A Matrix-Based Approach to the Facility Re-Layout Problem

Kwan Hee Han, Sung Moon Bae and Dong Min Jeong

Abstract—External environment of enterprise are rapidly changing brought about majorly by global competition, cost and profitability pressures, and emerging new technology. In order to sustain competitiveness, manufacturing organizations should provide the sufficient flexibility to produce a variety of products on the same system. To cope with these challenges, a manufacturing company attempts to organize its facilities in the most efficient way to serve the particular mission of that plant. Facility layout problem is classified into 2 areas: Green field design and facility re-layout problem (FRLP). Until today, most research on facility layout focuses on green field design whereas the facility re-layout problem is more common than green field design. Since layout change is unavoidable to adapt in today's dynamic environment, our focus is on the FRLP.

A matrix-based approach is proposed to compare existing layout with new changed one in this paper, which is a subset of SLP (Systematic Layout Planning) procedure. In this approach, layout alternatives are evaluated procedurally by the criteria of traffic volume·distance. Their performance is also verified by 3D discrete event simulation. Proposed method is a practical approach for layout changes without requiring deep mathematical knowledge. This approach deals with dynamic aspect of manufacturing system such as product mix and order quantity change by calculating traffic volume for future production schedule.

Keywords—Facility Layout, Facility Re-Layout Problem (FRLP), Layout Change, Traffic Volume, Systematic Layout Planning (SLP)

I. INTRODUCTION

In today's dynamic business environment, manufacturing organizations are thus faced with the need to optimize the way in which they function in order to achieve the best possible performance within necessary constraints. In particular, the unpredictability of market changes, the growing product complexity and continuous pressure on costs force enterprises to develop the ability to respond and adapt to change quickly and effectively.

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Kwan Hee Han is with the Department of Industrial & Systems Engineering, Engineering Research Institute, Gyeongsang National University, Korea. (e-mail: hankh@gnu.ac.kr)

Sung Moon Bae (Corresponding Author) is with the Department of Industrial & Systems Engineering, Engineering Research Institute, Gyeongsang National University, Korea (email: bsm@gnu.ac.kr)

Dong Min Jeong is a graduate student in Department of Industrial & Systems Engineering of Gyeongsang National University, Korea (dongmin8606@hanmail.net)

To cope with these challenges, most enterprises are pursuing continuous improvements such as layout change, reduction of manufacturing lead time, enhancement of machine availability and labor utilization.

A manufacturing company attempts to organize its facilities in the most efficient way to serve the particular mission of that plant. Facility layout change occurs due to following changes: introduction of new parts, introduction of new process method, changes of order quantity and so on. Nicol and Hollier surveyed 33 companies of average size, and nearly half of these companies reported that they had an average layout stability of two years [12].

Facility layouts organized for variable routing can have a variety of possible configurations, so they influence on performance such as material movement cost and total throughput time. Therefore, where to locate facilities and the efficient design of those facilities are important and fundamental strategic issues facing any manufacturing industry.

Well-designed facility layout proved to be successful by offering many benefits, such as:

- Reduction in total material travel distance
- Increase in storage space for raw materials and finished goods
- Increased safety through better equipment arrangements and reduced employee travel distance
- Reduced product damage
- Reduction in WIP (Work-In-Process)
- Improved supervisory control

However, the task of layout change is not easy because it needs additional investment and production delay during layout change period. Since facility layout change has a significant effect on productivity, decision making for facility layout improvement is vital to manufacturing firm's competitiveness.

Determining the physical organization of a production system is defined to be the facility layout problem (FLP). FLP is classified into 2 areas: Green field design and facility re-layout problem (FRLP). Most of the literature on facility layout focuses on green field design, which is a design of a new facility without influence or constraint of an existing facility. In practice, the FRLP is more common than green field design since both manufacturing and service industries operate in highly volatile environment which motivate them to redesign their layouts [7].

The approaches to the new layout design often fall into two major categories as algorithmic and procedural approaches [19]. Algorithmic approaches usually simplify both design constraints and objectives in order to reach a surrogate objective function. Major solution methodologies are exact procedure, heuristics, meta-heuristics, and intelligent approaches such as neural network and fuzzy logic [5, 14, 15].

Procedural approaches can incorporate both qualitative and quantitative objectives in the design process. For these approaches, the design process is divided into several steps that are then solved sequentially. Most famous methodology is Muther's system layout planning (SLP) which has 11steps for layout creation as depicted in Figure 1 [10]. The SLP begins with PQRST analysis for the overall production activities. The type of data collected includes P (Product), Q (Quantity), R (Routing), S (Supporting Service), and T (Timing).

Besides these two approaches, Han *et al.* proposed parametric layout design of FMS (Flexible Manufacturing System) [6]. FMS layout in this approach is determined rapidly by choosing standardized design parameters in each FMS station. It reflected the today's trend that modern automated manufacturing systems have a modular and hierarchical structure and are constructed by 'assembling' standard resources (or catalog items).

Since layout change is unavoidable to adapt in today's dynamic environment, our focus is on the FRLP. For FRLP, it is necessary to compare existing layout with new changed one in terms of performance criteria. Existing methods for layout alternatives evaluation fall into 3 categories: 1) simulation approach, 2) AHP (Analytic Hierarchy Process)/DEA (Data Envelop Analysis), and 3) Hybrid approach integrating simulation with AHP/DEA.

Simulation is a useful tool for evaluating the multiple performance measures in a complex system. Various performance measures with different dimensions have been selected for the simulation analysis of facility layout change.

The AHP is one of the most widely used multi-criteria decision making methodologies due to its simplicity, ease of use and flexibility. Layout alternative evaluation can be performed by quantifying intangible aspects and relative measurement. DEA is one of efficiency measurement method based on linear programming when there is a difficulty to the comparison of direct causal relationship between multiple inputs and outputs. Categorization of resolution approaches to facility layout problem (FLP) is summarized in Figure 2.

The main objective of this paper is to propose a new approach for the evaluation of layout change alternatives. It is a matrix-based approach, which is a subset of SLP procedure, in which several matrices are constructed and layout alternatives are evaluated procedurally by the criteria of total traffic volume multiplied by distance within a facility layout. Hereafter, detailed 3D discrete event simulation is conducted for the performance evaluation of new layout.

The rest of the paper is organized as follows. Section 2 reviews related works. Section 3 describes a proposed matrix-based approach and its application. Finally, the last section summarizes results and suggests directions for future research.

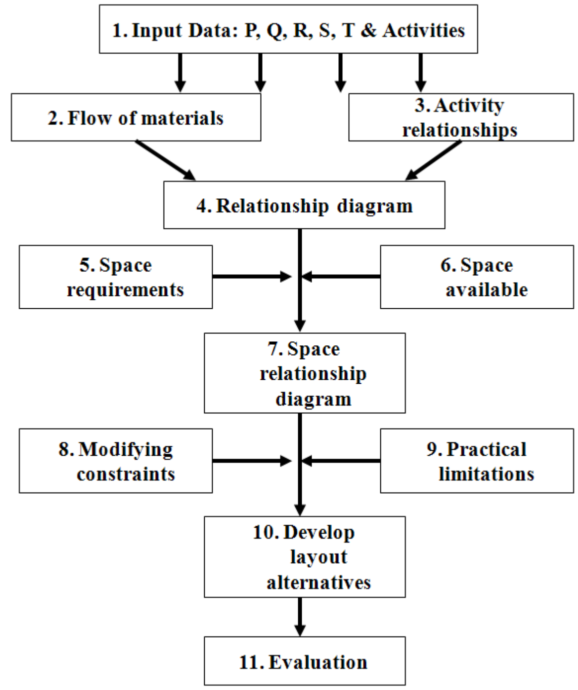


Figure 1. SLP Procedure

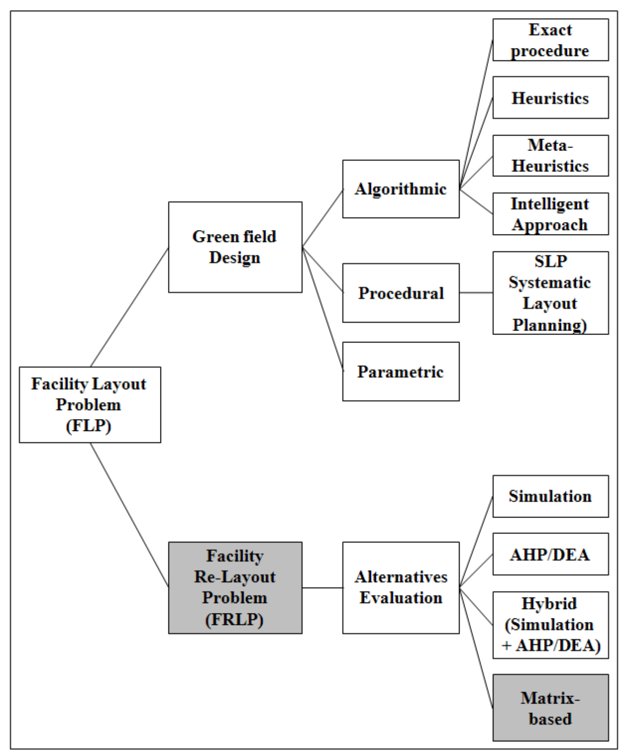


Figure 2. Resolution Approaches to FLP

II. Related Works

State-of-the-art reviews were made on facility layout problems to deal with the current and future trends of research on FLPs based on previous research including formulations, solution methodologies [3, 7, 8, 9 and 14]. However, all of these review papers focused on the solution of green field design of facility layout. Only Kulturel-Konak addressed that facility re-layout design is needed as a future research directions [7].

Since algorithmic approach requires for advanced training in mathematical modeling techniques, SLP was adopted in industries as a viable approach in the past few decades. Yang *et al.* applied the SLP as infrastructure and the AHP for evaluation of the design alternatives to solve a fab layout design problem [19].

Van Donk and Gaalman also applied the SLP to layout planning of food industry, in which hygienic factors were dealt additionally [17]. Cellular manufacturing layout design based on SLP and selection of facilities layout design by AHP was applied to a case study of an Electronic Manufacturing Service (EMS) plant [11].

As mentioned in the first section, evaluation methods for layout alternatives in FRLP fall into 3 categories: 1) simulation approach, 2) AHP (Analytic Hierarchy Process)/DEA (Data Envelop Analysis), and 3) Hybrid approach integrating simulation with AHP/DEA.

Among these, simulation approach is most popular due to its capability of multiple-criteria performance evaluation. Simulation model using ProModel was proposed to assist decision making on expanding capacity and plant layout design [16]. Major criteria for alternatives evaluation are machine utilization and WIP (Work In Process) level.

The performance evaluation of current and re-designed layout was presented by using ARENA [1]. In this approach, redesigned layout was developed by means of rank order clustering and CRAFT.

There was an approach using colored Petri Nets (CPN) and simulation techniques, integrating decisions on warehouse activities in general (receiving, storage, picking and shipping) at strategic, tactical and operational level all together [2].

Within the second category, Gao applied the AHP and DEA to facility layout selection [4]. In this approach, after determining the factors that affect the facility location decisions, pure output DEA is used to construct the comparison matrix, and then AHP is applied to calculate the weights of the alternative locations. In this method, the known data is fully used and the influence of personal factors is avoided.

Yang and Kuo proposed a hierarchical AHP and DEA approach to solve a plant layout design problem [18]. Qualitative performance measures were weighted by AHP. DEA was then used to solve the multiple-objective layout problem.

As a hybrid approach, Xu *et al.* presented case study that integrates a simulation study with AHP, applied to the layout design of a transmission line in a Korean automotive company [20]. They developed various alternatives and performance measures were obtained by the simulation experiments. Then, four criteria and seven alternatives were selected to determine the final layout design using AHP.

Shahin proposed an integrated approach of simulation, fuzzy AHP and Quality Function Deployment (QFD) and Multiple Criteria Decision Making (MCDM) for facility layout design improvement and optimization [13]. In this approach, computer simulation has been used to determine quantitative measures. AHP has also been used to determine the weight of qualitative measures for layout alternatives. Non-equal weights have been derived with respect to the quantitative and qualitative criteria. QFD has been used to determine weights of criteria and the importance of the alternatives in relation to quantitative and qualitative measures. Finally, Topsis (Technique for Order Preference by Similarity to Ideal Solution) tool has been used for ranking the alternatives and identifying the best alternative.

III. Matrix-based Approach and its Implementation

When considering layout changes for an existing facility, it is important to recognize whether or not a re-layout would actually benefit the production line and solve any existing problems.

Important indicators of re-layout considerations include product changes, process changes, location changes, and cost reduction. If many of the above indicators can be identified as hindrances towards the production line, it is clear that a facility re-design should be considered.

Usually, the layout is planned to minimize a particular criterion: for example, minimizing total traveling time, total cost, and total delays. There are also situations in which the layout may be designed to maximize a criterion: for example, maximize quality, flexibility, or space utilization.

Major criterion in this paper is to minimize the total traffic volume multiplied by distance within a facility layout (i.e., Total Traffic Volume·Distance: TTVD).

In order to evaluate the performance of as-is and to-be layout in terms of TTVD, it in needed that 3 matrixes is constructed in the proposed approach: First of all, for determining the amount of material flow between facilities, the production quantity of each type of parts must be converted into a consistent unit for movement. This unit is called transportation units (TUs) in this paper. The TU is the number of containers for a specific part to be moved between machines for production.

In other words, scheduled production quantity of each part in the master production schedule is converted to transportation units (TUs) to calculate the traffic volume. TU of part x is calculated as Equation (1):

$$TUx = \left(\frac{PQx}{UTQx}\right) \tag{1}$$

where TUx = number of transportation units of part x, PQx= scheduled production quantity of part x, UTQx = unit transportation quantity, i.e., container capacity for a specific part to be moved in one time between machines.

The definition of 3 matrixes for total traffic volume·distance (TTVD) is as follows:

1) Traffic volume matrix (TV)
   where TVij= $\sum_{x=1}^{n}(\sum_{i=1}^{m}\sum_{j=1}^{m}(i \cdot j) \cdot TUx)$ (i=1 and j=1 when there is a process route from i^{th} to j^{th} facility to produce part x, otherwise i=0 and j=0; where n=number of parts; m=number of facilities).
2) Distance matrix (D)

where Dij =distance from i^{th} facility to j^{th} facility.

3) Traffic Volume·Distance matrix (TVD)
where TVDij=Dij·TVij

Based on 3 matrices, total traffic volume·distance (TTVD) between facilities of a specific layout is calculated as:

$$\text{TTVD}= \sum_{i=1}^{m} \sum_{j=1}^{m} \text{TVDij} \quad (2)$$

By using TTVD, proposed method deals with dynamic aspect of future production schedule rather than only considering static distance reduction.

Proposed matrix-based approach is rooted in SLP concept. As mentioned in the first section, SLP procedure has 11 steps [8]. Step 1 is "the PQRST analysis" for the overall production activities. Step 2 is "the flow of materials analysis", in which all material flows from the whole production line are aggregated into a from-to-chart that represents the flow intensity. Step 3 of "activity relationship" performs qualitative analysis towards the closeness relationship decision among different departments.

The step of "relationship diagram" (step 4) positions departments spatially. For those, departments that have strong interactions and/or closeness relationships are places in proximity. The steps of "space requirements" and "space available" (step 5 and 6) determine the amount of floor space to be allocated to each department.

Step 6 is "the space relationship diagram" which adds departmental size information into the relationship diagram from step 4. Additional design constraints and limitations are considered before the start of block layout generation in steps 8~9. Step 10 then develops layout alternatives as design candidates. Step 11 chooses the final design from these design candidates.

Among 11 steps of SLP, our approach follows 3 steps which are step 1, step 2 and step 11.

III-1. Matrix-based Approach for Facility Layout Alternatives Evaluation

Developed system in this paper is called decision support system for layout change (DSS4LC), which consists of 3 parts. And it is an MS Excel spread sheet application, in which VBA (Visual Basic for Application) functionalities are added.

First part of DSS4LC is master data preparation. Master data is comprised of process plan, from-to distance matrix of as-is layout, and unit transportation quantity (UTQ) data.

In a job shop manufacturing system, layout type is usually a process layout where similar pieces of equipment that perform similar functions are grouped together. For example, all drill machines are grouped and placed together for drilling operation. In process layouts, a variety of different products are manufactured in small and medium batch sizes. Therefore, there exist complex routings among machines within a process plan. The UTQ is the quantity of parts to be moved in one time between machines dependent on the part geometry and transporter characteristics. It is used for calculating traffic volume of each part.

Second part is input data for to-be layout alternative. It consists of master production schedule (MPS) of next planning horizon, and from-to distance matrix for to-be alternative layout. The planning horizon of MPS can be a month, quarter or half-year. The future MPS reflects the dynamic aspects of production environments rather than static situation. And a process plan in the master data, which indicates the process route from a machine to a machine, can be modified or added to reflect the environmental changes as an input data.

Third part is evaluation report which compares as-is layout with to-be layout in terms of following criteria: TTVD (Total traffic volume·distance), top 5 from-to distance, and top 5 from-to traffic volume·distance between facilities.

The main menu of DSS4LC is shown in Figure 3.

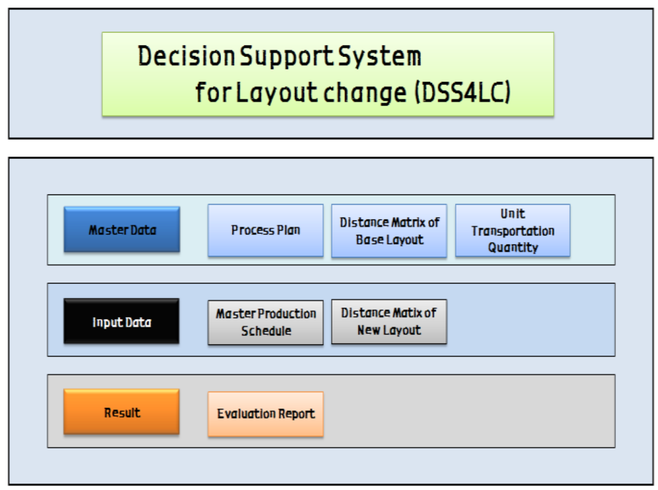


Figure 3. Main menu of DSS4LC

III-2. Case Study

The redesign of existing layout is a challenging task. There are many physical and economical constraints as well as practical limitations that must be considered. However, the result can be beneficiary.

Recently "Company S" in this case study obtained orders from new customer. So, they have a plan to produce construction machinery parts. Company S mainly produces agricultural machinery parts in Korea. Its production characteristics include high product varieties (over 300 different part types) and small production volumes. As a result, it has adopted a process layout and batch production system which makes routings more complex. So, there are wide varieties of process route from one to sixteen steps required to produce one part. Part of process plan is shown in Figure 4. For example, part name of PS-03 has six routing steps for production.

Usually, 200 parts is monthly produced in S company. In the case study, monthly production schedule is prepared for 50 parts which majorly influence on TTVD of to-be layout. And distance matrix is built up for 75 machines. The part of distance matrix for as-is layout is shown in Figure 5.

Process Plan

About Process Plan | Main Menu

No	Part Name	Routing									
1	8011	PS-03	MCH-02	LE-03	GY-01	GY-07	WS-04				
2	2011	MCH-02	LE-03	MK-01	PM-04	GY-01	GY-07	WS-04			
3	7201	GF-03	PS-02	GA-03	GA-02	MR-03	MR-03	PM-04	WS-04		
4	S18140280	GC-10	HB-07	GDW-01	SV-08	MC-07	GF-03	SP-01	GI-01	NC-06	WS-04
5	3421	HB-03	GF-01	PS-01	CG-01	WS-04					
6	0026	BR-01	MK-01	SV-01	PM-03	GF-04	MR-01	WS-04			
7	S18140190	HB-01	HB-01	GDW-01	SV-01	SV-01	GF-03	SP-01	GI-02	MK-02	WS-04
8	S18140300	HB-09	GD-02	BR-01	GF-03	MK-01	WS-04				
9	0111	MC-02	LE-03	GY-01	GY-07	WS-04					
10	M4070	GS-03	HB-02	HB-02	SV-01	SV-02	DR-01	PM-03	GF-01	GDW-01	CG-01
11	1005	BR-01	GF-01	GDW-01	WS-04						
12	K51406340	SV-08	GF-04	PS-02	GY-04	GY-04	WS-04				
13	0904-00	PS-03	NC-01	WS-04							
14	5058-00	PS-03	NC-05	PM-14	WS-04						
15	1352	BR-01	GF-04	PM-04	WS-04						
16	5115	BR-01	GF-01	WS-04							
17	4552	DB-01	GF-03	NC-01	PM-04	MR-06	WS-04				
18	K51404560	WS-04									

Figure 4. Part of process plan

Distance Matrix of Base Layout

About Distance Matrix of Base Layout | Main Menu

		1	2	3	4	5	6	7	8	9	10	11
	Facility Name	BG-02	BGS-02	BL-01	BR-01	CG-01	DB-01	DB-02	DB-04	DR-01	GC-01	GC-02
1	BG-02		6	2	4	8	4	4	6	4	8	4
2	BGS-02	6		6	2	6	4	2	2	4	2	2
3	BL-01	2	6		4	10	2	4	4	2	8	4
4	BR-01	4	2	4		6	4	0	4	4	4	2
5	CG-01	8	6	10	6		10	6	8	10	6	8
6	DB-01	4	4	2	4	10		4	2	0	6	2
7	DB-02	4	2	4	0	6	4		4	4	4	2
8	DB-04	6	2	4	4	8	2	4		2	4	2
9	DR-01	4	4	2	4	10	0	4	2		6	2
10	GC-01	8	2	8	4	6	6	4	4	6		4
11	GC-02	4	2	4	2	8	2	2	2	2	4	
12	GC-05	2	4	2	2	8	4	2	4	4	6	2
13	GC-09	4	2	4	2	8	2	2	2	2	4	0
14	GC-10	20	18	22	16	12	22	16	20	22	16	18
15	GD-02	6	2	4	4	8	2	4	0	2	4	2
16	GD-03	12	12	14	10	6	16	10	14	16	12	12
17	GD-05	6	2	4	4	8	2	4	0	2	4	2
18	GDW-01	8	6	10	6	0	10	6	8	10	6	8

Figure 5. Part of distance matrix

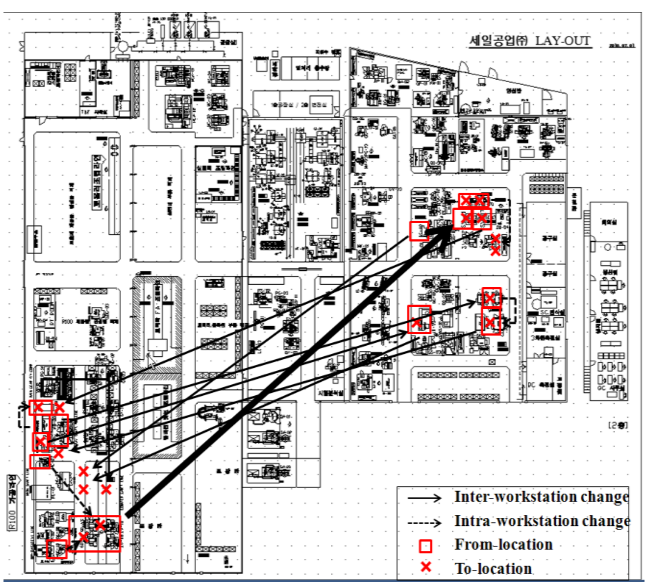


Figure 6. Scope of layout change

Major reason of the layout change in the case study is the introduction of new parts for construction machinery parts. The location changes between machines occur usually between workstations. In the to-be layout of case study, locations of 19 machines are changed as shown in Figure 6: 14 machines are re-located between workstations, and 5 machines are re-located within workstations. In Figure 6, line intensity represents the number of facilities relocated. Straight line represents inter-workstation changes, and dotted line represents intra-workstation changes.

Monthly master production schedule and UTQ (Unit Transportation Unit) of each part are shown in Figure 7 and Figure 8. For example, monthly production quantity of part number 8011 is 781, and its UTQ is 30. Therefore, 27 transportation units (TUs) will be moved for the processing of part number 8011 in this schedule.

Master Production Schedule

No	Part No	Production quantity
1	8011	781
2	2011	614
3	7201	13911
4	S18140280	540
5	3421	2145
6	0026	1158
7	S18140190	388
8	S18140300	415
9	0111	940
10	M4070	418
11	1005	634
12	K51406340	508
13	0904-00	500

Figure 6. Part of MPS

Unit Transportation Quantity

No	Part No	Transportation Unit
1	8011	30
2	2011	30
3	7201	100
4	S18140280	315
5	3421	120
6	0026	315
7	S18140190	120
8	S18140300	315
9	0111	120
10	M4070	120
11	1005	315
12	K51406340	315
13	0904-00	120

Figure 8. Part of UTQ

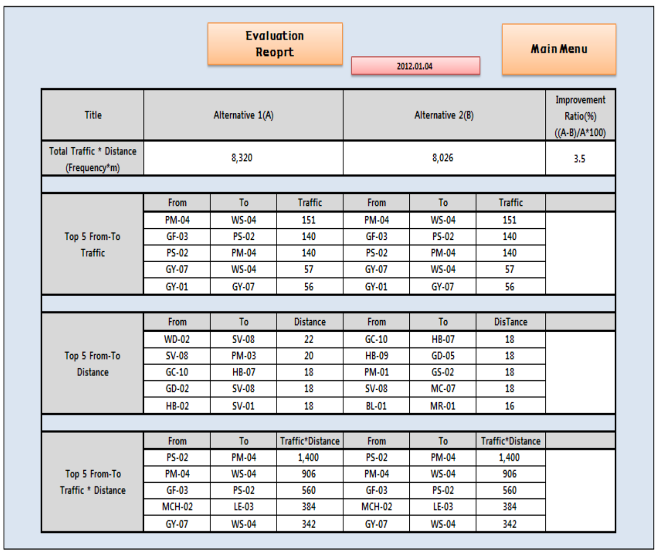
By using the constructed 3 matrices, TTVD is calculated in the evaluation report. The TTVD of to-be layout (8,320) has 3.5 (%) improvements compared with as-is layout (8,026) as depicted in Figure 9.

Besides TTVD, evaluation report provides additional information as follows: 1) Top-5 traffic volume between facilities. It has no difference between as-is and to-be layout because the input data of MPS and UTQ is same. 2) Top-5 distance between facilities of as-is and to-be layout. In the case study, average of top-5 distance between facilities is reduced from 18.8 meters of as-is to 17.2 meters of to-be layout. 3) Finally, top-5 traffic volume·distance between facilities. Using these detailed criteria, engineers can investigate the effect of new changed layout with various perspectives.

Conventionally, layout engineers of "Company S" consider two major factors when they change existing layout as follows:

1) The distance between facilities, and 2) number of part types from machine to machine. But, more important is traffic volume rather than number of part types because new layout must reflect the dynamics of production environment such as production quantity, process plan and UTQ.

However, it is difficult to calculate traffic volume intuitively. Therefore, computer-based tool such as DSS4LC in this paper is needed.



Title	Alternative 1(A)			Alternative 2(B)			Improvement Ratio(%) ((A-B)/A*100)
Total Traffic * Distance (Frequency*m)	8,320			8,026			3.5
Top 5 From-To Traffic	From	To	Traffic	From	To	Traffic	
	PM-04	WS-04	151	PM-04	WS-04	151	
	GF-03	PS-02	140	GF-03	PS-02	140	
	PS-02	PM-04	140	PS-02	PM-04	140	
	GY-07	WS-04	57	GY-07	WS-04	57	
	GY-01	GY-07	56	GY-01	GY-07	56	
Top 5 From-To Distance	From	To	Distance	From	To	DisTance	
	WD-02	SV-08	22	GC-10	HB-07	18	
	SV-08	PM-03	20	HB-09	GD-05	18	
	GC-10	HB-07	18	PM-01	GS-02	18	
	GD-02	SV-08	18	SV-08	MC-07	18	
	HB-02	SV-01	18	BL-01	MR-01	16	
Top 5 From-To Traffic * Distance	From	To	Traffic*Distance	From	To	Traffic*Distance	
	PS-02	PM-04	1,400	PS-02	PM-04	1,400	
	PM-04	WS-04	906	PM-04	WS-04	906	
	GF-03	PS-02	560	GF-03	PS-02	560	
	MCH-02	LE-03	384	MCH-02	LE-03	384	
	GY-07	WS-04	342	GY-07	WS-04	342	

Figure 9. Evaluation report

In this case study, if only distance reduction is a major concern, the amount of improvement will be slight in terms of TTVD as depicted in Table 1. In Table 1, distance reduction from as-is layout to to-be layout in the rank-1 distance (WD-02 → SV-08) is significant (22→ 4 meters). However, the amount of reduction in terms of TTVD is very small (18) because of low traffic volume (1).

However, if we consider traffic volume as a major concern, significant improvements can be made as depicted in Table 2. In Table 2, the TTVD of rank-1 traffic volume of base layout (PM-04→WS-04) is 906 even though distance between two machines is 6 meters short.

Therefore, distance reduction of 1 meter from PM-04 to WS-04 can make significant TTVD improvement (151) because of high traffic volume.

By using DSS4LC, layout engineers can have synthetic views considering distance and traffic volume in layout changes simultaneously.

Table 1. The TTVD comparison of top-5 distance

Top 5 From To Distance						
Rank	Form	To	Traffic (A)	Distance		Difference
				Base Layout (B)	New Layout (C)	A*(B-C)
1	WD-02	SV-08	1	22	4	18
2	SV-08	PM-03	2	20	2	36
3	GC-10	HB-07	2	18	18	0
4	GD-02	SV-08	3	18	2	48
5	HB-02	SV-01	4	18	2	64
Sum			12	96	28	166

Table 2. The TTVD of top-5 traffic volume of base layout

Top 5 Traffic Density (Base Layout)					
Rank	From	To	Traffic (A)	Distance(B)	Traffic * Distance (A*B)
1	PM-04	WS-04	151	6	906
2	GF-03	PS-02	140	4	560
3	PS-02	PM-04	140	1	140
4	GY-07	WS-04	57	6	342
5	GY-01	GY-07	56	1	56
Sum			544	18	2,004

III-3. Simulation for Performance Evaluation

DSS4LC in this paper evaluates layout alternatives only in terms of the total traffic volume·distance (TTVD). However, decision makers may need to consider other criteria such as average throughput time and machine utilization.

Discrete event simulation is a useful tool for evaluating the multiple performance measures in a complex system, and also for accurate description of system behavior and what-if analysis. For accessing the performance of layout alternatives, detailed simulation based on the realistic 3D (dimensional) layout was conducted by using 'Quest' commercial simulation package. 3D layout was built up by importing 2D AutoCAD layout file shown in Figure 10.

Basic input data are as follows: 1) a process plan, 2) a master production schedule, 3) machine list, 4) UTQ, 5) part's processing time at each processing step. The data of 1) ~4) were already prepared for DSS4PC. Processing time data are prepared additionally for simulation experiment as shown in Table 3. In the Table 3, E column (kj code) means part number, and H column (work time) means processing time.

It was executed for 1 week (5 day x 8 hours) and warming time is 8 hours. Figure 11 shows snapshot of animation display during simulation execution. Performance criteria for alternatives evaluation in this simulation are machine utilization, production quantities and system sojourn time which means the time from the start of production to the exit of system of each parts.

Table 4 shows the utilization and production quantities of 10 machines having highest utilization during the simulation run.

Utilization of each machine is calculated at the end of simulation.

Simulation result is summarized in Table 5. This result is consistent with that of DDS4LC since all criteria indicate the improvements of to-be layout: Production quantities are increased up to 7.7 %. System sojourn time is reduced up to 7.2 %. And machine utilization is increased up to 6.1 % as compared to existing layout.

Table 3. Processing time data

	A	B	C	D	E	F	G	H	I	J	K
1	번호	kijong	widobun	name	kjcode	설비	su	workti	soyotim	stadtim	workti
2	1	D-28	0097	GEAR. CAM SHAFT	DB14		75	40	40	0	
3	2	D-28	0097	GEAR. CAM SHAFT	DB14		120	50	50	0	
4	3	D-48	0063	GEAR, DRIVE			74	570	570	0	
5	4	KANZAKI	0111	프론트스핀들	PM15		460	200	200	0	
6	5	KANZAKI	2011	SHAFT,REAR AXLE	LE14		240	380	380	0	
7	6	KANZAKI	2011	SHAFT,REAR AXLE	LE13		136	200	200	0	

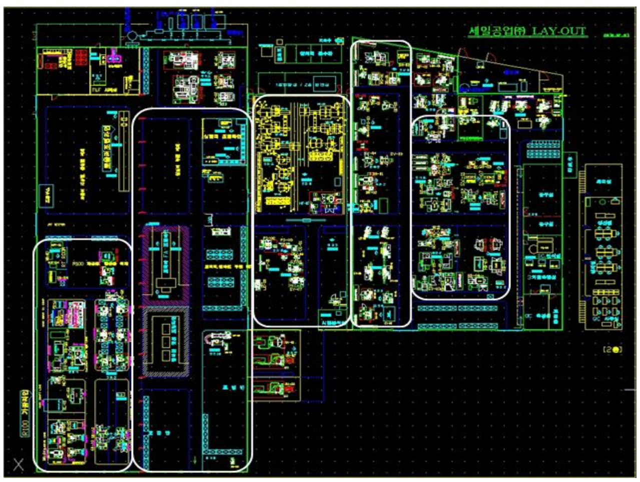


Figure 10. 2D layout

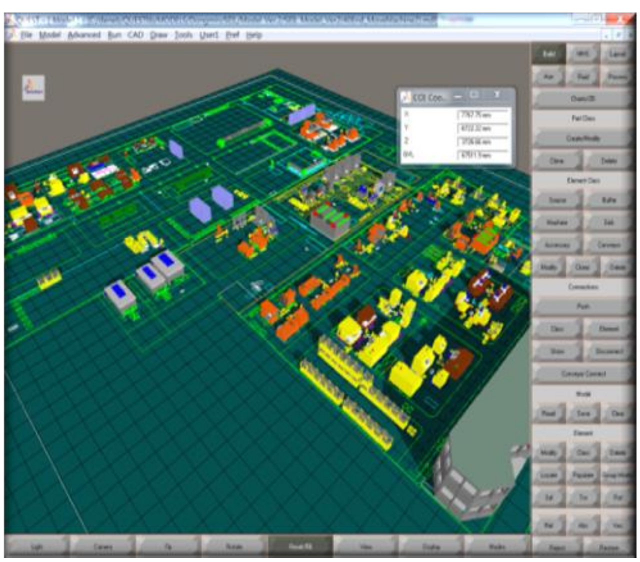


Figure 11. 3D layout of simulation model

Table 4. Machine utilization

Machine		
Name	Utilization (%)	No. of Products
GY_01_1	89.24	103
GY_07_1	81.11	112
SV_01_1	76.23	89
SV_02_1	67.21	95
SV_07_1	58.28	66
SV_11_1	77.49	65
HB_06_1	66.39	84
HB_01_1	57.98	78
HB_03_1	56.42	75
GS_01_1	72.85	65

Table 5. Simulation result

	AS-IS Layout (A)	TO-BE Layout (B)	Improvements ((B-A)/A*100)
Production quantities (ea)	3,952	4,235	7.7
Average sojourn time (hour)	29.37	27	7.2
Average machine utilization (%)	70.32	74.62	6.1

IV. Conclusion

Manufacturing industries are under great pressure caused by the rising costs of energy, materials, labor, capital, and intensifying worldwide competition. In other words, external environment of enterprise are rapidly changing brought about majorly by global competition, cost and profitability pressures, and emerging new technology.

In particular, to achieve a fast response to market changes in today's time-based competition environment, it is quintessential to change the facility layout rapidly and easily. The layout decision will certainly affect the flow of materials, in-plant transportation cost, equipment utilization, and general productivity and effectiveness of the business. Therefore, plant layout should be carefully arranged.

Until today, most research on facility layout focuses on green-field design whereas the facility re-layout problem is more common than green field design. Furthermore, as economies become ever more volatile and product life cycles constantly shorten, incorporating uncertainty in product requirements into facility design models is very important for the applicability of these models in real life scenarios of the global economy.

Proposed method is a practical approach for layout changes without requiring deep mathematical knowledge, which is based on SLP concept. This system deals with dynamic aspect of manufacturing system such as product mix change and order quantity change by calculating traffic volume for future production schedule. By using developed system in this paper, layout engineers can evaluate the effect of changed layout alternative with various perspectives and in less time.

However, current system has a time-consuming task of distance calculation between facilities for distance matrix. Therefore, as a further research, automatic distance calculation from the CAD file with constraint of existing path is required.

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