be represented by the formula:

$$Cumulative\ Distance\ Coverage = \sum_{i=1}^{n}\sum_{j=1}^{n} f_i\, d_j$$

f_i represents the frequency of the material handling and d_j is the distance between machine to machine. Each of the frequency and distance associated with cost.

Phase 1

The top 20 movements were selected to perform the theoretical analysis of the improved layout. The machines were moved to the more favorable position for minimizing the distance traveled between the highest numbers of movement. The machines that were close to the diagonal were not moved (Figure 5).

		fi (Movement)	*dj* (Distance)	*fidi* (Distance Coverage)
1	A-B	24	22.7	544.8
3	G-H	23	77.25	1776.75
2	B-K	22	247.2	5438.4
4	B-H	18	139.05	2502.9
5	A-H	16	154.5	2472
6	H-K	16	118.5	1896
7	B-I	12	4635	55620
8	A-K	11	260	2860
9	G-R	10	1915.8	19158
10	H-R	10	1864	18640
11	E-F	9	56.65	509.85
12	**B-S**	**6**	247	1482
13	H-F	6	54	324
14	H-N	6	1823.1	10938.6
15	K-M	6	103	618
16	A-I	5	33.47	167.35
17	G-T	5	1905.5	9527.5
18	G-AA	5	175	875
19	I-S	5	216.3	1081.5
20	A-C	4	61.8	247.2
		Total ∑*fidi*		136679.85

Figure 6. Best 20 movements from three months' data

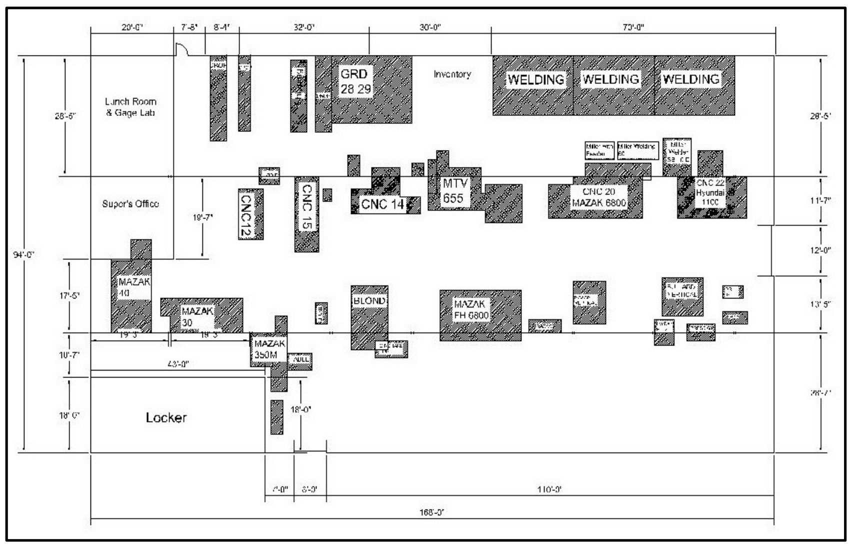

Figure 7. Original layout of XYZ job shop

To change the overall transportation situation, this layout was considered as a base for redesigning the layout (Figure 7). According to the chart, several distances were more than 50 feet, and movements were more than 15 times (Figure 6). These areas were the focus of the redesign to improve the overall transportation waste for XYZ job shop. In the next phases, all the changes were carried out according to the significance of the movements detailed in the *From-To* chart (Figure 5).

Phase 2

At this stage, machines were moved internally and externally in the layout without considering the cost of movement and flexibility of workers. In this phase, the goal was to reduce total distances of the top 20 movements. To accomplish this, the effected machines were placed close to each other. According to the calculation, cumulative value of phase 2 was considered as the lowest cumulative distance coverage as possible for the current conditions.

If the conditions (cost of movement and flexibility) remain the same, there would be a substantial improvement of the overall transportation. By analyzing the top 20 adjusted movements (Figure 8), the cumulative distance coverage was minimized by 95%. The reason for this improvement of the distance coverage was due to placing the machines that had higher movements adjacent to each other. Similarly, distances more than 50 feet and movements exceeding 15 were taken into highest consideration for theoretical layout planning. In this layout, highest utilization of layout space was the most important consideration (Figure 9).

		fi (Movement)	*fidi* (Distance Coverage)	*fidi* (Distance Coverage)
1	A-B	24	16.09375	386.25
3	G-H	23	18.025	414.575
2	B-K	22	25.75	566.5
4	B-H	18	41.2	741.6
5	A-H	16	20.6	329.6
6	H-K	16	33.475	535.6
7	B-I	12	41.2	494.4
8	A-K	11	20.6	226.6
9	G-R	10	30.9	309
10	H-R	10	28.325	283.25
11	E-F	9	41.2	370.8
12	**B-S**	**6**	48.925	293.55
13	H-F	6	32.1875	193.125
14	H-N	6	28.325	169.95
15	K-M	6	12.875	77.25
16	A-I	5	30.9	154.5
17	G-T	5	33.475	167.375
18	G-AA	5	23.175	115.875
19	I-S	5	20.6	103
20	A-C	4	47.6375	190.55
Total ∑*fidi*				6123.35

Figure 8. Top 20 movements theoretical layout

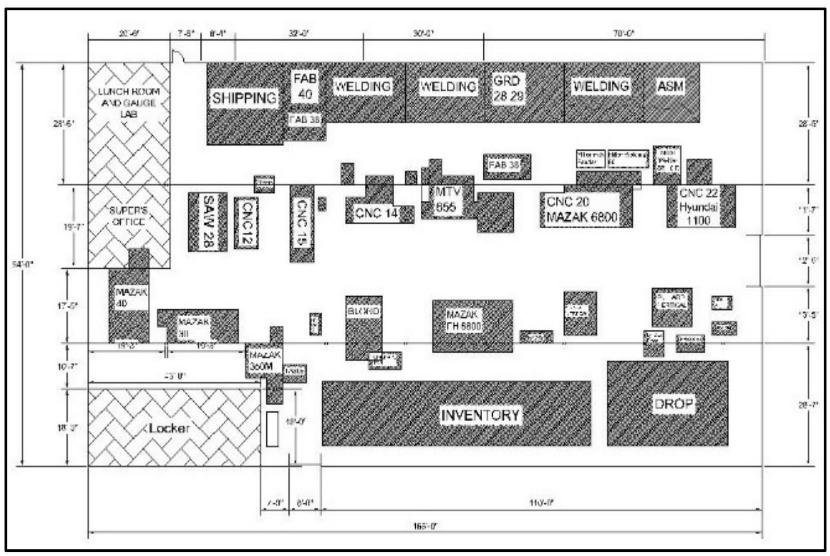

Figure 9. Theoretical layout, XYZ job shop

If cost of movement and flexibility remain the same, there would be a substantial improvement of overall transportation. By analyzing the top 20 adjusted movements (Figure 8), the cumulative distance coverage was minimized by 95%. The reason for this improvement was due to placing the machines that had higher movements adjacent to each other. Similarly, distances more than 50 feet and more than 15 movements were taken into consideration for theoretical layout planning. In this layout, highest utilization of space was the most important consideration (Figure 9).

Phase 3

This phase was designed for implementing the *From-To* chart and practicalities in the job shop, such as cost of movement and flexibility of workers, were taken into consideration. Practical situations, other than the travel time, included other variables as well. For that reason, the transportation cost for WIP was higher for this phase. Two types of costs were of highest importance for this phase: first, the cost of transportation should be compensated with the cost of shifting the machine to a favorable position, and secondly, the machine positioning should be flexible for the workers.

As in phase 2, in phase 3 the top 20 movements of WIP were taken into consideration to redraw the layout (Figure 11). In this phase, the main goal was to minimize total travel time by considering other conditions. In examining the other variables, travel distance was increased approximately 60% in comparison with theoretical layout and 91% in comparison with the actual layout. Shifting heavy machines was not possible in this layout. For changing the layout positioning, workstations were prioritized rather than the heavy machines due to the higher cost involved associated with shifting heavy machines. Fabrication workstations were more easily moveable than lathes, mills, routers and grinders. Secondly, for positioning machines, flexibilities of workforce were also taken under consideration. Above all, if the practical layout is compared with original one, the overall improvement of transportation waste is more than 91%, which is persuasive enough to accept the practical layout.

		fi (Movement)	*fidi* (Distance Coverage)	*fidi* (Distance Coverage)
1	A-B	24	35.32	847.74
3	G-H	23	21.19	487.45
2	B-K	22	16.48	362.64
4	B-H	18	57.69	1038.48
5	A-H	16	70.64	1130.32
6	H-K	16	51.81	828.90
7	B-I	12	28.26	339.09
8	A-K	11	23.55	259.03
9	G-R	10	37.68	376.77
10	H-R	10	17.66	176.61
11	E-F	9	42.39	381.48
12	**B-S**	**6**	**150.71**	**904.25**
13	H-F	6	44.74	268.45
14	H-N	6	14.13	84.77
15	K-M	6	58.87	353.22
16	A-I	5	30.61	153.06
17	G-T	5	57.69	288.47
18	G-AA	5	94.19	470.96
19	**I-S**	**5**	**167.19**	**835.96**
20	A-C	4	49.45	197.81
Total ∑*fidi*				9785.47

Figure 10. Top 20 movements, practical layout

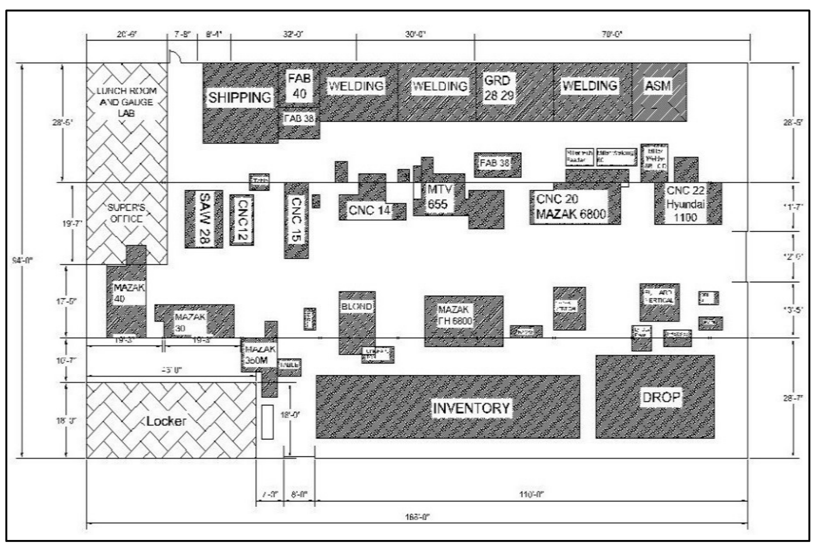

Figure 11. Practical layout, XYZ job shop

Comparison

After analyzing the three phases, the improvement can be mentioned in Table 1.

Table 1. Comparison within different phases

Phase	Distance coverage, feet	Improvements
1	136679	-
2	6123	95%
3	9785	91%

This table shows that the total achievement from theoretical future layout design is 95% and practical future layout design is 91%. This situation demonstrates that redesigning a layout using a *From-To* chart, drastically reduces transportation cost.

Conclusion

For implementing lean production, it is important to set machines in the right place to have less transportation waste. From the above discussion, it is proven that a *From-To* chart can be an effective tool for minimizing transportation waste for ensuring proficient production. It is necessary to access flow planning after regular intervals and thereby change existing layouts to achieve the lowest transportation waste and highest productivity.

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