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子計畫一：半導體需求資料探擷與知識發掘應用於產能配置最佳化之研究(2/3)

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行政院國家科學委員會多年期專題研究計畫期中報告

半導體供應往路決策促成技術研究子計畫三

半導體需求資料探擷與知識發掘應用於產能配置最佳化之研究（2/3）

Semiconductor Demand Data Mining and Knowledge Discovery for Optimization of Capacity Allocation

計畫編號：NSC 90-2218-E-002-046

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中文摘要

在需求供給的網路中，需求的不確定性不但會被散播更會在網路中被放大而導致整條供應鏈營運品質低落的連鎖效應。半導體製造網路為最複雜的需求供給網路之一，因此深受無用的需求資料之苦。特別是，以不正確的需求資料為基礎而建立的錯誤產能規劃，一直是近年來半導體製造商極力克服的問題。要處理需求的變動性，適當的需求分類和統計預測都是為人所知的有效方法；在本研究的第一年，我們已分析「群組」和「預測」與需求的關聯，也提供有用的知識來幫助實業界作有效率的需求規劃決策。本年度，我們根據第一年所發掘的知識，發展產能配置的需求群組決策，接著探究設備整體效能(OEE)的影響。以群組的需求為基礎所建立的設備產能配置，其效用將會以數學模式建構，此模型的目的在於幫助實業界了解需求規劃如何影響設備產能配置，並且決定最終之 OEE。

關鍵詞：需求規劃、產能配置、設備整體效能

Abstract

The demand signal is the most unreliable source of information that plagues the operation effectiveness in a demand-supply network. Moreover, the demand uncertainty is not only propagated but also magnified over the network and causes a chain effect on the operation quality of the entire supply chain. Semiconductor manufacturing network is one of the most complicated demand-supply networks and thus suffers greatly from the untrustworthy demand information. To manage the demand variability, appropriate demand grouping and statistical forecasting approaches are known to be effective. In the first year of this research, we have analytically studied the effect of grouping and forecasting interrelated demands and derived useful knowledge to help practitioners make quality demand planning decisions. In this year's research, demand-grouping strategies for capacity allocation will be developed based on the knowledge discovered in the first year. The effect on the overall equipment effectiveness (OEE) is then explored. The effects of demand grouping for equipment capacity allocation are then modeled mathematically. The model is aimed to help practitioners comprehend how demand plans work together with capacity allocation to affect the OEE.

Keywords：Demand Planning, Capacity Allocation, Overall Equipment Effectiveness (OEE)

1. Introduction

The objective of this year's research is to develop demand grouping strategies for capacity allocation. Take three-product-demand as an example. Suppose the three products are denoted as A, B, and C, respectively. There are five possible capacity allocation plans as shown in Figure 1.

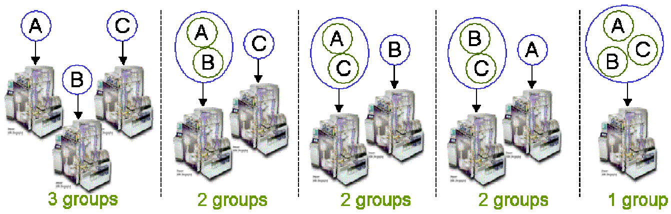

Figure 1 Equipment capacity allocation for three product demands

The first strategy is to assign different machines for different product demands; the second strategy is to prepare two machines: one for one product demand and the other for two product demands; and the third strategy would be to prepare only one machine for all the product demands. For the second strategy, there are also 3 possible grouping combinations as seen in Figure 1. Which strategy should be adopted depends on how the strategy affects the overall equipment effectiveness (OEE).

Overall equipment efficiency is used extensively to quantify the effect of flexibility on equipment efficiency in a manufacturing system. Leachman [2] proposed definitions and mathematical formulas for computing overall efficiency and data collection strategies. The OEE model includes four components [1]:

$$OEE = Availability \times Operating\ Efficiency \times Rate\ Efficiency \times Rate\ of\ Quality$$

The definitions of these components are [3]:

(1) Availability: Up time / Total time

(2) Operating Efficiency: Actual processing time /Theoretical processing time

(3) Rate Efficiency: Run time / Up time

(4)Rate Of Quality: (Total units processed – Total defect units) / Total units processed

The equipment status diagram from You [4] is shown in Figure 2, it helps understanding the meanings of the four components in the OEE model.

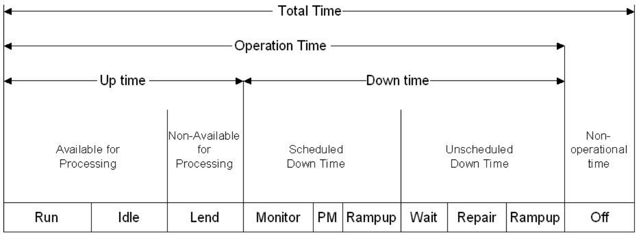

Figure 2 Equipment State

The capacity requirement for a type of machine can be then expressed as follows:

$$\text{Capacity Requirement} = \frac{\text{Demand} \times \text{Processing Time}}{\text{Overall Equipment Efficiency}}$$

As can be seen, OEE is a factor inflating equipment capacity required. In this year's research, we investigate thoroughly how the demand grouping for capacity allocation impacts OEE.

2. Demand grouping for tool capacity allocation

According to the static capacity models, the capacity demand can be obtained by product demands and processing time:

Capacity demand at time period $t = q_t = d_t \times \tau$

where d_t is the product demand at time period t, t=1,…,T and τ is the processing time required to by one product unit. The capacity requirement is then determined by the average capacity demand and the Overall Equipment Efficiency (OEE):

The capacity requirement= $Cr = \dfrac{\sum_{t=1}^{T} q_t}{T \times o}$

Where q_t is the capacity demand at time period t, $t=1,\ldots,T$, and o is the overall equipment efficiency

The number of tools must be integer. After capacity requirement is calculated, the tool requirement can be estimated by the capacity requirement. The tool requirement is calculated as follows:

$$Tr = \left\lceil \frac{\sum_{t=1}^{T} q_t}{T \cdot o \cdot Cpm} \right\rceil$$

where Cpm is the capacity provide by one tool at one time period

As previously illustrated, our objective is to develop strategies that group demands of multiple products to achieve minimum tool requirement and variability. For example, if we have 3 products, 1, 2 and 3. There will be 5 groupings types:

(1) all are separated;
(2) 1 & 2 are grouped and 3 is alone;
(3) 1 & 3 are grouped and 2 is isolated;
(4) 2 & 3 are grouped and 1 is alone; and
(5) all are grouped together

The objective is to find the best way of grouping among these five possible options. To answer this question, we first develop a matrix form to express these different grouping types. We build a matrix with columns representing the products and rows representing the groups. Since in this example, there are 3 products, that can be grouped into 3 groups at most, we build a 3×3 matrix as follows:

$$\begin{array}{cc} & \text{product} \\ & (1 \quad 2 \quad 3) \\ \text{group} \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix} & \begin{pmatrix} x_{11} & x_{12} & x_{13} \\ x_{21} & x_{22} & x_{23} \\ x_{31} & x_{32} & x_{33} \end{pmatrix} \end{array}$$

$$\text{where } x_{ij} = \begin{cases} 1, & \text{if product i is grouped into group } j \\ 0, & \text{otherwise} \end{cases}$$

There exists a "uniqueness" problem for this matrix form representation. For instance, grouping all products into tool group 1 is equivalent to grouping them into group 2 or 3. Different matrices could represent the same grouping type. The following three matrices all represent the grouping type (5), which groups all products together.

$$\text{group}\overset{\text{product}}{\begin{pmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}} \quad \text{group}\overset{\text{product}}{\begin{pmatrix} 0 & 0 & 0 \\ 1 & 1 & 1 \\ 0 & 0 & 0 \end{pmatrix}} \quad \text{group}\overset{\text{product}}{\begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{pmatrix}}$$

The remedy is to let the group number to be and only be the smallest product number in the group. In other words, when product 1, 2 & 3 are all grouped together, the smallest product number is 1, and so is the group number. Thus the first matrix above represents the grouping type (5). The other 2 matrices are not allowed. Let's use the grouping type (2) as another example to explain the rule. In the grouping type (2), products 1 and 2 are grouped together. Since the smallest product number is 1, the grouped products are named group 1. And the second group is formed by only product 3, 3 is thus the smallest product number and is also the group number. The matrix form becomes:

$$\text{group}\overset{\text{product}}{\begin{pmatrix} 1 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}}$$

The following 3 matrices represent the other 3 grouping types (3), (4) and (5), respectively:

$$\text{group}\overset{\text{product}}{\begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix}} \quad \text{group}\overset{\text{product}}{\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 0 \end{pmatrix}} \quad \text{group}\overset{\text{product}}{\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}}$$

The grouped products are then allocated to machine groups. Thus, we define a "machine group matrix" that represents assignments of product grouped for machine allocation. The steps to encode grouping type into a machine group matrix are:

1. Assign numbers to products
2. Choose the smallest product number in each machine group as the machine group number.
3. Build an $n \times n$ *machin- group matrix* **M**.

$$\mathbf{M} = machine\ group \begin{pmatrix} 1 \\ 2 \\ \vdots \\ n \end{pmatrix} \overset{\displaystyle product \atop \begin{pmatrix} 1 & 2 & \cdots & n \end{pmatrix}}{\begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nn} \end{pmatrix}}$$

where $x_{ij} = \begin{cases} 1, & \text{if product i allocated to machine group j} \\ 0, & \text{otherwise} \end{cases}$

subject to the following constraints:

$$\sum_{i=1}^{n} x_{ij} = 1 \qquad (1)$$

$$x_{ii} = 1 \text{ and } x_{ij} = 0 \text{ for } j < i \quad \text{when } \sum_{j=1}^{n} x_{ij} \neq 0 \qquad (2)$$

Constraint (1) is because each product can be only assigned to one machine group. Constraint (2) aims to avoid illegal matrices. $\sum_{j=1}^{n} x_{ij} \neq 0$ means there are products in machine group i so that i should be the smallest product number in this machine group; i.e. $x_{ii} = 1$ and $x_{ij} = 0$ for $j < i$. We then define a *capacity-demand-group matrix* **D**:

$$\mathbf{D} = group \begin{pmatrix} 1 \\ 2 \\ \vdots \\ n \end{pmatrix} \overset{\displaystyle product \atop \begin{pmatrix} 1 & 2 & \cdots & n \end{pmatrix}}{\begin{pmatrix} D_{11} & D_{12} & \cdots & D_{1n} \\ D_{21} & D_{22} & \cdots & D_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ D_{n1} & D_{n2} & \cdots & D_{nn} \end{pmatrix}}$$

where $D_{ij} = \begin{cases} C_i, & if\ x_{ij} \text{ in matrix } \mathbf{M} \text{ is } 1 \\ 0, & if\ x_{ij} \text{ in matrix } \mathbf{M} \text{ is } 0 \end{cases}$

and C_i is capacity demand of product i, $i = 1,...,n$

Recall that **M** is the machine-group matrix defined earlier. If machine group matrix is

$$\mathbf{M} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 0 \end{pmatrix},$$

then capacity demand group matrix will be

$$\mathbf{D} = \begin{pmatrix} C_1 & 0 & 0 \\ 0 & C_2 & C_3 \\ 0 & 0 & 0 \end{pmatrix}.$$

3. Impacts of demand grouping for machine allocation on

Overall Equipment Efficiency

The overall equipment efficiency (OEE) measures four components of equipment performance:

$$\text{Overall Equipment Efficiency}$$

$$= Availability \times RateEfficiency \times RateOfQuality \times OperatingEfficiency$$

$$= \frac{\text{Up Time}}{\text{Total Time}} \times \frac{\text{Product Time}}{\text{Up Time}} \times \text{Yield} \times \frac{\text{Theoretical Processing Time}}{\text{Actual Processing Time}}$$

$$= Availability \times Utilization \times Yield \times Efficiency$$

The OEE will be influenced by machine allocations to product groups. In this section we try to model the impacts of product grouping for machine allocation on the OEE.

Since both the scheduled down time and the unscheduled down time are not likely to be affected by product grouping, the availability, the first component of OEE, is assumed to be a constant, say 75%. The utilization of a machine group will increase as more products are allowed to be processed on a same machine. This is due to the fact that the more the product types processed by the same machine, the higher the flexibility of production scheduling, i.e. the more the product types grouped for the same machine group, the higher the utilization of this machine group. The yield, however, will decrease when more products types are allocated together because product changeovers often cause unstable processing conditions. That is, the more the product types in the same machine group, the lower the yield of this machine group. Similarly, the efficiency will also decrease by grouping more product types together for the same machine because the actual processing time is the theoretical processing time plus the changeover time. That is, the more the product types in the same machine group, the lower the efficiency of this machine group.

To take the overall equipment efficiency into account to develop strategies for best product grouping to minimize the capacity requirement and it's variability, we develop three models to describe the impacts of product grouping on the three components of OEE.

3.1 Utilization Model

Utilization of a machine group increases with more product types allocated to it due to a higher flexibility. Nevertheless, there should exists an upper bound of utilization even when all different products can be processed by the same machine, and a lower bound when only a product is allocated to be processed by a machine group. In addition, different manufacturing system may have different utilization increasing rates as the manufacturing flexibility increases.

In the following model, there are four parameters:

$$\text{Utilization} = U - (U - L) \times r^{n-1} \qquad r < 1 \qquad (3\text{-}1)$$

Where U: upper bound of utilization
L: lower bound of utilization

r : utilization enhancing factor

n: number of product types in the machine group

The value of r controls the utilization convergence speed to the upper bound. The smaller the value of r the faster the utilization converging to the upper bound. In Figure 2, we illustrate the influence of product grouping for U=0.9, L=0.8 and r=0.2, 0.4 and 0.6..

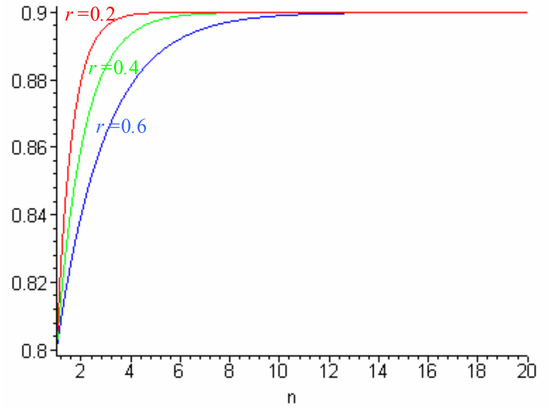

Figure 2 Number of grouped product types vs. utilization

A special case of the above utilization model is that the increase of utilization is characterized by an exponential function:

$$\text{Utilization}=U-(U-L)\times\exp(-(n-1)) \qquad (3\text{-}2)$$

This is equivalent to set r to $1/e$=1/2.71828=0.36788. In the following Figure, r = 0.36788, U=0.9 with L= 0.8, 0.7, and 0.6:

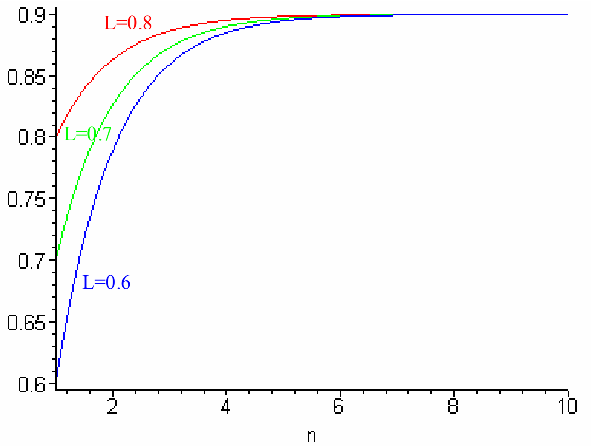

Figure 3 Exponentially increasing rate of utilization

3.2Yield Model

In order to establish the yield model, we define "yield group" first. "Yield group" means product groups that maximize the machine yield. This is because some products will diminish the yield if they are processed by the same machine group and some products won't. We define the product group, in which different product types processed together on the same machine do not diminish the yield, as a "yield group". The products can be grouped into several "yield groups", and a yield group matrix, similar to the *machine group matrix*, can be used to represent it.

The steps to encode a *yield-group matrix* **Y** are:

1. Group n products into several groups to maximize the yield.

2. Choose the smallest product number in each group as the group number.

3. Build an n×n matrix.

$$\mathbf{Y} = \textit{yield group}\begin{pmatrix}1\\2\\\vdots\\n\end{pmatrix}\overset{\textit{product}\\ \begin{pmatrix}1 & 2 & \cdots & n\end{pmatrix}}{\begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n}\\ y_{21} & y_{22} & \cdots & y_{2n}\\ \vdots & \vdots & y_{ij} & \vdots\\ y_{n1} & y_{n2} & \cdots & y_{nn}\end{bmatrix}}$$

where $y_{ij}=\begin{cases}1, \text{ if product } j \text{ belongs to yield group } i\\ 0, \text{otherwise}\end{cases}$

$$s.t. \quad \sum_{i=1}^{n} y_{ij}=1 \qquad (1)$$

$$y_{ii}=1 \text{ and } y_{ij}=0 \text{ for } j<i \quad \text{when } \sum_{j=1}^{n} y_{ij}\neq 0 \qquad (2)$$

Based on this yield-group matrix, grouping products belonging in the same yield group is desired because that will diminish the yield least. But unavoidably, a machine group can be formed by products from different yield groups. Now we want to model the impacts of product grouping on the yield under the following situations:

(1) Each yield group has its own initial yield. The initial yield is the yield when only products in the same yield group are grouped into the same machine group for production.

(2) Grouping products from different yield groups in the same machine group will lower the yield.

(3) When products from different yield groups are grouped into the same machine group, the product yield with a relatively larger demand will have a less yield drop, because the time proportion this product is processed on the machine is higher than others.

Multiplying the capacity-demand-group matrix **(D)** by the transpose of the yield-group matrix **(Y)**, we obtain:

$$\mathbf{DY}^{\mathrm{T}}=\begin{pmatrix} D_{11} & D_{12} & \cdots & D_{1n}\\ D_{21} & D_{22} & \cdots & D_{2n}\\ \vdots & \vdots & \vdots & \vdots\\ D_{n1} & D_{n2} & \cdots & D_{nn}\end{pmatrix}\begin{pmatrix} y_{11} & y_{21} & \cdots & y_{n1}\\ y_{12} & y_{22} & \cdots & y_{n2}\\ \vdots & \vdots & \vdots & \vdots\\ y_{1n} & y_{2n} & \cdots & y_{nn}\end{pmatrix}$$

$$=\begin{pmatrix} DY_{11} & DY_{12} & \cdots & DY_{1n}\\ DY_{21} & DY_{22} & \cdots & DY_{2n}\\ \vdots & \vdots & \vdots & \vdots\\ DY_{n1} & DY_{n2} & \cdots & DY_{nn}\end{pmatrix}$$

where $DY_{ij}=\sum_{k=1}^{n} D_{ik}\times y_{jk}$. DY_{ij} indicates the capacity demand of products in machine group i, that belong to yield group j. DY_{ij} =0 means no products in machine group i belong to yield group j.

Now, we can define the yield for DY_{ij}, and then the yield for the entire machine group i can be obtained by first weighting the DY_{ij} yield by demand volume and then taking a weighted average. Since DY_{ij} belongs to yield group j, when only DY_{ij} is processed by the machine group i, the yield will be the initial yield denoted by I_j. But when products belonging to other yield groups are grouped into the same machine group (i.e. the other nonzero entries in the row i of the matrix $\mathbf{DY}^T$), the yield will be diminished by a yield discount factor and the volume of DY_{ij}. We therefore define the yield of DY_{ij} as:

$$\text{Yield}(DY_{ij}) = I_j \times p^{(N_{yi}-1)} \times q^{(1-\frac{DY_{ij}}{\sum_i DY_{ij}})} \tag{3-3}$$

where I_j is the initial yield of yield group j, N_{yi} is the number of different yield groups in machine group I,q is the yield discount factor (<1), and p is the heterogeneity penalty factor (<1). The first term of DY_{ij} yield is the initial yield. The second term of Eq.(3-3) is heterogeneity penalty that is controlled by a heterogeneity penalty factor p based on the situation (2) of the yield model. N_{yi} is the number of different yield groups in machine group i and is equal to the number of nonzero entries in row i of the matrix $\mathbf{DY}^T$. When N_{yi} equals to 1, the second term also equals to 1; i.e., there is no heterogeneity penalty and the yield is not diminished. The last term of Eq.(3-3) follows the situation (3) of the yield model. Here, we let the last term be Q, i.e.

$$Q = q^{(1-\frac{DY_{ij}}{\sum_i DY_{ij}})} \quad (q<1).$$

Then, the range of Q will be $q<Q<1$. And $DY_{ij} / \sum_i DY_{ij}$ is the proportion of DY_{ij} demand in the machine group i. When products from different yield groups are grouped together, the product yield with a relatively larger demand will have a less yield drop and have a larger Q. In the following Figure, we plot Q against the proportion of DY_{ij} demand (x= $DY_{ij} / \sum_i DY_{ij}$) with different values of p, (0.95, 0.9 and 0.85)

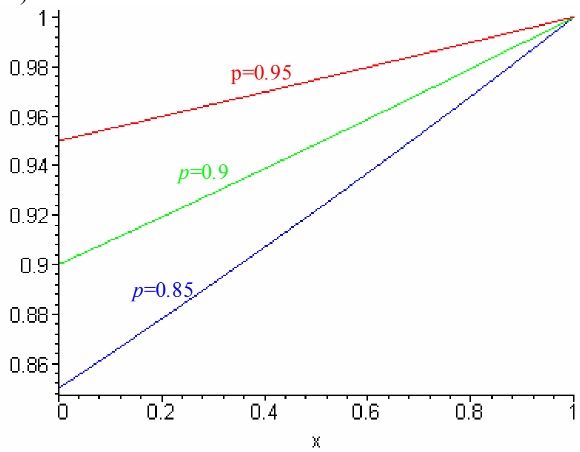

Figure 4 Q vs. DY_{ij} proportion with different values of p

Then, we take the weighted average of DY_{ij} yield to get the yield of machine group i:

$$Yield_i = \sum_{j=1}^{n} \frac{DY_{ij}}{\sum_j DY_{ij}} \times yield \text{ of } DY_{ij} \tag{3-4}$$

3.3 Efficiency Model

In order to establish the efficiency model, we also define an "efficiency group" similar to the "yield group". The efficiency groups are the demand groups that minimize the overhead time. Products can be grouped into several "efficiency groups". Again, a matrix similar to the machine-group matrix can be used to represent the efficiency groups. The steps to encode the *efficiency-group matrix* **E** are:

1. Group products into several groups to minimize the overhead time.
2. Choose the smallest product number in each group as the group number.
3.Build an $n \times n$ matrix.

$$\mathbf{E} = group \begin{pmatrix} 1 \\ 2 \\ \vdots \\ n \end{pmatrix} \overset{product \; (1 \;\; 2 \;\; \cdots \;\; n)}{\begin{bmatrix} e_{11} & e_{12} & \cdots & e_{1n} \\ e_{21} & e_{22} & \cdots & e_{2n} \\ \vdots & \vdots & e_{ij} & \vdots \\ e_{n1} & e_{n2} & \cdots & e_{nn} \end{bmatrix}}$$

$$\text{where} \quad e_{ij} = \begin{cases} 1, & \text{if product } j \text{ belons to efficiency group } i \\ 0, & \text{otherwise} \end{cases}$$

$$s.t \qquad \sum_{i=1}^{n} e_{ij} = 1 \tag{1}$$

$$e_{ii} = 1 \text{ and } e_{ij} = 0 \text{ for } j<i \quad \text{when } \sum_{j=1}^{n} e_{ij} \neq 0 \tag{2}$$

Then, multiplying the capacity-demand-group matrix **(D)** by the transpose of the efficiency-group matrix (**E**), we obtain:

$$\mathbf{DE}^T = \begin{pmatrix} D_{11} & D_{12} & \cdots & D_{1n} \\ D_{21} & D_{22} & \cdots & D_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ D_{n1} & D_{n2} & \cdots & D_{nn} \end{pmatrix} \begin{pmatrix} e_{11} & e_{21} & \cdots & e_{n1} \\ e_{12} & e_{22} & \cdots & e_{n2} \\ \vdots & \vdots & \vdots & \vdots \\ e_{1n} & e_{2n} & \cdots & e_{nn} \end{pmatrix}$$

$$= \begin{pmatrix} DE_{11} & DE_{12} & \cdots & DE_{1n} \\ DE_{21} & DE_{22} & \cdots & DE_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ DE_{n1} & DE_{n2} & \cdots & DE_{nn} \end{pmatrix}$$

where $DE_{ij} = \sum_{k=1}^{n} D_{ik} \times e_{jk}$, DE_{ij} indicates the capacity demand of products in machine group i, that belong to efficiency group j. DE_{ij} =0 means no products in machine group i belong to efficiency group j. When grouping products for machine allocation, a machine group can also be formed by products from different efficiency groups. And that will increase the overhead time. Now, we want to model the efficiency of this machine group under the following situation:

(1) The overhead time of a machine group is proportional to the number of different efficiency groups in this machine group.
(2) The theoretical processing time is the capacity demand because the capacity demand mentioned in Section 3.1 is the demand quantity of demand multiplied by the theoretical processing time per unit demand.
(3) The actual processing time is the sum of the theoretical processing time and the overhead time.

The overhead time of group i can be calculated as:

$$\text{Overhead}_i = (N_{ei} - 1)t \qquad (3\text{-}5)$$

The efficiency can be then easily calculated as follows:

$$\begin{aligned} &Efficiency_i \\ &= \frac{\text{Theoretical processing time of machine group } i}{\text{Theoretical processing time of machine group } i + \text{Overhead Time}_i} \\ &= \frac{\text{Capacity Demand of machine group } i}{\text{Capacity Demand of machine group } i + \text{Overhead Time}_i} \\ &= \frac{\sum_{j=1}^{n} DE_{ij}}{\sum_{j=1}^{n} DE_{ij} + (N_{ei} - 1)t} \qquad (3\text{-}6) \end{aligned}$$

where t is changeover time between efficiency groups; N_{ei} is the number of different efficiency groups in machine group i, and N_{ei} equals to the number of nonzero entries in row i of the matrix $\mathbf{DE}^T$

From the situation (1) of the efficiency model, the overhead time of a machine group is proportional to the number of different efficiency groups in this machine group. In Eq.(3-5), the overhead time is proportional to (N_{ei}-1), because when products are only from the same efficiency group, it won't waste capacity for changing over the products. From situaitons (2) and (3) of the efficiency model, the actual processing time is the sum of the capacity demand and the overhead time, and the efficiency of the machine group is the ratio of the theoretical processing time to the actual processing time. Taking the overhead time formulated in Eq.(3-5) into account, we can easily obtain the efficiency of the machine group by Eq.(3-6).

Conclusions

In this year's research, we have modeled how grouping of product demands for machine allocation affects OEE's three important factors: machine utilization, yield and efficiency. For the tool utilization, it is modeled as a function of the number of product types a tool is allowed to process. For the yield and efficiency, yield groups and efficiency groups are defined to be the products that can achieve highest yield and efficiency when grouped together. Machine yield and efficiency are then modeled as functions of the heterogeneity of products belonging to different yield groups or efficiency groups. The proposed models are the first in the literature that explicitly describe how demand grouping for machine allocation affect the components of OEE and can be used for further optimization, which will be the focus of our next year's research.

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