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CRITICAL EQUIPMENT DECISION SUPPORT SYSTEM FOR PROCESS LAYOUT ENVIRONMENT: A CASE OF WAFER FAB

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The high volatility of customer demands and the fast change in technology have resulted in production requirements with high variety and customization. A process layout of production design is capable of offering a high degree of potential product-mix to meet the customers' requirements. Despite the advantages of the process layout, it is difficult to detect the problems such as smooth processes flows and associated performance in the system while a lot of flows are looping or iterating. This research proposes a decision support system to determine the vital few types of equipment by applying the design structure matrix (DSM) technology if the issues of iterating are largely involved. A industry application in semiconductor wafer fabrication illustrates that our approach is implemented to show the results, which indicate the prioritized processes/equipments based on our finding assisting mangers decision-making for resources allocation and process improvement.

Significance: Our approach also benefits a start-up facilities layout planning and re-layout/reengineering in an existing system. Furthermore, the results that provide the rankings and critical equipments are supported by FAB managers in practices.

Keywords: Decision support system, Process layout, Design structure matrix, Semiconductor manufacture.

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1. INTRODUCTION

Firms require good business strategies in order to respond to customer demands and changes in a timely manner. It is necessary that they have the capacity to provide a wide variety of products or services. The production design, which is in line with the business strategies objective, is closely related to job shop manufacturing. This facilities layout trends towards the process layout design. High variety (defined as wide variety of product types) and high flexibility (defined as high degree of product-mix) characterize the process layout. In a process layout, similar functions or equipments are grouped together, and the jobs being operated during different processes are based on a specific route. The trajectory of a job often iterates between various processes and even where a job goes through the same process (or working center) several times. Focusing on the process is the main characteristic of the process layout in contrast with other layout types; however, such iterative routes behavior increases the complexity of the whole system operations. Therefore, it becomes more important to address the iteration issue in a process layout environment. In addition to concentrating on the critical processes, it is helpful to manage such a complex system. According to the Pareto principle, *vital few and trivial many*, it is valuable to determine the *vital few* from the *trivial many*, especially under a complex system (Juran, 1954). The purpose of this study is to find out the vital few (the critical processes/facilities) from the trivial many (the total processes in the system) in a process layout environment. We applied the design structure matrix technology (DSM) to determine the critical processes. DSM is a well-structured technology to perform both analysis and management of a complex system, and it is a widely-employed technology to facilitate the engineering/product design (Eppinger *et al.*, 1994; Smith and Eppinger, 1997). Moreover, one of the notable features of DSM is suitable to manage the process flow iteration issue; hence, we adapt the advantage of DSM to develop a decision support system that is beneficial for address the iteration issue. Different from greedy heuristics (or paired comparisons method), our approach are not presented in pairs to one or more judges (processes) and evaluating the greater performance in comparison with two judges at a time. It can both identify the critical processes and determine the priority of overall processes from a whole system view. Therefore, the purpose of this research is to apply DSM method as well as develop a more comprehensive and systematic method to solve the iteration problem in process layout environment.

2. PROCESS LAYOUT ENVIRONMENT

A good facilities layout design results in a more efficient, fluent, and flexible system, which is able to cope with high flow volume or capacity more effectively. The process design is always settled in the initial layout planning stage, constraining by the original capacity design. It draws up the flow, function, and characteristics of the process according to the firm's objective, goal, or future plan. However, the process usually becomes more inefficient or deviates from the primary design objective because of changes in the business environment, especially when the system has been in use for a long period of time. The configuration of processes is different from the original design at this time; thus, it is necessary to take strategic actions so as to improve its performance such as business process reengineering (Grover and Malhotra, 1997), business process management (Lee and Dale, 1998), total quality management, business process improvement, core process redesign and process innovation. By using these methods to improve the current status or re-design the existing system, achievement of future objective is to be ensured.

2.1. The nature of process layout environment

In general, the design facilities layout considers primarily the variety, flexibility and volume. Different layout design (e.g. process layout, product layout, group technology layout, fixed-position layout, etc.) have their unique advantage for specific production approach. The process layout, then, characterizes firms providing high degree of customization and producing various products/services combinations at low volume. Regarding this, the typical case of process layout is for the product or services with high variety and high flexibility. Most of the facilities processes in service industries are designed by process layout, for example, banks, hospitals, and government departments. Manufacturing employs process layouts including job shop and intermittent production such as semiconductor foundry, memory manufacturer, and liquid crystal display panel's manufacturer (Stevenson, 2005). A process layout design usually arranges the services/processes with similar characteristics or functions grouped together as a working center. For instance, a FAB manufacturing groups various processes－oxidation, deposition, lithography, etching, diffusion and ion implantation－into the same groups or locations. The final products go through different groups according to a specific route and thus require different operations. In summary, the process layouts possess the following advantages: handling a wide range of products or services; avoiding system failures; allocating high degree of flexibility to equipment or manpower; as well as comparatively low requirement of investment in equipments and maintenance costs. Nevertheless, the design of process layout have some limitations including high working in process inventory costs; low equipment utilization; long transportation distance; costly and inefficient material handling; and complicated routes (Finch, 2006). That is why one of the challenges of the process layout design is how to mange the complicated routes in such a complex environment.

2.2. Improvement methodologies

A manufacturing or service system is designed based on long-term or medium-term business planning; however, the system performance deviates from the original design objective when it has been operated over a long period of time. The main possible reasons are relevant influences from the macro-environment including economics, society, politics and technology; modifications of the value chain changes in the supply or demand end (e.g. the adjustment of the combination of products/services provided due to changes in customer preferences); strategic change of organization such as alteration in organizational vision, mission or objectives (Hofer and Schendel, 1978). Therefore, solving the problems above has aroused significant interests both in academia and practice. Some presented solutions are business process reengineering (BPR), business process management (BPM), total quality management (TQM), process analysis and model development techniques, system dynamics, and simulation. BPR and BPM are systematic, cross-functional, fundamental and radical change technology for improving overall processes of a company's operations (Elzinga *et al.*, 1995; Grover and Malhotra 1997).

TQM are performed by using a bottom-up, continuous and incremental improvement way, which focuses on customer needs. Other techniques such as modeling methods or simulations improve the process flows or enhance the system performances through a sequential procedure – understanding, modeling, analyzing and evaluating system. No matter what improvement methods or philosophy (i.e. incremental improvement vs. radical improvement, partial improvement vs. overall improvement) are employed, the first and foremost is to identify what the critical processes are or which processes need improving. Generally speaking, according to the rule of vital few and trivial many, it is necessary to allocate limited resources on the critical processes as well as enhance the vital from the trivial. Identification of the critical processes is the first step in these process improvement methodologies.

2.3. The iteration issue of the process layout environment

A process layout environment is designed main for the processes of products/services. The processes are integrated by operations/services flow, material handling or information process. This layout configuration consist of various manufacturing/service centers; accordingly, the possible sequences of flow movement could be repeat, in-sequence, by-passing or backtracking (Aneke and Carrie, 1986). Meanwhile, the flow direction could be one-way or bi-directed. The different flow movements (e.g. iterations, repeat and backtracking), directions (e.g. bi-directed), and the possible combinations of the flow movements and directions increase the difficultly for management and analysis. The issues of iterations (or loops) arise in the case backflow or backward of process flows, making it hard to manage and control the system performance. For example, the Project Evaluation and Review Technique (PERT) and the Critical Path Method

(CPM) are powerful technologies used to plan the activities of a project, but they are limited when handling iteration issues of a project.

The iteration issues not only arise in a process layout environment but also are observed in existing systems, which handle the post emergence events. Such as, more and more rigorous environmental policy and packaging regulations force companies to become more accountable for environmentally tasks. Reverse logistics policy in a company is an interesting case, which adds the backflows so as to handle the post emergence events or be required to cope with the specific regulations. Besides, reverse logistics includes product return, source reduction, recycling, materials substitution, reuse of materials, waste disposal and refurbishing, repair and remanufacturing (Stock, 1998). For instance, in manufacturing, a firm may establish its own green policy in accordance with the RoHS Directive; on the other hand, in services, it may deal with customer complaints through the feedback mechanism to improve customer satisfaction. Most of these operations are established in light of the emerging circumstances in practice. In addition, these circumstances add the backward operations in a company, yet which result in the loop or iteration flow issue, and increase the complexity of a whole system. Increasingly, the cases of reverse and backward operations take place in an existing system. These processes disturb the original system design and plan, resulting in the current status differing from the original intention consequently.

In summary, the iteration (loop) makes the system more complicated not only because of a process layout environment but also an existing system added by the post requirements. Both of these two cases increase the complexity to manage the whole system. Hence, the challenge as mentioned above is to find out a solution to address this issue. More detailed exploration will be presented in the next section.

3. DESIGN STRUCTURE MATRIX (DSM)

Design structure matrix (DSM) is developed by Steward (1981) and extended by Eppinger *et al.* (1994) and Smith and Eppinger (1997). DSM is a technique to model and analyze the complex systems, which goes through the study of activities mutual relative relations, and representation in a matrix form. A complex system is consisted of forward and backward flow, repeat, in-sequence, by-passing or backtracking. Those vary different possible results. Furthermore, DSM employs the matrix to represent the interrelations of these activities, and then the corresponding interdependency relations could be measured by: dependency strength, volume of information transferred, variability of information exchanged, probability of repetition, impact strength, etc. (Cronemyr *et al.*, 2001). Yassine and Braha (2003) suggest DSM be a project management tools which can perform both analysis and management of a complex system. In addition, it is also a concurrent engineering technology to address the product design issues such as iteration, parallelism, stability and decomposition; therefore, DSM is useful to solve the iterations (loops) issues of a system. DSM technology, a good feature in handling the iteration issue, is applied to explore the process layout model.

3.1. Process layout model of DSM

The design of facility layout starts from the analysis of overall operation processes which are decomposed into various activities and the relations of the activities afterward. The activities interrelationships can aggregate into a form-to chart representing the flow intensity among different operations centers or service departments. Thus, the corresponding flow intensity could be measured by the intensity of process flow (e.g. the volume of product/service transfer, the volume of information transfer or exchange, the volume of transportations) or closeness of the relationship.

Considering process layout and its characteristics, some notations are modified from the study of Smith and Eppinger (1997). The flow vectors f_t describes the amount of flow to be processed after iteration stage t, and the matrix M can be denoted by the flow intensity or the facilities closeness relationship. The flow is changed by its intensity. Every iteration stage produces a change in the flow vectors according to $f_{t+1} = Mf_t$. The initial flow vectors f_0 is assumed that it is a vector of ones, meaning all process have to perform at the initial stage. After stage t, the amount of flow could be represented as $f_t = M^t f_0$. The sum of flow vectors from stage 0 to T is:

$$F_T = \sum_{t=0}^{T} f_t = \sum_{t=0}^{T} M^t f_0 = (\sum_{t=0}^{T} M^t) f_0 \quad \cdots \quad (1)$$

Note that M can be decomposed into: $M = S \Lambda S^{-1}$, where Λ is a diagonal matrix of the eigenvalues of M, S is the corresponding eigenvector matrix. The powers of M can be found by $M^t = S\Lambda^t S^{-1}$. Therefore, F_T can be expressed as

$$F_T = S(\sum_{t=0}^{T} \Lambda^t) S^{-1} f_0 \quad \cdots \quad (2)$$

If we take the limit as T approaches infinity, $\lim_{T \to \infty} \sum_{t=0}^{T} \Lambda^t = (I - \Lambda)^{-1}$, we can obtain

$$\lim_{T \to \infty} F_T \equiv F = S(I - \Lambda)^{-1} S^{-1} f_0 \quad \cdots \quad (3)$$

As the equation (3) indicates, the total flow vectors F is determined by the eignevalues Λ and eigenvector S of the flow intensity M. According to the proof by Smith and Eppinger (1997), the slowest iterations converge corresponding to the largest eigenvalue. The problem which must be considered next is how to determine critical processes. The more important the processes are, the heavier loading the processes have. Hence, we first find out the largest eigenvlaue then analyzing its eigenvector. The value of the eigenvector reveals the importance relative to its processes. The processes have larger value that represents the processes are more critical in our process layout model. According to the findings of Smith and Eppinger (1997), the iteration issues converged could be ranked by the terms $F = S(I - \Lambda)^{-1} S^{-1} f_0$, $(I - \Lambda)^{-1}$ or $(I - \Lambda)^{-1} S^{-1} f_0$.

3.2. Illustrative example

In this section, we introduce the process layout model of DSM by a systematic layout planning (SLP) illustrative example. SLP is a step by step layout planning procedure from relationship analysis, space requirements, constraint requirements to developing layout alternatives (Muther, 1974). In the illustrative example, there are five departments (D_1, D_2, D_3, D_4 and D_5) in the layout. After the prior SLP analysis (e.g. PQRST analysis, flow of materials, activity relationships, space requirement/available, etc.), the preliminary results could be obtained as below: department relationship diagram (Figure 1) and from-to chart (Table 1).

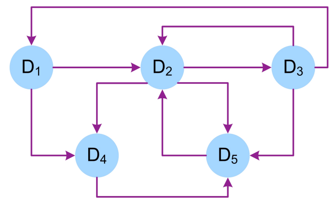


Figure 1. Department relationship diagram: illustrative example

Table 1. From-to chart: illustrative example

From \ To	D1	D2	D3	D4	D5
D1	U	O	U	I	U
D2	U	U	A	E	O
D3	E	I	U	U	A
D4	U	U	U	U	A
D5	U	I	U	U	U

Figure 1 and Table 1 show that the closeness relationship among the departments. The closeness relationships represent the relative degree of importance of each operations or departments. In general, a scale of vowel-letter closeness: A (Absolutely necessary), E (Especially important), I (Important), O (Ordinary closeness), and U (Unimportant) is employed to indicate the relative importance. In the illustrative example, department D_2 to department D_3 has an absolutely necessary closeness relationship 'A', and department D_3 to department D_2 then has an important closeness relationship 'I'. Although there are only five departments, we can observe a number of iterations. For example, $D_2 \rightarrow D_3 \rightarrow D_2$; $D_2 \rightarrow D_4 \rightarrow D_5 \rightarrow D_2$; $D_1 \rightarrow D_4 \rightarrow D_5 \rightarrow D_2 \rightarrow D_3 \rightarrow D_1$, etc. In order to transfer the closeness relationship (Table 1) into the flow intensity matrix M, we assign point values to each closeness relationship code, A, E, I, O, and U. A=16/16, E=8/16, I=2/16, O=1/16, and U=0/16 (Heragu, 1997). Therefore, the flow intensity matrix M can be presented as

$$M = \begin{array}{c} D_1 \\ D_2 \\ D_3 \\ D_4 \\ D_5 \end{array} \begin{bmatrix} 0 & 0.0625 & 0 & 0.125 & 0 \\ 0 & 0 & 1 & 0.5 & 0.0625 \\ 0.5 & 0.125 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0.125 & 0 & 0 & 0 \end{bmatrix}.$$

Furthermore, the results of eigenvalue Λ and eigenvector S matrices of the flow intensity matrix M are:

$$\Lambda = \begin{bmatrix} 0.6887 & & & & \\ & -0.3574+0.4444i & & & \\ & & -0.3574-0.4444i & & \\ & & & 0.0130+0.1863i & \\ & & & & 0.0130-0.1863i \end{bmatrix},$$

$$S = \begin{bmatrix} 0.1163 & 0.0058 - 0.1047i & 0.0058 + 0.1047i & -0.0406 + 0.4392i & -0.0406 - 0.4392i \\ 0.8394 & 0.8522 & 0.8522 & 0.2112 - 0.0296i & 0.2112 + 0.0296i \\ 0.4580 & -0.2621 + 0.2279i & -0.2621 - 0.2279i & 0.3911 + 0.0479i & 0.3911 - 0.0479i \\ 0.2212 & -0.0703 + 0.3199i & -0.0703 - 0.3199i & -0.7644 & -0.7644 \\ 0.1523 & -0.1170 - 0.1456i & -0.1170 + 0.1456i & -0.0099 - 0.1424i & -0.0099 + 0.1424i \end{bmatrix}.$$

Each eigenvector S (the value of eigenvector is only positive and real number) describes the degree of importance of the departments (D_1, D_2, D_3, D_4 and D_5) in this system. Examination of the term $(I - \Lambda)^{-1}$ reveals the largest eigenvalue (3.2126) that indicates the most slowly converging departments corresponding to the first eigenvector.

$$(I - \Lambda)^{-1} = \begin{bmatrix} 3.2126 & & & & \\ & 0.6654 + 0.2179i & & & \\ & & 0.6654 - 0.2179i & & \\ & & & 0.9783 + 0.1847i & \\ & & & & 0.9783 - 0.1847i \end{bmatrix}$$

The largest eigenvalue (3.2126) is relative to the first column of eigenvector $\begin{bmatrix} 0.1163 & 0.8394 & 0.4580 & 0.2212 & 0.1523 \end{bmatrix}^T$. The first column of eigenvector, as we have seen, the 2nd (0.8394) and 3rd (0.4580) departments have the largest value; so, the department D_2 and D_3 are the most critical departments in this example. Moreover, if we rank the importance of the departments in order the value of the first eigenvector, the result is as followed: D_2 (0.8394) > D_3 (0.4580) > D_4 (0.2212) > D_5 (0.1523) > D_1 (0.1163), listing in order the degree of importance of departments. This result offers valuable references for process improvement as well as provides the layout alternatives in SLP.

4. INDUSTRY APPLICATION: DSM DECISION SUPPORT SYSTEM

Gupta *et al.* (2006) argued some characteristics of a FAB as: the large number of processing steps, re-circulating flows, and the widely varied process flow. Uzsoy *et al.* (1994) also viewed the complex production processes of FAB as re-entrant flowshops and jobshops; therefore, we tried to apply the process layout model of DSM by using that to solve the re-circulating flows issue. The research case is a leading semiconductor foundry that manufactures advanced process ICs for applications spanning every major sector of the semiconductor industry. The company operates a number of advanced 300mm and 8-inch wafer FABs; its operations are centralized in Taiwan, primarily in the Hsinchu Science Park and the Tainan Science Park. Concerning this, we implement our process layout model for one of an 8-inch wafer FAB in the Hsinchu Science Park. The FAB contains about 70 types of machines and 150 equipments. A product usually needs 10 to 15 process routes with 5 to 80 steps each, and thus with 400 to 600 processing steps in total. Each product has a specific processing flow in FAB that consists of specific process routes; in deed, each route may contain several different steps and also could be deemed as a machine group or working center. For example (see Figure 2), product X contains 27 process routes (metallization, photolithography, etching, dielectric deposition, chemical mechanical polishing, etc.). Each route has about 3 to 42 steps, and there are 765 processing steps in total. Product X enters the metallization route which consists of 22 to 29 steps or machines (e.g. PVDAL, SCCD, POLSE …) 5 times during manufacturing. It is obvious to notice the phenomenon of iteration or loop processes (re-entrant or re-circulating) in the FAB case.

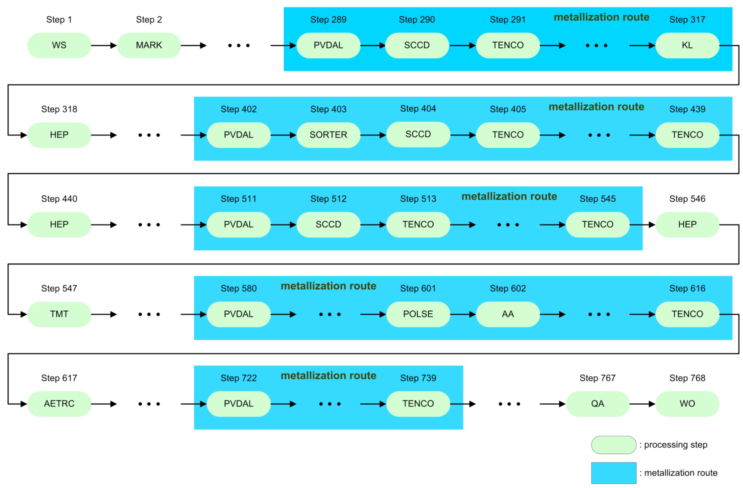


Figure 2. Operation processes for wafer fabrication: Product X

Designing the facilities layout and planning the capacity in start-up stage have a major impact on the plant's future performance. Therefore, in the initial layout planning stage, all of the facilities and processes are designed based on the plant's long-term objectives or plans (e.g. demanding applications, technology, or potential product-mix). Besides, the FAB tends to operate in a make-to-order production approach with its products made to the customer's requirements (Wu and Hung, 2008). However, semiconductor manufacturing machines are expensive and constrained by both original design and floor structure in practice. It is costly to move or re-layout the facilities in a FAB. Since the current status usually differs from the original planning, several layout software (e.g. CRAFT) and algorithms (LP, MIP, simulated annealing algorithm, etc.) have been used to improve the facilities layout performance. Concerning improvement methods, some researches have focused on greedy heuristics, brute force algorithms, trail and error, simulation, random method, or pair's comparisons method (Golany *et al.*, 2006). The process layout model of DSM, contrasting with the greedy methods – the comparison for one by one – is considered from the whole system view. This kind of model can determine the critical steps and the importance of the critical machines in order. We tried to find out the critical steps so as to provide the top managers with decision-making references that could also facilitate the managers to decide the scope of improvement (e.g. the most important top 10 steps or top 20 steps scope that require improvement) or the priority of improvement (e.g. to rank all steps in order by the importance of improvement reference).

The facilities layout of the FAB illustrated in Figure 3 is a block representation of the layout for a machine or processing step. Different lines depict the processes flows of various products between these machines or steps. The layout flow is very intricate and complicated (Figure 3 shows only three products). It is hard to identify which steps are critical if we only observe from Figure 3 straightforwardly. According to the requirements, we develop a decision support system (eDS-EP) for determining the critical equipments/processes in a FAB environment (Figure 4). The data is collected in one year data by equipment level which covers 20 products and 14,600 lots. The numbers of lots between equipments are presented in Figure 5. The results indicate the equipments priorities as shown in Figure 6.

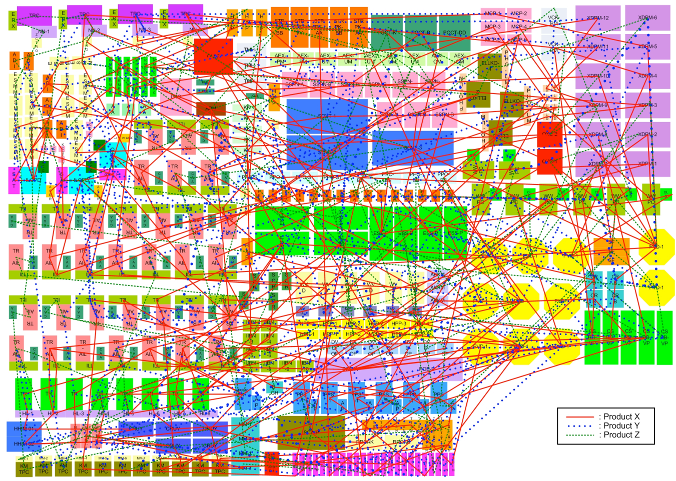


Figure 3. Process flow in facility layout: a FAB case

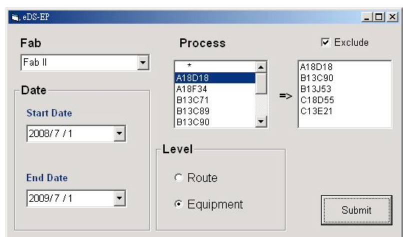
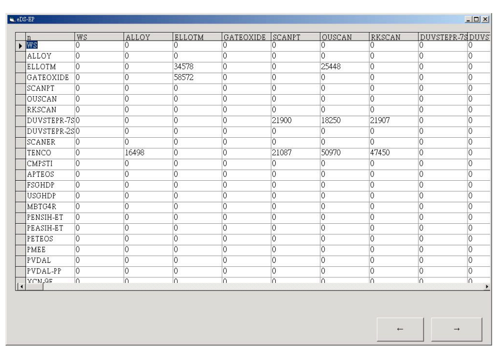


Figure 4. eDS-EP system



n	WS	ALLOY	ELLOTM	GATEOXIDE	SCANPT	OUSCAN	RKSCAN	DUVSTEPR-7S	DUVS
WS	0	0	0	0	0	0	0	0	0
ALLOY	0	0	0	0	0	0	0	0	0
ELLOTM	0	0	34578	0	0	25448	0	0	0
GATEOXIDE	0	0	58572	0	0	0	0	0	0
SCANPT	0	0	0	0	0	0	0	0	0
OUSCAN	0	0	0	0	0	0	0	0	0
RKSCAN	0	0	0	0	0	0	0	0	0
DUVSTEPR-7S	0	0	0	0	21900	18250	21907	0	0
DUVSTEPR-2S	0	0	0	0	0	0	0	0	0
SCANER	0	0	0	0	0	0	0	0	0
TENCO	0	16498	0	0	21087	50970	47450	0	0
CMPSTI	0	0	0	0	0	0	0	0	0
APTEOS	0	0	0	0	0	0	0	0	0
FSGHDP	0	0	0	0	0	0	0	0	0
USGHDP	0	0	0	0	0	0	0	0	0
MBTG4R	0	0	0	0	0	0	0	0	0
PENSIH-ET	0	0	0	0	0	0	0	0	0
PEASIH-ET	0	0	0	0	0	0	0	0	0
PETEOS	0	0	0	0	0	0	0	0	0
PMEE	0	0	0	0	0	0	0	0	0
PVDAL	0	0	0	0	0	0	0	0	0
PVDAL-PP	0	0	0	0	0	0	0	0	0
XCN-9F	0	0	0	0	0	0	0	0	0

Figure 5. The from-to chart of eDS-EP system

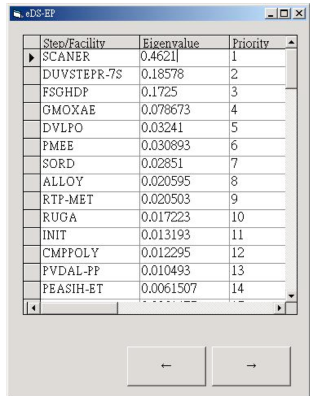


Figure 6. The priority of the critical equipments in FAB

The results (Figure 6) exhibit an overall priority ranking that reflects the degree of equipments importance. The results are verified by the managers of production planning department as they came up with similar conclusions. In their argument the 6 of the top priority 10 equipments (SCANER, DUVSTEPR-7S, FSGHDP, GMOXAE, DVLPO and RTP-MET) have been controlled and highlighted before our research was written. The six equipments were viewed as important and critical. Although they did not sense the importance of the rest equipments, the result of our research attracted their attention and inspired the direction for their future investigation.

There are two points worth noting from the results. Firstly, SCANER, DUVSTEPR-7S and FSGHDP are the most important machines (having extremely high eigenvalue relative to the others machines in the FAB), which are required improvement immediately. Thereafter, we suggest that parallel machines could be added or more resources could be directed to enhance its capacity. Secondly, our results (Figure 6) is helpful in determining the reengineering scope according to the priority; for example, we can improve only the most important top 10 machines/steps under the given limitation of resources (e.g. business planning or budget).

5. CONCLUSIONS

Identify the critical, focus on the vital, and then do the right thing is the successful way for decision making (Drucker, 1974). However, what are the *right* things? It is difficult to find the *right* things especially under a complex environment. To determine the *right things* (or *key processes*) has become a crucial factor which affects the whole system performance. In the study, it is valuable to indicate a right way – determining the critical processes. For our proposed system, there are two applications in practices, as follows:

(1) *Layout alternatives in start-up facilities layout planning*: After the prior SLP analysis steps such as activities relationships and space requirements, several layout alternatives need to be generated. Layout designers could generate alternatives in the initial phase by the greedy heuristics or comparison method. The study proposes another method to generate the layout alternatives that is more close to the whole system view.

(2) *Re-layout/reengineering in an existing system*: An existing system trends toward production inefficiency when it has been working over a long time. The main reason results from the current environment change, the system itself objective alteration or the exception event increasing. In order to address the issue, it is necessary to re-layout or reengineering the existing system. The first and foremost is to find out which processes need improving; thus, it would be a success to identify the critical processes and show the results in the above FAB case. According to the results, we can only strengthen these critical workstations if we are restricted within current resources (e.g. annual budget, human resources) and realistic limitations (e.g. space, machines, capacity, pine/duct assembly, etc.).

Although this study only focuses on how to determine the critical processes in a process layout environment, it still has contribution to determine the *right* things (the vital few), which refers to the first step of the layout or process improvement. Subsequently, the next steps referring *do the things right* are also the rooms for future research such as: how to perform the strategic actions according to the results of our proposed model; how to allocate the resource of a firm based on the priority of the study suggestion.

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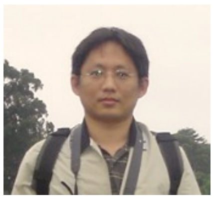

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