PLANT LAYOUT COMPARATIVE ANALYSIS: A CASE STUDY OF CARTON PRODUCT

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ABSTRACT

This research aims to investigate and compare the layout of a carton manufacturing plant in the production process to increase productivity, reduce production costs, and minimize the movement time of workers and materials. The study utilizes the Systematic Layout Planning (SLP) method, starting by identifying issues through an experiment (4M) such as Methods, Machinery, Man, and Materials to understand their compatibility and the characteristics of the production process. The subsequent steps involve studying the paper box manufacturing process by analyzing the time and distance used in production. Subsequently, the research applies the SLP method, using Flow Process Charts and Relationship Charts, to design a new plant layout. This layout is then compared with the existing one. The relationship and mutual benefits between each department, which in the traditional layout lacked design based on proper facility layout principles, resulted in adjacent departments that might not have any relationship. However, the newly designed layout ensures that adjacent departments can mutually benefit from one another. In the traditional layout, the distance was 42.99 meters, while the proposed layout reduced the distance to 40.04 meters, representing a 6.86 percent reduction. Regarding time, the traditional layout required 143.846 seconds, whereas the proposed layout reduced the time to 126.189 seconds, a 12.27 percent decrease.

KEYWORDS: Carton Product Plant, Material Flow Process Chart, Relationship Diagram, Systematic Layout Planning

1. Introduction

In the current situation, the corrugated carton product manufacturing industry faces intense competition due to the presence of numerous manufacturers. Additionally, the economic downturn has reduced customer purchasing power. Moreover, the fluctuation in the cost of corrugated paper, the impact of the minimum wage increase, and the rising overhead production costs driven by market mechanisms are all key factors affecting production costs and the price of the carton product.

Designing a factory layout for an industrial plant is considered the first and most crucial step for ensuring the success of industrial operations. A well-designed layout allows for cost-effective production, enabling easy control over manufacturing processes.

In the case of a carton product manufacturing plant, the facility receives bulk orders from customers, necessitating the storage of production materials in the manufacturing area. This space is also occupied by machinery used in the production process, leading to limited space for material movement and employee mobility, resulting in production delays.

Therefore, this project aims to study and propose improvements to the factory layout, specifically in the production process of the carton product company. The goal is to increase production output, reduce manufacturing costs, and minimize the time spent by employees and materials in transit.

2. Conceptual Framework

2.1 Optimal Space Utilization

The primary thrust of plant layout is the judicious utilization of available space. This encompasses the strategic arrangement of workstations, production lines, and storage areas to minimize wastage and ensure the efficient use of the facility's footprint.

2.1.1 Workflow Optimization

Plant layout targets the harmonization of material and information flow within the facility. The layout mitigates bottlenecks by judiciously positioning workstations and production processes, ensuring a smooth and logical workflow.

2.1.2 Flexibility and Adaptability

A practical plant layout is designed with flexibility, capable of accommodating changes in production volumes, product lines, or technological advancements without significant disruptions or the need for extensive redesign.

2.1.3 Minimization of Material Handling

Plant layout endeavors to curtail material handling distances, reducing the time and effort required to move raw materials, work-in-progress, and finished goods. This results in heightened efficiency and cost-effectiveness.

The methodology employed for plant layout is a thorough and systematic approach focused on strategically arranging diverse components within an industrial facility. This section delineates essential methodologies in plant layout design, underscoring their importance in attaining an effective and productive spatial arrangement.

2.2 Systematic Layout Planning (SLP)

In the Systematic Layout Planning (SLP) research project, the investigators delved into relevant studies to serve as guiding principles. A comparative overview of SLP-based plant layouts is presented, incorporating findings from specific research initiatives. Phonsing et al [1] conducted a study in which they used SLP to shorten material handling lengths and improve overall process efficiency in the LED lighting production sector. Their study demonstrated how SLP may be used to intelligently arrange workstations and optimize material flow, resulting in notable decreases in handling time and travel distance. According to another study by Kumar and Malleswari [2] indicates that by applying SLP, facilities can achieve more efficient material flow, reduced transportation distances, and improved overall operational efficiency. Their work emphasizes the systematic approach of SLP, which includes analyzing relationships between departments, determining space requirements, and developing an optimal layout configuration. In essence, this study reinforces the value of SLP as a tool for enhancing facility layout design to achieve operational improvements, Eksiri and Phromhitathorn [3] focused on utilizing SLP for warehouse layout design and production planning, analyzing the impact of optimized warehouse configurations on operational performance. Their findings revealed that SLP facilitates effective space allocation, efficient stock positioning, and systematic flow design, thereby minimizing picking times, reducing errors, and improving overall warehouse management efficiency.

These studies collectively demonstrate the effectiveness of Systematic Layout Planning in optimizing industrial spatial arrangements, leading to improved efficiency and reduced operational costs. The methodologies employed, including data collection, simulation, and comparison with traditional layouts, provide valuable insights for implementing systematic plant layout approaches.

3. Experimental Procedure

A case study of a carton manufacturing company with limited and congested space faces challenges in product movement, inter-machine product transfer, employee movement space, and diverse product placement areas. The existing factory layout lacks a systematic design, prompting researchers to recognize the importance of implementing a Systematic Layout Planning (SLP) to enhance the factory layout. [4, 5]

Studying has revealed the main reasons for the need to modify the plant layout to align with current production:

The flow of raw materials and similar products, along with the distances between machinery departments and walkway areas, is relatively narrow.

Due to the factory's production process being a small-scale business with uncertain production and diverse product patterns based on customer orders (Made by order), the production format is semi-industrial. This necessitates finding the most suitable plant layout that aligns with the factory's production capacity.

The research team has outlined the operational process to ensure accuracy, clarity, and detailed documentation.

3.1 General Information Study Related to Carton Manufacturing Plant

The study involves understanding human operations, machinery, workforce, and raw materials. It aims to identify production patterns, considering the variety and quantity of products produced in each production cycle. The lack of a systematic layout has led the researchers to emphasize the need to study and improve manufacturing processes by focusing on a specific product.

3.2 Study of Processes in Carton Manufacturing

The research delves into the production processes of cartons. It collects data on production challenges, such as the extended time required for each product due to product diversity. The study aims to document and analyze the production steps, facilitating a better understanding of the workflow.

3.3 Systematic Layout Planning (SLP) Theory Study for Factory Layout Improvement

The research team explores the SLP methodology, including steps such as data collection, workflow analysis, qualitative data analysis, relationship chart analysis, space requirement evaluation, space relationship diagram, and consideration of specifications and constraints. Various tools, such as flow process charts, plant layouts, and relationship charts, are employed to assess and select the most suitable factory layout [6].

3.4 Collection of Production Process Data and Determination of Flow Distances

Measurements of distances between departments and machines are taken to identify the flow paths of people and materials. This information aids in creating a new factory layout aligned with current production requirements. Additionally, direct time measurements are taken to refine the factory layout further [7].

3.5 Comparison of Factory Layouts Before and After Adjustment

After designing the new factory layout, a comparison is made between the adjusted and traditional layouts using flow process charts. This analysis helps identify the advantages and disadvantages of each layout, summarizing the time and distance measurements for the flow paths before and after the factory layout adjustment [8].

4. Results and Discussion

The researcher directly measured the time and distances used in moving materials, workpieces, and products to gather data for decision-making in factory layout planning.

1) Production Time of carton Manufacturing: The time study involved capturing time for ten cycles to calculate the average time for each machine's sub-process.

2) Creation of the Current Product Flow Process Chart: After capturing time and studying the material flow, a product flow process chart was generated to illustrate activities, distances, and times for each production step. The chart reflects variations based on the

product type, providing insights into material transportation distances and process times in each production step. The results are presented in Table 1.

Table 1 Carton flow process chart (before adjustment)

	Symbol	**Current**		**Improved**		**Difference**	
		meters	**seconds**	**meters**	**seconds**	**meters**	**seconds**
Product: Carton	○	6	33.37				
	⇨	7	99.55				
	□	-	-				
	D	-	-				
	▽	2	-				
	Distance	42.99					

Symbol ○	⇨	□	D	▽	**Detail**	**Distance (meters)**	**Movement Time (seconds)**
				●	1. Material storage	-	-
	●				2. Move to cutting machine 1	2.44	6.567
●					3. Cut according to pattern	-	0.954
	●				4. Move to cutting machine 2	5.77	13.669
●					5. Cut according to pattern	-	0.690
	●				6. Move to printing machine	6.55	15.486
●					7. Print color according to design	-	1.854
	●				8. Move to grooving machine	12.36	27.457
●					9. Chop groove according to pattern	-	3.673
	●				10. Move to adhesive department	7.85	17.658
●					11. Apply adhesive and assemble	-	14.676
	●				12. Move to packing machine	3.32	7.792
●					13. Pack product	-	11.527
	●				14. Move to storage	4.70	10.923
				●	15. Storage	-	-
					Total	42.99	143.846

4.1 Designing the factory layout using systematic layout planning

The factory layout redesign aims to maximize available space to facilitate potential production expansion and accommodate products with changing patterns. Adequate space for product placement becomes crucial when introducing new products. Evaluating the new factory layout compared to the previous one, utilizing metrics like distances and transportation times, assists in identifying the most optimal factory layout.

1) Relationship Chart: The research team has organized diverse activities within each department, each comprising sub-processes with various machines. The researchers have analyzed the relationships between pairs of activities to gauge the degree of interdependence [3, 9] as shown in Table 2.

Table 2 The relationship level.

Level	Relationship
A	Very high
E	High
I	Moderate
O	Low
U	Very low
X	No relationship

The relationships [10] obtained in each pair of each activity can be shown in Figure 1.

2) The obtained relationship diagram is used to create a Relationship Diagram by taking the relationships from the relationship chart of each activity and writing them down in an activity table. This calculates the total closeness rating (TCR) based on predefined criteria. The activity with the highest score will be placed first on the chart [11-13] as shown in Table 3.

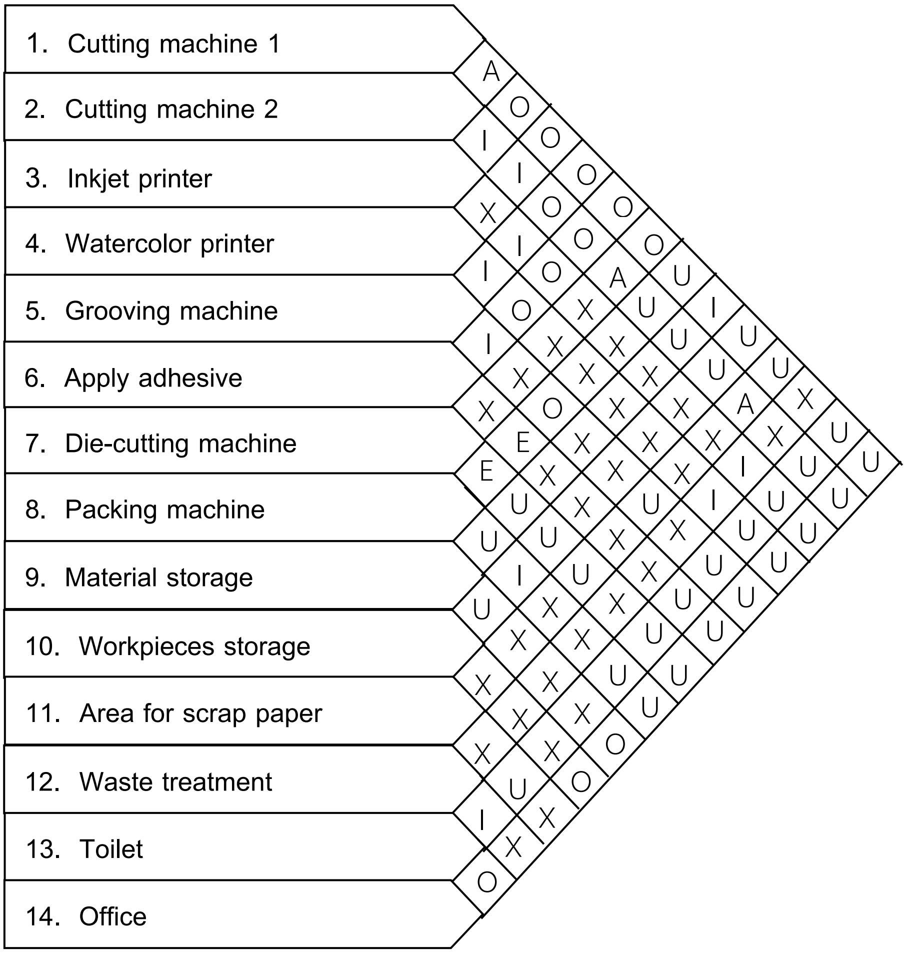

Figure 1 Relationship chart of factory layout

Table 3 The criteria for rating relationship levels.

Level	Criteria for Rating
A	10,000
E	1,000
I	100
O	10
U	0
X	-

The relationships obtained from the relationship diagram are used to calculate the overall closeness rating (Total Closeness Rating: TCR) based on the predefined criteria. The overall closeness rating can be summarized according to the process layout as follows in Table 4.

Table 4 **A summary of the overall proximity scores according to plant layout method**

No.	Machine														Quantity						Score
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	A	E	I	O	U	X	
1	-	A	O	O	O	O	O	U	I	U	U	X	U	U	1		1	5	5	1	10150
2	A	-	I	I	O	O	A	U	U	U	A	X	U	U	3		2	2	5	1	30220
3	O	I	-	X	I	O	X	X	X	X	X	I	U	U			3	2	2	6	320
4	O	I	X	-	I	O	X	X	X	X	X	I	U	U			3	2	2	6	320
5	O	O	I	I	-	I	X	O	X	X	U	X	U	U			3	3	3	4	330
6	O	O	O	O	I	-	X	E	X	X	X	X	U	U		1	1	4	2	5	1140
7	O	A	X	X	X	X	-	E	U	U	U	X	U	U	1	1		1	5	5	11010
8	U	U	X	X	O	E	E	-	U	I	X	X	U	U		2	1	1	5	4	2110
9	I	U	X	X	X	X	U	U	-	U	X	X	X	O			1	1	4	7	110
10	U	U	X	X	X	X	U	I	U	-	X	X	X	O			1		4	7	100
11	U	A	X	X	U	X	U	X	X	X	-	X	U	X	1				4	7	10000
12	X	X	I	I	X	X	X	X	X	X	X	-	I	X			3			10	300
13	U	U	U	U	U	U	U	U	X	X	U	I	-	O			1	1	9	2	110
14	U	U	U	U	U	U	U	U	O	O	X	X	O	-				3	8	2	30

4.2 Comparing material flow distances and times

Comparing the material flow distances and times of different factory layout methods for analysis. The flowchart and measurements of material flow distances in the factory layout are shown in Table 5.

Table 5 Carton flow process chart (after improvement)

Product: Carton	**Symbol**	**Current**		**Improved**		**Difference**	
		meters	**seconds**	**meters**	**seconds**	**meters**	**seconds**
	○	6	33.37	6	30.29	0	3.08
	⇨	7	99.55	7	95.89	0	3.66
	□	-	-				
	D	-	-				
	▽	2	-				
	Distance	42.99		40.04		2.95	

Symbol					**Detail**	**Distance (meters)**	**Movement Time (seconds)**
○	⇨	□	D	▽			
				●	1. Material storage	-	-
	●				2. Move to cutting machine 1	2.44	6.560
●					3. Cut according to pattern	-	0.859
	●				4. Move to cutting machine 2	5.77	13.660
●					5. Cut according to pattern	-	0.590
	●				6. Move to printing machine	6.45	15.480
●					7. Print color according to design	-	1.584
	●				8. Move to grooving machine	9.63	22.990
●					9. Chop groove according to pattern	-	2.973
	●				10. Move to adhesive department	5.56	12.970
●					11. Apply adhesive and assemble	-	13.766
	●				12. Move to packing machine	4.74	10.855
●					13. Pack product	-	10.527
	●				14. Move to storage	5.45	13.375
				●	15. Storage	-	-
					Total	40.04	126.189

5. Conclusion

The researchers have designed and laid out various factory layouts using the principles of the relationship chart and utilized the total closeness rating method. As the factory produces a diverse range of products based on customer orders, the study focused on production processes, material flow, and the transportation of raw and finished products during production. This preliminary data served as a basis for improving the factory layout, emphasizing convenience for the production processes and minimizing the overall distance for material and product transportation.

For the factory layout improvement experiment, the researchers systematically designed a new factory layout by studying the flow of materials and products. The evaluation of the efficiency of the designed layout revealed that the new factory layout could reduce both distance and work time compared to the traditional layout, leading to increased productivity [14, 15].

1) Analysis of the proposed factory layout

Following the evaluation of results and distances, which includes the time required for material transportation in the updated factory layout, the key determining factor is the comparison of distances and time for material transportation, as illustrated below in Tables 6 and 7.

Table 6 Material flow distance comparison

Product	Distance (meters)	
	Before Adjustment	After Improvement
Carton	42.99	40.04
Distance decreased by 6.86 percent.		

Table 7 Material flow time comparison

Product	Time (seconds)	
	Before Adjustment	After Improvement
Carton	143.846	126.189
Time decreased by 12.27 percent.		

2) Analysis of the differences between old and new factory layouts

The interrelations and advantages of each department, which were not structured following standard factory layout principles, led to adjacent departments potentially lacking reciprocal connections. In contrast, the newly designed factory layout ensures that neighboring departments benefit mutually. The traditional factory layout had a distance of 42.99 meters. In comparison, the proposed factory layout reduced the distance to 40.04 meters, representing a reduction of 6.86 percent in the distance and a 12.27 percent reduction in time.

6. Recommendation

From the research conducted on the design and layout of the carton manufacturing plant, it is evident that there should be improvements in the workflow and the internal environment of the plant to ensure efficient operations and produce higher-quality products. The plant should consider making the following improvements based on the recommendations:

The plant should have in-house engineers to oversee and control the employees' work practices, ensuring that operations are carried out correctly and providing knowledgeable guidance to the workers.

The plant should design layouts and positions of machinery, personnel, and raw materials that align with the actual production processes in the facility.

Clear symbols should be implemented to delineate the work areas of the machinery, ensuring a safe working environment.

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