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Overhead Allocation and Capacity Utilization

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ABSTRACT

With the introduction of high-tech into the production and manufacturing fields, the capital intensive investment increases, consequently the capacity in many firms is expanding rapidly and the capacity costs form a large part of the overhead costs. Since the costing accuracy directly affects the decisions on pricing, performance evaluation, production planning...etc, a measurement toward "real product cost" is critical. On the other hand, a costing strategy should aid the firm toward efficient and productive management. The activity based costing (ABC) system does not solve the problem of over capacity cost allocation. Therefore, a remedy might be necessary to improve the ABC system.

The linear programming and capture ratio methods can greatly improve the cost-efficiency. Particularly, when the large portion of the total cost is the overhead, both methods can help the firm to define the constraints of capacity, as well as provide the basis for overhead allocation. Using the LP model, firms can allocate the overhead based on the bottleneck usage of each product, therefore increase the efficiency of constraint capacity usage and maximize the throughput value of the whole system. The CR method is more efficient in the digital control manufacturing and CAM. Especially, if a firm is confronted with idle capacity problem and the allocation of the idle capacity becomes difficult, the CR method can be applied to allocate the idle capacity to each product. LP and CR models are applicable in different situations. When the capacity utilization is stable, consistent and smooth across a certain range of time, LP can be used to define the capacity utilization and applied in overhead allocation. On the other hand, when the capacity utilization is very fluctuating, inconsistent and remains within given production constraints, the capture ratio method might be ideal to define the capacity used (captured) and allocate the overhead accordingly. For example, if a firm has seasonal demands on the production, it also associates with seasonal idle capacity. To define the average or normal capacity usage is difficult. Therefore, the capture ratio is useful in deciding the capacity utilization and overhead allocation.

When a firm produces a large volume of products, or when a firm has a mass production process, the LP model is more appropriate in both capacity utilization definition and overhead allocation. On the other hand, when a firm has small order, low volume production, or when a firm is in a job-order production situation, the capture ratio method is appropriate. Because in the low volume production firms, the interrupts of the production are much more frequent.

In summary, both LP and CR models are very useful in defining the capacity utilization and the associated overhead allocation strategy. Our future research will focus on either the simulation or field study to test the applicability of both models.

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Introduction

One of the most popular topics in managerial accounting nowadays is the allocation of overhead costs. Such popularity is due to the modernization of manufacturing, particularly the application of high tech into production field. The high tech needs more capital intensive investments and as a consequence, the proportion of overhead costs increases in the total costs structure. Such increase greatly threatens the validity of the traditional labor-based overhead allocation method. The relatively small portion of labor cost can no longer be used to allocate the large portion of overhead costs. Also, the traditional volume-based and machine-hour-based single rate can also distort the real product cost under the contemporary situation. Cooper and Kaplan (1988) have shown how the traditional cost accounting distorts product costs. Therefore, they promoted a new method, namely, activity-based costing (ABC) method.

ABC system has solved part of the cost allocation problem. An important issue, however, brought up by high tech manufacturing, namely, the capacity utilization, is overlooked. Cooper and Kaplan (1988) mentioned capacity problem that under ABC, "the costs of excess capacity should not be charged to individual products," instead, it "should be treated as a separate line item - a cost of the period, not individual products " (P.101, Cooper and Kaplan 1988). Implicitly, the capacity cost is irrelevant to the product costs, and the extent of capacity utilization does not affect the product costs.

As computer aided manufacturing (CAM) and other high tech application in production greatly augment capacity of the production, the traditional assumption of "normal" or "stable" capacity demands is no longer valid. The capacity utilization is more fluctuating than before. If the absorption costing or full costing method is adopted, the capacity utilization can greatly affect the product cost. More attention should be paid to this issue.

This paper aims at the connection between cost allocation and capacity utilization. Section 1 discribes the relationship between capacity utilization and product costs, namely, overhead costs. Section 2 shows the cost allocation stages. Section 3 illustrates the overhead allocation in consideration of capacity utilization, the theory of constraint is applied. Section 4 uses linear programming to detect the bottleneck and the allocation of overhead based on LP. Section 5 presents the application of an economic data processing method, the capture ratio, into the costing and capacity utilization measurement method. Finally, section 6 shows the significance of implementing such costing systems.

The Relationship Between Capacity Utilization and Costs

The augmentation of overhead costs is largely due to the expansion of capacity costs. That is, high tech investments increases the depreciation costs of such investments. Appropriate depreciation method can determine a great deal of overhead costs. If the depreciation cost is related to the production volume, or capacity utilization, the changes in the capacity utilization can certainly affect the total overhead costs and unit product cost if the full costing method is adopted.

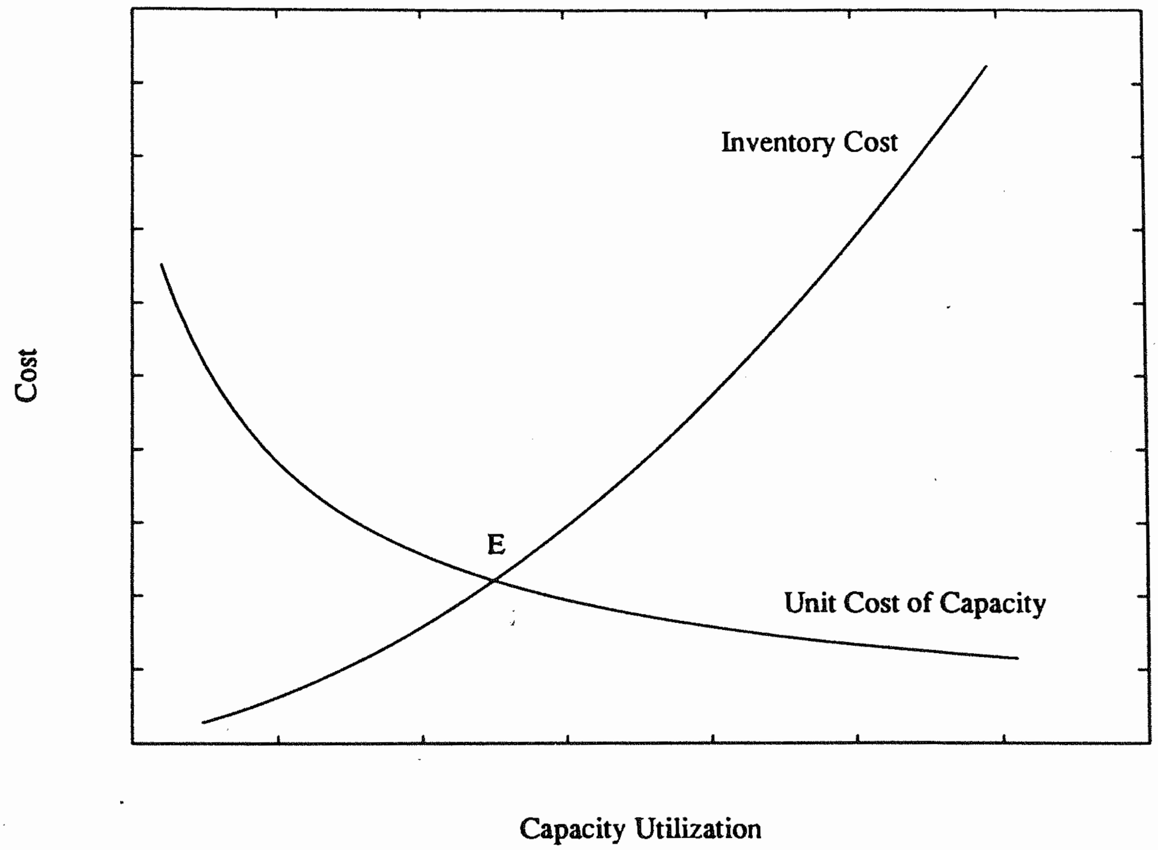
As we know, the high tech brings enormous expansion of capacity, and consequently the redundant capacity appears in firms. Facing such redundancy, two strategic production choices can be considered: either to keep full or normal stable capacity usage, or curtail the capacity usage with the demands and leave capacity idle when the demands are low.

The cost considerations in relation to the strategy involves the cost of idle capacity, setup cost, inventory cost (including work-in-process and finished goods). The relationship between the unit capacity cost and inventory cost is shown in figure 1.

Figure 1 shows that the higher the capacity is used, the more inventory cost might be incurred due to the possible blockage (bottleneck) of the production flow. On the other hand, the higher the capacity utilization, the lower the unit cost absorbed by each product. Comparing different costs of capacity utilization, we can choose an optimal cost saving strategy.

The effect of inventory costs on capacity utilization is enormous. If inventory costs (e.g., WIP costs, finished products inventory costs, the costs of funds occupancy, interest costs) are higher than the capacity wasted costs plus setup costs, the capacity utilization can be kept at low level, and firms can implement as a "stop and go" policy to meet the demands. On the other hand, if inventory cost is lower than the capacity costs, firms can keep on producing at the highest capacity utilization and leave the undemanded products in inventory. The point E in Figure 1 gives the optimal point for capacity utilization (the lowest cost of the sum of capacity cost and investory cost). Such an equilibrium point can be obtained by comparing the capacity cost and inventory cost.

Figure 1. Relationship Between Inventory Cost and Capacity Utilization



In practice, the first scenario is more popular. As the capacity expands, the cost of inventory if the "smooth flow" (high capacity exploitation) happens is very high. Such situation forces many firms to implement the "stop and go" policy. Therefore, the capacity is not always at its full usage. The redundant capacity is a very common phenomenon in modern production industries. The standard or pratical capacity utilization is normally at 80-85%.

Assume EC as the cost of excess capacity (the variable part with production volume and setup times), and IC as various inventory costs. Then the basic strategy is

if EC > IC keep on producing at full capacity;
if EC < IC, stop and go, excess capacity resulted;

Here, EC and IC need to be further defined. Theoretically, the capacity cost is an unavoidable costs or sunk cost or irrelevant cost. Such cost would not matter to the pricing or production decision. However, as the amount of capacity expands, and the potential idle capacity is expected to occur, the full costing including capacity cost would encourage the utilization of capacity and reasonably reflect the real cost of products. The capacity cost in total product costs includes capacity depreciation cost and setup costs.

On the other hand, by encouraging utilization of capacity, a firm has to balance the costs with inventory cost, IC. Inventory cost is the cost incurred due to the "unsmoothed" products flow from input to output process. If there is a constraint at certain stage of input-output flow, there must be queuing of products in process. Such queuing results in the inventory. The cost of inventory includes interest of funds (opportunity costs) occupying at the inventory stage, the cost of safeguarding the inventory, the space taken by the stock piles...etc. The cost of inventory becomes one of the important criteria in judging the level of modern production management, which in turn is a function of capacity utilization.

Since capacity utilization affects the inventory costs, consequently affects the profitability of a firm, it should be reflected in the cost allocation strategy. In the presence of capacity constraint, products which use more units of capacity should bear more overhead capacity cost, to encourage the efficiency of the capacity utilization. Therefore, allocating the overhead costs in relation to capacity utilization of each product can reflect the image of real consumption of costs by the products and improve the capacity utilization. Cost allocation should be based on the cost of providing scarce capacity that is consumed or used up in making a given product.

Two Stage Cost Derivation

How to allocate the overhead costs to individual products ? How to trace the overhead cost to each cost object ? How to deal with those untraceable costs ? These are questions mostly discussed nowadays. Many proposals have been put forward. For example, the Activity Based Costing (ABC) system is one of these popular methods.

Traditionally, the allocation of overhead cost to products is based on the two stage system. In the first stage, the overhead costs directly traceable to individual production cost centers (workshops) are grouped by production departments or cost pools. In the second stage, these direct costs, along with indirect costs containing common or shared costs, are allocated to individual products based on the pre-fixed direct labor hours or machine hours contributed in each product. Fig.2 shows the specific procedure of the 2-stage costing system. The problems of such system come from the second stage. The smaller proportion of labor cost is used to allocate the larger portion of overhead cost. It is certainly inappropriate.

As it is argued, a large part of overhead costs, which were traditionally considered as fixed costs, are variable with certain transaction or activities of firms. Therefore, the variable part of costs should be allocated according to these cost drivers. ABC system is designed for such reality. With ABC, the overhead cost allocation can be discribed as in Fig.3.

In fact, ABC is a process which uses multiple cost drivers[1] to predict and allocate costs to products and services. As an accounting system, it collects financial and operational data on the basis of the underlying nature and extent of business activities in order to attach costs to products based on the activities performed to produce, distribute, or support these products. However, due to the expansion of capacity investment, a large part of overhead cannot be traced directly to each product. This is because the untraceable overhead costs consist mainly of excess capacity cost. The ABC system alone cannot trace much of overhead costs. The untraceable costs form the common or shared costs for all the products. Therefore, in the presence of large capacity costs, the ABC system approaches to the traditional costing system. With the absorption cost system, the allocation of untraceable costs can affect product costs greatly.

1. Cost drivers are the activities which result in or create costs for the production process.

Figure 2 : Two-stage Costing Systems : allocation of overhead costs to products

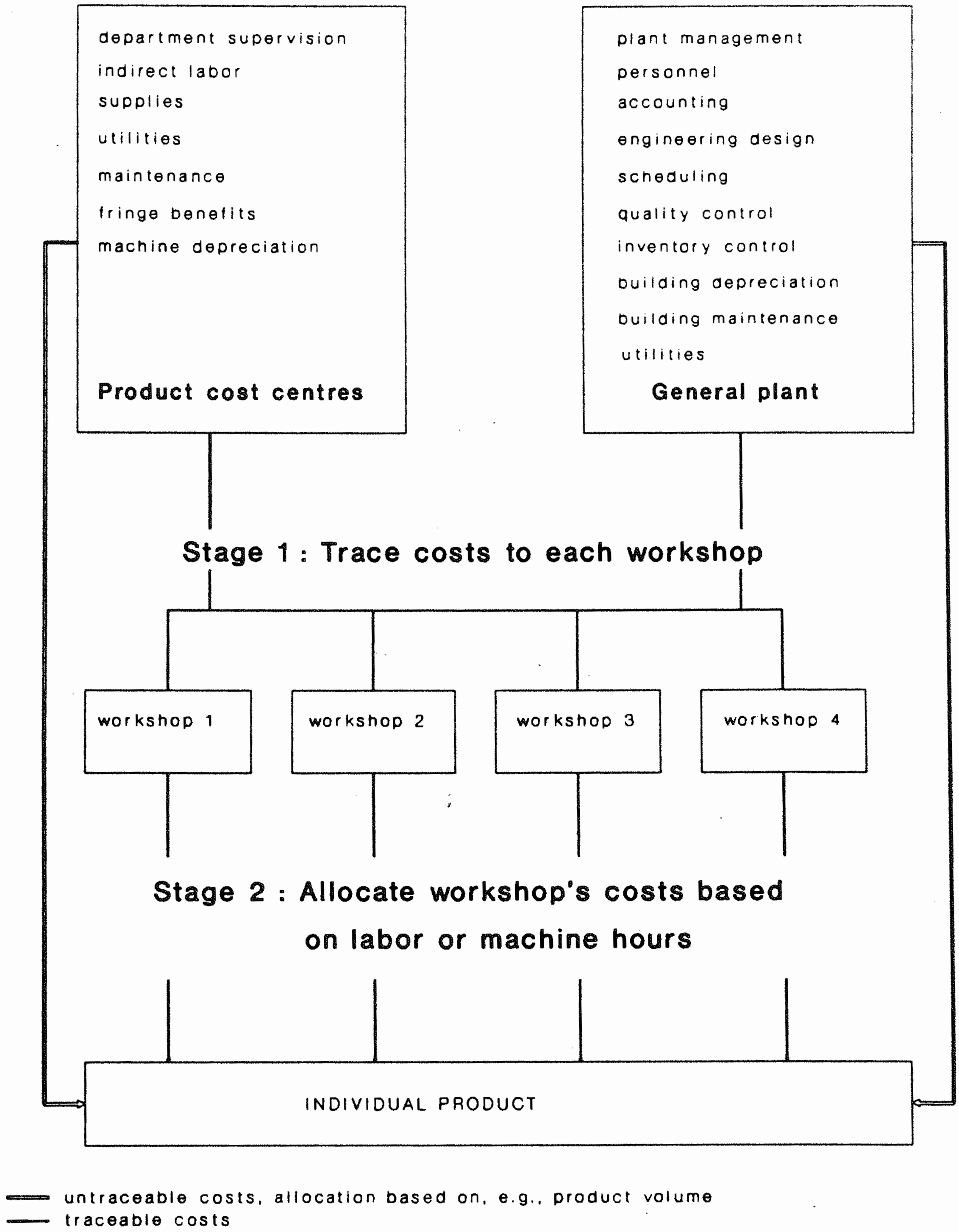
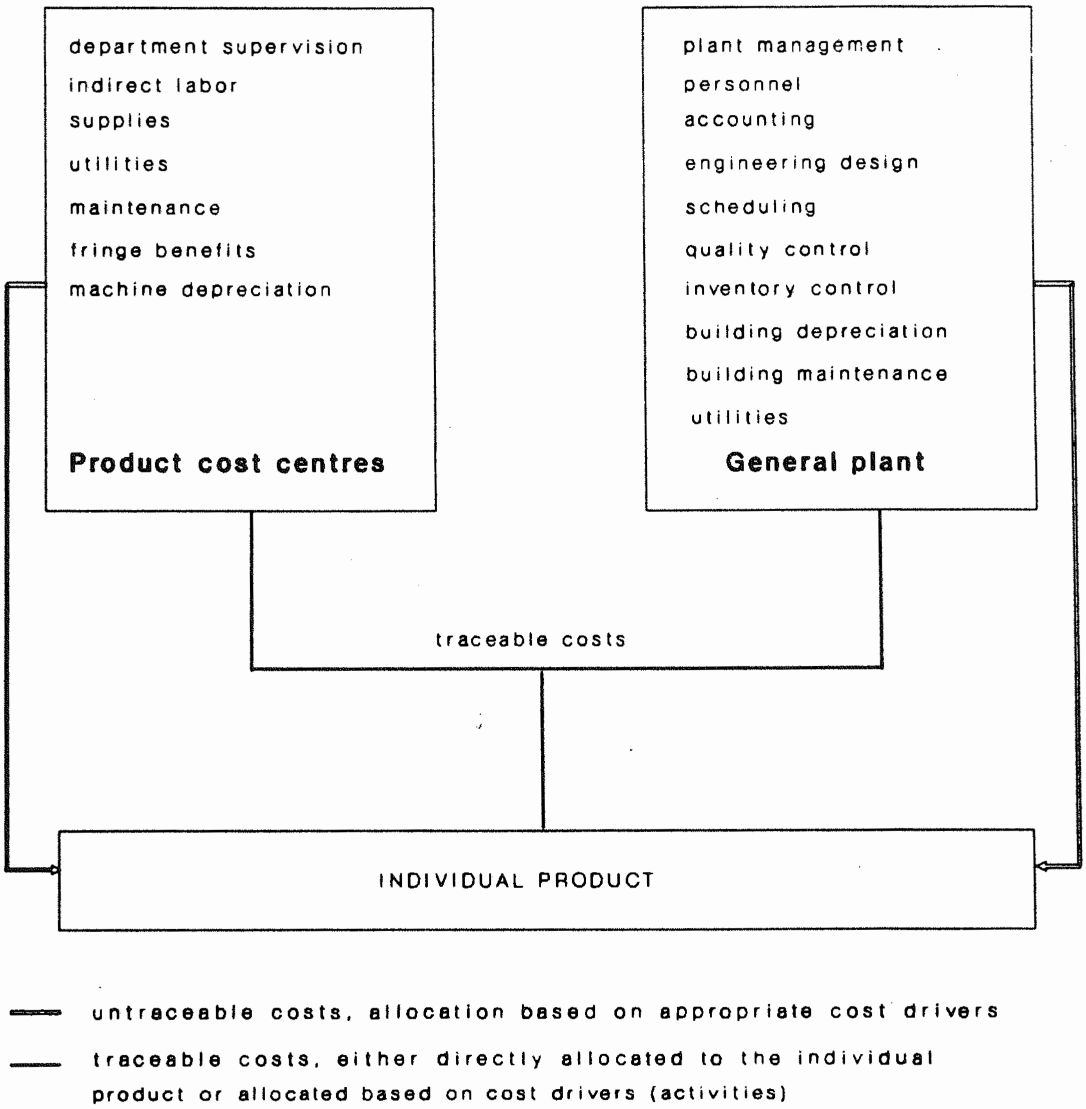


Figure 3.: ABC System For Allocating Overhead Costs



Theory of Constraint and Overhead Allocation

Most of the untraceable overhead costs come from the capacity depreciation. A significant costing system should measure cost object's consumption of resources. When certain productive or distributive capacity or resources are finite or constrained, the firm should attempt to obtain the best possible return on the consumption of these key resources.

If a firm has certain capacity constraints in its input-output process, Goldratt's theory of constraint(TOC) might give us some suugestions about overhead allocation. We refer to the capacity constraints as "bottlenecks" during the process. A bottleneck therefore decides the output rate of the process. In their book, "The Goal", Goldratt and Cox described vividly the TOC. As they mentioned, the criteria of a good production performance depends on three elements, namely, throughput, inventory, and operating expenses. With existence of the constraints, a firm should maximize the volume of throughput in the bottleneck department or machine as an overall strategy. Instead of contribution margin, TOC considers the throughput value as the maximized target. A throughput value is a measure of the net revenue of a given product less those costs directly traceable to and caused by the existence of that product in the mix. That is:

$$TV = P - DC - TIC \qquad (1)$$

where TV = Throughput Value,

P = the price or revenue of a product,

DC = direct costs of a product,

TIC = traceable indirect costs.

Since ABC can reduce part of overhead cost (traditionally considered as "fixed"), the throughput value differs from the contribution margin. Any output which cannot go through to the final consumers but adds to the intentory of the firm has no throughput value. Instead, the firm has to incur costs in storage and expediting, as well as the risk of obsolescence or parts stockouts opportunity. So, maximization of the throughput value is equivalent to optimization of the capacity utilization at the bottleneck.

In order to maximize the throughput value, a cost allocation should be based on the bottleneck consumption of each product. The bottleneck problem of TOC can be focused on reducing the product bottleneck consumption. The product with high bottleneck consumption but low throughput value generating ability should be punished.

As mentioned above, the bottleneck decides the throughput value of the whole operation. The bottleneck dictates the pace of whole process. An hour loss in the bottleneck is equivalent to an hour loss of throughput value in the whole system. If the overhead cost can be allocated based on the bottleneck usage of each product, the products with more consumption of bottleneck will be punished.

Another reason for allocating overhead costs based on bottleneck is that bottlenecks dictate inventory as well as throughput. Normally, a product's throughput time (the time from input to output) consists:

Throughput time = Process time + Setup time + Queue time + Wait time

$$TT = PT + ST + QT + WT$$

Here, we assume the constraints are based on the time[2]. Queuing time is the time the part spends in line for a resource while the resource is busy in working on something else ahead of it. Wait time is the time the part waits, not for a resource, but for another part so they can be assembled together.

Normally, parts that are going through bottlenecks have significantly positive queuing time, while parts that are going through non-bottlenecks have significantly positive waiting time. Since the waiting parts are those waiting for parts coming from the bottlenecks, they are virtually inventory (work-in-process). Therefore, the bottlenecks dictate inventory as well as throughput.

We have emphasized the importance of the bottlenecks in deciding the inventory and throughput value. When we allocate the overhead cost, such factors should be considered. Traditionally, the overhead cost was allocated based on either machine hours or production volume. Such allocation assumes all processes of operations either have equal usage rate, or they are all bottlenecks (constraints). The consequences are : (1) that the non-bottlenecks are equally important as bottlenecks, (2) that the overhead allocations are indifferent to capacity constraints, (3) that the consumption of the non-bottlenecks are encouraged, (4) and that the

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2. A capacity limitation can consist of the power, the financial fund, the consumer demands..etc. However, the most common capacity constraint is the time limitation of capacity.

inventory goes up. Accounting as a management tool might be readjusted to avoid such consequences.

In summary, allocating the untraceable overhead cost based on bottleneck usage rate of each product can encourage the reduction of bottleneck usage of each product, punish the over consumption of bottleneck capacity, and reduce the work-in-process inventory[3].

Detecting the Bottlenecks and Allocation Techniques

Simple Detection. Theoretically, when the production demands are greater or equal to the capacity limits, the bottlenecks appear. The capacity can be expressed in terms of volume or time. Here, we take the time limits as capacity amounts. The other capacity measurements can be easily extended as well. A bottleneck therefore can be defined as:

$$\sum_{i=1}^{N} (PT + ST)_i \geq CT$$

CT = Capacity time limitation, i=product i.

That means, a bottleneck appears when the total process and setup time for products i to N is greater or equal to the avoidable capacity.

As mentioned before, another phenomenon of bottlenecks is that QT or WT at certain processes within the whole system is positive. In this case the flow of the product process is blocked and we can observe the bottleneck(s) at certain processes.

Linear Programming. When a firm has some bottlenecks and the bottlenecks appear at different processes across time, linear programming might be used to detect the bottleneck(s). A linear programming model in this case can be discribed as:

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3. A commonly made mistake is to allocate overhead cost based on the throughput value of each product. It is certainly a wrong strategy. Such method punishes the product with high throughput value and low capacity consumption. It is just opposite to what we should do.

Maximize: $TV_1P_1+TV_2P_2+\ldots+TV_nP_n = TTV$

Subject to:

$$R_{11}P_1+R_{21}P_2+R_{31}P_3+\ldots+R_{n1}P_n \le C_1$$
$$R_{12}P_1+R_{22}P_2+R_{32}P_3+\ldots+R_{n2}P_n \le C_2$$
$$\vdots$$
$$R_{1k}P_1+R_{2k}P_2+R_{3k}P_3+\ldots+R_{nk}P_n \le C_k$$

Where TTV = Total throughput value;

TV_i = Throughput value of product i;

R_{ij} = Resource j consumed by each unit of product i;

P_i = Amount of product i produced;

C_j = Capacity j available for production.

The solution of this linear programme is the optimal product mix in the presence of capacity constraints. In this case, the throughput value is maximized (note, it is not the traditional contribution margin). If any of the constraint is binding (that means, the slack variable is non-positive), the capacity becomes the bottleneck.

The throughput value is calculated as

$$TV_i = MP_i - DC_i - TC_i$$

That means, a throughput value of products is equal to the market price (MP) minus those direct costs of the product and those traceable overhead costs based on ABC. The difference between TV and contribution margin depends on the traceability of overhead cost.

The unit time consumption of each product R_j includes the process time, setup time, queuing time and waiting time of the product. It is measured product by product.

Finally, the various capacity constraints should be discussed. The constraints include supply, production, distributive and marketing constraints. Generally, we can classify them into resource constraints and marketing constraints. The resource constraints include machine hour constraints, labour hour constraints, over-time labour constraints, and material supply constraints. The marketing constraints are mainly external sales and internal demands limits.

The above LP model can also be expressed as a dual model as follows:

Minimize $C_1DV_1+C_2DV_2+...+C_kDV_k$ (=TDV)

Subject to

$$R_{11}DV_1+R_{12}DV_2+R_{13}DV_3+...+R_{1k}DV_k \geq TV_1$$
$$R_{21}DV_1+R_{22}DV_2+R_{23}DV_3+...+R_{2k}DV_k \geq TV_2$$
$$\vdots$$
$$R_{n1}DV_1+R_{n2}DV_2+R_{n3}DV_3+...+R_{nk}DV_k \geq TV_n$$

Where DV_j = Dual value of each capacity resources;

TDV = Total dual value = TTV

The dual value is equal to marginal throughput value of each constraint capacity. The DV should be zero if the capacity is non-bottleneck. This means, as long as any constraint is binding, the dual value of that constraint would turn out to be positive. This is an alternative to detect the bottleneck process.

Allocating the Overhead Costs. The theory of constraints tells us that the traditional cost accounting allocates the overhead costs irrespective of the capacity usage. Consequently it would encourage the non-bottleneck usage and thus increase the inventory. If we allocate the overhead based on the bottleneck usage only, such problem would be greatly reduced.

Basically, if overhead is allocated based on the bottleneck capacity, each unit of bottleneck capacity should allocate overhead as

$$\text{OH per Unit of Bottleneck} = OV/TT_j \qquad (1)$$

TT_j is the total throughput time of the process j. It is equal to the total capacity of the bottleneck j.

Then each unit of product should bear the overhead:

$$\text{OH Allocated to } P_i = (OV/TT_j)*R_{ij} \qquad (2)$$

An alternative is to use the dual value if the TT_j is not easily observed. Generally,

$$DV_j = (\sum_{i=1}^{n} TV_i)/TT_j \qquad (3)$$

$$TT_j = (\sum_{i=1}^{n} TV_i)/DV_j \qquad (4)$$

Substituting (4) into (2):

$$\text{OH Allocation to } P_i = OV * (DV_j * R_{ij}) / (\sum_{i=1}^{n} TV_i) \qquad (5)$$

Equation (5) ,shows that if product i does not consume bottleneck resources, $DV_j=0$, it does not need to bear the overhead costs. As soon as it consumes bottleneck resources, it has to bear the overhead cost in proportion to the value of the bottleneck resources. Explaining eq.(5) intuitively, we find it is consistent with the method described by Salkin and Kornbluth (1973)[4]:

$$\text{OH allocated to } P_i = \text{Total OH} * \left(\frac{\text{Value of resources used by } P_i}{\text{Total Value of all resources}}\right)$$

We replace the total value by throughput value of all products. The above equation turns out:

$$\text{OH allocated to } P_i = \text{Total OH} * \left(\frac{\text{Value of bottleneck used by } P_i}{\text{Total throughput value}}\right)$$

This method has two advantages: (1) it considers the capacity constraint as an allocation basis; (2) it uses the value of bottleneck consumed by the product. Therefore, the product consuming more bottleneck resources is punished by bearing more overhead costs.

The LP method is useful only in the case when there is (are) bottleneck(s). This is an important assumption. If there is no capacity constraint, such LP method would greatly lose its significance.

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4. Although Salkin & Kornbluth (1973) did not mention the effect of capacity usage and TOC, apparently their proposed method has taken the capacity utilization into account.

In summary, with the presence of capacity constraint, the LP method uses the ratio of value of bottleneck consumed and the total value of the capacity as overhead allocation basis. Such cost allocation strategy can greatly improve the capacity utilization and rationalize the relation between the throughput value and the inventory problem. The LP method can locate the bottleneck as well as provide a better allocation base for untraceable overhead costs.

Capture Ratio and Nonbottleneck

If we consider only the production capacity, many firms do not have urgent capacity problems. As the modernization and automation introduced by the hi-tech, firms frequently operate in a situation of under-capacity. That means, the excess or idle capacity appears and no bottleneck exists. Facing such situation, the LP cannot be applied. A possible method, called capture ratio, used in the field of Economic Data Processing in allocating the computer usage time might be adopted for overhead allocation purpose. The capture ratio method can first measure the capacity utilization, then allocating the machine time to each product in order to allocate the overhead costs. Here, the problem of allocation of overhead becomes the allocation of idle capacity to each production unit.

As we defined in the last section, the total capacity time consists of process time, setup time, queuing time, and waiting time. If there is no bottleneck in the whole production system, part of capacity will be wasted.

Product Throughput Time = PT + ST + QT + WT

If we consider the capacity utilization, then:

$$\text{Total Capacity (TC)} = \sum_{i=1}^{n} (PT_i + ST_i) + IT$$

Where IT = wasted capacity. If IT = 0, the corresponding capacity is a bottleneck. If IT > 0, the corresponding capacity is a nonbottleneck. In other words, the idle capacity appears if

$$TC > \sum_{i=1}^{n} (PT_i + ST_i)$$

If we can distribute IT properly to each product, the overhead costs can be allocated based on the capacity usage. The allocation base is mainly the amount of capacity usage as:

Capacity Usage of Product i = $PT_i + ST_i + IT_i$

where IT_i is the allocated idle capacity of product i.

The capture ratio is the ratio of the idle capacity a product (or service) has to bear. There are many methods to calculate the capture ratio.

Method 1.

The capture ratio solves the problem of distributing:

$$IT = TC - \Sigma(PT_i + ST_i)$$

to each product i.

Assume $T_i = \Sigma(PT_i + ST_i)$,

and $T_{tot} = \sum_{i=1}^{n} T_i$

Then according to the traditional machine hour based method,

$$IT_i = (T_i/T_{tot}) * IT$$

Hence the total capacity usage by the ith product is given by

$$T_i' = T_i * (1 + IT/T_{tot})$$

The capture ratio for the ith product is defined as

$$CP_i = T_i/T_i' = 1 / (1+ IT/T_{tot}) = CP_{tot}$$

The capture ratio indicates the percentage of measured capacity usage of the total capacity. The closer it approaches to one, the more capacity is used. Note that the capture ratio of this method is the same for every product. The capture ratio also shows the extent a capacity usage can be traced to each product.

Having known the capacity usage and the capture ratio of a product about each capacity, we can allocate the IT to each product by:

$$T_i * 1/CP_i = T_i' = T_i (1 + IT/T_{tot})$$

Then we can allocate the overhead costs by:

$$\text{OH allocated to Product i} = (\text{ OH } / \sum_{i=1}^{n} T_i') * T_i' = \text{OH} * T_i' / \sum_{i=1}^{n} T_i'$$

That means, overhead costs are allocated based on the machine hours used and traced by each product.

Method 2.

In the situation of Computer Aided Manufacturing (CAM), a firm used to have mass multi-products and multi-capacity systems. A single capture ratio seems inaccurate in measuring the efficient capacity usage and tracing the wasted capacity to each product. A multiple regression might be useful in deciding the capacity ratio.

The multiple regression problem can then be formulated as follows:

$$T_{11}X_1 + T_{21}X_2 + \ldots + T_{n1}X_n = I_{.1}$$
$$T_{12}X_1 + T_{22}X_2 + \ldots + T_{n2}X_n = I_{.2}$$
$$\vdots$$
$$T_{1j}X_1 + T_{2j}X_j + \ldots + T_{nj}X_n = I_{.j}$$

where $I_{.j}$ = the time length of the measurement interval j, T_{ij} = the amount of time used by ith product during the measurement interval j. Notice that $I_{.j} \neq \Sigma T_{ij} = \Sigma(PT_i + ST_i)_j$. By forcing the equation to be held and run the multiple regression, the coefficients X_i gives the capture ratio:

$$CP_i = 1/X_i$$

and given a measured T_i for the ith product, the allocated machine hours is

$$T_i' = T_i/CP_i = T_iX_i$$

Then allocate the overhead based on such scheme gives:

$$\text{Overhead allocated to i} = \text{OH} * (T_i' / \sum_{i=1}^{n} T_iX_i)$$

This method sometimes has a serious convexity problem: there is no guarantee that the solution $X_i \geq 1$, so that the capture ratio is smaller than or equal to one.

The problem occurs in particular if products with small machine hour measurements are included in the model. This is related to a second problem: a multiple regression only makes sense if there is enough independency between the various X_i. Hence, only large, independent production or service processes should be modelled. Sometimes, the problem can be solved using an intercept term in the model, which acts as a noise factor:

$$T_{11}X_1 + T_{21}X_2 + ... + T_{n1}X_n + Z = I_{.1}$$
$$T_{12}X_1 + T_{22}X_2 + ... + T_{n2}X_n + Z = I_{.2}$$
$$\vdots$$
$$T_{1j}X_1 + T_{2j}X_j + ... + T_{nj}X_n + Z = I_{.j}$$

Then allocating Z and calculating the capture ratio as

$$CP_i = T_{ot} / (X_i * (T_{ot} + Z))$$

whereby

$$T_{ot} = \sum_i (\sum_j T_{ij}) * X_i$$

which reduces to the previous solution for Z=0. The overhead allocation is then again the same as before.

This method is applicable when firms can mearsure each product's consumption of capacity at different intervals. Each interval $I_{.j}$ includes process time, setup time, and wasted time.

Method 3.

This method assumes that the non-capture capacity is best distributed on the basis of the interrupt-generating events in a production system such as processing time and setup time. This method is different from method 2 in the sense that method 2 accumulates the data interval by interval, while method 3 accumulates the data on the product basis.

Given

$$F_i = PT_iX_i + ST_iX_i$$

where X_i = coefficients of each event time. It reflects the relative importance of each event.

$$F_{tot} = \Sigma F_i$$

Then the ith product receives the following IT portion:

$$IT_i = (F_i/F_{tot}) * IT$$

Hence the total traced capacity time for ith product is given by:

$$T_i' = T_i + (F_i*IT/F_{tot})$$

and the cature ratio for the ith product is given by:

$$CP_i = T_i \ / \ (T_i + (F_i * IT/F_{tot}))$$

Then the overhead costs allocation is

$$\text{OH allocation to } i = [OH \ / \ \Sigma(T_i/CP_i)] * T_i' = OH * (T_i' \ / \ \Sigma T_i')$$

The advantage of this method is that it assigns each capacity consumption event a relative importance coefficient in deriving the capture ratio for each product. Consequently, the allocation of overhead costs is affected by such strategy. For example, given a high coefficient to the setup time (ST_i) of product i, the capture ratio of that product is reduced, and more overhead cost is allocated to that product. Such allocation strategy can punish those product occupying the capacity for non-productive (or non-value-added) activities.

In summary, in a digital controlled or CAM production environment, the capacity utilization is always difficult to measure. Using the capture ratio to measure each product's bearing rate of capacity and allocate overhead costs based on capture ratio can improve the product costing (a step closer to "real and efficient costing"). All three methods are applicable to overhead allocation based on different situations. However, as soon as the capture ratio is estimated, the overhead costs allocation can be allocated more easily.

Conclusion: the significance of implementing LP and CR method

With the introduction of high-tech into the production and manufacturing fields, the capacity is expanding rapidly and the capacity costs form a large part of the overhead costs. Since the costing accuracy directly affects the decisions on pricing, performance evaluation, production planning...etc, a measurement toward "real product cost" is critical. On the other hand, a costing strategy should aid the firm toward efficient and productive management. The activity based costing (ABC) system does not solve the problem of over capacity cost allocation. Therefore, a remedy might be necessary to improve the ABC system.

The linear programming and capture ratio methods can greatly improve the cost-efficiency. Particularly, when a large portion of the total cost consists of overhead costs, both methods can help the firm to define the constraints of capacity, as well as provide the basis for overhead allocation. Using the LP model, firms can allocate the overhead based on the bottleneck usage of each product, therefore increase the efficiency of constraint capacity usage and maximize the throughput value of the whole system. The CR method is more efficient in the digital control manufacturing and CAM. Especially, if a firm is confronted with idle capacity problem and the allocation of the idle capacity becomes difficult, the CR method can be applied to allocate the idle capacity to each product.

LP and CR models are applicable in different situations. When the capacity utilization is stable, consistent and smooth across a certain range of time, LP can be used to define the capacity utilization and applied in overhead allocation. On the other hand, when the capacity utilization is very fluctuating, inconsistent and remains within given production constraints, the capture ratio method might be ideal to define the capacity used (captured) and allocate the overhead accordingly. For example, if a firm has seasonal demands on the production, it also associates with seasonal idle capacity. To define the average or normal capacity usage is difficult. Therefore, the capture ratio is useful in deciding the capacity utilization and overhead allocation.

When a firm produces a large volume of products, or when a firm has a mass production process, the LP model is more appropriate in both capacity utilization definition and overhead allocation. On the other hand, when a firm has small order, low volume production, or when a firm is in the job-order production situation, the capture ratio method is appropriate. Because in the low volume production firms, the interrupts of the production are much more frequent. The third method of CR is therefore applicable.

In summary, both LP and CR models are very useful in defining the capacity utilization and the associated overhead allocation strategy. Our future research will focus on either the simulation or field study to test the applicability of both models.

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