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Process Layout Design with Association Rule Mining: A Case of a Built-in Furniture Factory

W. Laosiritaworn, T. Rungsriwattna and R. Kusolanusorn

***Abstract*— This paper applies association rules to design process layout in a built-in furniture factory. Process layout groups similar activities to form departments according to the process or function they perform. A major concern of this type of layout is where to locate departments in relation to each other to minimize transportation distance. Association rules is a data mining technique that analyzes the relationship among variables. This research applied association rules to identify the relationships between machines. Machines with a close relationship are placed near each other. A layout designed with association rules reduced load distance by 38.53%.**

***Index Terms*— facility layout; process layout; association rule mining; built-in furniture**

I. Introduction

FACILITY layout significantly affects manufacturing productivity. Proper design of facility layout helps production run smoothly, minimizes movement and material handling cost, eliminates bottlenecks and promotes product quality. There are four basic layout types: fixed position, process, product and cellular [1]. A process, or functional, layout locates similar activities or machines together in the same department. This type of layout has several advantages; it is highly flexible, difficult to disrupt and easily supervised [2]. Due to its flexibility, this type of layout is suitable for job shop or batch production, in which customized products are made in small lots.

In a process layout, products flow through departments with different paths according to their varied needs. However, certain departments or machines might have movement to each other more often than the others. Therefore, the major problem in designing a process layout is where to locate the departments or machines so that total movement is minimized.

Various methods have been applied to solve facility layout problems, including genetic algorithms, graph theory, neural networks, expert systems and various optimization methods[3-5]. Association rule mining is one of the techniques used to help design facility layout

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Association rules is a data mining technique that uncovers relationships among variables. A common use of association rules is market basket analysis, in which items that customers buy are analyzed for their associations with or likelihood of buying other products. Association rules has often been applied to solve manufacturing problems, such as detecting defects[6], improving quality[7, 8] and improving storage allocation[9].

Association rules analysis has been applied to several facility layout problems, including as a cell-formation approach for cellular manufacturing system configuration [10] and, more recently, as a modified association rules approach (called weighted association rule-based, data-mining algorithms) that allows for differentially weighting each item in a layout design [11]. Association rules has also been applied to service layout problems, including for a supermarket; by analyzing customer buying patterns, a category correlation matrix was created and used to improve the in-store conversion rate[12].

This research used real data from a case study company – a manufacturer of built-in furniture located in northern Thailand. The factory produces built-in furniture from particle board for hotels, condominiums, houses and offices. Built-in furniture is custom made to fit the actual space, which varies from project to project.

The process of making built-in furniture starts from acquiring the raw material, or particle board. The boards are then cut to the required dimension, after which the edges are sealed by an edge-bending machine. Finally, holes are drilled into each board to allow assembly at the site. The factory layout is shown in Fig. 1.

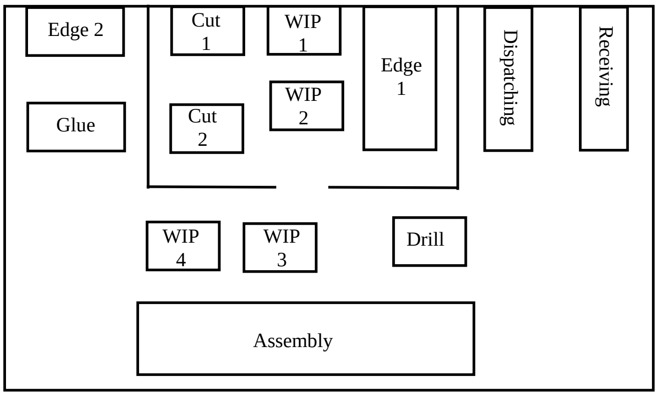

Fig. 1. Layout before improvement

The current layout of the factory has several problems. The flow of materials is complex and long, as the materials have to travel back and forth to different machines that are located far apart. In addition, work in process (WIP) occurs as the materials do not flow smoothly.

To solve these problems, the flow of materials needs to be analyzed carefully in order to locate machines with strong relationships near each other to minimize material handling. Block diagramming and association rules were applied and the resultant load distances compared.

II. BACKGROUND THEORIES

A. Block diagramming

Block diagramming is one of the simplest methods used to design process layout. This method starts from collecting unit loads, which is the measurement of load travelled between each department in the form of a 'from/to' chart. Then, composite movements between departments are calculated and ranked. Trial layouts are placed on a grid with the objective of minimizing nonadjacent loads or distance further than the next block[1].

B. Association rules

Association rules is an important data mining technique. It searches for recurring relationships in data[13]. Let I = {i1, i2, …, in} be a set of items. Association rules is defined as $A \Rightarrow B$, where $A \subset I$, $B \subset I$, and $A \cap B = \varnothing$ [14]

Support and *Confidence* typically measure whether the rules are 'strong'. Support suggests how often the itemset occurs; it is calculated from the proportion of transactions in the database that contain the interested itemset. Confidence indicates how often the rule is true, and can be calculated as follows:

$$confidence(A \Rightarrow B) = \frac{support(A \cup B)}{support(A)} \quad (1)$$

Strong rules are those that satisfy both the minimum support and confidence thresholds.

III. RESEARCH METHODOLOGY

A. Data collection

The current layout of the factory was diagramed to capture what activities occurred where, including data about the activities, machines, and space requirements. A flow process chart was constructed to record process flow, distance and time of each activity. Unit loads, measured by the number of particle boards that traveled between each machine, were collected in the form of a 'from/to' chart.

B. Block-diagramming layout

A 3×3 grid was used to allocate the eight activities in the case study factory. The current layout was roughly placed on the grid and the non-adjacent load was calculated by summing the unit load of the activities located farther than the next block. Then, the activities were relocated on the grid in an effort to minimize the non-adjacent load, after which the space required for each activity was added and adjusted to fit the actual space.

C. Association-rules layout

Generating the association rules requires two steps. First, the frequent itemset, or the set of items, that satisfies minimum support is generated. Several types of algorithms are available to mine this frequent set, for example, Apriori, TreeProjection and FP-Growth algorithms. This study used the FP-Growth algorithm; it generates frequent patterns by constructing a frequent-pattern tree (FP-tree). An FP-Growth algorithm only needs to read the database file twice, while an Apriori algorithm must read every iteration; FP-Growth is much faster than Apriori.

Second, association rules are generated. The frequent itemset that satisfies minimum support in the first step is used to generate rules by firstly for each frequent pattern p, general all non-empty subset. Then, for every non-empty subset s, output the rule $S \Rightarrow (p\text{-}s)$, if the confidence of the rule calculated from support(p)/support(s) is more than or equal to minimum confidence.

This study used RapidMiner Studio 7.3 software to identify the frequent itemset and generate the association rules. Minimum support was set to 10% and minimum confidence was set to 80%. Layout was developed based on these strong rules by locating activities with strong relationships near each other.

D. Layout evaluation and selection

The current layout, block-diagramming layout and association-rules layout were compared based on load distance, which is the summation of product between unit load and distance travelled. The best layout with minimum load distance was selected.

IV. RESULTS AND DISCUSSION

A. Activities and their space requirement

Flow process chart analysis revealed eight essential activities in this factory. The descriptions, abbreviations and space requirements of these activities are summarized in Table 1.

TABLE I
ACTIVITIES AND THEIR SPACE REQUIREMENT

No.	Description	Abbreviation	Space (m^2)
1	Receiving material	Receiving	24
2	Cutting machine 1	Cut 1	19.61
3	Cutting machine 2	Cut 2	19.61
4	Edge bending machine 1	Edge 1	7.7
5	Edge bending machine 2	Edge 2	7.7
6	Drilling machine	Drill	20.21
7	Assembly	Assembly	30
8	Dispatching material	Dispatching	15

B. Block-diagramming layout design

The unit load between activities, measured as the number of particle boards, was summarized in the form of a 'from-to' chart, as shown in Table 2. Data in this table were collected from one built-in project that consisted of 14 room types (53 rooms in total).

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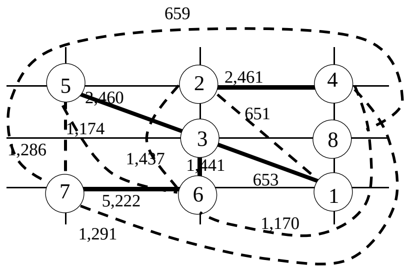
TABLE II
FROM-TO CHART OF UNIT LOADS BETWEEN ACTIVITES

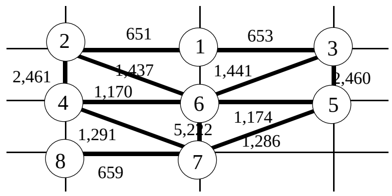
From \ To	2	3	4	5	6	7	8
1	651	653	0	0	0	0	0
2		0	2,461	0	1,437	0	0
3			0	2,460	1,441	0	0
4				0	1,170	1,291	0
5					1,174	1,286	0
6						5,222	0
7							659

After obtaining the unit load, each of the eight activities from Table 1 was assigned a rough position in the 3×3 grid. Fig. 2a shows the assignment of the current layout. The loads between non-adjacent departments are displayed with dashed lines, while the loads of adjacent departments are displayed with thick solid lines. The current layout has six non-adjacent pairs (between activities 1-2, 2-6, 4-6, 4-7, 5-6, 5-7, and 7-8) with a non-adjacent load of 7,668 meters.

An improved layout was developed with the objective of minimizing the non-adjacent load, as shown in Fig. 2b. This new assignment resulted in a non-adjacent load of zero, as all non-adjacent activities were eliminated.



a) Current layout: non-adjacent load = 7,668



b) Improved layout: non-adjacent load = 0

Fig. 2. Block-diagramming grid assignment

The improved grid assignment in Fig. 2b was expanded into the final layout shown in Fig. 3 by adding the space required (from Table 1) for each activity.

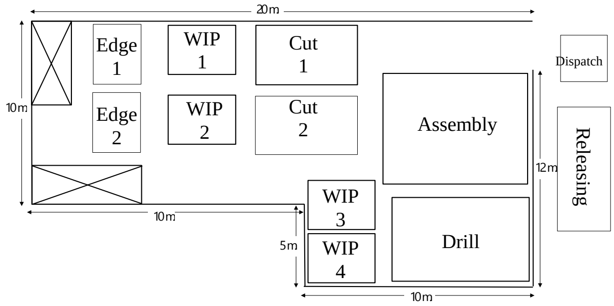


Fig.3. Final block-diagramming layout

C. *Association-rules layout*

To develop the association rules, data were prepared in the format shown in Table 3. Each row represents one particle board and each column represents the activity performed. If a particle board move to that activity, the value of that activity becomes 1, otherwise it is set to 0. For example, particle board number 1 passed the cutting and drilling activities, but did not pass the edge-bending activity. The total number of 7,555 particle boards were used to develop association rules.

TABLE III
EXAMPLES OF DATA USED FOR ASSOCIATION RULES

Particle board ID	Cut	Edge	Drill
1	1	0	1
2	1	1	0
3	1	0	1
….	….	….	….
7,555	1	1	1

RapidMiner Studio 7.3 software was used for association rule mining. RapidMiner implements tasks by constructing a RapidMiner “process”. The RapidMiner’s process is a collection of “Operators”. Each operator performs a specific task and then sends the output to the next operator.

Fig. 4 shows the RapidMiner’s process used to implement association rules in this research. “Retrieve” is the first operator in the process; it loaded the data table into the workflow. The “numerical to binominal” operator transformed 1 or 0 into TRUE or FALSE. The “FP-Growth” operator found the frequent itemset that satisfied the minimum support of 10%. Finally, the “create association rule” operator generated the association rules that passed the minimum confidence of 80%.

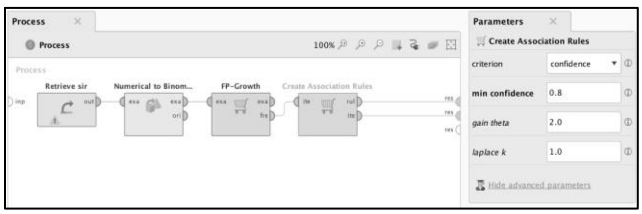


Fig.4. RapidMiner’s process of association rules

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The results of implementing the association rules are shown in Table 4 and Fig. 5. Table 4 summarizes the strong rules discovered from association rule mining. Association rules use "if/then" statements to uncover relationships in data. The premises column in Table 4 is the "if" part, while the conclusion column is the "then" part. Support is the probability that both premises and conclusion are found together in the database. Confidence measures how often the rule has been found to be true. For example, rule number 1 (Drill $\Rightarrow$ cut) showed support of 0.718 and confidence of 1; this means that in 71.8% of the data analyzed, the drill and cut machines were used together to manufacture a particle board, and 100% of the particle boards that were drilled were also cut.

The strong rules are also displayed as a graph in Fig 5. Association rule graph showing each process in rectangle box with rounded corners. Strong rules are represented by arrows connecting between box with a label of rule number followed by the support and confidence values in brackets. As shown in Fig. 5, the cutting process is a center and correlate to other processes.

Rules were used to create a block diagram (Fig. 6) according to their support and confidence values. Blocks were expanded to final layout, taking into account the space requirement of each activity. Fig. 7 shows the final layout according to the association-rules analysis.

TABLE IV
STRONG RULES DISCOVERED

Rule no.	Premises	Conclusion	Support	Confidence
1	Drill	Cut	0.718	1
2	Edge	Cut	0.565	1
3	Drill, edge	Cut	0.303	1

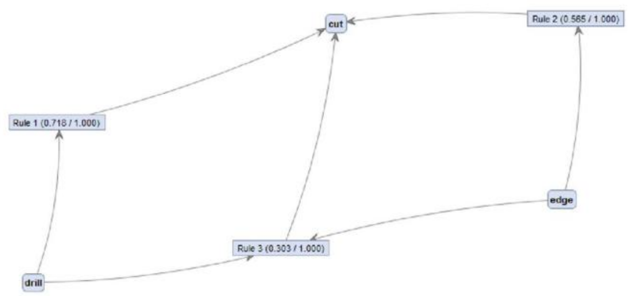

Fig.5. Graph of the association rules

Cut 2	Edge 1	Cut 1
Edge 2	Drill	Dispatching
	Assembly	Receiving

Fig.6. Block diagram for association rules

D. Layout evaluation

The final layouts from block diagramming (Fig. 3) and association rules (Fig. 7) were evaluated based on load distance. The distance between the activities in the block-diagramming and association-rules layouts are displayed in Tables 5 and 6, respectively.

The load distance for each activity was calculated by multiplying the loads from Table 2 with the distances from Tables 5 and 6. For example, the load distance between activities 1 and 2 in the block-diagramming layout = 651×22.4 = 14,582.4 meters. The load distance for the entire layout was calculated by summing the load distances of all activity pairs.

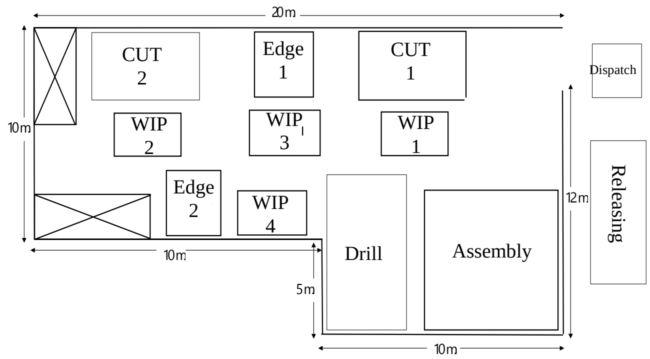

Fig.7. Final association rules layout

TABLE V
DISTANCE IN METERS OF EACH ACTIVITY FOR BLOCK-DIAGRAMMING LAYOUT

From \ To	2	3	4	5	6	7	8
1	22.4	22.9	0	0	0	0	0
2		0	8.4	0	16.9	0	0
3			0	8.4	13.4	0	0
4				0	23.0	15.0	0
5					19.0	14.4	0
6						8.5	0
7							8.5

TABLE VI
DISTANCE IN METERS OF EACH ACTIVITY FOR ASSOCIATION-RULES LAYOUT

From \ To	2	3	4	5	6	7	8
1	16.2	25.8	0	0	0	0	0
2		0	12.6	0	11.5	0	0
3			0	9.4	14.7	0	0
4				0	11	12.2	0
5					7.7	9.5	0
6						5.1	0
7							12.9

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Before improvement, the load distance of the current layout was 332,252.4 meter. The load distances of block diagramming and association rules were 251,555.10 and 204,244.70 meters respectively. As shorter load distances are better, the association-rules method produced the best layout for the case study factory; it reduced the load distance from the original layout by 38.53%.

V. CONCLUSION

The purpose of this research was to improve the layout in a built-in furniture factory by minimizing the load distance travelled between activities. After gathering current loads (in terms of the number of particle boards moved between each activity) two methods, block diagramming and association rules, were applied to try to develop an improved factory layout. Both layouts were compared based on load distances. Association rules produced the best layout, reducing the load distance by 38.53% compared with the block diagramming.

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