Chapter 12

DECISION SUPPORT

1. INTRODUCTION

The president opened this session reminding those present that the objective is to work as a team and supplement each other, and not to argue about who contributes more to company success. Our group deals with production technology. The topic of this session is management contribution to cost reduction. This topic was proposed by production manager director, and let him now explain what he means by that.

Mr. PM: We had a good discussion regarding cost reduction by enhancing production planning methods. However, in all proposals and methods we were constrained by management decisions. I propose that in this session we will elaborate on this issue.

Manufacturing system is basically an engineering system. It can assist management by supplying information and simulations needed to make decisions of an engineering nature, such as resource planning, expansion of the manufacturing capabilities, and introduction of new manufacturing technologies.

One of the main constraints is the available resources which constrain process planning and thus processing efficiency. Process planning is an important link in the manufacturing cycle. It defines in detail the process that transforms raw material into the desired form. More precisely, process planning defines the operations, sequence of operations, facilities for each operation, and operation details.

Our conclusion to use the process planning table method (PPTM) eased up the constraint by introducing flexibility, but it does not remove this constraint entirely. Processing efficiency establishes the plant level of performance and thus the ability to compete on the market. Processing efficiency is not the only parameter that affects competitiveness, but it is the only one that is relative to our discussion. A company that its resources are better suited to a product mix, have an edge over all other manufacturers.

Resource planning is a management task, and thus it constrains the ability of the engineering production planning stages to achieve full competitive capabilities.

The president rejects the accusation made regarding resource planning. Management of an enterprise is overwhelmingly based on economic considerations. Managing of a company calls for many economic decisions such as capital investment, product line product mix, and resource planning and purchasing. Management regards resource as one of the crucial decisions which it has to make. Management is aware that processing efficiency establishes plant level performance and thus the ability to compete. In order to make a sound decision for resource replacement management relies on economic models and techniques (e.g., total value analysis, ROI, etc.) management turns to the engineering stages with a request for the data that drive the economic models. The engineering recommendations (and economic models) are the basis for the decisions of which resource to purchase is made.

Mr. PM: The engineering data that are fed into the economic model, are those that being asked by management, and not necessarily the ones that will lead to an efficient decision. The need to make investments in resources frequently arises in order to replace old resources. The life of a resource is estimated as 10-20 years. This means that 5-10% of resources have to be replaced every year. New resources usually possess more capabilities than the old ones. Merely replacing resource numbers in the routing file will result in inefficient manufacturing methods. A sound economic decision made in the past, might not be a sound decision at present, in view of the changes and modifications occurred. If optimum processes are to be used, all company routings should be examined and new process plans prepared. However, it is impractical, by using today's techniques, to prepare a new set of process plans whenever a resource is added to the plant. It is a huge job and seldom done in general practice. Processes that might benefit remain unchanged. Thus the data fed to the economic models are incomplete.

Mr. C: An organization for operation is continually undergoing modification and changes in the product mix and quantities of manufactured products. New resources and technologies are introduced and developed. That means that sound decisions made in the past are deteriorating in time and in order to remain competitive a periodical evaluation of the resource efficiency must be made, examining our competitiveness compare to the other companies on the market or the present available technology.

Mr. PP: Such an evaluation requires much expense and work, which probably would not be economically justified. Therefore, it will be done only in cases of crisis (or value analysis) and on a limited scale.

The trend in resource development is toward computerized high-power resources and toward machining centers. The new resources are better qualified and more efficient, but their price is accordingly high. There is no doubt that employing such modern resources may save setup times, increase uptime and quality, reduces material handling, and simplified production planning. However, it is questionable whether they reduce production costs. In many cases a 35 KW machine with 5 degrees of freedom, that costs about $800,000 is employed in drilling a series of ¼" holes. Such an operation may be carried out more efficiently, by a $1000 drill press. In the metal cutting process a rough cut usually preceeds finish cut. A rough cut (in metal cutting) does not require accuracy and may be produced by an old inaccurate resource, which probably was fully depreciated. Employing modern resources for all operations no doubt will reduce manufacturing time and result in ease of managing. However, it will not always result in the minimum production cost. Therefore, re-evaluation of process planning of all products should be made and supply to management to make the decision.

Mr. CC: The process planning table method (PPTM), as was demonstrated in chapter 9 (table 9-1), solves this problem automatically. The computer program selects the sequence of operations and which resource will perform each operation. The automatic resources probably will be selected for maximum production optimization, but not for minimum cost optimization. If we based our production planning, stock allocation, production scheduling, job released, and shop floor control on the PPTM than the same tool can be used for evaluating the compatible of resources to the product mix, and it can be done by a computer program in a very short time.

Mr. C: I do not understand how the process planning table method can evaluate our competitiveness to other manufacturers. To do so we must have the routings of all other manufacturers, and I doubt if they will supply such data to us. PPTM was excellent for our production planning tasks, but not for evaluation.

Mr. CC: PPTM was partially described before by showing table 9-1 and its uses. But it did not explain how such table was constructed, or can be constructed. Let me do it now.

PPTM is part of a Computer Aided Process Planning (CAPP) program. The CAPP program is composed of three stages:

- Technology,
- Transformation,
- Decision (mathematics).

The Technology stage generates a TP - Theoretical Process. The Transformation stage constructs the table. The Decision (mathematical) stage solves the table and generates a dynamic process plan according to the immediate shop dynamic requirements.

A Theoretical Process is a fixed universal reference point. Its value is based on actual available technology. It considers only technological constraints. It assumes an imaginary resource; that is, no resource constraints are considered. Thus, the TP process plan is practical from an engineering standpoint and theoretical from a specific shop standpoint. Its value does not include set-up cost. Consequently, it is free from sales, lot sizing, grouping, and scheduling effects. It is a theoretical value that most probably will never be achieved. However, it is a fixed value, representing the state of technology. The numerical value of the TP is expressed in time or cost units. The conversion from time to cost is accomplished by multiplying the processing time by hourly rate. The hourly rate for the imaginary machine can be set as the lowest hourly rate used. This guarantees that the dispersion will be to only one side of the fixed reference point.

The transformation stage constructs the process planning table. The equations for transformation are straightforward; a computer program can easily be developed to perform this task.

The content of the table is $T_{i,j}$ which is the time to perform each theoretical operation (i) on each one of the practical candidate resources (j). The theoretical operations (TP) are translated and adjusted to comply with each individual resource features. It is obvious that the machining time cannot be decreased, it may only be increased. The adjustment considers the following factors: resource physical size, accuracy, special features, available power and torque, available speeds and feeds, number of tools, type of controls, handling time etc. A resource file containing resource specifications is used for the conversion.

Solving the PPTM is a Practical Process - PP; it is a fixed specific shop reference point. Its value is based on the available resources in a specific shop. The PP is practical from the standpoints of technology and available facilities and theoretical with regard to production and capacity planning, that is, the availability of the required machine at the required time.

2. RESOURCE LEVEL OF COMPETITIVENESS

Mr. PM: Management is responsible for the available company resources; the role of engineering is merely a consultant one. When a resource is candidate for replacement, merely replacing it by another resource that performs the same operations will result in inefficient manufacturing methods. New resources call for re-evaluation of all routings. However, it is a huge job and seldom done in general practice. Processes that might benefit remain unchanged. Thus the data fed to the economic models are incomplete.

The proposal of the PPTM method can be used for the evaluation of all routings in a very short period of time and be economical. This is due the fact that with PPTM there is no fixed routing; routings are not stored, but recomputed every time they're needed. What is stored are a list of operations for each item, and a list of all available resources (at the time of generating a routing) and the computer program which devises a routing.

The resource level of competitiveness is defined as the suitability of the available resources to the company product mix. A company that has the most suitable resources has an edge in competing in the market. The level of competitiveness is defined as a machinability ratio - MR. MR is measures on a scale from zero to one, where one is the most suitable resources.

The ratio of time (cost) to produce an item with the existing resources (PP) to time (cost) to produce the part by existing technology (TP) establishes the MR is:

$$MR = TP/PP \qquad (1)$$

Mr. PP: Can PP be supplied by a process planner and not by the PPTM system?

Mr. PM: No; PP must be computed by the PPTM system. Remember that the method measures company efficiency and not specific process planner expertise. To rank process planner level of expertise we may compare his routing (MPP - manual process planning) to PP:

$$\text{Process planner rank} = MPP/PP \qquad (2)$$

Mr. PS: I do not understand how this equation can establish the company level of competitiveness, as it is based on only one item. In our company any resource is used to process many items, the computation must include all or several items.

Mr. CC: The machinability rating for several items may follow the logic of the single item resource rating equation (1). The rating is the sum of single item MR divided by the number of parts, and will have the following form:

$$MR = \frac{1}{p}\sum_{i=1}^{p}\frac{TP_i}{PP_i} \qquad (3)$$

Where MR = machinability rating, p = number of items, PP_i and TP_i = practical and theoretical processing time of item i.

Mr. PS: Equation 3 is an improvement, but it ignores the quantity effect. It does not make sense that all items are produced with the same quantity. Can the equation be further improved?

Mr. CC: You are right, to consider the quantities of each item, a modification to equation 3 is made. MR is replaced by MRQ, were each individual item gets a weight according to its quantity. To arrive at MRQ for an individual item, its MR is multiplied by its quantity. The sum of the individual MRQs is divided by the total quantity to arrive at the company MRQ value. Thus, the equation is:

$$MRQ = \frac{1}{\sum_{i=1}^{p} Q_i}\sum_{i=1}^{p}\frac{TP_i}{PP_i}\times Q_i \qquad (4)$$

MRQ represents the routing efficiency of product mix of p items (not products).

Mr. F: I am not sure that the averages have any practical meaning. More important is to know the effect of each order, or each item separately. Such data may be used to determine which items are best suited to our available resources, which are not. Furthermore, the company might have the best resources for producing items, considering the quantities, yet its competitiveness might be jeopardized by resource idleness, i.e. not having enough loads to keep it occupied. To arrive at overall optimization, management must have a load profile and data on resource utilization.

Mr. CC: At your request we will define machine utilization rating - MUR. MUR is defined as the load rating. Single resource load rating is defined as the resource load to the “maximum load resource” value. Load is defined as the processing time on the resource. This definition is best explained by an example.

Table 12-1. Routine for part "sample"

Operation	Resource	cost	time
010	4	1.62	1.62
020	1	2.13	0.71
030	5	3.52	1.76
040	2	10.32	7.37
Total		17.59	11.46

Table 12-1 gives the PP process, it calls for four operations and four resources, the processing time and cost of each operation is specified. The load on resource 2 is the greatest; hence it is the "maximum load resource". Therefore MUR on resource 4 is 1.62/7.37= 0.22; resource 1 is 0.71/7.37=0.096; resource 5 is 1.76/7.37=0.239; and resource 2 7.37/7.37=1.00. The average load (if it has any practical meaning is (0.22+0.096+0.239+1.0)/4=0.389.

Mr. PM: Let have an example of the method, and follow Mr. F note; the most useful data to management is the rating of individual item, and individual resource. Table 12-2 demonstrates an example of computing item and resource rating, for individual and the average.

Table 12-2. Example of computing MR and MUR

Item	TP	R1	R2	R3	R4	R5	R6	PP	MR
1	7.37	0.71	7.37		1.62	1.76		11.5	0.67
2	12.3	2.28	9.4	5.93	4.78	5.6		28.0	0.44
3	4.80		3.21	2.83	3.15	1.24		10.4	0.46
4	17.5	6.25	8.65	9.64	6.38		12.5	43.4	0.40
5	13.5		4.03	7.83	4.38		1.51	17.7	0.76
6	14.9	3.89		11.1	8.76	4.58	8.05	36.4	0.41
∑	time	13.1	32.7	**37.3**	29.0	13.2	22.1	∑	3.14
MUR		0.35	0.87	1.00	0.78	0.35	0.59	MR	0.52

These results can be presented to management as a diagram, as shown in Fig. 12-1.

Engineering are not economist experts; their task is to supply data to management, as the one proposed here, at let management make decisions. The decision might be to change the product line, push sales of slow moving products, or purchase new manufacturing resources.

Mr. F: The order quantity has an effect on the processing time and thus on resource utilization time, but I notice that it was not taken into consideration in the rating.

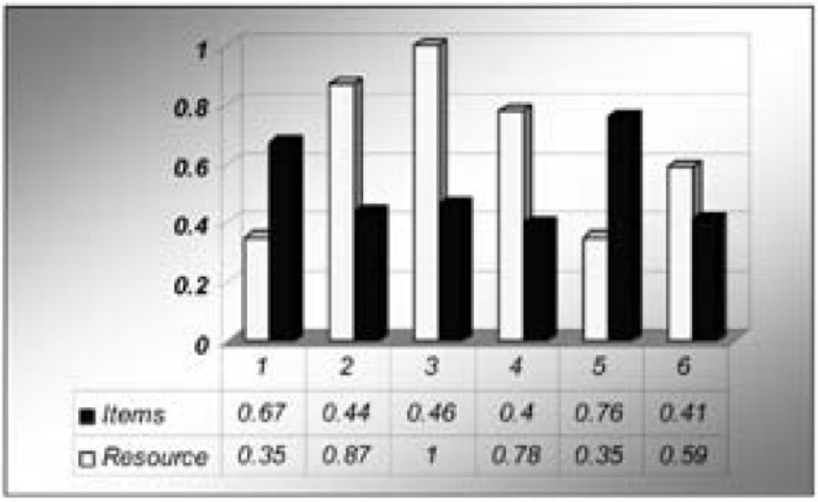


Figure 12-1. Items and resource rating

Mr. PM: the quantity is not an engineering data, and it is a variable. The proposed example is the framework of computation. Management may add the quantity to the equation and the table, and then compute the utilization rating.

3. RESOURCE PLANNING

Mr. PR: When the need to purchase a new resource arises, a list of alternate resources is assembled, usually based on catalogs, vendor information, and specification of old resources, or random choices. We issue to the candidate a request for quotation. The quotations are returned to the process planner for evaluation.

Mr. PP: We evaluate the proposals, generate a process plan for each resource and transfer recommendations to management for economic decision, and then back to purchasing to negotiate terms with the selected supplier.

It would take quit a lot of time, cost and effort to evaluate all the alternate resources, and the effort would probably not be economical. Therefore, the process planner proposes a limited number of alternatives (if at all) and let the economist decide which one of them to select. Hence, the "best" alternative might not be even being considered, and a biased decision might be reached.

Mr. PR: We are at execution stage; our objectives are to obtain the required items and resources, at the required quantity and quality at the right time. It is not for us to question why the need is specified. Our decisions are concerned with selecting a supplier subject to the optimization criteria of quality, quantity, delivery date, and cost.

Mr. PS: We have to work with the given resources, routings. Once the process planner makes a decision, it becomes a constraint. An artificial constraint; they are in effect only because of the sequence of decisions made. Another decision might result a different set of constraints, and therefore results in a different schedule.

Mr. C: The method described is quite discouraging; each stage is doing his task efficiently, but the total system suffers from artificial constraints that prohibit the competitive effort. How can we eliminate artificial constraints?

Mr. CC: The concept of PPTM that we discussed before was developed to overcome the problem of artificial constraints. By this concept a process is generated using only real constraints. By employing the theoretical process - TP concept, the process planner generates a process plan in the usual way, but using an imaginary resource.

The TP process is theoretical from a specific shop viewpoint, but it is practical from a technological standpoint. It does not violate any physical or technological rule. In this sense the TP indicates the most desirable resource characteristics and features. The term "imaginary resource" might be ambiguous and frightening. It is a resource with unlimited power, with infinite speed etc. However, one does not have to be alarmed. The "imaginary resource" is the resource that possesses the requirement specifications to perform the TP process plan. Several operations are required to produce a part. There are rough operations that require heavy forces and limited accuracy, while finishing operations require light forces but a significant accuracy. The process considers many real constraints such as part specifications, part shape and strength, fixture etc. Therefore most operations will require commercially available resources, and only few operations might require special resources.

Each operation specifies the power, moment, forces, speed, revolutions per minute, feed rate, size of part, the accuracy required by the operation etc. These data are actually points to the "best" characteristics that a resource should possess, in order to perform the particular operation in the most economical way.

Therefore, the needs of the individual TP operation will be used as a specification for RFQ - Request for Quotation that will be distributed to suppliers.

Mr. PP: To evaluate the proposals, I may use the PPTM method to generate a routing, but instead of using available resources the RFQ proposals are used as the available resources.

At this stage the characteristics of each individual resource are known by the quotation received. Adjustment of the theoretical operation for each individual resource can take place and the process planning table is ready to generate routings. By using PPTM the solution is transferred from a technological problem to a mathematical one. This method can be used to generate alternative routings. An alternative routing is generated by ignoring a resource from the table and re-computing a routing. The financial planner can generate as many alternatives as he or she desires. Such alternatives can be put into a spreadsheet to compute the optimum investment according to company policy.

Mr. F: The economic model may vary from one plant to another. However, the basic data that goes into the model are similar. The required general data might include: machine cost, finance cost, installation cost, maintenance cost, energy consumption cost, labor cost, life cycle, etc. These data are available from the quotation supplied by the machine manufacturer and plant economic accumulated experience. The required technical data include the machining time per part, the cost of machining a part can be furnished by the process planning table.

In resource planning application, the target is to evaluate cost - performance of alternative resources. The role of the process planning table is to supply objective data to management, who will make the decision. To accomplish this task the computer program is programmed to generate many alternative processes, using different resources, and different criteria of optimization, different lot sizes, and penalties. The purpose of generating the alternatives is to prepare data that reflect machining time and cost as a function of the investment in purchasing a new resource.

For demonstration purposes assume that the RFQ proposed six resources, their purchasing cost is specified, and assume that processing hourly rate is proportional to the purchasing cost.

The assumed relative purchasing cost is as follows:

RFQ#1	RFQ#2	RFQ#3	RFQ#4	RFQ#5	RFQ#6
1.0	0.5	1.5	1.3	0.7	0.3

The process planning table generated 10 alternatives as shown in table 12-3

Table 12-3. Alternative resources

Alternative	Resources	Total time	Total cost	Relative investment	Coefficient of investment
1	5	9.64	6.75	0.7	233%
2	6	32.32	9.70	0.3	**100%**
3	3; 5	**7.66**	8.00	2.2	733%
4	2; 3; 5	8.50	7.45	2.7	900%
5	5; 3	9.09	8.18	2.2	733%
6	6; 3; 5	12.45	8.32	2.5	833%
7	2; 5	8.65	**5.39**	1.2	400%
8	5; 2	9.74	6.61	1.2	400%
9	6; 2; 5	13.10	6.76	1.5	500%
10	3; 2; 5	8.81	6.93	2.7	900%

The "Relative investment" gives the relative cost of the resource RFQ that has to be purchased. If more than one resource RFQ is used in the alternative then the sum of the relative cost is given. For example alternative 1 requires only resource 5 whose relative cost is 0.7. Alternative 4 requires the use of resource 2; 3; 5 therefore its relative cost is the sum of these three machines 0.5+1.5 + 0.7 = 2.7.

The "coefficient of investment" column is the cost relative to the minimum cost of investment. The smallest relative machine cost is that of resource 6 which is 0.3, and is regarded as the 100% investment. All other alternative "coefficient of investments" are computed relative to this minimum value. Hence alternative 2 will be 100%, the minimum required investment. While the investment for alternative 4 (or 10) is (2.7/0.3) x 100 = 900% meaning 9 times that of the minimum investment.

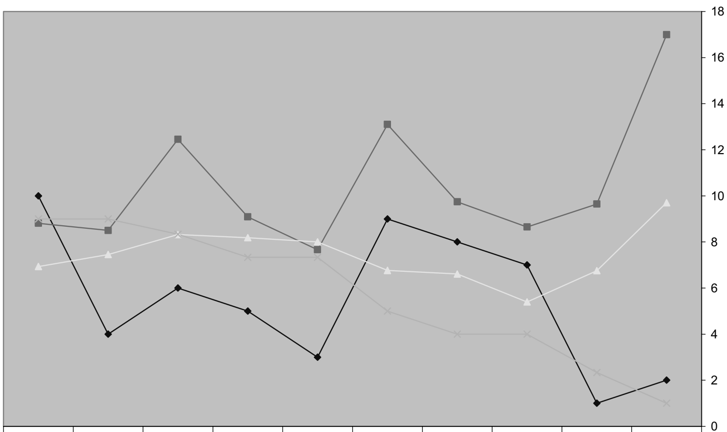
The effect of the amount of investment on machining time and cost, is shown in Fig. 12-2 sorted by investment cost.

Mr. C: Examining the data in table 12-3 and the Fig. 12-2 reveals some astonishing facts; increase in investment by no means assures better optimum (alternative 7). Furthermore, it indicates that the "best" machines for the maximum production criterion of optimization (alternative 3) are not the same as for minimum cost criterion.

The data clearly indicates that there is no direct correlation between the investment and optimum process plans. Alternative 2 is the lowest relative investment and the process the gives the worst machining time, four times longer than the optimum machining time (32.32/7.66 = 4.22); however, it may result in one of the two best investments from the ROI standpoint.

Mr. CC: It seems that management will have a challenging task in deciding which resources to purchase. Comparing the minimum time (alternative 3) to the minimum cost (alternative 7) indicates that increasing the machining time by 13% (from 7.66 minutes to 8.65 minutes) will reduce machining cost by 67%, (from $8.0 to $5.39) and the investment may be reduced by 55% (from 733% to 400%).

The decision as to which resource to purchase must consider many parameters. The PPTM method is not intended to make an economic decision; its sole purpose is to supply sound engineering data to the decision makers.



	10	9	8	7	6	5	4	3	2	1
Alternative	10	4	6	5	3	9	8	7	1	2
Processing time	8.81	8.5	12.45	9.09	7.66	13.1	9.74	8.65	9.64	16.99
Processing cost	6.93	7.45	8.32	8.18	8	6.76	6.61	5.39	6.75	9.7
Relative investment	9	9	8.33	7.33	7.33	5	4	4	2.33	1

Figure 12-2. Relationship of Investment to machining time and cost

Mr. PM: The utilization time of each resource can be crucial in making a decision. This information is also immediate available from the solution of the PPTM. Naturally, this figure is a function of the quantity required. The PPTM solution handles the unit time and cost. The quantity affects the (penalty) but not the direct machining time. However, the total utilization time per a period can be computed.

Mr. PS: Naturally, the total required quantity has to be taken into consideration. For a very low quantity resource 6 (alternative 2) will probably be preferred. For higher quantity resource 5 (alternative 1) should be preferred. However, if single resource 5 cannot handle the load, then 2 resources 5 are needed. In that case, it is better to purchase one resource 5 and one resource 2 thus reducing the investment from (0.7 x 2=) 1.4 to 1.2. The best combination may be decided by examining the data in table 12-3 and figures 12-2.

Mr. FM: It is unlikely that any single item will supply complete load to any resource and balanced the load for several resources. Increasing load and load balancing may be done by considering other items. Therefore, considering many items in one run is preferred. The parts might all be from one new product, or parts already in production.

The president thanks the participants in this session. It is management's responsibility to make resource planning decisions; however the proposed method allows management to work with a computer model that will supply engineering data, in any desired form, instead of calling the engineer each time information is needed. Different plants will use different economic models. Therefore, we regard the proposed method as a data generator and not as a recommended mode. The method by which the table presents the data may vary from one plant to another. Additional data, if required, may also be retrieved from the PPTM format method.