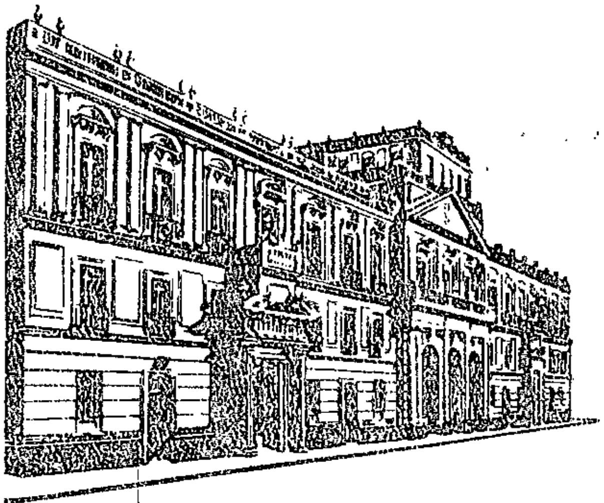

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78

SEMINARIO DE ACTUALIZACION EN ADMINISTRACION DE PRODUCCION E INVENTARIOS

Duración: 24 h
Fechas: del 8 al 13 de Mayo
Horario: lunes a viernes de 17 a 21 h
y sábado de 9 a 14 h
Coordinador: Ing. Francisco J. De Regil

En colaboración con la Sociedad Americana de Control de Producción e Inventarios

centro de educación continua
división de estudios superiores
facultad de ingeniería, u n a m

A QUIEN VA DIRIGIDO

A Ejecutivos en las operaciones de la empresa que necesitan conocer mejor el enfoque moderno de la administración de producción e inventarios. Igualmente a ejecutivos de otras especialidades que necesitan obtener una comprensión adecuada sobre producción e inventarios.

OBJETIVOS

Proveer al asistente los conceptos fundamentales y las técnicas y prácticas sencillas que le permitan identificar, comprender y analizar los problemas de su empresa relacionados con la obtención de máximo servicio a los clientes, máxima eficiencia de la operación y mínima inversión en inventarios.

NATURALEZA

En este seminario se parte de la premisa de que los recursos son siempre limitados y que la empresa que desea vivir saludablemente y triunfar en su campo debe optimizarlos, independientemente del tipo de producto que proporcione.

Esta premisa es excepcionalmente válida en el área de administración de materiales ya que la inversión y el gasto en estos es generalmente cuantioso y en muchas empresas ambas partidas son las de mayor importancia económica.

El desarrollo sobre estos conceptos, técnicas y prácticas ha sido explosivo en los últimos años, tanto por el empuje que dió la investigación de operaciones como por los medios masivos de manejo de información que cada día se instalan en mayor número de organizaciones. Muchas técnicas antiguas bien conocidas han sido modificadas o superadas y otras nuevas han hecho su aparición para crear un nuevo enfoque coherente de los conocimientos.

ESTRUCTURA BASICA

El énfasis en conceptos fundamentales permite al asistente relacionarlos con los problemas díarios de su trabajo y el énfasis en técnicas sencillas le permite comenzar una aplicación inmediata.

Así mismo, el abordar diversos aspectos de la problemática involucrada en el ejercicio de las funciones primordiales, de la administración de producción e inventarios, le proporciona una visión de conjunto que permite apreciar la interrelación de las partes en un buen sistema formal que ayude a la empresa a alcanzar sus metas fijadas.

TEMARIO

1. LA MISION DE LA ADMINISTRACION DE PRODUCCION E INVENTARIOS
2. PREPARACION Y EMPLEO DE LOS PRONOSTICOS EN LA ADMINISTRACION DE PRODUCCION E INVENTARIOS
3. LAS CLASIFICACIONES DEL INVENTARIO
4. ADMINISTRACION DE INVENTARIOS
5. ADMINISTRACION DE ALMACENES
6. PLANEACION DE PRODUCCION
7. LA PLANEACION DE REQUERIMIENTO DE MATERIALES (MRP)
8. LA PLANEACION Y CONTROL DE LA CAPACIDAD
9. EL CONTROL DE PISO
10. INFORMES DE DESEMPEÑO Y SISTEMAS

PROFESOR

ING. FRÁNCISCO J. DE REGIL

Nota: Este curso puede servir como base para presentar un examen y obtener un certificado de conocimientos que otorga la Sociedad Americana de Control de Producción e Inventarios.

Los cursos tienen cupo limitado.

Es recomendable inscribirse con oportunidad pára garantizar su asistencia.

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El control de asistencia se llevará a cabo a través de la persona encargada de entregar las notas del curso. Las inasistencias serán computadas por las autoridades del Centro, con el fin de entregarle constancia solamente a los alumnos que tengan un mínimo del 80% de asistencia.

Se recomienda a los asistentes participar activamente con sus ideas y experiencias, pues los cursos que ofrece el Centro están planeados para que los profesores expongan una tesis, pero sobre todo, para que coordinen las opiniones de todos los interesados constituyendo verdaderos seminarios.

Es muy importante que todos los asistentes llenen y entreguen su hoja de inscripción al inicio del curso. Las personas comisionadas por alguna institución deberán pasar a inscribirse en las oficinas del Centro en la misma forma que los demás asistentes, entregando el oficio respectivo.

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SEMINARIO DE ACTUALIZACION EN ADMINISTRACION DE PRODUCCION E INVENTARIOS

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Coordinador Educacional en la
República Mexicana de la
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SEMINARIO DE ACTUALIZACION EN ADMINISTRACION DE PRODUCCION E INVENTARIOS

INDICE DE ARTICULOS

MAYO, 1978

Palacio de Minería Calle de Tacuba 5, primer piso México 1, D. F. Tel.: 521-40-20 5 Líneas

REQUIREMENTS PLANNING SYSTEMS

JOSEPH A. ORLICKY
IBM Corporation

INTRODUCTION

When it comes to managing inventories, there are two alternate basic approaches, or two sets of techniques, that can be employed in a manufacturing enterprise. They are:

1. *Statistical Inventory Control* (also called Order Point techniques – I will use these terms interchangeably)
2. *Requirements Planning*

Order Point is part-based, whereas Requirements Planning is product-oriented. Order Point utilizes data on the historical behavior of a part, while Requirements Planning ignores history and instead words with data on the relationship of components (the bill of material) that make up a product. Order Point looks at the past. Requirements Planning looks toward the future (as defined by a manufacturing master schedule).

Both types of these inventory management techniques are in current use, but Order Point predominates. The reason for this is historical, and the field has been conditioned in favor of statistical inventory control. The pioneering theoretical work in inventory management that has been done during the past decades is generally confined to the areas of Order Point and Order Quantity.*

Prominent examples of this fact are publications by such authorities as Evert Welch, Bob VanDeMark, Arnold Putnam, and Robert G. Brown.

This work (and the word of others) has been stimulated by the fact that problems of Order Point and Order Quantity lend themselves to the application of mathematical/statistical methods – which have been known, and available, for quite some time. The inventory control problem was perceived as being essentially mathematical, rather than one of massive data handling, the means for which have been unavailable in the past.

This tradition persists, despite the recent dramatic advances in computer technology, which removed all obstacles to the kind of data handling and data manipulation required for inventory control purposes. Statistical Inventory Control still dominates literature and academic curricula. In this case, the literature and curricula are so unbalanced that the subject of Requirements Planning is virtually excluded and ignored. This is so, probably because the mechanics and applications of requirements planning techniques are considered vocational rather than scientific, and pedestrian rather than sophisticated.

Order Point is a fundamental concept of inventory management, and I stress that its techniques are entirely valid. But Order Point does not always work, because that depends on *where* you apply it. Order Point specialists tend to create the illusion of universal applicability, which fosters misapplication. The fact is that in a manufacturing industry environment the applicability of Order Point technique is quite limited, which I hope to demonstrate convincingly a little later on. Disappointing results of inventory management in many companies are directly traceable to misapplication of this kind.

* See, however, "Order Point or not to Order Point," by O. W. Wight, Prod. & Inv. Mgmt. Journal, November 1968

I submit that, as we move into the Seventies, it is time to right the imbalance, to recognize and avoid misapplication. The time has come to strike a counterblow in favor of Requirements Planning Systems, and to highlight their superiority as an inventory management tool in companies that manufacture assembled products.

DEPENDENT-INDEPENDENT DEMAND

The fundamental principle that should serve as a guideline to the applicability of Order Point or Requirements Planning is the concept of *dependent* vs. *independent demand.* I first formulated this principle in 1965 and I would like to define and interpret it here as follows.

Control of total inventory is the sum of control actions planned, or taken, on each of the individual items comprising that inventory. When using the various inventory analysis or classification techniques, people examine the various attributes of the individual parts, e.g., cost, lead time, past usage, etc., but an all-important attribute, namely, the *nature* of demand, is usually overlooked.

It is my thesis that the nature of demand is the key to inventory control technique selection and applicability.

Demand for a given inventory item is considered INDEPENDENT when such demand is unrelated to the demand for other items, particularly higher level assemblies or products. Demand is defined as independent when it is not a *function* of demand for other inventory items. Independent demand must be forecast.

Conversely, demand is considered DEPENDENT when it is directly related to, or derives from, the demand for other items or end products. Such demand can, of course, be calculated. Dependent demand need not, and *should not*, be forecast. It can be *determined* from the demand for those items to which it is component (as raw material or a component part).

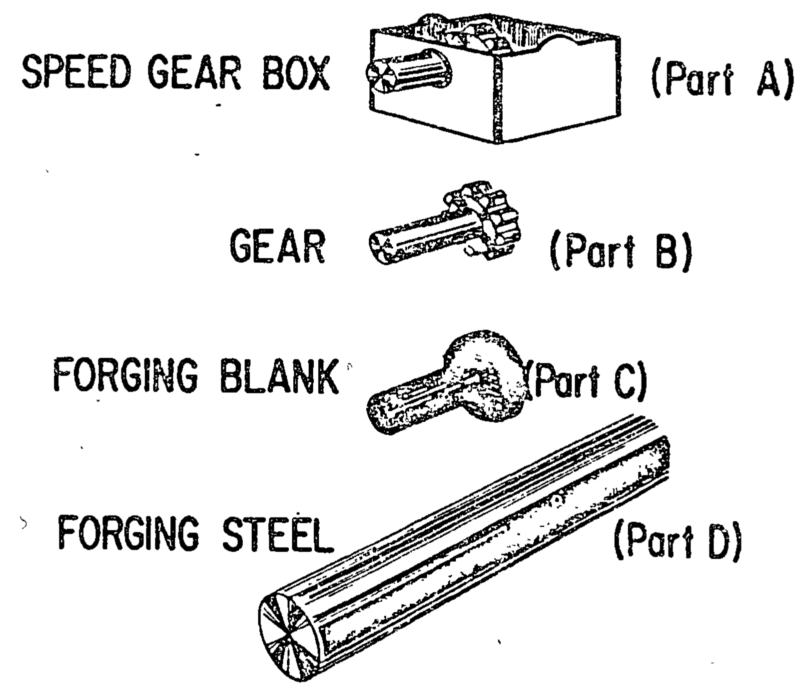

FIGURE 1

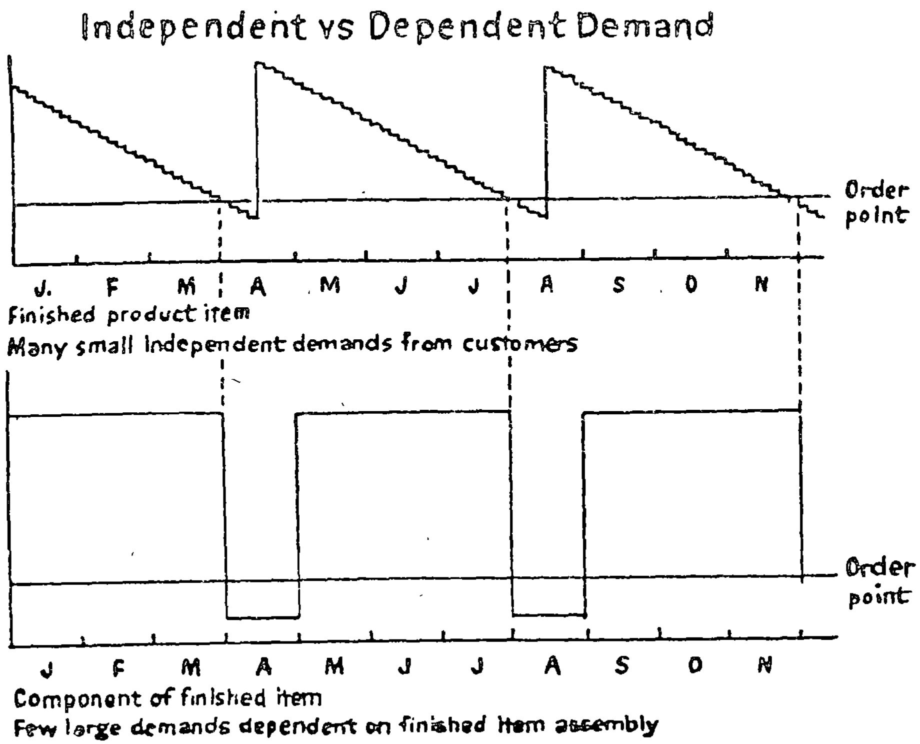

FIGURE 2

All forecasting (intrinsic, as well as extrinsic) attempts to use past experience to determine the shape of the future. Forecasting succeeds only to the extent that past performance is repeatable. But in a manufacturing environment, future demand for a given part may be quite unrelated to its past demand.

It follows then that we should not forecast unless we *have to*. When *do* we have to? When we can't extract, determine, derive it from something else. All forecasting methods are relatively unreliable. We should fall back on forecasting techniques only as a last resort. In cases of dependent demand we don't have to forecast, because dependent demand (by definition) is derivable, calculable.

In companies that manufacture assembled products we typically face the kind of relationship as shown in Fig. 1, between raw materials, semi-finished parts, components, sub assemblies and assemblies, each of which is considered as a part number in its own right, and as such represents an inventory item that must be controlled. In my example the steel is made into a blank which, in turn, is made into a gear, which then becomes one of a number of components used in assembling the gear box. We could trace this further: the gear box will "go" into a transmission, which will be used to build the final vehicle, which is also an assembly.

I should point out that the demand for the end product (or a service part) may have to be forecast, but none of its component items (including raw material) need be forecast *separately*. It can be calculated from the product forecast figures.

If I manufacture wagons, for instance, I may have to forecast how many I will sell, and when. I do not have to forecast the wheels, however. (Provided, of course, that Engineering will make available the information as to the number of wheels per wagon!)

This is certainly elementary, but my point is that the wagon wheels *can* be forecast independently, perhaps using the most sophisticated statistical techniques. Many people do, in effect, just that. The results must, of course, be less than satisfactory.

LIMITATIONS OF STATISTICAL INVENTORY CONTROL

In most manufacturing companies the bulk of inventory items (purchased and manufactured) are components of highly engineered, more or less complex, assembled end products. Statistical Inventory Control techniques *can* be applied (they possess no inherent feature to prevent misapplication) but when applied to DEPENDENT demand items, the outcome tends to be unsatisfactory, and sometimes nothing short of disastrous.

Order Point techniques are totally oblivious to the existence of possible relationship of one inventory item to other items. Order Point, in effect, looks at the past behavior of a given item in isolation from the behavior of all other items. It is as though each part had a life of its own. Sometimes, it does. But in a manufacturing company, in most cases it does not, as I have shown.

When components are ordered independently of each other, their inventories will not match assembly requirements well, and the cumulative service level will be significantly lower than the service levels of the parts taken individually. This is caused by the adding up of individual forecast errors of a group of components needed for a given assembly. Even an amateur statistician will readily confirm that if there is a 90% chance of having one item in stock when we need it, two related items needed *simultaneously* will have a combined chance of 81% of being in stock. When we get to ten items, the odds of all of them being available have dropped to 33%. (Even with the service level set at 95%, the odds on ten items would be no better than 56%).

This kind of service level would be unacceptable at the finished product level, but many companies live with such a low service level between component and assembly. This is where expediting, rush work, disruption and increase in manufacturing costs come in to compensate.

Order Point assumes relatively uniform usage, in *small increments* of the replenishment lot size. The underlying assumption of *gradual inventory depletion* in Order Point, Safety Stock, and Econ. Order Quantity will render all of these techniques invalid, when this basic assumption is grossly unrealistic.

For components of assembled products, requirements typically are anything but uniform, depletion anything but gradual. Inventory depletion tends to occur in discrete "lumps" due to lot sizing at higher levels. The example in Fig. 2 shows this clearly. You may think of the gear and the forging blank from the previous example. Gears are not made in quantities of one. When we place an order for a quantity of gears we must withdraw a corresponding quantity of blanks, which will reduce the blank inventory in one sudden swoop, likely driving it well below reorder point.

Speaking of lot sizing, Romey Everdell of Rath & Strong has pointed out that literature is obsessed with the problem of quantity (both triggering reorders and of the orders themselves), but once lot sizes are introduced at any level the question of *timing* becomes more important than the quantity – that is why you see lots being split in the shop.

Components often are not available when actually needed because they have been ordered independently of the *timing* of end item requirements. Even with high safety stock, if two or more different assemblies require an Order Point component simultaneously, it may not be available in sufficient quantity because Order Point assumes that annual demand will average out (on, typically, a weekly basis).

I might add that the square root approach in the EOQ calculation does nothing to balance out the lot size with the timing of actual requirements. For that matter, neither does it do this for the *quantity* of actual requirements. Order Point only implies timing, based as it is on average usage. Working with average usage is inappropriate in many cases, because average usage is meaningless for most practical purposes in an environment of lumpy, dependent demand. Because Order Point basically assumes continuity of demand, subject only to random variations, it also assumes

1. that it is desirable to have at least *some* inventory on hand *at all times*
2. a need to replenish inventory as soon as depleted. This is clearly *unnecessary* with

discontinuous, lumpy demand (see Fig. 2 for an example of excessive inventory carried in time of no need), and *undesirable* if inventory level is to be kept low.

Let's now take a close look at misapplication, and its results.

MISAPPLICATION

To use Order Point techniques for inventory items with dependent demand is a gross misapplication of a technique, not only in its parts but in the totality of its concept. Practically all Statistical Inventory Control techniques spring from the branch of statistics known as Probability Science, and from its mainstays, the normal distribution and the effects of random influences. Seldom is a real check made in practice to see whether the normal distribution curve adequately describes the situation in question. The most fundamental assumptions underlying the so-called laws of probability don't obtain for dependent demand items.

Some of these assumptions are:

1. The continuity and relative uniformity of demand
2. Independence of unit demands
3. Actual demand in a given period considered as random sample of the demand universe
4. Random fluctuation about the mean
5. Normal distribution of random errors
6. Gradual depletion as a result of all of the above.

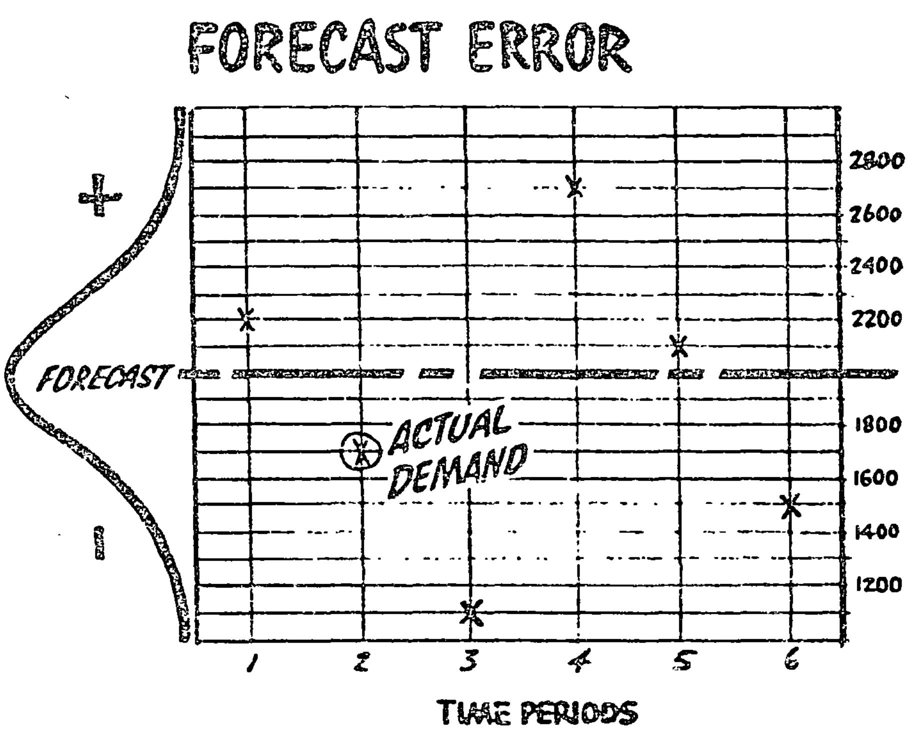

FIGURE 3

None of these assumptions fit in any degree, as far as dependent demand items are concerned. In reality, the demand is discontinuous, directly dependent on lot sizing at higher assembly levels, there is no random influence on demand whatsoever, and non-gradual depletion is the rule. It follows, therefore, that when Statistical Inventory Control is applied, the results must be completely invalid.

Let's come down to cases:

1. *Safety Stock*

The function of safety stock is to assure a desired level of service, by compensating for the forecast error. This error is expressed in standard deviations (also in mean absolute deviations or MAD) from the mean. The example in Fig. 3 comes straight from a textbook and it shows the normal distribution curve, which implies randomness of error. Because of known properties of the area under the curve, we can calculate the likelihood of occurrence, and set safety stock accordingly.

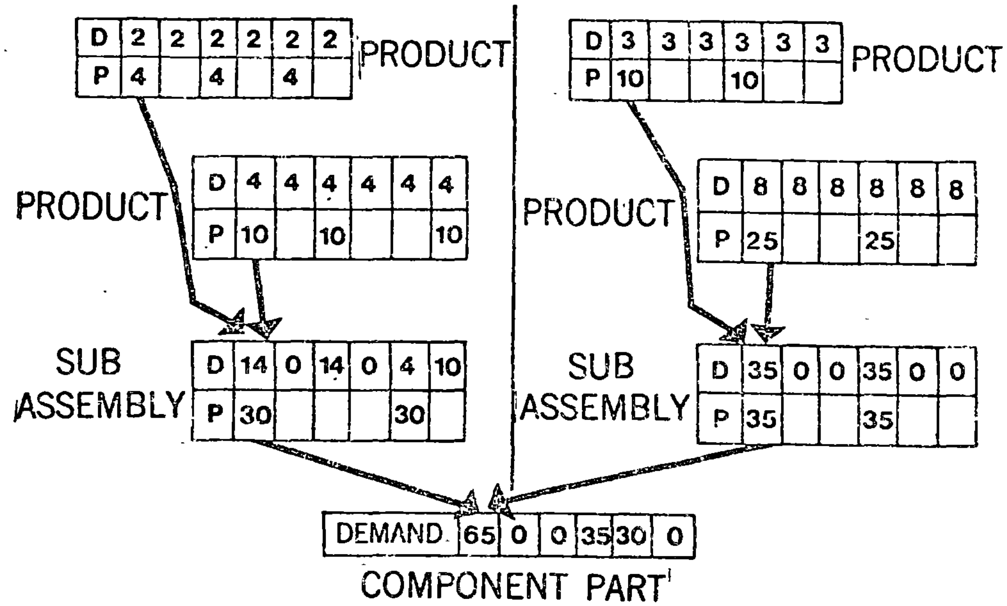

FIGURE 4

But if the scatter of actual demands is caused not by random factors but by the dependence of demand, the whole approach is totally invalid. Consider that the forecast (heavy broken line in Fig. 3) itself is a mean of presumably random past demands, and the safety stock leans on both this mean and the probability of deviation from it!

Safety stocks *can* be set this way for dependent demand items, but to claim that they have been set scientifically would be absurd.

2. *Order Point*

Order Point is determined by forecasting demand during replenishment lead time, and by adding that on top of the safety stock quantity. Randomness of demand during lead time, and gradual inventory depletion are the main assumptions here.

3. *Order Quantity*

The derivation of the EOQ formula assumes gradual depletion (see saw-tooth graph in any EOQ text), therefore figures the average lot size inventory to be one-half of order quantity. The classic EOQ equation also projects past usage into the future – a questionable procedure for (dependent) components.

I myself have in the past done enough work on, and with, EOQ to be able to state that the only element of the formula which is really accurate in any case is the "2" in the numerator. It is interesting to note that a whole literature is devoted to making just a little more accurate what is a conglomeration of inaccuracies in the first place.

DEPENDENT DEMAND AND EXPONENTIAL SMOOTHING

$$\left(\text{NEW FORECAST} = \text{OLD FORECAST} + \propto \left[\text{LAST DEMAND} - \text{OLD FORECAST}\right]\right)$$

FORECAST	14	24	19	15	19	21
DEMAND	65	0	0	35	30	0

FIGURE 5

Average demand = 17
$\propto$ = .2

EXAMPLES OF MISAPPLICATION

At this point, may I demonstrate the results of misapplying Statistical Inventory Control. Fig. 4 depicts the relationship of a component part that is common to two subassemblies. Each of these two subassemblies, in turn, is common to two (different) assemblies or end products.

In each of the little inventory records the letter D stands for demand, P for production. Each record extends six periods into the future. Please note that the demand for these four fictitious end products is perfectly level and continuous. Each product, however, is actually being assembled in some lot quantity which is different from the quantity of demand per period. Because subassemblies will be needed every time a lot of product is assembled, we can construe the demand on the subassemblies by combining the product assembly lot quantities in the respective periods. The result is shown in Fig. 4.

The subassemblies are produced in lot quantities of their own, and the demand on their common component is derived in the same fashion. This example illustrates the principle that the demand for a component is a function of lot sizing at higher levels.

Please note what may not be readily apparent, namely that the *average* demand for the component part is seventeen per period (see end product demand: 2+4+3+8).

Having *pre-calculated* the component part demand, let's now also apply exponential smoothing and *forecast* it all over again. The forecasting technique itself is excellent where properly applicable, but here the results can only prove unsatisfactory. If we feed the data from Fig. 4 (assuming demand in immediately past period, not shown, to have been zero) into the standard equation for first-order exponential smoothing, the results will be as shown in Fig. 5. We observe that there is a rather wide disparity between the forecast and the actual demand in every single period.

This can be shown better in graphic form (Fig. 6). We see immediately that the large error between forecast and actual is *consistent.* What may require a second look is to note that where

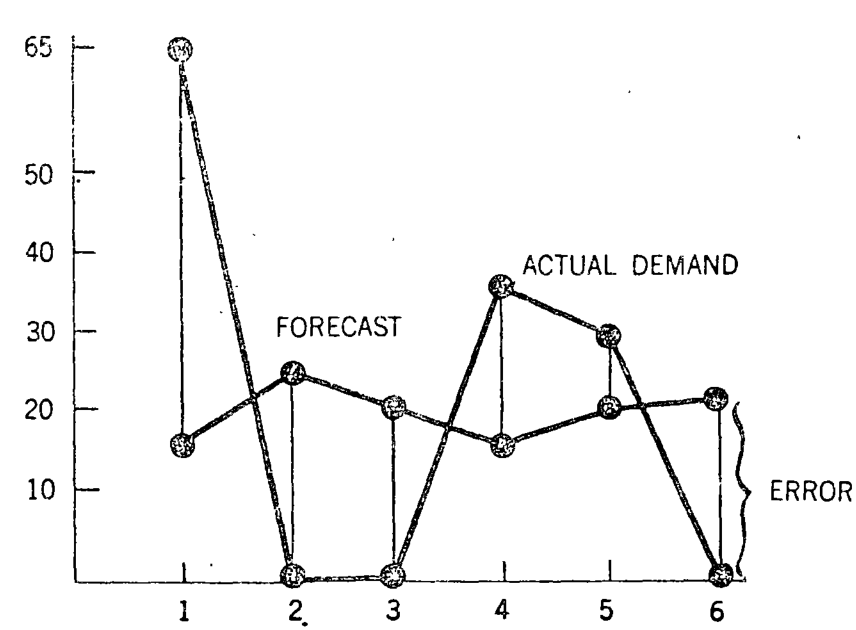

FIGURE 6

the forecast points *up* (periods 2, 5, 6) the actual demand goes *down.* When in period 4 the forecast points *down,* the actual demand goes *up.*

This is obviously worse than worthless. A roulette wheel would very likely produce better figures. It is, in fact, hard to see how a worse job could be done in this case. (Actually, making the smoothing more "sensitive" by increasing the alpha factor, will produce an error that will be consistently even larger).

In this case, if you insist on statistical forecasting, a straight average would work best. Smoothing, in any degree at all, only aggravates the situation, as anyone can clearly see on this example.

Misapplication of Statistical Inventory Control can be carried over into shop scheduling and dispatching. I know of at least two companies where what I am going to demonstrate in the next example has actually been done. This example shows an improper application of the Critical Ratio sequencing technique. The technique itself is a good, sound one. Like everything else, however, it can be misapplied and abused.

In the next example, we will use the CR formula designed to be used with Order Point inventory control, and will apply it to the component part from the previous example which, as we remember, was under Order Point control.

Fig. 7 shows the basic CR formula. The idea here is to use

1. The disparity between the order point and the "on hand" quantities as a measure of need
2. the disparity between "time remaining" and "total lead time" (i.e., percentage of completion of the manufacturing order) as a measure of response to that need.

Thus, when stock is, say, 30% below the order point quantity, the replenishment order should be 30% completed for an ideal ratio of "1", or "on schedule".

Let's now apply this formula to our component from the previous example. In Fig. 8 we assume that inventory at the start of the first period is 95, and that the order point is 60. We have superimposed the demand (known from the previous example) and have computed ratios for every period. As the first period demand reduces inventory to 30, a replenishment order is generated. At

CRITICAL RATIO – ORDER POINT

$$\text{RATIO "A"} = \frac{\text{STOCK ON HAND}}{\text{ORDER POINT}} \qquad \frac{80}{100} = .8$$

$$\text{RATIO "B"} = \frac{\text{REMAINING MANUFACTURING TIME}}{\text{TOTAL LEAD TIME}} \qquad \frac{10}{20} = .5$$

$$\text{CRITICAL RATIO} = \frac{\text{RATIO "A"}}{\text{RATIO "B"}} \qquad \frac{.8}{.5} = 1.6$$

CRITICAL RATIO VALUE

1.0	– SATISFACTORY – NO ACTION REQUIRED
LESS THAN 1	– EXPEDITE
GREATER THAN 1	– SLACK AVAILABLE

FIGURE 7

CRITICAL RATIO APPLICATION

INVENTORY: 95

ORDER POINT: 60

ORDER QUANTITY: 100

DEMAND	65	0	0	35
RATIO	.5	1.0	1.0	.0
WORK COMPLETED	0%	50%	50%	50%

FIGURE 8

that point, inventory is 50% of order point, but 0% of the work on the order is completed. The critical ratio of ".5" indicates a high priority (behind-schedule condition) accordingly.

The CR technique used here, which is designed for *gradual depletion,* assumes that generally the order will be released when the order point is reached. The ratio at that point would then equal "1", representing an on-schedule situation. In our case, however, we fell right through the order point, down to 50%, due to one lump withdrawal.

The initial ratio, therefore, shows considerable alarm at ".5" and a high priority is established The CR technique will push the order through the starting operations on a rush basis, until the ratio changes to "1" or on-schedule. This will happen when the order is 50% completed.

Because there is no further depletion in periods 2 and 3, the CR will hold the job low on the priority list, and prevent further work from being done. The order is effectively frozen until the next stock withdrawal in period 4. Then we need 35 pieces but only have 30 on hand – a stockout. At this point the disparity between "order point" and "on hand" is total. The ratio of "0" indicates highest priority possible, and the job must be rushed through on an emergency basis – after it has sat there for two periods untouched.

This is why some factory people call the CR priority schedule "the Yo-yo report." The typical reaction to this kind of performance is to conclude that the CR doesn't work, the computer system doesn't work. The starting department foreman tends to get all work "behind schedule" and then notices that the order is not being worked on later on. The finishing department foreman notices that when the orders that have just been "sitting" get to him, they are triple-rush.

I repeat that this example is based on an actual case. The people in that company said that the CR system doesn't make sense and, in that context, it does not. When misapplied, the technique does not work *for* you, it definitely works *against* you. Again: there is nothing at all wrong with the technique – if it is not grossly misapplied. Here we have seen both a wrong approach to inventory control and the wrong type of ratio being applied.

When we ponder this example, it is difficult to imagine how it could be made worse – but (like in the previous example) there is a way. Suppose we refine the whole system, make it more sophisticated. Let's introduce Floating Order Point. The order point will then shoot up in period 1, and the ratio will indicate an even higher priority. The goose eggs will pull the order point down twice successively, thus increasing the ratio and generally stopping work on the order sooner, and aggravating the whole situation at the time of the stockout.

These horrible examples of *results* of misapplication illustrate a problem that never should exist at all, yet is encountered in all too many manufacturing companies. Order Point is totally inapplicable to inventory items with dependent demand. Using statistical inventory control techniques inappropriately represents:

1. The use of a scientific method in an unscientific way
2. A sophisticated execution of an unsound plan
3. Force-fitting a technique onto a real life situation by neglecting to examine underlying assumptions

Requirements Planning Systems are the correct answer here. Such systems embody a set of rather straightforward techniques designed expressly for companies with assembled products whose parts and raw materials have a demand that is, by definition, dependent.

REQUIREMENTS PLANNING SYSTEMS

This type of inventory management system is a set of procedures and decision rules designed to determine requirements of inventory items on all levels below the end product, and to generate order action to meet these requirements.

Main input is the product forecast or the master manufacturing schedule, and the two principal files are

1. Product structure (bill of material)
2. Part master (inventory records)

Many versions of Requirements Planning Systems are in existence – crude or refined, gross or net requirements, product lot oriented, time-period oriented, etc. They differ from one another in the scope of the planning horizon they cover and in the size of the so-called time buckets into which they segment the record data. Some regenerate all requirements and allocations in every requirements planning cycle. Som. are non-regenerative (called "Net Change") in that they update old record data by processing only net changes to the previous master schedule.

These systems also differ in the frequency of re-planning. The most advanced, and most useful, version is a non-periodic, non-batch, Net Change system with time-phased (time series) requirements and an automatic order generation capability.

Because of the high data volume that must be handled by a Requirements Planning System in a company with tens, and sometimes hundreds of thousands of records, as well as because of the high frequency of re-planning, requirements planning represents a job that can only be done on a computer.

It is one of the classic computer applications, enabling us to do a job that would have been impossible, or at least quite impractical, in pre-computer days.

The best implementations of Requirements Planning Systems afford full information on

- Status
- Picture of the future demand
- Planned orders
- Currently required action

at all times up to date, for every item covered by the system. The system is "transaction-driven" (Maintained), and all affected records are automatically updated (requirements and orders re-planned) upon each pertinent change in records at higher levels.

A SUPERIOR APPROACH

Where applicable – and this includes virtually all assembled products – Requirements Planning Systems are a superior tool of inventory management, for these reasons:

1. Inventory investment is at a minimum
2. Order quantities are related to requirements
3. The *timing* of requirements, order actions, etc., is emphasized
4. System provides a look into the future, on a part-by-part basis
5. Inventory control is *action* oriented, not clerical-procedure oriented

Requirements Planning Systems are reactive, change-sensitive. They have an important built-in capability to re-examine open order due dates, which is a prerequisite to truly good dispatching and shop floor control. A sound Requirements Planning System constitutes a solid basis, a gateway, for other applications, e.g., scheduling and purchasing.

Let me quote from the APICS Special Report #2, due to be published soon. This report is based on a 1969 workshop on "Requirements Planning by Computer," sponsored by Plossl and Wight, and attended by twenty-one individuals representing thirteen companies.

"In reply to the question of whether or not the introduction of requirements planning generated benefits, the group's answer was an overwhelming 'yes.' Results can be found in four primary areas:

a. Reduction of component inventory levels
b. Improvement of customer service
c. Reduction in product cost, principally direct labor
d. Reduction in inventory and production control personnel

Company 'A' has decreased inventory by 36%.

Company 'B' has reduced component inventory by 33% Service has improved slightly.

Company 'C' has reduced inventory by 22%. Service is up approximately 20%. The number of people in inventory control handling the ordering of components has been reduced 35%.

Company 'D' has reduced component inventory by 33%. The number of late orders (this is a make-to-order company) has been reduced 90% to 95%. The cost of the product is down 7%. Indirect labor has been reduced by 25%."

THE FUTURE

During the Seventies, Requirements Planning Systems will be more widely adopted by manufacturing companies. The systems themselves will be further improved and advanced. In my view, the advanced system of the Seventies will have the following characteristics:

1. It will be non-batch, i.e., will have the capability to operate continuously, in parallel with the activities it plans and controls, which also are continuous.
2. It will be designed on the Net Change concept. It will be non-regenerative and thus always up-to-date.

(Another quotation from the mentioned workshop: "The more experienced companies at this workshop used a Net Change System and felt strongly that Net Change was the only way to go.")

3. Inventory control and requirements planning will be integrated into one function.
4. Records for all items (incl. order point items such as spare parts) will be time-phased, to permit
   a) explosion of component items and raw materials along a time axis
   b) projecting inventory into the future
   c) availability of planned-order loads.
5. System communications (and action) oriented with on-line terminals, providing timely data flow between the factory, Purchasing, vendor, and customer.

Is it desirable that we go this way in the future? Let me quote once more from the APICS Special Report: "The general conclusions that can be drawn from this workshop are:

1. Requirements Planning is a powerful tool, useful in a company making products that have components with dependent demand.
2. The tool has proven its power and usefulness by successful application in a number of companies.
3. The number of companies using the tool is a very *small fraction of those who could benefit from such use."*

This last statement is significant. As a matter of fact, it is shocking Is *your* company part of that "very small fraction"? If not, it very likely means that you could reap large benefits by changing your system over from statistical inventory control to requirements planning.

The future belongs to Requirements Planning Systems, today's Cinderella A superior tool for the management of inventories has been fashioned – therefore cannot fail to triumph.

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CAPACITY PLANNING AND CONTROL

George W. Plossl and Oliver W. Wight

George W. Plossl

When we were invited in 1971 to address the APICS International Conference in St. Louis, Oliver Wight and I selected as our topic, capacity planning and control, with the focus on machine loading. We recognized the need to prepare ourselves more fully to handle this interesting aspect of production control. While it has been around a long time, machine loading has not been well understood and is rarely, if ever, well done. During the year, we visited many companies and talked with many people who had experience using this technique. This research culminated in a two-day conference in September at Lake Sunapee to which we invited a small group to review our conclusions.

We regret that this work was not completed in time to have our presentation included in the Conference Proceedings, but we believed it more important to verify our conclusions and present the latest thinking on the subject rather than to meet a publishing deadline. We wish to thank the people who gave so freely of their time and experience to help us assimilate their knowledge gained from actually using scheduling and loading techniques. While emphasizing that we assume full responsibility for the conclusions presented, we want particularly to express our appreciation to the following men: James Burlingame, Twin Disc Incorporated; Dr. Joseph A. Orlicky, IBM Corporation; Thomas Putnam, Markem Corporation; Alex Willis, IBM Corporation; and, of course, our associates, Walt Goddard and Ernie Theisen.

There is a great deal of confusion in the meaning of the terms "Capacity" and "Load." While both are simple in concept, successful application appears to be extremely difficult in the real world; part of the problem is confusion in meaning. Figure 1 uses a bathtub to illustrate the difference. The

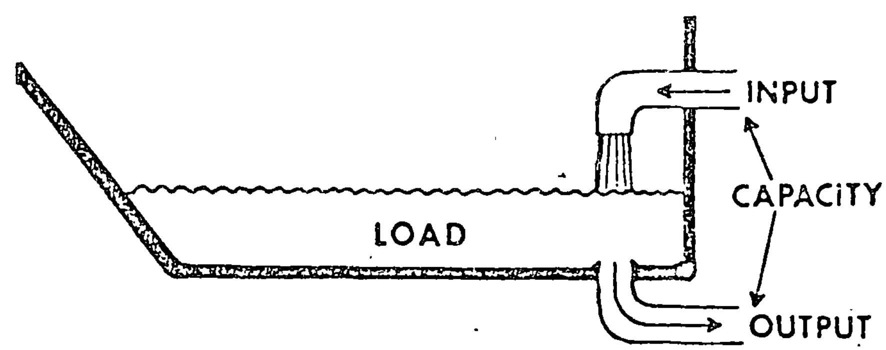

Figure 1. Load vs. Capacity

*This article was presented at the APICS International Conference in St. Louis, Missouri on November 4, 1971.

"Load" is the level of water in the tub; the "Capacity" (input or output) is the rate at which the water is flowing. These are closely related concepts but quite different in meaning.

Almost every company has tried machine loading but few succeed in really making it work. Production control people are about equally divided between the "haves" and the "have nots" and both groups appear to be equally dissatisfied. Often, in speaking to APICS and other groups, we will ask the group, "How many of you have a machine load program?" and usually between 40 and 50 percent raise their hands. Our next question is, "How many of the rest of you would like to have one?" This brings the balance of the hands up. Our third question is, "Of those having such a program, how many find that it is really being used?" and usually one or two will raise their hands. The obvious question, then, is, "Well, what do the rest of you want it for?" While it is the second oldest production control technique (only expediting has been around longer) available since Henry Gantt showed us how to make bar charts about 1903, it has had little effective use.

On the other hand, not too many companies have really tried capacity planning. Recently, however, because of the availability of computer programs, there has been a rapid growth in interest in capacity planning and more companies are attempting it now. This will be covered in more detail later.

Let's review some definitions starting with "Infinite Loading." This is really "loading to infinite capacity" and, shown in Figure 2, begins with a schedule of work orders.

The schedule is based on calculations or estimates of the elements of lead time shown in Figure 3.

Setup and running time are frequently covered by labor standards; preparation and move times can be estimated along with want-to-move times, but some rule of thumb is generally used to provide queue times. Some sophisticated scheduling systems may also include inspection time, calibration, or similar operations following completion of actual work on the product.

Infinite loading is usually based on backward scheduling, starting with the date wanted as shown in Figure 4. The total lead time calculated for operation 50 is deducted from the date wanted and this establishes the start time for this operation in its work center. In like manner, the lead times for operations 40, 30, 20, and 10 are deducted successively to set start dates in the work centers involved. These starting dates determine the time periods in which it is assumed the load will hit the individual work centers. As shown in Figure 2, the second step in infinite loading is to total up the load from all jobs in each time period for the individual work centers. Updating an infinite load is simple; completed jobs are removed and new jobs added as they are released.

Schedule Work Orders
Load Work Centers
Update - Remove Finished
Add New

Figure 2. Infinite Loading

Preparation
Setup
Running Time
Move Time
Queue Time

Figure 3. Elements of Lead Time

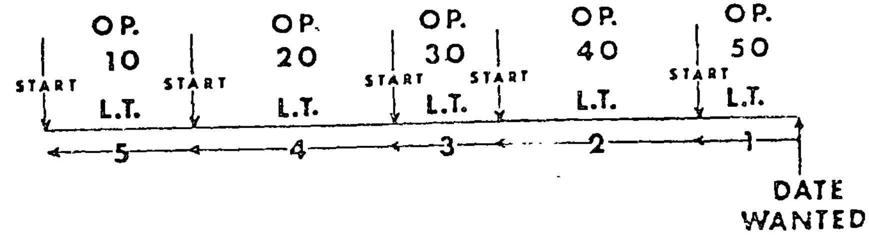

Figure 4. Backward Scheduling

Finite Loading, really "loading to finite capacity," is not simple and requires considerably more work. As shown in Figure 5, it also starts with a schedule of work orders determined in the same way as for infinite loading.

Schedule Work Orders
Set Priorities - Components
Set Work Center Capacities
Load Work Centers - in priority sequence
Reschedule overloads
Update - Start Over

Figure 5. Finite Loading

Before finite loading can begin, however, priorities must be set on individual orders. Obviously, the highest priority orders should get first claim on available capacity in each work center. The next step is to set limiting capacities for each work center. This is usually done with two values: "standard" capacity and "maximum" capacity, the latter including overtime or an added shift. The jobs are then loaded into the individual work centers in priority sequence. As soon as a work center is filled to its limiting capacity, additional jobs are rescheduled either earlier or later until they find available capacity. Because of the requirement to load based on priority, a finite load cannot be updated using the same add-and-deduct approach as an infinite load. The only way to revise a finite load is to start over, rearranging jobs in the new priority sequence and reloading.

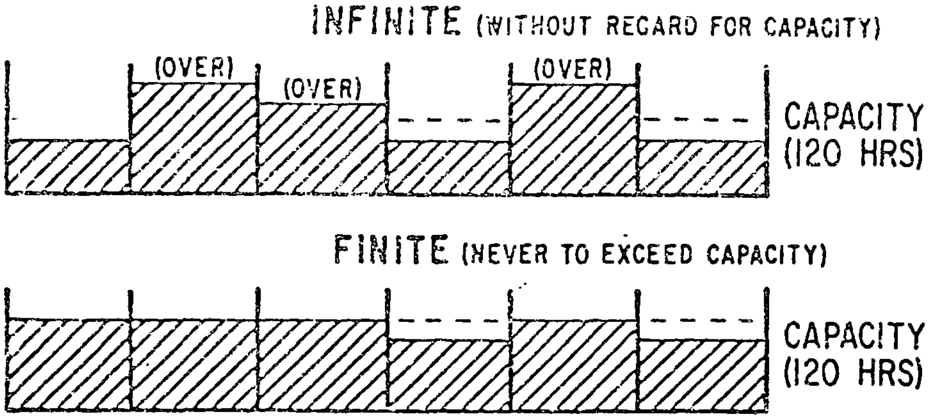

Figure 6. Loading Methods

Figure 6 illustrates the difference between finite and infinite loads. The infinite load shows both overloads and underloads because the jobs were loaded in without regard to capacity limitations. It identifies and measures these overloads in addition to showing the time periods in which they will occur. The detailed load information gives the specific jobs involved so that overloads can be analyzed. The finite load, in contrast, does not permit overloads; it reschedules jobs to earlier or later time periods. It will show underloads, however, when the full nominal capacity is not utilized.

Finite loading is supposed to develop realistic schedule dates based on priorities assigned and the capacity limitations assumed for the various work centers. It is interesting to note that if the Master Schedule covering the finished products to be assembled could be handled properly, the infinite load picture in Figure 6 would look like the finite load. In effect, then, infinite loading measures the inability to schedule properly at the end product level.

Capacity planning answers the question, "How much is enough?" showing the output required to meet the total demand forecast and also bring the total inventory to planned levels. Obviously, if the inventory is to be reduced, the factory must produce less than is shipped and vice versa. The equation in

$$I_S + P - S = I_E$$

Where: I_S = total inventory at start of planning period

I_E = total inventory at end of planning period

P = total production

S = total shipments

Figure 7.

INPUT	w 1	w 2	w 3	w 4
plan	270	270	270	270
actual	270	265	250	
dev.		-5	-25	
OUTPUT				
plan	300	300	300	270
actual	305	260	280	
dev.	+5	-35	-55	

Figure 8. Input/Output

Figure 7 is used to calculate capacity needed.

A form of capacity plan more useful for individual work centers is shown in Figure 8. Here, planned rates of both input and output are shown for future weekly periods. In this particular example, output is planned to exceed input by 30 hours each week and for three weeks to reduce the level of work-in-process inventory now in this work center. Actual data for both input and output rates are posted to the plan as they develop. Deviations are calculated for input and output and these are most useful figures. Applying these simple concepts, though, has given many people serious problems.

Oliver W. Wight

Last year, in an attempt to solve some of the problems with standard scheduling and loading techniques, I wrote a paper on a technique we've had great success with called "Input/Output Control." The concept is simple: First, for a given work center, you plan your capacity requirements; then you average these to give the foreman a level, realistic production rate; then actual production in standard hours is measured against this planned rate. This planned rate, of course, would be the "output" required. Output is simply the number of standard hours completed by the work center.

I suggested also that we should plan the input rate to a work center and measure that also; that is, measure the standard hours of work coming into that work center as well as going out. Now the reasoning behind planning both the input and the output was very simple: lead time in practically any company is a function of backlog. Backlog, obviously, is a function of the input/output relationship. If output is higher than input, the backlog will drop and the lead time will be reduced. If input is higher than output, the backlog will increase and the lead time will increase. Input/Output Control was designed to focus attention on this vital relationship.

In my article on Input/Output Control, I mentioned that, particularly for starting work centers, there is no reason—and we have done this in practice many times—why the actual input from the inventory system or the scheduling system couldn't be smoothed out. If, for example, a production rate of a screw machine work center is planned at 240 hours per week, there's no reason why planners can't smooth out the release of work rather than releasing 600 hours one week and 150 the next. If the input isn't smoothed out, larger backlogs or queues will be needed in the work center to absorb the fluctuation. I also mentioned that if backlogs started to build up in the shop, it would be better to hold work back rather than keep feeding it in. I probably should have mentioned that this would be a temporary expedient since the real cure for a backlog problem is to get the output or capacity and, if you can't get it, ultimately you will have to change the Master Schedule. So the idea behind the input/output concept was to focus our attention on the *production rates that caused backlogs and lead time problems* when they get out of control as opposed to focusing on the backlogs themselves. The I/O technique in application has proven to be very satisfactory. In retrospect, however, I do wish I had put a little less attention on leveling input to a starting work center because I think this diverted many people's attention from the real significance of Input/Output Control.

There has been a great deal of confusion in the minds of practitioners about all three of the "Capacity Planning" techniques we've discussed. The debate over infinite loading vs. finite loading has raged for years with the "infinite loaders" claiming finite loading wasn't a valid technique and vice versa. In practice, both sides have been proven partially correct; *neither technique* has been used very satisfactorily! Recognizing, then, that there has been some misunderstanding, let's look at the *apparent problems* with these three techniques:

1. Infinite Capacity Is Not Infinite

   The opponents of the infinite loading concept have objected to it because they recognize that you simply can't load work into a plant without regard for its capacity and assume that the plant is going to respond. In fact, if production control simply accepts orders and actually loads the plant to infinite capacity, they are doing little more than passing the buck. On the other hand, proponents of infinite loading have hastened to point out some serious problems involved with finite loading. Their most vehement objection has been:

2. Finite: Deliveries Will Be Extended

   Obviously, if each order comes along and is fit into the capacity available and nothing is ever done to increase capacity when an increase is required, customer service is likely to be very poor indeed. Many people have pointed out a problem with the third technique:

3. I/O Control: Difficult to Control Input

   It takes quite a bit of effort to identify all of the items the inventory system is likely to feed into a given starting work center and then to smooth out this flow. Beyond that, of course, the problems involved in smoothing out the flow of input to downstream work centers are virtually insurmountable.

Before discussing these *apparent* problems any further, let's go back to infinite loading and try to understand some of the real problems that have existed with this technique in practice a little better.

Even where practitioners using the infinite loading technique have tried not to abuse it and have tried to load their shop as realistically as possible, they have run into serious difficulties. The typical machine load report almost always shows a large backlog in the past due period. It is not only large, but it's almost always *unbelievable.* In one company, for example, 60 percent of the entire load is past due in the fabrication department, yet the plant superintendent points out that the factory is really "on schedule" since assemblies are going out the door on time.

What causes this situation? Obviously, if the machine load report says that most of the work is past due and it really isn't, little credibility will be given to this report. Its value as a capacity plan will be seriously impaired.

Really, what we see here is due to a breakdown in the "priority planning" system. By priority planning, we mean the system that puts "due dates" on orders. It tells us what material we want and when. Usually the inventory system, in most companies, does the "priority planning." This problem of establishing *and maintaining* proper priorities is a very serious one. As a matter of fact, in most companies, the "formal system" simply doesn't do it well. Nevertheless, the priority problems vary from company to company. Let us think of companies in four general categories from the point of view of *priority complexity:*

1. One Piece, Make to Order Shop

   This could be a shop that makes and sells forgings. The customer sends in an order and *he* establishes the order priority. Production control tries to fit it into the load somewhere and then acknowledges a delivery date. This becomes the priority. In this kind of company, the date due is the customer promise date. This isn't to say that the customer doesn't sometimes change this due date by requesting a reschedule. But even when he does, *it's easy to see that the due date is changed!* In the more complex types of businesses, from a priority point of view, one of the great difficulties is knowing that the priority really has changed.

In the second type of company, the priority problem becomes much more complex:

2. Assembled Product, Made to Order

In this type of company, *priorities are dependent*. Any change in the assembly schedule will mean changing the required dates for all components. Another type of rescheduling must take place when any one of the components going into a sub-assembly or assembly must be rescheduled because the original lot was scrapped, for example. There is no sense in bringing through all of the other parts when the assembly can't be put together. This is what we meant about the difficulty of recognizing a priority change. In most companies, if one part is scrapped, the original due dates remain on all other parts even though it's obvious that it would be far better to use available capacity to make some parts that could be put together into an assembly and shipped.

The third type of company has a somewhat different priority problem:

3. One Piece Product, Made to Stock

Here the problem is to update priorities, *after* shop and purchase orders have been released. A stock replenishment order, for example, is released when a reorder point is tripped. This reorder point has built into it some kind of estimate of future demand over lead time. Obviously, the due date placed on this replenishment order will be determined based on that lead time. Whenever the forecast of demand over lead time isn't exactly right — and it's not likely to be very often — the due date on the replenishment order should be updated. In practice, particularly with manual systems, this was very difficult to do and, as a consequence, most companies tried to pretend that the original due date they put on the order was going to be valid throughout the entire lead time. The natural result was that many items went out of stock *and then* the expediting started! And many other orders were "late" but not needed.

The fourth type of company combines the problems of companies 2 and 3:

4. Assembled Product: Made to Stock

Obviously, the stock replenishment due dates have to be kept up to date and this has to be related to the components going into the assembly. Once again, if any one of the components is scrapped and can't possibly be completed by the required due date, the other components going into the assembly should be rescheduled to give them valid priorities.

With the manual system that companies had for years, keeping priorities valid was virtually impossible in all but the one piece, make to order type of company. The amount of calculation and recalculation simply wasn't practical. So the *Formal System* usually didn't attempt it. But somehow someone had to find out about at least some of the changed priorities in order to keep the factory operating and the bulk of the shipments going out the door. This became the expediter's main task. Even though priorities weren't officially

updated, he found out about some of the material that was *really* needed when the items showed up on shortage lists and backorder lists.

The expediters in a company making an assembled product, for example, usually pulled the parts required to make an assembly out of the stockroom; "staged" (or "accumulated") them; made up shortage lists; and expedited the missing parts. Of course, this *Informal System* always found the shortages too late to do anything about them without generating chaos in the factory, in the purchasing department, and with vendors. As a result, expediting is a dirty word in most companies. But it's also a necessity when the formal priority planning system simply doesn't work.

The four categories of companies listed above are intended to be representative rather than all inclusive. There are companies that don't make assembled products, for example, that do have the dependent priority problem. Consider a company making mechanic's hand tools. They make a forging, process it through some preliminary operations, and then put it into semi-finished inventory. When they wish to make a given size of box wrench, for example, they will draw the proper forging out of inventory and run it through the finishing operation. One semi-finished forging could make a number of different wrench sizes. Note that while this isn't a classical assembled product, the demand on the semi-finished forging *is dependent*.

In fact, a "bill of material" for this particular type of product would look "upside down" as compared with a normal bill of material for an assembled product. An assembled product is made up of a number of parts. The semi-finished item can be finished to make a number of different items.

The practitioner should recognize that even though he doesn't have an assembled product, he may very well have the dependent priority type of problem. The breakdown of the formal priority planning system is indicated when expediters must spend a large part of their time trying to find out *what the real priorities are*.

The inability of most formal priority planning systems to keep priorities properly updated has been one of the most significant causes of machine load reports that simply aren't credible to shop people. One of the reliable features of the informal priority system is that it *expedites and never unexpedites!* Figure 9 attempts to show this graphically. The vertical line represents the original due date put on eight different shop or purchase orders. The expediter has discovered that four of these shop orders are needed sooner than originally planned. But he has not been able to determine that a number of these orders should be rescheduled to a later date. After all, expediting takes a lot of time and effort. There is none left over for unexpediting.

The result is a system that says, "Work on all the orders to meet the original dates unless they're needed sooner." Of course, this means plenty of late orders that aren't really needed. *The consequence is a machine load report that's badly overstated in the early time periods!* It usually shows a

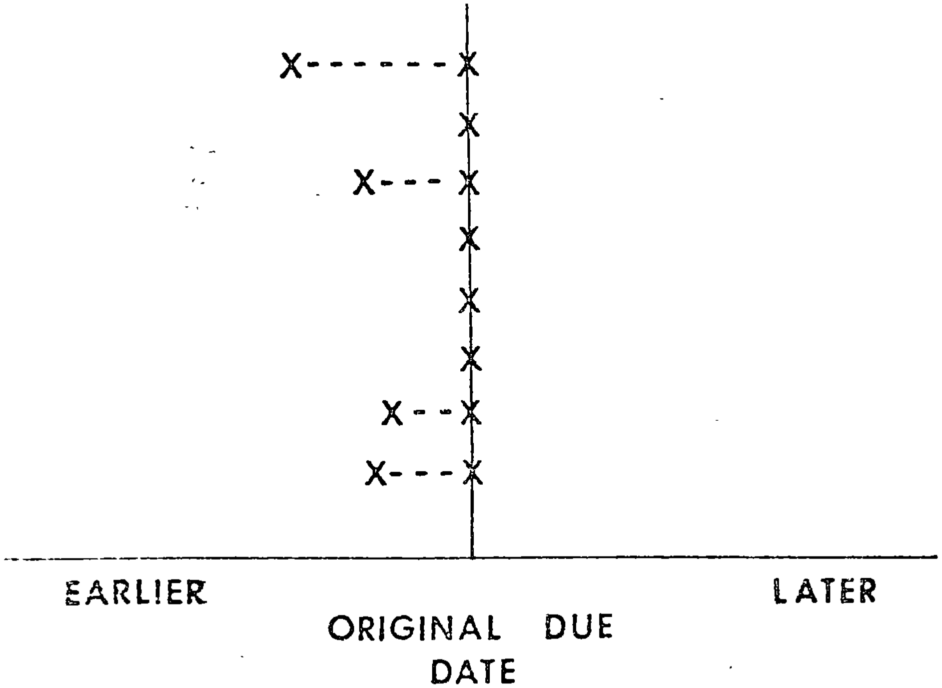

Figure 9.

large past due load because jobs that are not needed have not been rescheduled. The result: Nobody believes the machine load report.

We can conclude, then, that capacity planning is not going to be very effective until priority planning is effective. If there are many "late" jobs around that are not really needed, capacity plans will always be overstated and they won't be credible to the users. *A prerequisite to an effective capacity planning system is an effective priority planning system.*

The function of the priority planning system is to put the proper due dates on orders and to maintain those due dates so that they are correct. Until this can be done successfully, capacity planning will not be able to generate credible information.

George W. Plossl

Successful scheduling and loading requires accurate priorities for individual jobs: these priorities are set by the ordering system. There are two basic systems: the Order Point/Order Quantity System and Material Requirements Planning. Figure 10 illustrates how the order point system works to set priorities. Item Y2L has a forecast of 200 per period with an order point set at 300, a lot size of 600, and a lead time of 1 period. There are 700 on

O P = 300

Y2L		PERIOD 1	2	3	4	5	6	7	8
PROJECTED REQUIREMENTS		200	200	200	200	[illegible]	[illegible]	[illegible]	[illegible]
SCHEDULED RECEIPTS			600				[illegible]		
ON HAND	700	500	900	700	500	300	700	500	[illegible]
PLANNED ORDER RELEASE						600			[illegible]

Figure 10.

hand at the start of the planning period and a quantity of 600 is on order, due in period 2. If the 200 forecast for period 1 are actually used, the projected balance on hand will then be 500. Using another 200 and receiving 600 would give a balance on hand at the end of period 2 of 900. Using 200 per period, the available balance on hand would drop to the order point of 300 in period 5 and the system would then trigger a new order to be released to replenish the inventory. With a lead time of 1 period, the order would be scheduled to come in in period 6. This would establish its priority relative to other orders in the system; those due in earlier weeks would have higher priority and those due later would be lower.

Figure 11 shows how Material Requirements Planning sets priorities. Here the data shows rather lumpy demand in the 8 periods because the Y3L is required in a variety of assemblies at higher levels. The quantities shown are calculated from the Master Production Schedules to make the end product assemblies. The order quantity is 350 and the lead time is 2 periods with a quantity of 400 pieces on hand to start the planning period. Using the projected requirements, the on hand figure would drop to 300 in period 1, 150 in period 2, and would show a negative balance of 120 in period 4. In require-

O Q = 350 L T = 2

Y3L		PERIOD 1	2	3	4	5	6	7	8
PROJECTED REQUIREMENTS		100	150	120	150	100	90	[illegible]	[illegible]
SCHEDULED RECEIPTS					350			[illegible]	
ON HAND	400	300	150	30	-120 230	130	40	[illegible] [illegible]	[illegible]
PLANNED ORDER RELEASE			350			350			

Figure 11.

ıts planning, this is the period in which we need more material and 350 ld be scheduled to be received in period 4. This would establish priority his item relative to other items also on order. The release date would be cated by backing off 2 periods (lead time); the first order should be ased in period 2.

ecause of basic differences between the two systems, significantly differ- priorities can be developed. At the 1970 APICS International Conference incinnati, Dr. J.A. Orlicky used an example to illustrate how uniform de- id for finished products results in very lumpy demand for components. data are shown in Figure 12. The demand for each of the four end ducts is uniform in each week. Their inventories are replenished by run- g the lot sizes indicated on the "Production" line. The sub-assemblies have demands for 14 and 35 in alternate time periods as shown in the ter section. The part common to both sub-assemblies has extremely ipy demand; although its average demand is 17, individual period de- nds vary from 65 maximum to 0 minimum.

he order point system would plan replenishment of this item as shown in upper section of Figure 13. The demand would be forecast at the average 17 and actual demand would reduce the available balance week by week il it had dropped below the order point of 85. The system would then say, art a new order and schedule it in at the end of its planned lead time of r weeks."

Contrasted to this, the bottom section of Figure 13 shows how require- nts planning would handle this. The requirements would be calculated as wn and the available figure projected into the future indicating that the entory on hand would be used up in the last week shown. This would then

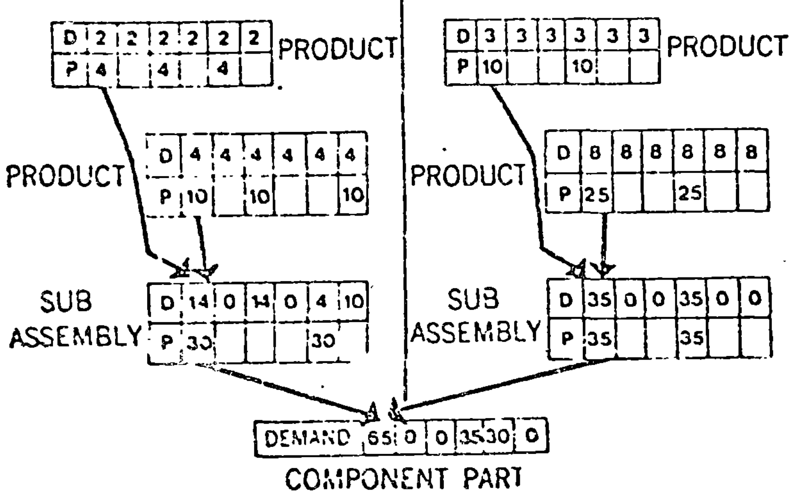

Figure 12.

ORDER POINT

O.P.=85 L.T.=4 O.H.=180

FORECAST	17	17	17	17	17	17	17	17	17	17
ACTUAL	65	0	0	35	?					
AVAILABLE	115	115	115	80						

START ----L.T.---------> DUE

MRP

REQ'D	65	0	0	35	30	0	35	0	0	35
AVAILABLE	115	115	115	80	50	50	15	15	15	-20

START <------L.T.------- DUE

Figure 13.

be the due date for a new order which would be scheduled to start the lead time of four weeks earlier. Notice the two weeks difference in priorities for this item between the two systems.

Many practitioners feel they can overcome this problem by installing a dynamic priority system such as Critical Ratio. Let's examine how Critical Ratio would work under these conditions. Figure 14 illustrates the basic formula for Critical Ratio with a numerator based on the balance on hand of

$$CR = \frac{OH/OP}{LTR/LT}$$

O.P.=85
L.T.= 4

WEEK	1	2	3	4	5
OH	80	50	50	15	15
OH/OP	.94	.59	.59	.18	.18
LTR/LT	1.0	.75	.50	.25	.12
CR	.94	.79	1.2	.72	1.5

Figure 14. Critical Ratio

parts remaining in stock and a denominator reflecting how the replenishment order is moving through the plant. When the order point system triggered an order, the On Hand balance was 80 compared to the order point of 85 so the numerator ratio is 0.94. Since work had not been started, the full lead time remains and the lead time ratio is 1. The Critical Ratio is then 0.94 and the system says: "You are essentially on time." Critical Ratios between 0.95 and 1.05 indicate "on time"; for smaller ratios, expediting is indicated and for larger ratios, slack time is available and the job can be set aside.

In week 2, an additional quantity of 30 has been used so the On Hand figure is now 50 and the On Hand/Order Point ratio 0.59. Assuming the job progressed normally through the plant (since it was not being expedited), the lead time remaining is three weeks and this ratio is 0.75. The Critical Ratio is 0.79 which says, "Expedite, you are behind schedule." In week 3, no more parts were used so the numerator remains 0.59. Assuming that a normal week's work was accomplished, the lead time ratio would drop to 0.5 and the Critical Ratio would rise to 1.2, indicating that the job is no longer critical and saying, in effect, "You did it, fellows, you got back on schedule. In fact, you are now ahead and can relax." In week 4, however, an additional quantity of 35 was issued; dropping the numerator to 0.18. Since no extra effort was being put on the job, perhaps only one week's work was finished and the lead time ratio would be 0.25, indicating a Critical Ratio of 0.72. This says in effect, "Get on the ball again because this job is now urgently needed." At the end of week 5, with no more parts being used, the numerator remains unchanged. Whatever work is done to reduce the remaining lead time might drop the denominator to 0.12 and the system could easily again indicate slack time available. In this kind of environment with lumpy demand, Critical Ratio behaves like a yo-yo.

Obviously, there is no way to cope with use of the wrong ordering system through fancy scheduling, priority systems, loading, or any other technique. Using the wrong ordering system, the wrong due dates will be established. With incorrect dates, the schedule, the priorities, and the projection of when the load will hit individual work centers will be fiction.

In such an environment, the informal system usually takes over and the real priorities are set by the "hot list" based upon known shortages at assembly. The number of jobs *apparently* past due invariably rises, but the factory people know most of these are not really needed and pay attention only to the informal system priorities. The credibility gap widens until the formal system is ignored or discarded. I know one company with 93 full-time expediters working to five different priority systems—one indicates jobs needed 10 days hence, one 5 days hence, one tomorrow, and one (called the "drop dead" list) covers items without which the assembly line will shut down within the hour. Guess what the fifth priority system is? That's right—when there are no higher priority jobs to do, work to the "date wanted" on the order. Only 8 percent of the orders come through on the original wanted date. No wonder the credibility gap exists.

Effective scheduling and loading requires the elements shown in Figure 15.

Plan	*Control*
Priorities	Capacity
Capacity	Priorities

Figure 15.

There must be a priority planning system that works; this means using the proper ordering system for independent and dependent demand items. There must be a capacity plan to insure that adequate capacity is available to handle the work. There must be a control system to see that capacity is adjusted to meet changes in both customer requirements and in the factory's output. And there must be a priority control system to respond to changes, adjusting priorities to bring the proper jobs through in the right sequence. No machine load or scheduling system will work when based on the wrong priorities. Let's now take a closer look at infinite loading and how it works.

Oliver W. Wight

Remember that there are two fundamental ways to go about loading; one is to show the load in the time period when it's scheduled *regardless* of the available capacity (infinite capacity loading), and the other is to load to "finite capacity" which means, of course, that even though the load may be scheduled in a given time period, if capacity isn't available in this time period, the load will be moved to another time period.

Whoever coined the term "loading to infinite capacity" really did the field of production and inventory control a disservice. When you think about it, it's pretty obvious that a company *should start* by doing some kind of "infinite loading." Certainly finite loading doesn't even show them the capacity they *need!* It just assumes that this capacity is absolutely inflexible. The first step is to find out what capacity is needed. You must start with "infinite loading" rather than "finite loading."

Let's review the steps in scheduling and loading. Figure 16 shows a typical shop order. Note that this shop order is due on calendar day 412. We're working with a shop calendar that shows only the working days to facilitate scheduling. Note that the standard hours for each operation have been calculated based on the quantity on the shop order; in this case, 300 pieces. Assume also that we're working with some scheduling rules. In this case, our scheduling rules allow two days for inspection and two days "transit time" between operations in different departments. The job is due to be completed on day 412; it has to be out of the polishing operation on day 410. This company works on eight-hour shift so two days will have to be allowed for the polishing operation. Since two days are allowed between operatons in different departments, the job must be completed out of grinding on day 406. In this manner, the job can be "Back Scheduled" to determine when each operation must be finished (and/or started) and a "schedule date" can be assigned to each operation.

Part No. B-			Shop Order No. 50043 Quant. 300 Due 412			Release		
Oper	Dept.	Mach.	Description	Setup	Per Piece	Std. Hrs.	Start	Finish
10	08	1322	Cut off	.5	.010	3.5		
20	32	1600	Rough turn	1.5	.030	10.5		
30	17	5660	Heat treat					
40	32	1204	Finish turn	3.3	.048	17.7		
50	32	1204	Drill, ream	1.2	.035	11.7		
60	12	1466	Mill slots	1.8	.025	9.3		
70	03	1742	Grind	.6	.010	3.6		
80	22	1003	Polish	.3	.029	9.0		
90	11		Inspect					
						65.3		

Figure 16.

		WEEKLY LOAD IN STANDARD HOURS						
DEPT.	MACH.	376 380	381 385	386 390	391 395	396 400	401 405	406 410
03	1742							
08	1322							
12	1466							
22	1003							9
32	1204							
32	1600							

Figure 17.

Note that nine standard hours of polishing work will the required in work center 1003 and must be completed by day 410. Figure 17 shows the weekly load report in standard hours. The nine hours have been loaded in the proper work center in the proper week. By doing this with all of the shop orders, an "infinite capacity load" would be developed.

As we've pointed out, *it's essential that we know what capacity is needed* and only this kind of approach will do that. We frankly think that *the biggest problem with infinite capacity loading is the name!* If we had been astute enough to give it a name that properly described the function, this technique would have had far better acceptability and more intelligent use. My nomination for a more descriptive term is *CAPACITY REQUIREMENTS PLANNING.*

We have Material Requirements Planning (MRP) that tells us what material we need and when we need it. Capacity Requirements Planning should tell us what capacity we need and when we need it. How is Capacity Requirements Planning different from infinite loading? Since I have coined the term, allow me to define it. Capacity Requirements Planning uses exactly the same logic as the old "infinite loading" with one minor difference. In addition to picking up the released orders or "load," it also picks up the *planned orders* from MRP. These planned orders *are not real shop orders.* MRP simply generates a part number, a quantity, and a time period when an order is to be released. MRP uses these planned orders to generate lower level material requirements. But they can also be run against the routing file, each planned order can be back-scheduled and a forecast of capacity requirements can thus be developed.

Capacity Requirements Planning is certainly an essential function in any production and inventory control system. But let's stop using that emotion-laden word "Infinite" right now! Nobody can really load a plant to infinite capacity! But certainly we do need to have an idea of capacity requirements before we start trying to load the plant to a given capacity.

Remember Figure 15 that showed the four basic elements in a production and inventory control system:

Plan Priorities / Plan Capacities / Control Capacities / Control Priorities

The inventory control system (usually MRP) is the priority planning function. Capacity Requirements Planning is the capacity planning function. Dispatching is the priority control function in the shop. But how about *capacity control?*

We frankly don't believe that the typical machine load report was ever designed to be a "control system." A control system has four fundamental elements to it:

A NORM / TOLERANCE / FEEDBACK / ACTION

The wall thermostat is our favorite example of a control system. The temperature is set to the desired level, then the actual temperature is monitored via a feedback system. Whenever the actual has deviated from the norm—or "Plan"—by a predetermined amount (tolerance), action is taken to get the temperature restored to the norm.

Think of the typical machine load report. Is there a norm? Where is there a plan that's practical? A plan that you can hold people responsible for executing. Certainly when you have tremendous variations in the amount of load in a work center each week, *there's no way* you can hold the foreman responsible for working to that production level. It simply isn't practical in most factories to have dramatic fluctuations in capacity. Manpower and machine capacity are limited and it is most economical to hold them as stable as possible from one week to the next.

By the same token, where is the comparison of "actual" with "plan" in the typical machine load report? Very seldom does the load report show the output from the work center involved and if output is shown, it's usually only shown for one week. Obviously, output for one week is hardly representative of the ability of that work center to meet the capacity plan. Actual output should be compared with planned output for a number of weeks.

Certainly two essentials that ought to be involved in any kind of "capacity control" or "output control" system are:

A practical plan

Feedback to compare "actual" with the plan.

1.	284	6.	286
2.	61	7.	50
3.	321	8.	147
4.	139	9.	695
5.	531	10.	176

Figure 18. Capacity Requirements

Let's look briefly at a Capacity Requirements Plan. When all of the hours by work center, by time period, are accumulated, the result would look something like Figure 18. This shows capacity requirements for 10 weeks for a given work center in standard hours. Note that there is a random variation from week to week.

How can this random variation be smoothed out? The most practical way is simply to *add it up and average it out*. The minute you get a week out into the future, your prediction of how many hours are going to be at what work center at what time is an approximation at best. The average weekly capacity requirement from Figure 18 would be 270 hours per week.

	W1	W2	W3	W4	W5
PLANNED	270	270	270	270	270
ACTUAL	250	220	190		
DEVIATION	-20	-70	-150		

Figure 19. Output Control

Now let's look at the capacity control device. Figure 19 shows the way this could be set up in an "Output Control" report. Remember that we're trying to show a "norm"—a realistic attainable plan that people can be held responsible for attaining. Below the *plan*, the *actual* standard hours of output are shown. Below that, of course, we show the deviation.

It would be a good idea, in practice, to determine a tolerance. How far away from the planned can the actual be allowed to drift? We've seen companies use this kind of report. By pre-determining what the tolerance was, the foreman coming into the weekly production meeting knew whether or not they were going to be required to work overtime or do something else to increase capacity. They were told, for example, "If the cumulative deviation is more than 50 hours off the plan, the burden is on *you* to get extra capacity—quick!" Setting the tolerance *in advance* saved a lot of debates in production meetings.

Infinite loading is dead; it has been replaced by *Capacity Requirements Planning*. There is nothing wrong with the technique *if it used properly!* We certainly need to plan capacity well out into the future. The term Capacity Requirements Planning—by definition—implies that we are using planned orders out of MRP as well as actual released orders. Then the leveled planned production rate is just the average of the weekly capacity requirements usually planned out three to four months in advance. This sets the production rate against which the actual output will be measured. Many people spend a lot of time trying to figure out what their capacity is when the actual current capacity is very easy to determine by looking at labor variance reports and other already existing reports that show the number of standard hours worth of work produced.

Note that the report I showed you, the Output Report, is really part of the technique that we called Input/Output Control. Let's think a little more about the real significance of this technique.

George W. Plossl

The traditional approach to developing a production and inventory control system has been to first design and install an ordering system—a set of procedures to trigger orders for both purchased and manufactured parts. This has been generally called "Inventory Control." The next step is to release immediately to vendors or to the factory the orders triggered by this system. Next comes an attempt to control the sequence in which these orders are worked on by activities in the plant under the general heading of "Production Control."

A popular technique among manufacturing people is to watch the backlogs in a machine load and attempt to use them as a tool for adjusting capacity. Unfortunately, this rarely works. Increasingly popular are shop floor control systems using dynamic priority techniques and data collection equipment. The basic idea seems to be that if we know where each job is, we can get it through when we need it. This, unfortunately, doesn't seem to be very effective either. In fact, both approaches are notl but a massive assult on the symptoms while the basic diseases of poor priority information and/or inadequate capacity go unchecked.

We now have two fine ordering systems and a basic principle to tell us when to use each of them. The independent/dependent demand principle clearly identifies where the order point/order quantity system should be applied and where to use Material Requirements Planning. With both systems, however, we still need dependable lead times and this means that queues or backlogs of work-in-process must be under control.

There are three reasons why queues (and lead times) are out of control:

1. Inadequate Capacity—if you are not making enough in total, then something must wait, queues grow and lead times get longer and more erratic.
2. Erratic Input—no ordering system releases work at a level rate matching the capacity of the plant. When the lumps and bunches of work triggered by either of the basic ordering systems hit the shop, it is obvious that all cannot move steadily through the plant. Backlogs and queues will increase and lead time will get longer and more erratic.
3. Inflated Lead Times—it is now well recognized that we can't "make it easy" for the plant or for the ordering system by simply allowing more time to get jobs finished. Increasing planned lead times triggers more orders and dumps more load into the plant without regard to its ability to handle it. Longer queues and erratic lead times result.

Lead times will never be controlled and a plant will never be on schedule unless it controls capacity. The Input/Output approach is the first available tool which has been successfully used in controlling capacity. Unlike the typical machine load shown in Figure 20, Input/Output measures and

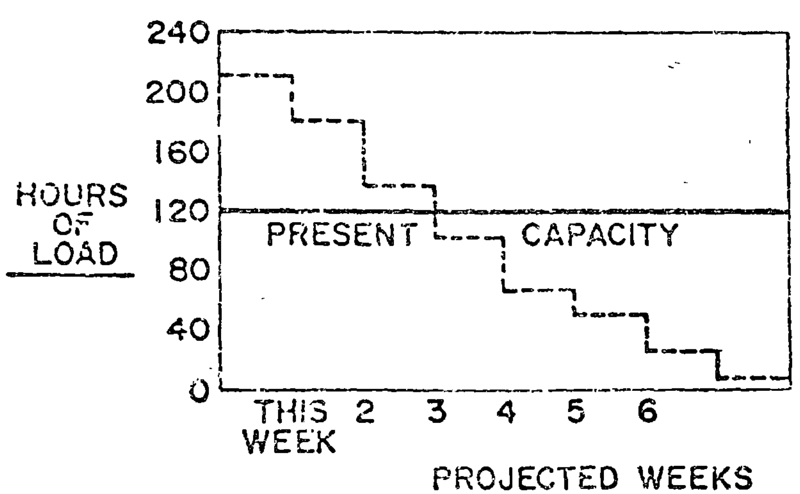

Figure 20. Typical Machine Load Pattern

attempts to control the *through-put*, the flow in and out her than the backlogs. Production control people look at the present overloads on the machine load in Figure 20 and tell the foreman, "You're in trouble." The foreman looks at the future underloads on the machine load and says, "You better believe it." They're thinking of something entirely different.

Recently, I sat with a plant manager, his manufacturing superintendent, and his production control manager looking at a report issued weekly for each major work center in the plant. This report showed standard machine hours of actual input, actual output, total backlogs and the past due portion of the backlog in each work center. The manufacturing superintendent said his people looked only at the backlog figures. I asked why they didn't use the actual output information and he said, "Notice how steady and level these figures are. They don't tell us much." I also asked why they did not use the input figures and he said, "Look how they jump up and down. What does that really tell you? We've run out of work before and there is no indication in these input figures we won't run out again. We use the backlog figures which are the only data giving us any *forward visibility at work* in the plant." Could you argue with him? With future *planned* capacity data lacking, what else could he do?

The biggest hangup on applying the Input/Output Control approach seems to be the difficulty of seeing how to control input in secondary work centers. Input can really be controlled only at starting operations and at assembly or sub-assembly areas where we have control of the orders released from the planning system to the plant. However, *average rates* of work input can be planned and *actual rates measured* at all work centers. This gives very valuable information as illustrated in Figure 21. Against a planned average rate of 210 standard hours per week, actual output has fallen short by a cumulative total of 300 standard hours. Looking at the output figures only, a logical conclusion would be that this department needs more capacity. However, the input figures make it obvious that the real problem must lie in the departments feeding this work center. Its input total is more than 300 hours behind the plan. Measuring input focuses attention on the real capacity problem areas.

Extending the planned figures into the future as shown in Figure 21 gives manufacturing people that forward visibility which is so vital to them in controlling capacity. Another company decided to apply Input/Output Controls and immediately ran into difficulty in getting sufficient data to plan input and output rates and to measure input at major work centers. They decided to go ahead, however, with the data they had. They ranked all new orders released by the inventory planning system in priority sequence. They completed the routings on all orders, estimating time standards in major work centers where they were missing. Using an infinite capacity machine load program they had running on their computer, they tested what load these orders would place on each work center. Since they had no formal scheduling system, they ignored the time delay from starting an operation in one work center and

WORK CENTER 0162
(ALL FIGURES IN STANDARD HOURS)

WEEK ENDING	505	512	519	526
PLANNED INPUT	210	210	210	210
ACTUAL INPUT	110	150	140	130
CUMULATIVE DEVIATION	-100	-160	-230	-310

PLANNED OUTPUT	210	210	210	210
ACTUAL OUTPUT	140	120	160	120
CUMULATIVE DEVIATION	-70	-160	-210	-300

Figure 21. Input/Output Control

having it reach a subsequent work center some days or weeks later. They assumed each job hit each work center immediately when it was released, just as if all were starting operations.

From payroll data, they logged the actual hours of output in each of the major work centers and carried a weighted running average. When the scheduled orders to be released exceeded this average actual output in any work center, they rescheduled some orders to minimize such overloads. Their objective was to *put into each work center less work than it was turning out.* In a period of six weeks, the work-in-process was reduced almost 40 percent, lead times came down proportionately and their ability to get needed jobs through the plant increased rather dramatically.

The real use of Input/Output Control techniques is, of course, to measure actual versus planned data as a basis for control. Control of all priorities and inventory levels depends on controlling capacity. Among the elements of the effective production control system shown in Figure 15, the key is controlling capacity. With adequate capacity, even if you can't level out the input, you can manage long queues of work and long average lead times *if you have a priority planning system that works.* Without adequate capacity, you can only hope to minimize the pain or isolate it.

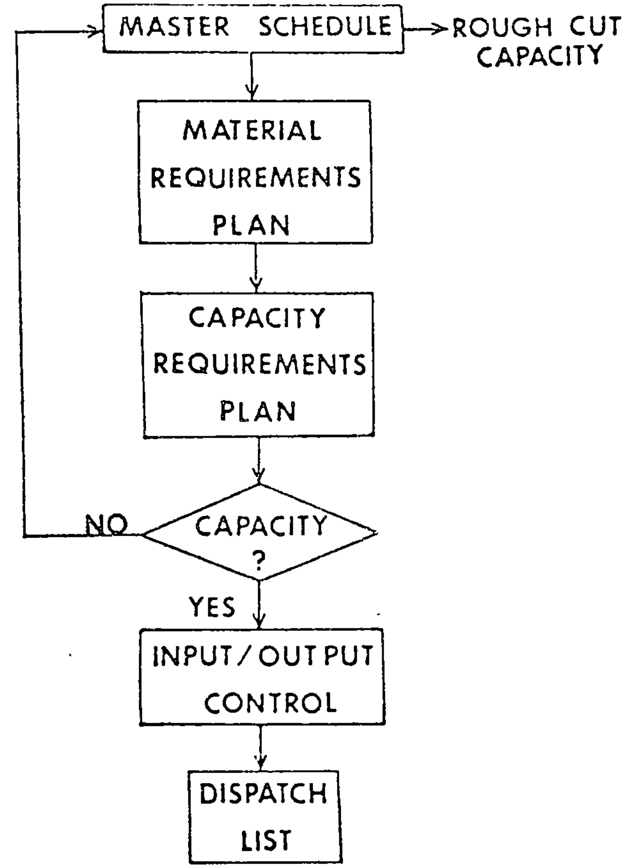

Figure 22.

Oliver W. Wight

We've talked about planning and controlling priorities and capacities. Let's see how the techniques we have discussed fit into this overall format.

Priority planning — the *Material Requirements Planning* technique will be used in most companies.

Capacity planning — this is where we need to use *Capacity Requirements Planning.*

Capacity control — Input/Output Control.

Priority control — Dispatching in the shop, follow-up in Purchasing.

Figure 22 shows the overall relationship of the elements in a production and inventory control system. Starting with a Master Production Schedule, it goes into a Material Requirements Plan; the Capacity Requirements Plan can then be developed from both released orders and planned orders. Then a decision is indicated. Can the plant meet the capacity requirements?

Obviously, they should try to meet these if this is at all practical and economical. If the capacity requirements look reasonable, Input/Output Control could be set up as a capacity control device. A Dispatch List — probably issued to the shop daily — would be used to communicate priorities to the shop floor as they are revised by the Material Requirements Plan. Looking at this schematic, you recognize that it illustrates the functions of planning and controlling priorities and capacities. The Material Requirements Plan is *priority planning*. Capacity Requirements Planning is *capacity planning*. The Input/Output technique is used for *controlling capacity* and the Dispatch List is used for *controlling priorities*.

Note that if capacity is not available, the Master Schedule *must be changed!* There are really two alternatives when capacity requirements are in excess of actual capacity:

Change capacity.
Change the schedule.

Note by the way, that a rough cut at capacity requirements might be made as part of the Master Scheduling function. In other words, before going through the detail of the actual Material Requirements Plan and the Capacity Requirements Plan, some long range determination of requirements against resources might be calculated. This is a rough cut just to make sure that the Master Schedule is in the ball park before going through the detailed calculations.

This schematic is anything but theory. There are companies that have Material Requirements Planning, Capacity Requirements Planning, Input/Output Control, and Dispatching working. And very successfully, I might add. Once these techniques are functioning properly, an entirely different approach to running a manufacturing company emerges. With a formal system like this *that works*, decisions are put into their proper perspective ahead of time. Let me give you an example.

One company that I've worked with has all of the techniques mentioned above working successfully. The results from using these techniques have impressed me. But the thing that's impressed *them* more than anything else is their ability to spot problems ahead of time and make good, strategic decisions.

The Director of Manufacturing for this company told me some years ago that he'd be pleased the day he could answer some of the questions put to him honestly. For example, when the President says, "We've got to get a new product out the door in much less than the standard lead time, *can we really do it?*" Without the kind of system that will generate this kind of information, the only course open is to say, "Yes," and try.

Let me show you how this company handles this type of problem today. This past September, the President said he wanted a particular product introduced into the schedule immediately and available for shipment November 1st. The Director of Manufacturing had the load profile for this new product calculated on the computer and superimposed on top of his current Capacity Requirements Plan. He could see immediately that an impossible backlog would have resulted in front of one of his numerically controlled work centers. There wasn't any chance of getting this work subcontracted for a great many reasons including lack of available capacity in the immediate geographical area. The detailed backup report for the capacity plan showed the actual parts that were causing the capacity requirements. Looking at some of these parts, he traced these to the assemblies they went into. Then he went to the President and showed him that if one of the products that was declining in sales could be removed from the Master Schedule for November, there would be enough capacity available to make the new product. The President readily agreed and this plan was implemented. I might also add that the new product was introduced in November on schedule and everyone was very pleased.

In the past, this Director of Manufacturing pointed out to me that he would have added the new product without being able to determine ahead of time what some of the alternate plans were. And he probably would have been criticized severely if the product that had the declining sales had experienced longer delivery times! Since he had the information available to call it to the attention of the President ahead of time, this was anticipated, and when it materialized, people understood that this was the cost of launching a new product in considerably less than standard lead time.

One manufacturing executive made a very astute observation on this. He said, "You know, a manufacturing executive without the proper information can never say 'No.' All he can do is say 'Yes' and try to meet impossible plans and then be criticized afterwards because something else suffered!" But what a new ball game. The ability to point out ahead of time what the alternatives are, what the consequences are, and to pick out ahead of time what will suffer and recognize why this choice was made. In the next five years, I hope to see the emphasis change from developing systems to learning to use systems to manage. Many managements are going to have an entirely new world to work in when they have the alternatives in front of them *ahead of time*.

Let's come back to our overall schematic of production and inventory control. One point should come through loud and clear:

Lesson #1: WORK LOAD ON A PLANT WILL BE LEVELED VIA THE MASTER SCHEDULE.

The first job is to *get* the needed capacity, if possible and practical. When capacity is not available, the Master Schedule must be revised. Large lumps of capacity requirements will be smoothed out in the Master Schedule.

We have talked a lot about the Master Schedule. Perhaps a couple of words about the types of Master Schedule that different companies might use would be in order. In a company operating strictly off backlog, the Master

Schedule would be primarily customer orders. Most companies don't have the luxury of having enough backlog to work from. They need to forecast what orders they're going to have to manufacture. Under these circumstances, the forecast must be "bled out" constantly as actual demand materializes. The short term Master Schedule consists of actual customer orders, the middle term Master Schedule is a combination of forecast and actual, and the long term consists of forecast only.

The Master Schedule in different types of companies can take many different forms. In a company manufacturing stocked finished goods, the Master Schedule would be the production plan that tells the total number of units that they're going to make for a particular type of product. This could then be allocated for various part numbers as a production forecast and that would be used to create a Material Requirements Plan and Capacity Requirements Plan. In a foundry, the Master Schedule might be expressed in very general terms showing the number of molds to be made per day per work center.

Every company has one or more Master Schedules, even though they may not explicitly recognize this! The Master Schedule drives MRP which drives the rest of the production and inventory management system. It is also the key to better management strategy.

Lesson #2: THE MASTER SCHEDULE CAN BE USED TO SIMULATE AND SHOW THE CONSEQUENCES AND IMPLICATIONS OF VARIOUS POLICY DECISIONS.

When a new product is to be introduced, when production is to be increased or decreased, the Master Schedule will be the point of entry to show the consequences of this change in plan. It's the very guts of production and inventory control. Therefore, if the company doesn't explicitly recognize that they have to have a Master Schedule, their chances of being able to control the production and inventory function are very slim indeed. Back in the days of the informal system, few companies had a recognizable Master Schedule. In the days of formal systems, every company should.

But as we look back at our schematic in Figure 22 again, there's something disturbing. *What became of Finite Loading?* We seem to have handled the four fundamental functions of production and inventory control without even touching on Finite Loading!

George W. Plossl

Let's take a more detailed look at finite loading. As discussed earlier, jobs must be loaded in priority sequence, since we want the highest priority jobs to have first claim on available capacity. When priorities change, we must rerun the whole finite loading program. The problem is further complicated by "dependent priorities." Components going into an assembly should have a priority dependent upon the status of other components. It is obvious that

there is no need to rush one part through if it will just wait for others before the assembly can be completed.

Load data is really a forecast of when work will hit the work center involved and, like all forecasts, will be less accurate for periods farther out in the future; in other words, for longer lead times. It's certainly optimistic, at the least, to say, "Job 123 will hit this work center 15 weeks from now," and really believe it. With all these problems, few companies have attempted finite loading. It is a good question *if any of them has succeeded.*

The two best known computer programs for finite loading are the PICS Capacity Planning and the CLASS program, both put out by IBM. In Business English, the PICS program says, "If you know all the products you are going to manufacture in the next year, if you have a complete bill of material for each of them, if you have routings and standards for each manufactured item in this bill of material and if you have accurate stock status and open order files, then the computer can calculate for you the load on each work center in each time period over the planning horizon and, in addition, can rearrange this load to meet capacity limitations. Figure 23 shows the steps in the PICS Capacity Planning program. Using the Material Requirements Planning program (RPS), the computer translates a Master Production Schedule into planned orders for components; it then schedules both planned and released orders and develops an infinite load profile for each work center. If the user elects to do finite loading, the computer will then reschedule orders with low priority which hit work centers having inadequate capacity. The program will show which orders were rescheduled, how many hours of load are involved and the specific work centers affected. The user must then analyze the rescheduled orders to determine the effects on the end product Master Schedule and decide whether he can live with these or if he must make other changes. The user can assign job priorities or the system will use the Earliest Start Dates or the Latest Start Dates developed by the

CAPACITY PLANNING

MASTER PRODUCTION SCHEDULE

PLANNED ORDERS – COMPONENTS

SCHEDULE ALL ORDERS

INFINITE LOAD

OR

FINITE LOAD

ANALYZE ORDERS RESCHEDULED

REVISE MASTER SCHEDULE

REPEAT

Figure 23. PICS

schedulin rtion of the package. The user must define capacity available in each work center; he has an option of putting in a table showing a planned level and a maximum level of capacity. The difference might be working Saturdays or other overtime periods or transferring a number of men between work centers. The program does not handle unplanned loads such as scrap and rework, machine breakdowns, operator training, and other capacity-wasting activities.

There has been considerable publicity given to another IBM program called called CLASS. CLASS stands for Capacity Loading And Scheduling System, a classic finite loading program developed by Werner Kraus for IBM in Germany. The sequence of activities followed is shown in Figure 24. Unlike PICS capacity planning, CLASS starts with individual work orders and does not require a Material Requirements Planning program to generate them. It does need to know how these orders relate in a product structure since it uses this information to tie the priorities of components to that of the final assembly. The first step is to schedule the work orders and the next to develop an infinite load showing how each work center would be affected if the schedule were followed. The user then adjusts work center capacities as best he can to meet the loads.

Based on user-established priorities on the assemblies, the system develops a finite load attempting to schedule the parts in assembly priority sequence to match available capacity in each work center. The user must then analyze how assemblies were rescheduled to see if he can live with this. If he cannot, he must make other decisions about capacity or priorities and start over. CLASS has an interesting feature in that it simulates the progress of each job through the plant to see if it will be affected by *future overloads*. If jobs #1 and #2 are competing for capacity in one work center, but #1 will be delayed at a subsequent work center, job #2 is given first claim on capacity. Both PICS Capacity Planning and CLASS are truly elegant computer programs and are beautifully designed. They both require massive amounts of computer time because of the tremendous number of calculations involved.

The basic requirements for success with finite loading would appear to be

SCHEDULE WORK ORDERS

INFINITE LOAD

ADJUST WORK CENTER CAPACITIES

SET PRIORITIES – ASSEMBLIES

FINITE LOAD

RESCHEDULE ASSEMBLIES

UP-DATE – START OVER

Figure 24. CLASS

a well-ordered environment, few Master Schedule changes, tight discipline on data accuracy *and a priority plan that is valid.* It is hard to imagine an operation where the work of finite loading programs would be justified by improved results over simpler, more effective techniques. Oliver Wight and I have wondered for a long time if finite loading will ever be a practical technique.

Oliver W. Wight

Finite loading is certainly an excellent example of "barking up the wrong tree." When a company finite loads the individual shop orders, there's bound to be one predictable result. Some orders won't be able to be completed on time. Obviously, if these orders can't be completed on time, the Master Schedule must be changed. But, as we pointed out before, Capacity Requirements Planning will quickly identify a capacity requirement that can't be met and that the Master Schedule must be changed. Why bother with all the sophistication of finite loading? If ever a technique fell in the general category of "using 300 horsepower to blow the horn," finite loading is it.

Beyond being an over-sophisticated technique, it simply isn't valid. If finite loading were to be done correctly, it would result in endless iteration. Consider a company where they have dependent priorities—parts that go into assemblies, for example. If one part can't be fit into the capacity and its due date has to be extended, then the Master Schedule should be changed for the assemblies using this part. *But when this Master Schedule is changed, the finite load that caused the schedule change is no longer valid.* Some of the load that kept the part in question from being made on time was probably being generated by other parts going into the same assemblies. The minute the Master Schedule is pushed out, some of this load will be pushed out. Now we must finite load again, but, once again, something probably won't be completed on time. Back to the Master Schedule! This, again, will generate the need to recalculate the finite load. If done properly, finite loading would be an endless iteration. One of the companies, using the IBM CLASS program on an IBM 360 Model 40 (certainly not a small computer!) requires *35 hours* to make their computation. When we called to their attention the fact that it's important in most companies to have a daily dispatch list, they pointed out that while they were anxious to do this, they had yet to figure out how to squeeze 35 hours of computer time into a 24-hour day!

But what if we don't change the Master Schedule? Suppose we don't reschedule all of the other parts that go into the assembly. Well, this is certainly a waste of capacity. If any one item can't be made, it's usually necessary to make some other item, particularly if it's important to meet a monthly shipping budget of some kind. When this is true, it's essential to change the Master Schedule and thus reschedule all the parts that aren't needed so that capacity will be available to make the parts that are needed.

One point comes through very clearly: *Overloads will be resolved via the*

Master Schedule. Load leveling is going to take place in the Master Schedule. The only load leveling left to be handled will be minor weekly variations in load that are usually not very significant or controllable!

Finite loading, then, was a great way to attack the symptoms, but, in practice, it doesn't work very well. Let's look at the *problems with finite loading:*

1. **Assumes Predictable Job Arrival.**
   Going through the precise detail of determining when each job will be at each work center and leveling out this work load assumes that we can predict when jobs will arrive at work centers in the future. The folly of this is obvious to anybody who has ever worked in a factory.
2. **Component Priorities Are Usually Dependent.**
   The literature of production and inventory control, be it the order point/order quantity literature or the literature on scheduling has been obsessed with methods for handling individual independent items. In the real world, most items simply aren't independent. They are parts that go into assemblies, they are raw materials that go into a product. These priorities cannot be looked at independently as so many people have tried to do with order point type systems which apply only to independent priority items. By the same token, *they cannot be scheduled independently.* A new revision in the schedule of any of these items will affect all of the other items that are related to it. This gets to be a complex problem and we have to focus our attention on what's important and what isn't important. In a company that makes an assembled product, for example, optimizing the schedule of any one component is an exercise in triviality. The important thing is to get all of the components together at the right time to make the product. Having any one of them without the rest of them is valueless. And, as we pointed out above, the computations involved in a genuine finite loading exercise where there are dependent demand components would result in endless iteration.

   One of the difficulties, of course, is that at the end of each one of these iterations, the Master Schedule would have to be revised. This would require human intervention before the program could continue in its operation. This probably wouldn't be practical. Therefore, some people have suggested that the Master Schedule should be revised automatically by the computer. *Don't do it!* There is a major problem with finite loading:
3. **Automatic Master Scheduling Is Risky.**
   As was pointed out, the Master Schedule drives the entire production and inventory control system. A lot of considerations go into the Master Schedule. It's attempting to deal with the real world where some large customers of a company may get preferential treatment in practice, where things like a dock strike may cause an export order to have a higher priority than it normally has and where an order for a new customer who was sold based on the company's ability to give service might have to be given preference. These are the normal day-to-day things that have to be addressed in the real world factory. To try to capture all of that logic in a computer program may intrigue the theoretician. The practitioner recognizes how futile—and silly—it is.

   The name of the game is to plan capacity requirements and see if we have this capacity. If we don't, get the capacity or change the Master Schedule. Probably the greatest reason for not using finite loading in most situations is:
4. **There Are Easier, Better Ways To Do The Job.**
   Finite loading assumes a very stable environment where a lot of logic can be captured in a computer program and executed. It is filled with pretentious precision as it tries to predict which jobs will arrive at what time at what operation in a factory. Yet, in practice, the company that does finite loading only learns what they could have learned by way of much simpler techniques: when there is a capacity requirement in excess of available capacity, it must be met — or the Master Schedule must be changed.

If this is true, why has finite loading even gained credence? To be sure, it is not something that *most practitioners* view as logical. But a few do.

Well, let's take a look at one prime example. It has often been stated that there are "200 users of the IBM CLASS program in Europe." First, we have to define users. What this really means is that there are 200 people who have accepted a free program from IBM. Then we are likely to hear that there are 30 companies that are actually "running" it, but this usually means that these 30 companies have the program running on the computer. Whether or not anybody uses the output is questionable. As we tried to pin it down further, we find that there are a few companies who are actually supposed to be running their factories this way. The only one that has had much written about it actually makes magnets. Fundamentally, a one-piece product without many dependent priorities and a very simple manufacturing environment. Questionable that they really need finite loading. The fact that is worked under these circumstances is interesting, but not particularly significant.

We also hear that there are "a number of companies" using it in the United States. We've tried to track this down and have learned some very interesting things. At one company, for example, the Manufacturing Vice President and Data Processing people speak very highly of finite loading. They are located in a corporate office in Chicago. It works there. Unfortunately, when you get down to the plant in Moline, you find that it does not work.

How can we determine whether finite loading works or doesn't work? First, we've got to understand what the function of finite loading really is. It isn't a capacity planning technique; it certainly isn't a capacity control technique; it isn't a priority control technique either. *It's really a priority planning technique.* It takes the priorities generated by the Material Requirements Plan and attempts to revise them in order to level out the work load. Perhaps a more appropriate name for it would be something like "Order Release Planning," since it addresses the problem of releasing orders into starting work centers in an attempt to level work load.

How do you determine if finite loading is actually working, then? The test is simple: *Does the company using it actually run to the priority list generated by the finite loading system?* This is the only way you can determine if finite loading is working. If they are not running to this priority list, *finite loading does not work.*

I went to a company recently, for example, where they were using the IBM PICS Infinite Loading and Finite Loading packages. They claimed great results from the finite loading system. I was skeptical. Looking at the priority list generated by the finite loading reports confirmed my skepticism. They certainly were not following it. In fact, they worked to a hot list and then crossed the jobs off the weekly computer generated priority list as they were done in the sequence dictated by the hot list.

They did get some lead time reductions, however. They mistakenly attributed this to finite loading! In calculating the infinite load—a prerequisite to finite loading in the IBM package—they had to develop some scheduling rules. The result of using these scheduling rules was to come up with shorter planning lead times than they had been using. Shortening the lead times reduced the input to the factory. Reducing the input dropped the backlogs. Dropping the backlogs cut the lead time. Now normally this would result in a *temporary reduction in lead time* because, in most companies, since they're used to working with the informal capacity planning system, the minute visual backlogs decrease, the output tends to drop off. But this company's production control manager, who is a pretty clever guy, had come up with a capacity control device very similar to Input/Output Control. He took the infinite load report, *discounted 40 percent of the backlog in the current period,* and then averaged that load out over the next 12 weeks. He then set this as a production plan and got the foremen working to this plan. The result: Having reduced input and controlled output, backlogs stayed down, lead time decreased. Finite loading had nothing whatsoever to do with the excellent results these people attained.

People often ask us how IBM could have presented the Finite Loading package in PICS if it isn't a legitimate technique. The answer is—it was an honest mistake. Finite loading looked good. We've got to remember that a lot of the computer people tend to favor the sophisticated. As Townsend said, "These people are complicators—not simplifiers." While blanket indictments like that are never fair, it certainly is true that data processing and systems people generally have favored the sophisticated approaches. The people who develop application programs for computer companies are usually systems people, not practitioners. It's hardly surprising that they would pick up something like finite loading, especially since the reaction of most practitioners to "Infinite Loading" was negative!

Our research this year, our discussions with a lot of people, indicates to us that *not one responsible professional we have talked with believes that finite loading is a valid scheduling and loading technique in a machine shop!*

I hasten to add that George and I both are very much in favor of the IBM PICS package. We favor standardization rather than reinventing the wheel. We applaud IBM for their outstanding contributions with these packages, such as the RPS or Material Requirements Planning portion of PICS. We have a number of clients who have used it and used it successfully. We are very much in favor of the infinite loading or "Capacity Requirements Planning" part of their capacity planning module in PICS, but we feel obligated to tell other practitioners that we simply cannot endorse finite loading as a valid production and inventory control technique.

Does that mean that finite loading will die? Hardly. There is a latent appeal to finite loading and the chances are that it will be with us for some time to come. There are three basic reasons for its appeal:

1. It's the Apparent Alternative to Infinite Loading.

Probably the biggest reason that finite loading was ever invented is because of that inappropriate term, "Infinite Loading." If the two choices are infinite loading and finite loading, obviously any man in his right mind is going to take the alternative of finite loading because infinite loading, by definition, just doesn't make sense. When we understand how a production and inventory control system fits together, we recognize that the actual "Finite Loading" is going to take place via the Master Schedule, not by some sophisticated detailed scheduling and loading algorithm.

Perhaps a more insidious reason for wanting to use finite loading was the basic misunderstanding of the relationship of the elements of production and inventory control because finite loading was an:

2. Apparent Way to Reschedule the Backlog.

Where there is a large amount of past due work in a machine load report, it's apparent that there's a need to reschedule. So it often looks to top people like the way to handle this is finite loading. Rescheduling that load will get that backlog out of there and put the load out in a realistic time frame. Unfortunately, they don't see how the pieces of the system fit together. Rescheduling the load in front of screw machine, for example, will only result in having to change the Master Schedule because screw machine parts won't be coming out as scheduled. They should have determined ahead of time what the capacity requirements were, and if they couldn't meet these capacity requirements, then the Master Schedule should have been changed ahead of time rather than after a large backlog had built up. So, finite loading seems like a way to reschedule the backlog when, in fact, that backlog is only really going to be rescheduled by changing the Master Schedule. Why not do it directly? Why go through all the nonsense of finite loading?

In the company I mentioned above where they were supposed to have finite loading working, they had to discount the infinite load report by a substantial amount in order to set up their actual capacity plan. Why did they have these large backlogs in the infinite load report? For a very simple reason—they had a Master Schedule that was feeding the Material Requirements Planning system and this Master Schedule was no longer valid. There was a lot of work in there that was late and had never been rescheduled, never put out in the time periods when it was really going to be produced. The result—a large past due backlog. *Finite loading for them was a mirage; it was an attempt to reschedule that backlog.* What a great way to assault the symptoms. The real disease was in the Master Schedule.

Of course, in the twilight of the age of naive sophistication, as I have chosen to call the early years of computer application, we cannot fail to recognize that finite loading has an appeal:

3. It Is Sophisticated.

You must remember that many people believe that the more sophisticated approach is the better one. This, of course, is nonsense. It usually results in getting systems so complicated that no flesh and blood mortals can use them intelligently and these systems soon crash down around the designer's ears. They never seem to recognize that if people don't understand systems, they won't use them intelligently.

Many of you know how I have been on the warpath against sophistication. How strongly I feel that this is one of the biggest single reasons for systems failure in most companies. *Sophistication as an end in itself is an immature preoccupation.* So often the man who develops a sophisticated technique doesn't really understand the problem. To express this, I have formulated "Wight's 7th Law: *WHENEVER PEOPLE DO NOT UNDERSTAND FUNDAMENTAL RELATIONSHIPS, THEIR SOLUTIONS TO BASIC PROBLEMS WILL BE OVER-SOPHISTICATED.*"

Certainly finite loading falls into that category!

Finite loading violates another principle that is fundamental in designing systems: *SYSTEMS ARE TO SUPPORT PEOPLE, NOT TO SUPPLANT THEM.*

Finite loading attempts to build too much logic into the computer system. Most of it is trivial logic that doesn't really matter in the real world. Thus, the natural result is for people to throw up their hands and either obey it blindly or ignore it completely. People can understand the *intent* of systems; if the systems are "transparent," they can use them quite intelligently. The systems designer who feels that he is doing something smart by sophisticating the system has a lot to learn—the hard way! This is not to say that Capacity Requirements Planning and Input/Output Control give us precise control over a factory. It's very questionable that we ever will have precise scheduling and loading in the real world of factories. The objective is to come up with a system that's better than what we've got today. Many people tend to take the attitude that until they can solve all of the problems, they aren't very interested in solving any of them. It's well to remember:

BEST IS THE ENEMY OF BETTER.

We suspect that finite loading will be around for a long time. Many people will try to do it just to prove that it can be done. There's no question that it can be done, the question is whether it's a worthwhile, practical technique. Everest is there—must we, therefore, climb Everest? It certainly is not a responsible business attitude to want to try to do things just for the sake of doing them when they have no practical value and there are better ways, simpler ways, of doing the same thing.

Let's review then, the apparent problems with the three techniques we've talked about:

1. Infinite: Capacity Is Not Infinite.

Of course, it isn't, but the purpose of Infinite Loading—or better, Capacity Requirements Planning—is to determine what capacity is really needed.

2. Finite: Extending Deliveries.

That's right. Loading to finite capacity will extend deliveries. As a result, the Master Schedule will have to be changed. But we don't need to go through all the gyrations of the sophisticated finite loading computation to determine that.

3. Input/Output Control: Difficult to Control Input.

Controlling input is fine. But *controlling output* is the real important thing. Undoubtedly, too much emphasis was put on the subject of controlling input in some of the things that have been written on Input/Output Control. Perhaps a better name for it would have been Output/Input Control since *it is the only practical tool that we have seen for controlling capacity.* Planning what the input level should be and monitoring the total number of hours going into the downstream work center can give us valuable information. But the prime function of Input/Output Control is *capacity control.* It serves a purpose that no standard production control technique really addressed.

Let's evaluate, then, the opinions we've arrived at about scheduling and loading techniques:

1. Infinite: Function Is "Capacity Requirements Planning."

The technique we used to call Infinite Loading should be called Capacity Requirements Planning and it should pick up the *planned orders* out of Material Requirements Planning to extend the planning horizon rather than just try to measure backlog. Obviously, no plant can be loaded to infinite capacity. This is a planning technique, not a loading technique.

2. Finite:

A. WORKS FOR ONE WORK CENTER.
B. MISGUIDED SOPHISTICATION IN A MACHINE SHOP.
C. LOAD LEVELED BY MASTER SCHEDULE.

There's no question but that one starting work center—or, as I've called them before, "gateway work centers" (indicating the first *significant* work center in the sequence) can be finite loaded. Work can't be precisely controlled going into all the subsequent work centers. There are too many other things that affect the flow of work into downstream work centers. A detailed finite load can be planned on paper. It certainly isn't going to work out that way in a factory.

Finite loading will tell us that certain items aren't going to be finished on time. The result: The Master Schedule must be changed. Actually, if the Capacity Requirements Plan is used, it can show us where capacity requirements exceed available capacity and where the Master Schedule needs to be changed without going through all the details and sophisticated calculation of finite loading. Remember that the load eventually will have to be leveled by changing the Master Schedule.

3. Input/Output: Function Is Capacity Control.

Input Output Control is an excellent technique. People have used it and had very good results. The fact that it focuses attention on backlog and, consequently, lead time, is one of its greatest attributes. But, in essence, it's a capacity control device. It's a way to monitor the capacity plan to see if the production rates required to meet the Master Schedule are actually being attained.

We've spent a good deal of time in the past year gathering information, visiting companies, learning more about Finite Loading. We went into this with an open mind. Certainly the last thing we want to do is tell people that a technique isn't practical and later have it proved to be practical. We hate to take a negative stand on anything. It's much easier to just ignore it and make

believe it doesn't exist, but we felt a responsibility. A lot of people have asked us about Finite Loading. A lot of people have asked us to take a stand to help them to understand it better. We have done our homework, in our opinion, and we have taken our stand. We don't believe that Finite Loading is a valid technique for scheduling and loading a machine shop. Certainly this doesn't say that any company that wishes to support pure research shouldn't pursue Finite Loading. For companies that cannot indulge in this luxury, the mirage of Finite Loading should be avoided.

George W. Plossl

To summarize, we've been discussing Input/Output Control, Infinite and Finite Loading. We have concluded that Input/Output might more accurately be called Output/Input Control and that Infinite Loading is really Capacity Requirements Planning. We seriously question that finite loading is a valid technique. The best that can be said for it is that it may be a fine-tuning device for very special applications.

We have worked hard to dispel some of the fog surrounding this important area of production management. Production and inventory control is obviously no longer a collection of loosely related techniques. There are underlying principles and sound techniques for applying these principles. It is now possible to see how a plant can be kept on schedule with a priority planning system that works. Capacity Requirements Planning, control of output and a dynamic priority control system to respond to real world changes.

Keeping on schedule requires three basic actions:

1. Load leveling via the Master Schedule. You must smooth out the peaks and valleys as much as possible and scheduling only what you're capable of producing.
2. Some jobs must be started early. You must reach ahead either through the Master Schedule or by individual starting operations and release some jobs *before* the planning system says it is necessary. The plant must be fed at a level rate with a balanced mix of work.
3. You need a two-way priority system which recognizes jobs needed later as well as those needed earlier. Tom Putnam of Marken Corporation at our Sunapee conference stated this very clearly. He said, "You must push out the orders you don't need."

Jim Burlingame of Twin Disc in his article, "Finite Capacity:" in the 2nd Quarter, 1970 issue of the APICS Journal, *Production and Inventory Management*, stated the basic fact as well as it can be said, "The answer to a capacity problem is not to retard the job but to find a way to do it." The vital need is for adequate capacity, not sophisticated computer finite loading and scheduling programs.

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Y CONTROL DE LA CAPACIDAD

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EN LA ADMINISTRACION DE PRODUCCION E INVENTARIOS

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SEMINARIO DE ACTUALIZACION EN ADMINISTRACION DE PRODUCCION E INVENTARIOS

I: EJERCICIOS

ING. FRANCISCO J. DE REGIL

MAYO, 1978.

MATERIALES 102

SESION 5

EJERCICIO 1

CONSIDERE UN ARTICULO CON UNA DEMANDA ANUAL DE 24,000 UNIDADES Y UNA CANTIDAD POR PEDIDO DE 1000 UNIDADES. EL TIEMPO DE REABASTECIMIENTO PARA UN ARTICULO ES DE SEIS SEMANAS Y LA ADMINISTRACION HA ESTABLECIDO UNA POLITICA DE NO MAS 2 "0" EXISTENCIAS POR AÑO.

CALCULE EL PUNTO ESTADISTICO DE REORDEN MENCIONANDO EL NUMERO DE UNIDADES A QUE DEBE REORDENAR EL MATERIAL. EL MAD PARA ERRORES SEMANALES DE PRONOSTICO ES 200 UNIDADES.

ASUMA 50 SEMANAS AL AÑO Y USE LAS TABLAS DE SU TEXTO QUE CREA NECESARIAS. SI EL VALOR QUE BUSCA NO ESTA EN LA TABLA, USE EL MAS CERCANO.

ADMINISTRANDO EL INVENTARIO MAS SIMPLE DEL MUNDO 1º. PARTE

INSTRUCCIONES: Actualmente Ud. esta colocando 12 ordenes al año (4 por artículo). Manteniendo el total de ordenes al año en 12, Ud deberá determinar el número de ordenes por cada -- artículo que le de el más bajo TOTAL de inventario promedio.

CODIGO	CONSUMO ANUAL	ORDENES AL AÑO	CANTIDAD EN ORDEN	INVENTARIO PROMEDIO
A	$4900	4	$1225	$612
B	900	4	225	112
C	400	4	100	50
TOTALES	$6200	12	$1550	$775

ADMINISTRANDO EL INVENTARIO MAS SIMPLE DEL MUNDO 2º. PARTE

INSTRUCCIONES: Ud. está a cargo de tres artículos:

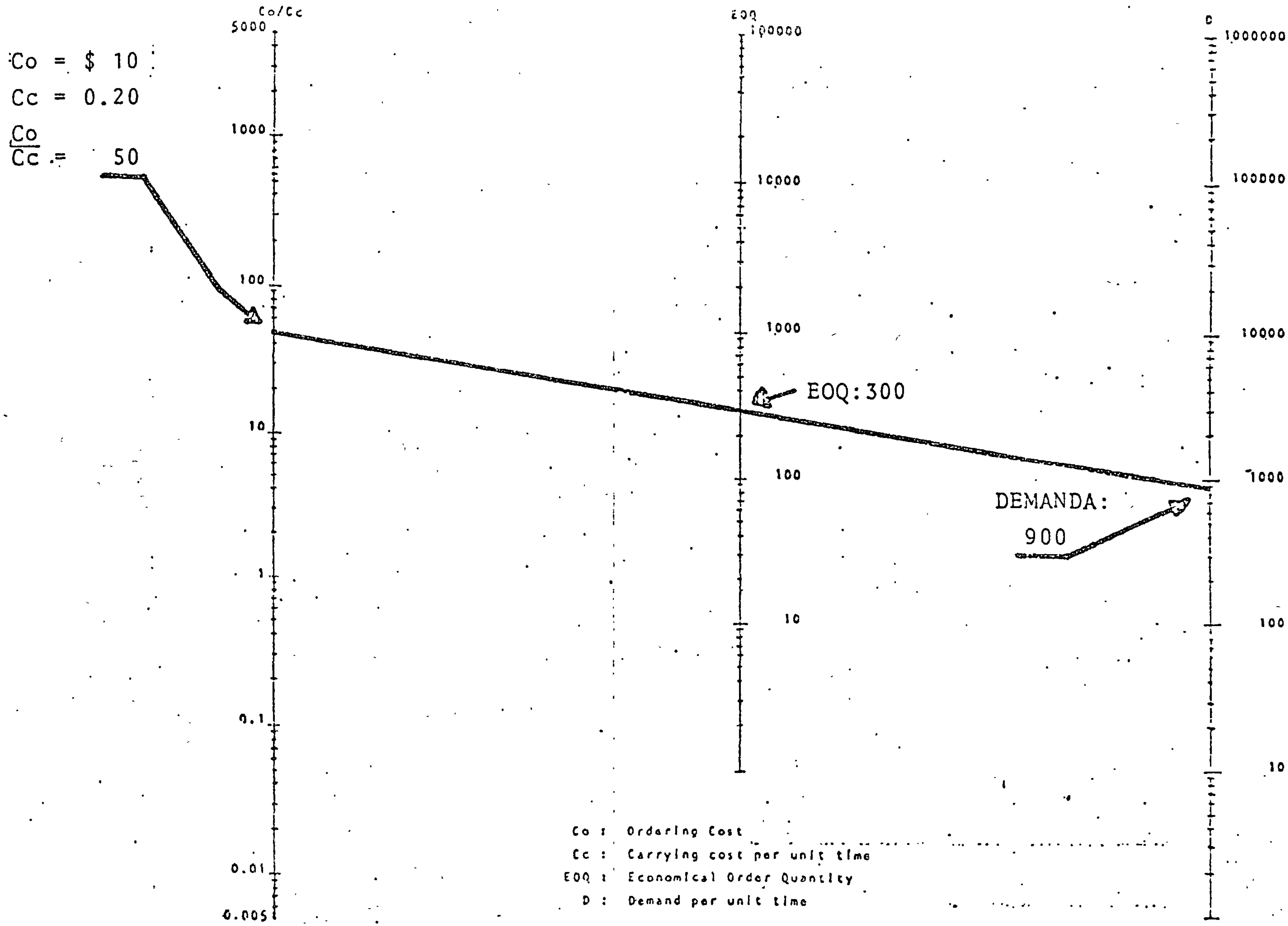
Parte A con consumo anual de $4900; parte B con consumo anual de $900; y parte C con consumo anual de $400.
Ud. deberá "experimentar" con varios números de ordenes al -- año para cada artículo hasta que halle la respectiva cantidad más económica de ordenes al año (la de costo total más bajo).
Para este ejercicio use 20% para el costo de almacenamiento y $10 para el costo de adquisición. Su formato debe seguir el si guiente ejemplo:

PARTE X (Consumo Anual $10,000)

(1) ORDENES AL AÑO	(2) CANTIDAD EN ORDEN	(3) INVENTARIO PROMEDIO	(4) COSTO DE ALMACEN	(5) COSTO DE ADQUISIC.	(6) COSTO TOTAL
1	10,000	$ 5,000	$ 1,000	10	1010
2	5,000	2,500	500	20	520
Etc.	Etc.	Etc.	Etc.	Etc.	Etc.

(2) = CONSUMO ANUAL/ (1)
(3) = (2)/2
(4) = (3) x COSTO DE ALMACENAMIENTO (%)
(5) = (1) x COSTO DE ADQUISICION
(6) = (4) x (5)

ECONOMICAL ORDER QUANTITY NOMOGRAPH



Co : Ordering Cost
Cc : Carrying cost per unit time
EOQ : Economical Order Quantity
D : Demand per unit time

PREPARED BY: ____________ APPROVED BY: ____________

TABLA DE LOTES ECONOMICOS

CONSUMO MENSUAL ($)			LOTE A ORDENAR (MESES)
ARRIBA DE		$ 2,400	0.5
$ 800	-	$ 2,400	1
$ 400	-	$ 800	1.5
$ 240	-	$ 400	2
$ 160	-	$ 240	2.5
$ 100	-	$ 160	3
$ 60	-	$ 100	4
$ 40	-	$ 60	5
$ 25	-	$ 40	6
$ 15	-	$ 25	8
$ 10	-	$ 15	10
ABAJO DE		$ 10	12

COSTO DE ORDENAR: $ 10

COSTO DE MANTENER: 20% ANUAL

EXACTITUD DE LA TABLA ± 1%

de México, S. A.

C	0.03	250	1000	1250
CLASE	COST. STD.	MIN.	LOTE	MAX.

2	1	0	1	125
INV. SEG.	T. AUM	T. ENT. (F)	T. ENT. (P)	CONSUMO

ROLDAVA STD. 6"

No. DE PARTE N 733-1 LOCALIZACION CS12 LINEA RADIOS POR 500

FECHA	CLAVE	CCO OO CLIENTE	NO. DOCUMENTO	REGISTRO	FECHA PROGRAMA	MOVIMIENTOS RECIBIDO	SURTIDO	COMPROM	REQUERIDO	SALDOS REQUERIDO	EXISTENCIAS	COMPROM	ASIGNAD
6-1	100			7409	7-6				1000	1000	140	0	(1140
7-2		70		A3201	7-6			500		1000	140	(500)	(640
7-2		75		A3202	7-20			90		1000	140	(590)	(550
7-4	5		9182	7400		474				526	614	(590)	(550
7-6	5		9183	7409		526				0	1140	(590)	(550
7-6	2		2413	A3201			500			0	640	(90)	550
7-9		67		A3321	7-11			300		0	640	(390)	(250
9	100			7437	7-21				1000	1000	640	(390)	(1250
7-11	2		2418	A3202			90			1000	550	(300)	(1250
7-18			2421	A3321			150			1000	400	(150)	(1250
						1000	740	890	2000				

CLAVES:

100- NUEVAS ORDENES STOCK
1- ENTRADA POR PRODUCCION
3- ENTRADA POR ENVIO DE VERACRUZ
5- ENTRADA POR COMPRA
7- ENTRADA POR MAQUINADO
9- ENTRADA POR DEVOLUCION DEL CLIENTE
11- ENTRADA POR REMAQUINADO
99- OTROS
2 SALIDA POR VENTA
4- SALIDA POR DEVOLUCION AL PROVEEDOR
6- CANCELACION VENTAS
8- CANCELACION A PRODUCCION
94- SALIDA REMAQUINADO EN PRODUCCION
997- AJUSTE

Volante I

CONOCIENDO NUESTRO PROCESO

ESTE PEQUEÑO CUESTIONARIO LE AYUDARA A ANALIZAR EL INVENTARIO EN PROCESO Y SU RELACION AL TIEMPO REAL DE ENTREGA.

1.- ASUMIENDO QUE UNA UNIDAD EN UNA PLANTA DE ENSAMBLE TIENE UN COSTO PROPORCIONAL AL AVANCE EN EL PROCESO. SI LA UNIDAD DE PRODUCTO TERMINADO TIENE UN COSTO DE $1,200.00 Y LAS PIEZAS QUE SE ALIMENTAN AL PRINCIPIO DEL PROCESO TIENEN UN COSTO DE $600.00 ¿ CUANTO ES EL -- COSTO PROMEDIO DE LA UNIDAD EN PROCESO ?

R: ________________________________

2.- SI LOS ESTADOS FINANCIEROS INDICAN QUE EL INVENTARIO EN PROCESO ES $3,600,000.00 ¿CUANTAS UNIDADES HAY EN EL PROCESO?

R: ________________________________

3.- SI LA PRODUCCION SEMANAL HA SIDO DE 250 UNIDADES, ¿ DE CUANTAS SEMANAS ES EL TIEMPO DE ENTREGA PROMEDIO ?

R: ________________________________

4.- SI EL TIEMPO TOTAL ESTANDAR DE OPERACION POR UNIDAD ES DE 1.6 SEMANAS, ¿ CUANTAS VECES ES MAYOR EL TIEMPO DE ENTREGA QUE EL DE OPERACION?

R: ________________________________

5.- ¿ CONOCE ALGUNA PLANTA QUE TENGA LA RELACION - TIPICA DE LA PREGUNTA ANTERIOR ?

R: ________________________________

Lh'

MATERIALES 102

SESION 8

EJEMPLO 1 PAGINA 1

UN GRUPO DE 5 ARTICULOS SON TODOS PROCESADOS A TRAVES DEL MISMO DEPARTAMENTO Y TODOS REQUIEREN DEL MISMO TRABAJADOR PARA PREPARAR LAS MAQUINAS ANTES DE CADA TIRO DE PRODUCCION. SU TIEMPO ESTA 100% SATURADO E INCLUYE 31 HORAS - DE TRABAJO ANUAL DE PREPARACION PARA ESTOS 5 ARTICULOS. EL RESTO DEL TIEMPO DE TRABAJO ESTA OCUPADO CON OTRAS PREPARACIONES EN OTROS DEPARTAMENTOS. SU COSTO DE MANO DE OBRA ES DE $5/HORA. EL INVENTARIO TIENE UN COSTO DE --- ALMACENAJE DE 20% AL AÑO. LOS DATOS DE LAS PIEZAS SE MUESTRAN EN LA TABLA - A CONTINUACION :

ARTICULO	CANTIDAD ANUAL (PIEZAS)	VALOR UNIDAD	TIEMPO DE PREPARACION HRS/ORDEN.	PIEZAS EN CADA ORDEN (ACTUALMENTE).
1	1000	0.1	2	500
2	980	10.0	1	245
3	800	4.0	4	400
4	5400	0.5	6	5400
5	2400	1.0	3	800

CALCULE EL INVENTARIO ACTUAL DE LOTIFICACION DE ESTOS 5 ARTICULOS Y MUESTRE - QUE ES POSIBLE REDUCIRLO SIN AUMENTAR EL TIEMPO DE PREPARACION REQUERIDO. ¿ CUAL ES LA MAGNITUD DE LA REDUCCION ?

USAR HOJA ANEXA.

MATERIALES 102

SESION 8

EJEMPLO 1, HOJA 2

ARTICULO	USO ANUAL $	COSTO DE PREP. P/ ORDEN $	COSTO DE ALMACEN. P/AÑO %	CANTIDAD ACTUAL EN CADA ORDEN $	COSTO DE PREP. ANU AL ACTUAL $	CANTIDAD DE PRUEBA EN C/ORDEN $	COSTO DE PREP. DE PRUEBA ANUAL $	CANTIDAD LIMIT EN C/ ORDEN $	COSTO DE PR LIMIT ANUAL $

MATERIALES 102

SESION 6

EJERCICIO 1

TERMINAR DE LLENAR LOS DATOS FALTANTES EN LOS CUADROS ANEXOS PARA LOS SUB-ENSAMBLES Y2L E Y3L, Y LA PIEZA 10314, LA CUAL SE USA UNA EN CADA UNO DE LOS SUB-ENSAMBLES ANTERIORES.

SUB ENSAMBLE DE PROYECTOR - Y2L

CANTIDAD EN CADA ORDEN = 600 UNIDADES

TIEMPO DE ENTREGA = 1 SEMANA (O PERIODO)

EXISTENCIA = 500 UNIDADES

ENTREGAS PROGRAMADAS = 600 UNIDADES EN 2 PERIODOS

		P E R I O D O							
		1	2	3	4	5	6	7	8
PROYECCION DE REQUERIMIENTOS BRUTOS		200	200	200	200	200	200	200	200
ENTREGAS PROGRAMADAS			600						
EXISTENCIAS	500								
ORDENES PLANEADAS POR LIBERAR									

SUB-ENSAMBLE DE PROYECTOR TSL

CANTIDAD EN CADA ORDEN = 350 UNIDADES.

TIEMPO DE ENTREGA = 2 SEMANAS (O PERIODOS)

EXISTENCIA = 400 UNIDADES

		1	2	3	4	5	6	7	8
PROYECCION DE REQUERIMIENTOS BRUTOS		100	150	120	150	100	90	110	120
ENTREGAS PROGRAMADAS									
EXISTENCIAS	400								
ORDENES PLANEADAS POR LIBERAR									

LENTE DE PROYECTOR - No. 10314

CANTIDAD EN CADA ORDEN = 1000 UNIDADES
TIEMPO DE ENTREGA = 2 SEMANAS (O PERIODOS)
EXISTENCIA DE SEGURIDAD = 200 UNIDADES
EXISTENCIA = 900 UNIDADES
REQUERIMIENTOS PARA REFACCIONES = 100 POR PERIODO

		PERIODO							
		1	2	3	4	5	6	7	8
PROYECCION DE REQUERIMIENTOS BRUTOS									
ENTREGAS PROGRAMADAS									
EXISTENCIAS	900								
ORDENES PLANEADAS POR LIBERAR.									

FACTORES DE SEGURIDAD

NIVEL DE SERVICIO	USANDO D.E.	USANDO MAD
50.00 %	0.00	0.00
75.00	0.67	0.84
80.00	0.84	1.05
84.13	1.00	1.25
85.00	1.04	1.30
89.44	1.25	1.56
90.00	1.28	1.00
93.32	1.50	1.88
94.00	1.56	1.95
94.52	1.60	2.00
95.00	1.65	2.06
96.00	1.75	2.19
97.00	1.88	2.35
97.72	2.00	2.50
98.00	2.05	2.56
99.00	2.33	2.91
99.18	2.40	3.00
99.38	2.50	3.13
99.70	2.75	3.44
99.86	3.00	3.75
99.93	3.20	4.00
99.99	4.00	5.00

TABLA DE CONVERSION DE INTERVALOS DEL PRONOSTICO

CUANDO INTERVALO = 1 Y TIEMPO DE ENTREGA:	DESVIACION ESTANDAR O MAD, MULTIPLICAR POR:
2	1.63
3	2.16
4	2.64
5	3.09
6	3.51
7	3.91
8	4.29
9	4.56
10	5.01
11	5.36
12	5.69
13	6.02
14	6.34
15	6.66
16	6.96
17	7.27
18	7.56

$$MAD\ AJUSTADO = MAD \left(\frac{T.E.}{INT.P.}\right)^{0.7}$$

SEMINARIO DE ACTUALIZACION EN ADMINISTRACION DE PRODUCCION E INVENTARIOS

SHORT RANGE PLANNING AND REPLANNING..... NOT FEEDBACK REPORTING

MAYO, 1978.

SHORT RANGE PLANNING AND REPLANNING.....NOT FEEDBACK REPORTING

By Rick McKelvy
Sheridan Associates
Interactive Information Systems Division

During the past five years, I've been working for a company that specializes in computer systems for Production and Inventory Control. This includes software, hardware, and the necessary training/implementation support to realize an effective system and obtain those magic results - reduced inventory, improved customer service, and improved productivity. My role has been one of defining the application design criteria for the various software modules and user assistance during pre and post implementation activities.

What this all means is that I've had the opportunity to visit numerous companies and review their current systems (both mechanized and manual) with respect to Production and Inventory Control....approximately 35 installations in all. Perhaps the most significant fact realized from this exposure is that, among the major Manufacturing system applications (Shop Floor Control, Inventory Control, MRP, CRP, and BOM), Shop Floor Control is the least understood. Somehow, we've defined this module as a system that collects and reports shop status information. Such data may be a necessary input to Shop Floor Control Systems, but the reporting of this information is not one of the application's primary objectives.

What, then, are these objectives? This question is the basis for my presentation which is structured in three parts. Part one develops the primary objectives of a Shop Floor Control System. Part two discusses the data files required and major processing logic necessary in a computer system to support these objectives. Part three reviews in detail the key output documents such a system should generate. These documents are presented in a problem solving mode using a chain hoist as the manufactured product.

Before jumping into Part one, however, I'd like to quickly review our past efforts with respect to computer systems for Manufacturing. This will provide some insight as to where we are and how Shop Floor Control, as it exists today, was created.

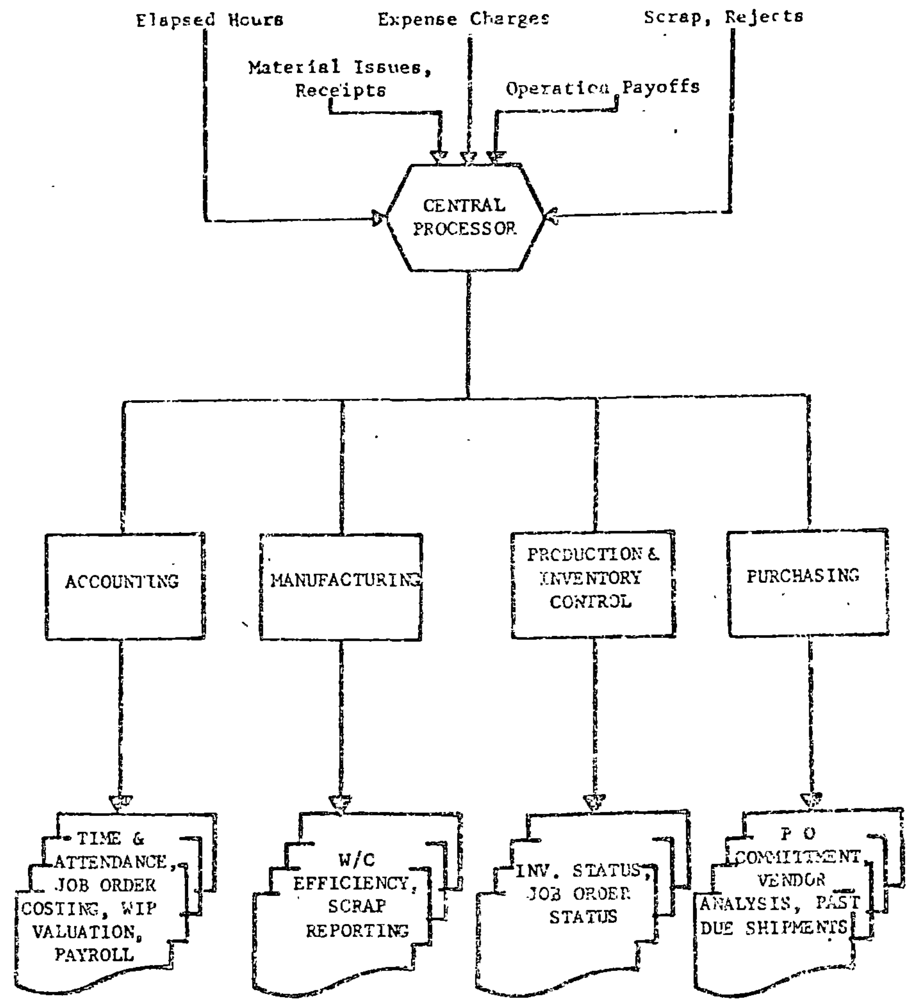
PAST

Manufacturing systems started something like this....First the Controller decided he would allow Manufacturing to use the computer (after Accounting and Payroll, of course). Next, a portion of the programming staff was split off to develop the required software. This group went to various shop personnel and asked a very logical question. What'a ya need? Our (the practitioner) response, however, was not so logical....we don't know! Not to be denied, the programmers then went off in their own direction. They looked around for something to mechanize, came up with all sorts of information, and started coding. Finally, we replaced the keypunched card with data collection devices which allowed for more data, faster.

Where did all this information go and how was it used? As shown on Exhibit 1, the typical data collected was elapsed hours by employee, expense charges by employee, material issues and receipts by order, operation payoffs per operation by worker, and scrap and reject figures by order. When data collection devices were used, the information was typically transmitted to a data pooler and then on to a central processor for user reporting. But was the user the Production and Inventory Control department? After all, that's the group we started out to help. Returning to Exhibit 1, we see numerous reports, only two of which can be considered helpful data for controlling what and when work should be released (or worked on) in the shop. Furthermore, as discussed later in Part one, such status reports don't really support the pr[illegible]y objectives of a Shop Floor Control System.

DATA COLLECTION

Exhibit 1



Next came the MRP crusade. It's theme was simple enough....The best way to help Production and Inventory Control is not through up-to-date shop status information, but rather in assisting them develop a realistic plan of material requirements consistent with customer demands. In other words, no matter how sophisticated the shop reporting system, if we start with an unrealistic plan (capacity) or place emphasis on the wrong jobs (priorities), the best such a system can do is tell us how late and/or out of control we are earlier than we might note this situation manually. After a few years, we decided this theme was probably right and in recent times have switched our attentions from detailed shop reporting to long range material planning or MRP.

This brings us to the present. Generally speaking, the MRP crusade is over. If you haven't grasped the dependent demand principle yet, I suggest you're resisting rather than trying to understand. However, MRP is not a cure all.

It has limitations. In fact, the limitations of MRP provide the basic framework for defining the objectives of a Shop Floor Control System. Obviously, this statement needs clarification which will follow directly. First, however, one final note on where we are. As practioners, once we realized shop reporting was probably last and not first in the development sequence of Manufacturing systems, we switched gears and started on MRP. Great, but along the way it appears we made an assumption I must now question. The assumption was that our efforts in the shop, although out of sequence, will none the less provide us the information tools to pick up where MRP leaves off. That is, controlling and executing the short range release plan. However, my experience to date with shop reporting systems does not support this assumption....a statement I will also explore further in Part one.

PART ONE - OBJECTIVES

In the preceding paragraph I made a statement about the limitations of MRP being the foundation for defining the objectives of a Shop Floor Control System. Now for some details. The major limitation in MRP is that is does not consider capacity restraints, particularly when reporting re-schedule situations (open job orders that should be moved up or back due to Master Schedule changes, cycle count updates, bill changes, etc). To compensate for this, an application called "Rough Cut Capacity Planning" is recommended. This involves the development of a series of general routings that represent the required hours by major work center for certain Master Schedule groups....the idea being to test the Master Schedule against these routings and determine feasibility with respect to plant capacity. There's no argument that this is a sound approach. However, let's look at it from the standpoint of supporting shop activity on a day-to-day or weekly basis. First, it's a gross average and by now we should all be aware of the potential problems associated with such figures. For example, consider the problems created when we took an item's yearly demand and divided by the lead time for order point. Aren't we in fact making a similar assumption when we state that if the Master Schedule looks good from a rough cut standpoint, it won't translate into daily or weekly capacity problems over the short range?

Does this mean rough cut should be fine tuned to reflect capacity on a weekly basis? Certainly not. If we ran a detailed CRP each week, reviewed its output, adjusted the Master Schedule accordingly, ran MRP, we'd probably get our planning reports one day before it's time to start regenerating. Furthermore, think about the computer time required to accomplish this task. The problem, however, is a real one and therefore must be addressed by one of our Manufacturing System applications. I feel this application is Shop Floor Control which leads us to the definition of our first primary objective. Namely, the ability to translate the short range release plan as reported by MRP (orders scheduled for release or re-schedule four to eight weeks out) into detailed capacity requirements by key work center based on the latest figures with respect to shop output restraints. Also, this ability must be provided on a timely basis since the mission of Production and Inventory Control personnel is clear once they receive their MRP output. This mission includes changing due dates on released orders, adding or revising planned orders, etc. If such changes are not feasible from a capacity standpoint, the user must know this almost immediately in order to make adjustments.

A second gray area or limiting factor with MRP is lead time. Almost all of the operating MRP systems I'm familiar with use a set of guidelines in this area. For example, all machine parts going through heat treat might have ten days lead time; no heat treat, six days; assembly, ten days; etc. I don't quarrel with this approach. Many users spend too much time getting lead time data down to an exact science only to find that MRP backs off from the end date of the previous week whenever it drops a level in the product structure. However, it does bring up the average problem again when considering work loads over the short range. Addressing this limitation then becomes the second primary objective of a Shop Floor Control System. Namely, including the capability to translate each order planned for release over the short range into a realistic opera by operation schedule based on its particular build sequence.

The third primary objective of a Shop Floor Control System is not related to MRP. In fact, it can't be related to any system but rather just happens to be the way things are. What I'm addressing is unplanned demands like a press that has never gone down before but will be out of commission for two weeks; or a customer who has a firm delivery date five weeks from now but just called and would like to know if we could possibly ship this week....and he's willing to wait ten minutes for the answer. Many small companies are faced with twenty-five to fifty of these inquiries each day.

For the most part, MRP can't help you with these problems. It's usually a regenerative application reported on a weekly basis. During the week, the shop's on its own. Therefore, the problems associated with unplanned demands over the short range must be addressed by the Shop Floor Control System which means offering capabilities that include:

1. On-line test for availability - this would enable shop personnel to evaluate the feasibility of shipping a product earlier than scheduled. The word test is important here because if a change can't be made, we don't want material reserved or order priorities changed unnecessarily.

2. On-line rescheduling of problem orders - when machines go down and we reschedule to alternate operations, does this just move the bottleneck from one area to another? We need to know this answer as soon as possible and, if it's a bad one, try something else.

So far we've discussed shop floor control from the standpoint of its interface with MRP and modifying schedules or material allocations based on unplanned demands. I consider these its primary objectives. However, executing the short range plan and data accuracy must also be addressed. This means including in the design of a Shop Floor Control System processing features such as:

1. Immediate allocation/de-allocation - where material, upon receipt, is automatically assigned in priority sequence to job orders in a reserved state that need the item. This insures stock is being utilized consistent with the latest decisions of the Production and Inventory Control Department. De-allocation is the reverse process. A good example would be cycle count updates that reduce the on-hand balance. For such updates, the system should immediately unreserve material allocated to reserved orders starting with the lowest priority job. This insures shortage or backorder conditions created by deallocation will be reflected on the expedite list as soon as possible.

2. File editing of shop completion entries at the operation level - this feature monitors shop feedback entries at the source and rejects any input where the quantity entered for a given operation is greater than that recorded to date for the preceding operation (± tollerance) or greater than the order's release quantity. If we've learned anything in the past about correcting record errors, it's the fact that the longer the time lag between when an entry was made and its error condition noted, the longer and more cumbersome the correction process becomes. As is true with any system, record errors are its worst enemy. Therefore, we should include every check possible in our Shop Floor Control System to ensure this enemy is controlled.

The list of processing features that should be included in a Shop Floor Control System to ensure the short range plan is executed accurately and in its proper sequence is rather lengthy. Coupling this with the fact that my paper is aimed at the objectives discussed previously, additional control fe s will not be addressed. This by no means indicates they are of lesser concern. One need only l- ' at the MRP systems that have failed because of inaccurate inventory data alize their importance.

PART TWO - THE SYSTEM

It's probably evident that in order to support the primary objectives discussed above, an on-line interactive system is required. Before deciding such a system is too sophisticated or the expense far outweighs its advantages (a typical response to on-line system suggestions in the past), let's review some current facts. I believe they negate this response.

1. On-line systems are easier to operate and require less training - this is true due to the elimination of numerous error reports that accompany batch processing systems....obviously because input edit and file update errors can be detected upon entry. Also, every input transaction flashes the necessary data on the input device thus eliminating the requirement that all shop personnel remember the data elements associated with each update entry.

2. Almost every computer on the market today is structured to support on-line processing. They believe it's the way of the future and for us not to utilize this capability seems foolish.

3. Computers are getting faster and cheaper each year. Consider the introduction of the mini computer. Most of these machines offer processing power equal to maxi computer output rates only a few years back, support on-line, are about one-third the size, and cost considerably less. I don't know if they will follow the pattern of hand calculators, but the trend seems comparable.

4. Programmers understand and are now fully competent with respect to on-line coding.

In summary, due primarily to increases in computer technology, on-line systems are no longer a luxury that only the rich can afford or the high volume user needs.

O.K., so in order to support the objectives outlined above we need an on-line system. What data files are required and what major processing logic is necessary? First the data files. As shown pictorally on Exhibit 2 and discussed briefly below the exhibit, five on-line files are required. These files need not be the massive data files typically associated with their names, however. For example, the Open Order file need only reflect job orders, customer orders (finished assemblies), and purchase orders scheduled for release over the short range. Also, these orders could be added to such a file mechanically as an output of MRP. The same is true for the Allocation file and Operation Detail file. They represent component requirements (bills of material) and operation steps (routings) for all job orders on the Open Order file. Therefore, they include only a small portion of the total bill and routing file data in a Manufacturing company. These files may also be updated mechanically by extracting data from the master files after an MRP generation.

As a point of interest this data, because of its relative size compared to the master files, could be placed on a mini computer which in turn could be located on the manufacturing floor. This is certainly a desirable feature as it would give the Production and Inventory Control Department its own computer and eliminate three complaints vocalized almost everywhere by shop personnel.

1. I don't get my reports on time.

2. We (the shop) never get processing priority on the mach

3. I know we have data accuracy problems, but it must be the data handling operation upstairs.

ON-LINE DATA FILES

Exhibit 2

WORK CENTER	INVENTORY MASTER	OPEN ORDER	ALLOCATIONS	OPERATION DETAIL

Work Center - This file should contain move, queue, and capacity figures for each work center in the plant.

Inventory Master - This file should contain balance information such as on-hand, on-order, reserved, etc. for each item fabricated, assembled, or purchased by the manufacturing facility.

Open Order - This file should contain a record noting due date, start date, quantity ordered, quantity received, quantity scrapped, etc. for all open shop or purchase orders either active or scheduled for release over the short range horizon (four to eight weeks).

Allocations - This file should contain the issue requirements (bills of material) for all shop orders on the Open Order file.

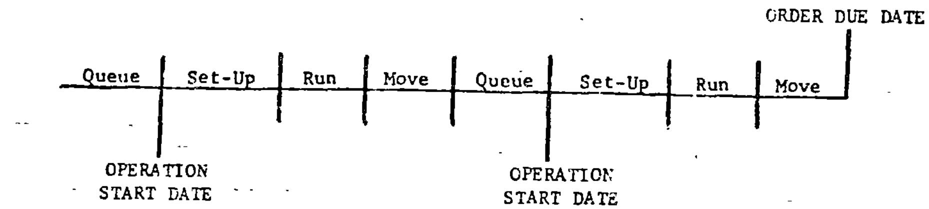
Operation Detail - This file should contain the standard run-time and setup values for each operation required on all job orders on the Open Order file.

There are two major processing features required in order to address the primary objectives of a Shop Floor Control System as outlined in Part One - prioritization of orders and operations, and scheduling of operation start dates. The prefix "re" should be added to both of these terms since today's schedules and priorities will no doubt be different from tomorrows. In fact, it's the reprioritization and rescheduling that is the key rather than designing sophisticated algorithms for each feature. Consider the following:

> Each week the Shop Floor Control System should shake hands with MRP and get it's new assignments. This not only includes additional planned orders for the future, but also adjustments to current planned orders (quantities, release dates, etc.) and expedite/de-expedite messages on open or reserved orders (move up, not needed on due date currently expected, etc.). After receiving this data the system, as quickly as possible, should then reprioritize and reschedule its short range plan and verify feasibility from a capacity and material availability standpoint. If the new plan is not feasible, this fact must be communicated as soon as possible in order for production and inventory control personnel to address alternatives. We all know it's easier and less costly to adjust schedules and priorities on orders that have not been released than it is to modify work-in-process jobs.

A second, and by no means less important reason for timely reprioritization and rescheduling is the fact that as soon as we verify the feasibility of MRP's adjustments and/or new assignments our unplanned demands will hit us (customer rush order requests and production problems). Therefore, these processing features must be on-line.

With regard to algorithms, simple critical ratio on jobs that have not been released is sufficient for ranking orders to determine material assignments. Slack ratio is recommended when addressing released orders to determine top billing at machine centers. The scheduling algorithm should be a straight forward back-scheduling technique using move and queue values from the Work Center file and time standards from the Operation Detail file. Its objective, of course, is to arrive at scheduled start dates per operation for every job order over the short range. This would then be followed by a loading process that summed the standard hours for each work center by time period and presented a load profile of required capacity to actual capacity. The back-scheduling logic is shown pictorally below.



There are two enhancements to this back-scheduling technique that should be considered. One is the elimination of move and queue time values when concurrent operations are performed in the same work center. The other is the ability to use less than a work center's full capacity when determining the start date for a particular operation. For example, if a center has four machines but only one is used for any single job, the back-scheduling technique should only consider eight hours a day (assuming one shift) as the allowed capacity and not thirty two (eight times four machines).

PART THREE - THE TOOLS

The primary output required to support the objectives outlined previously for a Shop Floor Control System include both video display and hard copy reporting. Although hard copy documents are not discussed in this paper, they are vital to the execution and control functions of the system. Typically these reports list, on an exception basis, jobs that need expediting, shortages that have been filled during the day's production effort, work center I/O performance, etc. For the most part, the on-line displays are used for planning, testing, and simulating re-plan decisions over the short range. Since this area is my main emphasis, only on-line display output will be reviewed in detail.

There are five basic displays that should be available on-line. These output, coupled with on-line scheduling and loading, provide Production and Inventory Control personnel the tools necessary to deal with MRP's adjustment requests and/or unplanned demands. For example, the allocation detail by order display shows the availability of component parts in stores for any job order that has not been released. If the order is in a reserved state, this display merely reports the quantities allocated (or backordered if not available). If the order is in a planned state, however, the display simulates what the status would be if the order were released today. The term simulation is important because it allows for testing conditions and/or alternatives without tying up material unnecessarily. Consider the example below. The order happens to be for a chain hoist assembly scheduled for release on November 10th (see Start Date field). Since today is October 24, this is a planned order for the immediate future and its availability figures represent simulated values. The display was triggered from a customer's request to ship this week, if possible.

ALLOCATIONS FOR ORDER 3867 LOT 0001

ASSEMBLY NUMBER	S	PRI	START	DUE	ORD.QTY	QTY.DUE
547364351R	0	1140	10-NOV-75	17-NOV-75	250	250

LINE	PART NUMBER	QTY/ASY	REQ.QTY	RES/PLN	BO/SHRT	ISSUED
001	5700439001	1.0	250	100	150	
002	5900473195	1.0	250	250		
003	591291067P	1.0	250	250		
004	6090741278	1.0	250	250		

As you can see, the display indicates all parts are available except one (5700439001) - which means the order can not be shipped this week. Or does it? Our output tools would be remiss if they did not allow us to investigate further. For example, questions like:

> Could it be that inventory does exist for our short part but it's reserved for other orders? If true, could or should we borrow? Borrowing typically depends on when we can give the material back which leads to a second series of questions. If I borrow, when will additional material arrive to fill the shortage I created robbing Peter to pay Paul? And if I don't borrow, is additional material coming in so that I can at least improve on my scheduled start date of November 10, 1975?

The next two videos address these questions. The first display is a request for the current allocations against our short part.

ALLOCATIONS FOR PART 5700439001 DESC: LIFT WHEEL

ORDER NUMBER	LOT	LINE	S	PRI	START	REQ.QTY	RESERVE	BKORDER
3180	0001	004	4	1017	27-OCT-75	300	300	
2211	0001	002	4	1130	31-OCT-75	200	200	
3867	0001	001	0	1140	10-NOV-75	250		

As indicated, there is more material on hand then the 100 we were able to utilize with our previous video. However, its reserved for other orders - 300 against an order due to be released early next week and 200 against an order scheduled for release late next week. The third order listed is our problem order. It has nothing reserved since it is still in a planned state.

Now we know it's possible to borrow which would eliminate our material shortage problem. However, what about the "Rob Peter, pay Paul" question? This can be addressed with a request for all open replenishment orders for our missing part which is the next display.

ORDER SUMMARY FOR PART 5700439001 DESC LIFT WHEEL

C	ORDER NUMBER	LOT	S	PRI	START	DUE	ORD.QTY	QTY.REC	QTY.DUE
3	1704	001	6	1015	14-OCT-75	30-OCT-75	400	100	300

As shown, there is presently a job order working in the shop that was released for 400, has completed 100, and expects the remaining 300 on October 30, 1975. This indicates that if we borrow 100 from order number 2211 to fill our immediate shortage problem, additional lift wheels should arri[ve in] stores replacing the material before order 2211 is scheduled for release (October 31, 1975). Furt re, our automatic allocation feature will insure the parts are assigned rder 2211 upon receipt in stores.

So far, so good. We've found a way around our material problems, but what about capacity. After all, we're moving a job up three weeks from where it is currently planned for release. What affect will this have on department A03, the area where order 3867 must be assembled? This question leads us to our fourth on-line display - Work Center Load Profile by department.

WORK CENTER A03 LOAD PROFILE

DESCRIPTION CHAIN HOIST ASSEMBLY

PER	START DATE	DAYS /PER	CAPAC HOURS	RESERVE HOURS	SCH HOURS	LOAD TO CAPACITY 0%......100%......200%	LOAD %
1	20-OCT-75	5	320.0	290.0	0.0	.XXXXXXXXX	90
2	27-OCT-75	5	320.0	300.0	0.0	.XXXXXXXXX	94
3	03-NOV-75	5	320.0	170.0	110.0	.XXXXXXXXX	87
4	10-NOV-75	5	320.0	110.0	200.0	.XXXXXXXXXX	97
5	17-NOV-75	5	320.0	100.0	205.0	.XXXXXXXXXX	95
6	24-NOV-75	5	320.0	50.0	200.0	.XXXXXXXX	78
7	01-DEC-75	5	320.0	0.0	350.0	.XXXXXXXXXXX	109
8	08-DEC-75	5	320.0	0.0	285.0	.XXXXXXXXX	89

This display indicates we have an extra 10% capacity this week in department A03 which will allow us to ship our order as requested without jeopardizing the status of other orders due in the same time period.

It should be noted that all of our questions have been addressed in a simulation or "what if" mode. As a result, up to this point nothing has been changed - only interrogated. Had the answers been negative, we would not have disrupted current priorities, schedules, etc. On the other hand, our answers where positive. Therefore, we should have the capability to enter this decision on-line which in turn should trigger the necessary processing steps to change priorities and schedules accordingly. These processing steps have been discussed earlier and include:

1. Re-allocation of material (part 570043001) from order 2211 to order 3867.

2. Rescheduling of order 3867 to reflect assembly this week.

3. Adjustment to the load profile for A03 to show an increase in week one (under reserved hours) and a decrease in week three (under planned hours).

Furthermore, since all of these processing features are on-line, the changes are made instantaneously and our next interrogation process for an unplanned demand or MRP adjustment will be based on information that reflects the incorporation of all prior decisions.

Although the data accuracy and execution reporting disciplines necessary for a complete Shop Floor Control System are not addressed in detail in this report, I would like to discuss one on-line output related to these topics. It concerns the communication of decisions as developed above to shop personnel working on the floor. In other words, what vehicle is used to insure changes in order priorities are communicated to area foremen so they in turn can adjust their job sequencing on the various machines? The next video display addresses this concern. It lists all jobs through a given date that are scheduled to

begin in the requested work center. Because this display is developed using the same on-line files the planning department analyzes and/or manip s when dealing with change requests, both schedule dates and priorities re the latest Production and Inventory Control decisions. Therefore, the l is closed between deciding on a last minute change and conveying this information to shop personnel.

OPERATIONS FOR WORK CENTER A03 THROUGH 25-OCT-75

ORDER NUMBER	LOT NO.	PART NUMBER	OP NO	PRI NO	LAST W.C.	QTY AVAIL	NEXT W.C.	ALLOW HOURS	S T
3172	0001	8651100819	020	.88	A02	120	END	20.0	P
3165	0001	5362849615	020	.93	A02	295	END	28.5	I
3867	0001	547364351R	010	1.01		250	END	26.1	R

SUMMARY

Following is a list of key points or conclusions presented in this paper. Their sequence follows the report's detailed text for easy reference to support information.

1. Among the major Manufacturing System applications (Shop Floor Control, Inventory Control, MRP, CRP, and BOM), Shop Floor Control is the least understood.

2. The majority of Shop Floor Control Systems currently operating today do not address the application's primary objectives. They only collect and report shop status and performance data after orders are released.

3. The primary objectives of a Shop Floor Control System include:

   a. Interfacing with MRP and dealing with its limitations over the short range horizon - rough capacity averages, general lead times and the assumption due date changes on open orders will not disrupt the shop.

   b. Handling unplanned demands such as customer order reschedule requests.

   c. Controlling the execution of the short range release plan.

4. To support the objectives listed above, an on-line interactive system is needed with the following capabilities:

   a. simulated test for availability with respect to support material for assemblies, sub-assemblies, and customer orders.

   b. on-line allocation/de-allocation of stores inventory to job orders in priority sequence.

   c. on-line prioritization of job orders scheduled for release.

   d. on-line back-scheduling by operation for all job orders over the short range release horizon (four to eight weeks).

   e. on-line loading of required capacity by work center by time period for all shop orders scheduled for release over the short range.

5. The following data files must be on-line to support the capabilities listed above.

   a. Inventory Master file - on-hand, on-order, reserved, etc. balance data for all parts.

   b. Open Order Detail file - quantity and due date status for all shop and purchase orders open or scheduled for release over the short range.

   c. Work Center file - move, queue, and capacity figures for each work center in the shop.

   d. Allocations file - single level bill requirements for all job orders on the Open Order file (short range horizon)

   e. Operation detail file - routing sequence with time standards for all job orders on the Open Order file (short range horizon).

6. The following on-line displays must be available to provide Production and Inventory Control personnel the information tools necessary to meet the primary objectives of a Shop Floor Control System.

   a. Allocations by order - this display addresses the "what if" question concerning material availability.

   b. Allocations by part - this display lists all orders needing a particular item over the short range.

   c. Orders by part - this display reports the current status of all replenishment orders for a given part or assembly.

   d. Work Center load profile - this display projects a load to capacity profile of all work scheduled through a particular work center over the short range horizon (in weekly time periods).

   e. Operations by Work Center - this display lists all operations scheduled through a particular work center by time period and priority.

7. Due primarily to increases in computer technology (both hardware and software), the Shop Floor Control System presented in this report can be designed to function on a mini computer. Also, the necessary hardware could be located in the shop and operated by Production and Inventory Control personnel. Three companies in the eastern United States currently have such a system operating in their Manufacturing Department using a DEC PDP/11 mini computer.

ABOUT THE AUTHOR

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Rick has a Bachelor of Science Degree in Industrial Engineering from the University of Ma[illegible]nd and is a member of the APICS Chapter in Columbus, Ohio.

TICKETS OR TERMINALS: WHAT'S HAPPENING ON THE SHOP FLOOR?

By William B. Todd
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INTRODUCTION

The job of manufacturing is frequently described as the management of change. As soon as we learn to solve one great problem, another pops up.

An example of this has been in the Material Requirements Planning Crusade. MRP has become an outstanding success at helping to reduce both inventories and lead times. But one thing leads to another. Our understanding of MRP and its techniques is being extended beyond simple order launching by time periods into Priority Planning of orders to help do a better job of scheduling. Simultaneously, progress is being made in Master Production Schedule Planning.

Continuous attention to better and better planning, however, needs to be counterbalanced by *increasing attention* to the *successful execution* of these plans. Otherwise it will certainly lead to diminishing returns for effort and resources invested.

This paper addresses the subject of feedback of data from the shop floor.

- Why the data is needed.
- How you can get it.
- What value it has for you.

The realization is becoming more widespread that planning and replanning cannot continually be improved without better data about what happened to the plans previously made.

FEEDBACK

Feedback is a strange word. Does it mean the feedback to you of data collected from the shop floor about the state of completion of each job and its location; or about the current load on each work center or production line; or the actual on hand and currently available inventory balance for each stocked item? Yes, it does.

But it also means the feedback from you to the shop floor about what to do next, about when the purchased components are expected in Receiving, etc.

Feedback is a *two-way street* running between Planning and Execution, between Dispatching and Machining, between feeder lines and production lines. More accurately it is Plant Data Communications (PDC) among all personnel, all departments, all functions, all locations and up through the organizational structure from bottom to top and back down again.

It is nothing new. Over the years we have called it many names, Data Collection being the most common. But Data Collection, like most reporting is a one-way street and rarely benefits the person collecting and reporting. Without being useful to the "reporter", it is frequently omitted, or illegible, inaccurate, late or all of the above. Benefits to the user of a PDC system will be addressed later in this paper.

Shop Floor Control is another phrase frequently misused when referring to the use of terminals in the shop to report manufacturing activity, inventory transactions, labor and attendance, etc. Shop Floor reporting is no more a control of the shop, than inventory reporting is a control of inventories.

Neither is Plant Monitoring and Control synonymous with Plant Data Communications (PDC). It is, however, descriptive of a great cluster of applications or functions, including PDC. Other applications are machine monitoring directly by instrumentation and computers or indirectly by the operator reporting what the machine is doing; machine control, such as Direct Numeric Control (DNC) of machine tools by computer; or Direct Machine Control (DMC) of stacker cranes, conveyors, test stands, etc. by computer.

Plant Data Communications (PDC) refers to the use of a system of terminals to:

- Report to a database the location and status of people, jobs, inventories, machines and other resources, eg. tooling.
- Permit inquiry into that database about the status of that job or resource.
- Create a visual display or printed copy of an exception notice to a particular station or individual.
- Through message switching capability, let one person direct a message to another individual.
- Let one person direct a broadcast message to all appropriate terminals simultaneously.

Essentially, then Plant Data Communications is the two-way feedback of raw data, edited and [illegible]ected data, plus already analyzed and processed information. A PDC System uses term[illegible] [illegible]sically connected by some form of communication lines to each other and through co[illegible] [illegible]ing devices to a host computer. The computer processes and stores the data about every communications transaction in a base.

That is all pretty abstract. Let's be specific by examining an example of one transaction. Incidentally, it was chosen as typical of the procedure in use in literally hundreds of manufacturing Stores Accounting applications of PDC.

EXAMPLE

Consider the following transaction. It illustrates many of the concepts of PDC. It is only one of many ways to do one transaction on one of many kinds of terminals interacting with a database.

1. A production worker appears at a raw materials stockroom.
2. He hands the stockroom worker his identification badge and a requisition card previously assigned him by his foreman. The requisition authorizes him to draw 30 pieces of Part Number 650793, for Shop Order #45, Operation #10, to be used at Work Center #3B.
3. The stockroom worker uses his terminal to enter the employee identification and the requisition data into the PDC System.
4. The terminal reads the appropriate data from the employee badge and from the requisition.
5. The data is transmitted to the computer, which recognizes this as a valid inventory requisition transaction.
6. Programs in the computer then call for segments of information from the database of information stored in an on-line direct access device.
7. The programs check whether:
   a. this is a valid employee clock number;
   b. this employee is currently assigned to Work Center #3B;
   c. this is a valid part number at the proper Engineering Change level;
   d. this quantity of parts is both on hand and available, or reserved for Shop Order #45 as a pre-planned allocation.
8. In our example, all is well and the stockroom worker's terminal displays an "OK to Issue" message, which includes the bin location of the 30 pieces of Part Number 650793.
9. He then indicates to the terminal that the issue transaction is completed. The total elapsed time will normally be only a few seconds.
10. The worker then goes to that bin location, draws the 30 pieces and hands them to the production worker.

Although it is a good exercise to examine all the "what if" questions, time and space do not permit it. Suffice it to say here that they can be, must be and are answered in a reassuring number of PDC systems in operation today.

Now look at what happened as a result of this transaction.

1. The production worker got what he needed *in a minimum of time,* without any paperwork. The badge is his permanent identification. The requisition had been generated and printed from a terminal by the Dispatching System.
2. The stockroom worker:
   a. performed his task in the minimum time,
   b. with no paperwork to write, or post to another record,
   c. was guided in issuing the parts as authorized, from a bin location he did not have to look up or remember.
3. The inventory records in the database were updated to show for Part Number 650793, as of right now:
   a. the new On-Hand Balance;
   b. the date, time of day and quantity issued;
   c. the new available or reservations balance relieved by this issue.
4. The Open Shop Order records in the database were updated to show, for Shop Order #45, that Operation #10, "draw 30 pieces of Part Number 650793 from Raw Material Stores" was completed as of this date, and time-of-day by Man Number_____.
5. The Product Cost records in the database were updated to show, for Shop Order #45 that 30 pieces of Part Number 650793 were used at a material cost of $_____.
6. The Bin Location Inventory records in the database were updated to show that Bin Location #4562AA is now empty, and available for storage of any new receipt to that stockroom that fits that bin classification.

CONSIDERATIONS OF THE EXAMPLE

Most important, perhaps, is that the database records of inventory balances reflect what is on-hand, available, reserved and where every unit is stocked as of right now. This provides a new level of validity to the Material Requirements and associated Planning Systems.

It also contributes to a higher level of integrity to Stores Accounting. Locking the stockroom is necessary, but reporting <u>all</u> the transactions accurately is vital.

The on-line (i.e., terminals to a computer database), real time (i.e., two-way communications between the system and the user) PDC system helps overcome one of the fundamental problems of manufacturing. That is, in the absence of good planning, good discipline, and good production (i.e., execution of the plan), workers do what they must to survive.

In our example, the reserved material was <u>issued</u> to the *appropriate, authorized shop order.* In many plants this would happen only by coincidence. Usually the only way to be sure of doing the jobs assigned when he is ready, is to draw the materials, the tooling, the gages and anything else required as soon as the job is assigned to him.

This results in stockpiles or banks of Work-In-Process inventory out on the floor, physically reserved till some future day when they will be used, maybe. It creates congestion by occupying production or aisle space. More importantly, it generally means that a first come, first served issuing of stock destroys any planned reservations, priority planning or priority dispatching systems. Material needed for one job is not on-hand. It was issued to another released shop order which had a lower priority, a later due date, but a worker who is more fleet of foot.

If you want to consider <u>cause and effect</u>, consider the following. If we report issues and receipts accurately, when made, using a PDC System, then we can learn to depend on the quantities recorded in the database, rather than upon card files or computer inventories updated by batches of completed requisitions.

If we can depend on the inventory accounting records to accurately reflect the balances as of *right now,* we can do a better job of Material Requirements Planning. The workers will gain confidence that when they go to draw stock, it will be there, reserved for them. Then we will reduce the need for physical allocations. Then we will reduce the amount of excess Work-In-Process. Then we will reduce the number and length of shortage lists, and the need for stock chasing.

We could continue this cause and effect examination right on through Scheduling and Loading simplification resulting from fewer jobs released to the floor competing for capacity, less expediting, etc.

Two final points.

1. Every event, every change of plans, every issue from stock, every piece that is scrapped, every job requiring rework, everything that happens has -- either a big direct impact, or a less obvious indirect effect on productivity.
2. A PDC System won't solve all your problems nor will it make the only contribution to productivity increases, but it can provide the tools and terminals to report what is happening into the *database.* Once there, it is <u>available</u> to answer your inquiries, or to generate a report.

Now let's move on to some of the difficulties common to most every manufacturer. Once we get by the symptoms to the real problems the solutions may become pretty obvious.

In any event, problems identified can be opportunities for improvement, leading to justifiable change. First the symptoms we recognize:

1. Excessive Lead Times for:
   - Product Design
   - Customer Order Processing
   - Purchasing
   - Shop Orders Paperwork Preparation
   - Manufacturing and Assembly
2. Excessive materials:
   - Raw stocks
   - Work in Process
   - Stocked Components — including service parts
   - Finished Goods
3. Inefficient utilization of stockrooms and other storage space.
4. Low utilization of capital equipment, which causes bottlenecks diagnosed as lack of capacity.
   - machine tools
   - material handling equipment
   - tooling and fixtures
   - inspection equipment and test stands

5. Missing expensed items

   - hand tools
   - expendable supplies
   - gages and micrometers

6. Excessive indirect overhead

   - supervisors
   - foremen
   - manufacturing engineering troubleshooters
   - stockchasers and expediters
   - timekeepers
   - inspectors and quality assurance troubleshooters
   - inventory analyzers
   - set up men
   - material handlers
   - maintenance men

REVIEW OF MANAGEMENT PRINCIPLES

A brief review of a few basic and almost universally accepted principles of management at any level are in order here. This is a reminder that there is little hope that any system will function properly without them. If they do not exist, or when poorly defined and improperly applied, they are the source of the problems.

1. Policies

   Specific guidelines are needed to explain to each level of employee what he is supposed to be doing.

   A few examples may help. Ask yourself whether your company has clearly stated, written-down policies in regard to the following.

   - Customer Service Levels, by product or family
   - Economic purchase order quantities or guidelines for commodities speculation
   - Economic production order quantities or lot-sizes
   - Priorities to decide conflicts or where competition exists for a resource
   - Stocking of service or spare parts
   - How to define planning lead times (for MRP) and production lead times (for scheduling and loading)
   - On what kinds of items will safety stocks be planned and used

Such policies and guidelines may not have been completely essential in the past, but their continued neglect is cause for alarm.

2. Objectives

   For each policy, each function, each department, there must be *clearly written* objectives directed to each employee at his level of responsibility.

   These objectives must be reasonable, precise, and measurable. Each of us has suffered that unpleasant anxiety which comes when we don't know whether a superior believes we are doing a good job or not. Worse, it may not be clear what it is we are supposed to be doing!

Here are some examples of specific, measurable objectives:

   - No more than ___% of all jobs in process are allowed to remain behind schedule more than ___work days.
   - Practice sensible Input/Output Control by releasing to the plant no more standard hours of work this week than was completed last week.
   - Prepare shop paperwork no more than ___days prior to release of the order.
   - Reduce the number of orders in queue or the backlog in at least ___% of the work centers to no more than___orders.

3. Systems and Procedures

   So much material is available on this subject that it is unnecessary to dwell on it. Suffice it to repeat that, particularly with PDC Systems the users of the terminals, at every level, must be participants in the design and implementation of the system. Education on the operation, and almost continuous reminding of the benefits to the users are vital.

4. Evaluation Techniques

   Methods must be designed to evaluate the new system *while it is being designed*, not after installation. Pride of authorship is always involved and usually underestimated. In the absence of objective evaluation techniques, the system will be promoted, defended, and explanations will be readily available to excuse any results experienced.

   Example: With PDC Systems it is advisable to have operator identification be the first data entry element. By doing so, all aborted or incomplete transactions can be sorted and analyzed to identify which operators need more training. It is not done to penalize the operator, but to help him become more productive sooner. This simple evaluation technique can measure the success of the operator training program.

5. Incentives

   There must be incentive to successfully achieve objectives, rewards for having succeeded, and options to select for improving performance when unsatisfactory.

   Example: For a stockroom manager, public recognition and a cash bonus for some level of inventory record accuracy. Agreement between database and cycle-count quantities within some % of error is the measure of accuracy.

6. Proper Tools

   The previous five items are frequently problems because they are totally absent or woefully inadequate. Production and Inventory Control people always have some tools of the trade:

   - telephones
   - weekly production reports (heavily annotated)
   - red tags
   - antacid tablets
   - clip boards
   - shortage and hot lists
   - Gantt charts or other schedule board

   A Production Control Manager I met had a blackboard in his office filled with a highly complex progress chart of every machine being constructed, with departmental loads, etc. It kept one Production Control man busy four hours a day to maintain. When I inquired how he could interpret and use such a complex presentation, his reply was "Oh, I don't use it. I can hardly read it, but it's extremely valuable in keeping Marketing off my back!"

   Those kinds of tools have kept us going in manufacturing for many, many years — and the habits and traditions are strong. But those kinds of tools and procedures are inadequate today. They no longer work in an airlines reservation system, nor in a wholesale distribution warehouse, nor even in a process industry continuous flow kind of manufacturing or production.

   A good PDC System offers the tools to provide the needed data — in the form needed, accurately, quickly, and as current as the last entry from an appropriate terminal.

   Let us examine briefly where the data originates that many manufacturing people must use now. Although you may not use them all in your operations, or within your company, they are all pretty common.

SOURCES OF DATA

Consider any one of your working reports. Trace back its content to the original source of the data. Not just down through a couple of more detailed or more frequently prepared reports, but back to the original source. Some source documents are on pre-printed forms, others are simply scraps of paper. In either case they are filled out by shop people.

   - move ticket
   - labor tickets — of hours by job for a worker
   - incentive labor production coupons
   - production counts or process yield quantities
   - scrap tickets
   - material requisitions
   - inspection tickets
   - machine down-time tickets
   - attendance cards
   - rework authorizations
   - route or process sheet with entries for hours and quantities
   - shop traveler, packet, job card or operation cards

— shortage lists
— expedite lists

You can probably add some of your own to this list. Some points to consider:

1. Are they accurate, complete and legible.
2. Were all of them prepared and gathered, or were some omitted or lost.
3. What was the time lag between the event and the reporting of some data about the event.
4. What was the time delay between the reporting and the analyzing, processing, transcribing and summarizing. That is, until the information was available to each of those people that need it.

A good PDC System places terminals where the activities and events occur. They make it as simple as possible to capture as much data as is economical. This data is edited at the source, transmitted electronically to a computer, processed, and the database of information *updated for immediate or future usage.*

Keep in mind that this eliminates the proliferation of carbon copies, or transcribed reports of the same data in different forms to different departments, etc. The information is available from the single source, the database, to anyone in any department at any time who is authorized to have it. Everyone is sharing the same information in its most current form.

APPLICATION FOR PDC

A PDC System is a tool, just as a telephone system, an NC machining center, a forklift truck, or a conveyor line is a tool. Where do we apply the tool? Anywhere in the plant where data must be communicated accurately, completely and fast.

Most of the data collected, and most of the communications in the plant involve the following basic elements.

1. Transaction type — identifies the piece of paper or kind of message, eg. time card clock-in.
2. Worker identification — a man, clock or social security number
3. Job, operation number
4. Batch, lot, or tub number
5. Quantity — received, sent, started, completed, scrapped, rework, short
6. Location — bin identification, building, work center, department, machine, production line
7. Date and time
8. Value — scale weight, test value, instrument reading
9. Requests for assistance — foreman, material handling, set-up maintenance or repair man, inspector, material, job assignment.
10. Messages — Harry call Tom on extension 245
11. Inquiries — status of job, man, machine; location of material; what do we do next.

There are other categories of data elements, but we are more concerned here with the application of PDC to your needs. Because the requirements for information are almost limitless we cannot address them all, but here are some of the most commonly used.

1. Priority Dispatching Guidance

   Generally a visual display is presented on a terminal in priority sequence, of the jobs, and the operations on those jobs, to be completed in this department. It is a guide to the foreman of what most needs to be done. He then assigns work based on his experience, and availability of his resources.

   It can provide a *comforting view* of the *backlog* that is dramatically less expensive than having the physical work in process sitting there. It also reduces the pressures on foremen from competing expediters.

2. Job Assignment

   Related to the above, the foreman can assign the work in queue, based on priority sequence and availability of the labor skills, tooling, materials and machine capability needed for each job. This applies whether he is distributing jobs across a cluster of more or less interchangeable machines in a job shop department, or leveling the backlog of work across production lines or assembly stations.

3. Inventory accounting

   A terminal at the stockroom counter simplifies the reporting of every issue, receipt, return to stock or adjustment — at the time of the event. This was discussed earlier in the example.

Incidentally, the inventory here may be any kind of inventory which affects *shipping* the product *on time.*

   — Raw Materials
   — Components, sub-assemblies and service parts
   — Finished and packaged goods
   — Maintenance replacement parts for your own equipment
   — Packaging materials
   — Tools, jigs, dies, fixtures
   — Inspection devices
   — Expendable supplies
   — Numerical control tapes
   — Product accessories — tool kits, installation kits, operating or repair manuals, serial number or U.L. tags

4. Manufacturing Activity Reporting

   This is the basic reporting by the direct workers formerly using labor and move tickets, or production line counts. Kinds of transactions reported through a terminal include:

   — Receive material
   — Set-up start, complete, interrupted and reason
   — Run start, complete, interrupted and reason, quantities
   — Tear down start, complete, interrupted and reason
   — Machine down and reason — eg. hydraulic, pneumatic, mechanical
   — Wait request — eg. for materials, foreman, inspection
   — Indirect start, complete and reason — eg. safety meeting

   Terminals here let the workers report the activities they must report now, but without the pencil pushing, legibility problems, and time delays. The data has updated the Open Order database. The data also can be used for other analyses, such as machine utilization and reasons for downtime, actual vs. standard set up, run and tear down time, etc.

5. Material Handling Activity Reporting

   Requests for moves, and reporting of moves from and to specific locations are entered from terminals situated throughout the plant.

6. Maintenance Activity Reporting

   This includes both Preventive Maintenance and Repair Activity. It is used to keep track of where each worker is; what he is doing; how long it takes him to respond to a call, diagnose a problem, and to fix it. Maintenance parts inventory was previously mentioned.

7. Resource Tracking

   This generally involves terminal inquiries to locate resources. "Stockchasing" is probably the most common usage here. It applies also to locating a person, a tool, or a job.

   There is certainly *no magic* involved here. We have just discussed transactions which involved essentially all workers reporting what they are doing, while doing it. This continuous updating of the database records of open orders, inventories, etc. simply means that the information formerly available only on pieces of paper or by visual inspection is now available in the database.

8. Inspection Activity Reporting

   The impact of being able to report scrap as it is created, and rework requirements, and test yield values as they are made is very significant.

   By doing so, future shortages can be anticipated days or even weeks sooner. It offers opportunities to make corrective decisions much earlier that cost much less. For example, the earlier a supplemental or make-up order can be made to replace a shortage, the fewer duplicate set-ups are required. In high volume lines, defect occurrence frequencies can be tallied in-line in time to stop the production line for adjustment, greatly reducing scrap rates or rework costs.

   There are numerous other applications which may not affect you directly. Examples are attendance reporting, and security guard route assignment and tracking.

RESULT AND BENEFITS

There is a certain analogy to be drawn between the status of Bills of Material ten years ago and now, with the status of the rest of the Plant Data. That is, then it was common practice for each major function to have its own Bills – Production Engineering, Manufacturing, Inventory Management, and Costing.

The problems with that are well known; different structures, Engineering change levels, maintenance. "One set of books" became the rallying cry, and now you have it – Bills of Material in a computer database shared by all, who now enjoy current, consistent and available information about them, presented in a variety of formats to suit the user.

The same is equally necessary for the rest of the Plant Data – capacities, loads, schedules, inventory position, location and status of things. Paper tickets, informal reporting, individual clerical files, lots of stockchasing, expediting, and "unofficial" safety stocks represent the same kinds of problems that those multiple Bills of Materials did.

In addition to the previous discussions of transactions and applications here are some of the results available to you, as well as to all others within your organization who need the information. Much of what is mentioned is an almost incidental by product of the PDC transaction logging within the system.

1. Job or Product Cost buildup by direct labor, material, machine hourly usage.
2. Job or Work-In-Process status reporting.
3. Production performance or variance from standard by job, contract, work center or production line, man or team, hourly, daily or periodically.
4. Backlog reporting by work center or line, that is by jobs on-schedule, or aged by date for past due jobs.
5. Machine utilization and downtime analysis.
6. Comparisons of actual vs standard times for set-up, run, inspect, move, repair, maintain.
7. Tool-life statistics for reconditioning schedules, vendor quality, lot-sizing.
8. Scrap analysis for Engineering Changes to the product or process, and for operator learning curves and training.
9. Attendance and labor reporting for absentee lists, manning stations on production lines, payroll accounting, efficiency reporting, overtime authorization accounting, and analysis of reasons for indirect labor time.
10. Inspection results for adjusting Quality Control procedures, for recalibration schedules, failure prediction, sampling statistics and yield analysis and test value documentation required by governmental agencies.
11. Security Guard monitoring for emergency assistance, security area entry control, insurance reporting.
12. Maintenance crew analysis for response times, time allocation experience and scheduling, multiple shift resource allocation, preventive maintenance scheduling.

BENEFITS TO THE USERS

The above results have to do with functions or organizational responsibilities. It is important to view the subject of PDC from another perspective, that is from benefits to the users of the System. The understanding of how the System works, and why it is of value to the individual user is absolutely vital to its successful operation. It requires *participation by users* in the design of the System, and *continuing education* about its operation and value.

A good rule to follow in understanding each level and its responsibilities is to remember that each man is primarily interested in doing well those things on which performance measurements are applied to him, and for which he is paid. They are outlined below...

1. Executive level: President, General Manager, Vice Presidents

   – Shorter lead times offer competitive advantages to marketing, and financial benefits through reductions in work-in-process and less complex scheduling.
   – Better customer service
     a. Ship the product he wanted
     b. Ship the quantity he wanted
     c. Ship at the right time
   – Optimize inventory investment
   – Higher productivity through better utilization of all resources
   – Appropriate level of quality, i.e., balancing Product Engineering against the cost of production inspection, rework and scrap.
   – Cost avoidance due to growth and inflation.
   – Tighter control over operations by reacting faster to changed conditions

2. Operating Managers – by department or function

   – Higher productivity by labor force
   – Higher productivity from better utilization of capital equipment and other facilities
   – Appropriate yield or level of quality
   – Minimal ratio of indirect to direct labor
   – Reduce scheduling and sequencing problems
   – Reduce clerical and administrative effort by managers
   – More accurate reporting of events – faster
   – Better status reporting of and control over his operations

3. Information Systems or Data Processing Management

   – Contribution to productivity of the company
   – Greater assistance to the Production areas and acceptance by them.
   – Reduced need for keypunching or other data entry operations
   – More productive thruput from less editing and fewer error corrections
   – Faster, more accurate and complete updating of Databases that service all levels of executive and operating management

4. Direct labor and other terminal users – non-managers

   – Correct paycheck resulting from accurate reporting and record keeping on labor hours and man identification numbers.
   – Potentially higher earnings from greater productivity, particularly on an incentive payroll or other bonus system.
   – Less pencil pushing and paperwork.
   – Pride in doing the job for which they are being paid, with fewer delays.

SUMMARY

Manufacturing is a business so complex that it is sometimes irresistable to believe that success is achieved when the products are shipped on time. Profitability and productivity, so long a concern only for a few senior executives, is now the direct concern of everyone.

The pace of business, the complexity of manufacturing processes, the proliferation of new products and feature options and competition from unexpected sources have forced a change away from business as usual.

This paper reflects a firm belief that current conditions and future considerations absolutely demand that we do a better job of communicating. The inter-dependencies across plants, departments and functions makes it imperative that we use the best tools and systems available to communicate what is happening.

Operating *Plans* must continually be *updated* and adjusted to reflect changed conditions. Senior management must have more accurate, current information about delivery capability, true costs and resource capacity to prosper in a competitive environment. *Consumerism* demands attention to product quality and performance.

Although it may sometimes seem that we are already engulfed in data, much of it is of little value. It is delivered too late, in the wrong form, with little confidence in its accuracy.

If we are to really know what is happening in the plant, to control it, to schedule, load and supply it with the proper inventory we must have information. Plant Data Communications Systems make a major contribution to profitable and productive manufacturing operations by providing much of this information.

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Bill developed and manages a series of Plant Data Communications Workshops, and frequently is a speaker on the subject. He has authored two IBM publications and worked on several projects which address PDC Systems. With a Masters Degree from the University of Illinois in 1959, Bill has a wife and three children, and has been a member of APICS since 1968.

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SEMINARIO DE ACTUALIZACION EN ADMINISTRACION DE PRODUCCION E INVENTARIOS

DESIGNING EFFECTIVE INFORMATION SYSTEMS

MAYO, 1978.

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DESIGNING EFFECTIVE INFORMATION SYSTEMS

OLIVER W. WIGHT

Back in 1959, the production and inventory control field was full of promise, particularly for the application of computers. Ten years later, I'm not going to hand out any congratulations – I think we have fallen far short of our potential. The number of companies having real success in applying computers to production and inventory control is extremely low. McKinsey & Company published the results of a survey of many companies titled, "Unlocking the Computer's Profit Potential"(1). This report said: "From a profit standpoint, our findings indicate, computer efforts in all but a few exceptional companies are in real, if often unacknowledged, trouble. Faster, costlier, more sophisticated hardware; larger and increasingly costly computer staffs; increasingly complex and ingenious applications: these are in evidence everywhere. Less and less in evidence, as these new applications proliferate, are profitable results."

I have to agree with this; I think that most of the systems I have seen around the United States would fall into one general category: not good enough to use or bad enough to throw out. The picture is tragic; and it is imperative that we face up to it. We could sum up efforts to apply the computer to production and inventory control in this country by paraphrasing Winston Churchill: "Never before in the history of human endeavor has so much been invested by so many to so little avail". More and more people see the similarity between "MIS" and MESS. Systems haven't paid off on their investment, either in money or in human time and effort. It's heartbreaking to see frustrated systems groups and frustrated groups of users, as well as frustrated groups of executives, many of whom have put in hours of toil to develop systems that have not really been successful.

Unfortunately, we seem to find an extension of a national pastime of buckpassing. Nobody seems to take much responsibility for doing anything about the problem. The systems people blame management for not giving them support and forcing people to use the system; they blame the user for being uninterested, and they blame the computer salesman for having romanced them into some embarrassing situations. Users of the systems, production and inventory control people themselves, blame the systems people for picking up computer techniques and installing them without really solving any of their problems. They blame management for putting in a computer because "It's the thing to do". Management blames the systems people for not having produced results; they blame the users for not being progressive. They blame consultants for having sold them some fancy techniques that don't really work as well as they should. They even blame professional societies for the fact that so many of their people seem to be more interested in doing things they can boast about than in making the company profitable.

Consultants tend to blame management: If a consultant is truly a management consultant he should be able to detect management deficiencies before a system has been fully developed. If he does, and decides to continue working on it, I question his professionalism. If he does not detect deficiencies, should he really call himself a management consultant? There are a number of consultants today whose efforts are entirely devoted to flow charting and programming; and most of them might more properly call themselves systems consultants.

These are harsh words, and are intended to be. Most people owe allegiance to their company, and can hardly afford to *think*, much less say, what they actually believe. I owe allegiance to no one, and feel strongly that it's time somebody jolted us out of our dream world of computer systems, back into the real world of business.

(1) McKinsey & Company, Inc., 245 Park Avenue, New York, NY 10017

McKinsey & Company made a good point in their booklet: "As yet, the real profit potential of the computer has barely begun to be tapped." It can be tapped; there is no question about it. A few companies are successfully applying the computer in production and inventory control. Having observed them, as well as the large number of failures, I propose some elements that I believe must be included into an effective information system.

A system includes not only the machine and the programs, but also the people. Too often this has been ignored.

ELEMENT NO. 1: A DESIGN TEAM

"Team" is getting to be a hackneyed word, but it's a crucial word. It is disappointing to see the tendency for polarization between users and systems people. Those of us who were interested in operations research years ago remember that the essential point of operations research was the team approach – the idea of a scientist, a user, and people from various fields working together to solve a problem. In a very short period of time, though, the operations research people developed their own jargon and their own interests. They found management ever more difficult to communicate with, while it became more and more fun to communicate with other operations research people. Management, meanwhile, found them more frustrating to work with. As a result, we now see less operations research activity in business than before. We've got to avoid this kind of polarization in systems if we're really going to achieve anything.

Look at a basic question: Who is going to design the system? One theory says that only the user can design the system, since he will be responsible for running it when it has been installed, and he knows the most about his actual needs. Another theory says that only a systems man can design the system, because only he understands the new techniques and how to apply them on a computer. To read some of the articles in the data processing magazines, you would think that the man who understands computers can very easily become a "systems superman" who understands all facets of the business, can analyze problems in all areas, and develop and install systems that will be used enthusiastically by responsible managers. Hardly.

The user has to assume the responsibility for the design, and be thoroughly inv[illegible] in it. I have yet to see a system successful where this approach was not t[illegible] instances the systems man designed the system, but then they made *hi*[illegible] made him run it.) I see a new role for the systems man. He should first i[illegible] problem, then develop general solutions in his own mind, and then for[illegible]ers to design a system themselves, while he assists them. He should resist the [illegible]on to design the system, and he should always try to sell ideas to other people a[illegible]them to accept them as their own. Too many systems men are trying to build monuments to themselves. Systems work takes a mature ego.

Too often, the relationship between the number of systems men on the job and progress seems to be an inverse one. Nothing seems to slow a task down like putting too many systems men in the act. Some people are beginning to ask if systems men won't be obsolete as the new breed of manager who is not mystified by the computer comes along Why will he need a go-between to communicate with the computer man? A very good point. However, we'll always have some systems technicians, although probably far fewer than we have to have today. This is good, because it means that we'll have more systems people available to go into management. If there's anything we really need, it's more system-oriented managers and more management-oriented systems people. I see the real systems man as more than a technician. He meeds to be a good analyzer, teacher, and "idea" salesman. I think the people who can't grow into that new type of job are going to be relegated to the computer room and kept out of the real world where we already have enough elegant but useless systems.

User responsibility cannot be emphasized enough. If you're developing a production control system, the production control manager himself should be pulled away from his job, full time, until the system is installed and working. At the very least, have his most logical successor as the responsible head of the systems team. If you can't get this kind of support and enthusiasm, it's just not worth embarking on a project that's going to result in one more lame duck computer system. So often systems people say, "If we had to wait for the users, we'd never accomplish anything," but when they're through, it becomes pretty apparent that they accomplished little, because the user won't make the system work.

ELEMENT NO. 2: ADDRESSES REAL PROBLEMS

In this day of computers we must remind ourselves that: mechanization is not a valid business objective. I offer another rule that might surprise many who've been working in this field: never do anything on a computer that you can do well manually. Mechanizing the system you already have is an exercise in futility. Another rule that might sound like heresy: don't design a totally integrated management information system. To quote McKinsey once again, " 'integrated total management information systems' drawing on a single data base, which have so often been touted as the wave of the future, . . . have not yet come to pass – and it is far from clear that they ever will". McKinsey goes on to say, "No company should embark on a program to develop a major management information system except to meet a specific, well-defined need".[2]

One of the problems to address is determining how the system really works. Many companies have inventory systems on the computer that look awfully good. They generate plenty of printout and a lot of instructions to the users; the users are occupied fulltime interpreting and analyzing the printout. Meanwhile, out in the shop, if you ask the plant superintendent how the system really works, he'll tell you that it doesn't. If you ask him how he gets the parts through that he needs to manufacture the product, he'll tell you that he has a parts inventory in every department. His foremen keep themselves well supplied. They also put heavy expediting efforts on parts that are going to be needed for next week's schedule and go to great lengths to pull assemblies from the storeroom far in advance. They have an expensive computer churning away, but the system that really gets the product out the door is the one that was used at the turn of the century.

We've got to come up with real solutions to our production and inventory control problems, rather than picking up cookbook solutions. Much of what we read in production and inventory control literature fails to define where a technique should or should not be used; but merely promotes techniques that are supposed to solve all kinds of problems. An example is the statistical inventory control we've been hearing about for years. It has great application when an item can really be ordered based on past history, because that's all statistical inventory control deals with. When statistical inventory control techniques are applied to the parts that go into an assembled product, the result is always bad. This type of inventory control technique will not get all the parts to the assembly floor on the date the assembly is put together.

Very few authors, particularly those who are great proponents of statistical inventory control, ever tell you where it should not be used. I think this is irresponsible. The most significant contribution to profitable inventory control application is the principle that Dr. Joe Orlicky of IBM suggested a couple of years back: the principle of independent/dependent demand. The demand for an item is independent when it doesn't tie in with anything else, such as an item in finished goods or perhaps a service part not used in current production. The demand for an item is dependent when it is a component being used on an assembly, with the demand "dependent" on the need to manufacture the assembly. The principle states that for dependent demand items, it is better to calculate requirements through a bill of materials. For independent demand items, a min/max or order point based on past usage may be used to reorder.

(2) Op C[illegible]ge 34

Figure 1 shows why order points don't work on dependent demand items. Suppose that Assembly A had the smoothest demand ever asked for – 10 per month – but sub-assembly B is made in lot sizes of 20. The demand for components going into sub-assembly B would be 20, 0, 20, 0, etc. Part C is made in lots of 40. Raw material going into that part will have a demand of 40, 0, 0, 0, 40, etc. An order point on the material used in part C simply won't do the job. Some people have suggested that if that material is used in more than one part, an order point probably would do the job. Can you imagine 3 sets of demands of 40, 0, 0, 0, 40 all coming into the same material? The demand doesn't tend to smooth out very much. Instead, it usually looks more like 40, 0, 0, 120, 0, 0, 80, and anybody who can believe that an order point will really control an inventory with that type of demand has a great imagination. If your people don't understand this independent/dependent principle, don't go any further with computer applications until they do.

	J	F	M	A	M	J	J
Ass'm A	10	10	10	10	10	10	10
Sub B	20	0	20	0	20	0	20
Part C	40	0	0	0	40	0	0

FIGURE 1

To cite another area in which I don't see enough recognition of the problems and proper solutions: lead time is a serious problem in most companies, and it is primarily a function of the amount of backlog a company has. The backlog out in the factory, for example, is a function of input versus the output. If you put in more than you take out, you'll build up backlogs and this will result in excessive expediting and a crowded shop. You bring backlog down by taking out more than you put in and vice versa.

Among our "classical" approaches to controlling production in a factory, the most commonly used is the machine load, which tells you nothing about input, and very little about output. Usually, it tells the actual output for one week; but that doesn't give much information, because it could have been much higher or lower the previous week. We need to see it for at least a few weeks to know what our real output is. Almost every machine load report tries to specify a work center's capacity. This is the theoretical capacity; it almost never represents what the department is really turning out. It only represents the number of men assigned to a work center and their potential output adjusted by some efficiency factor. People go out of their minds trying to keep that theoretical capacity figure correct on a machine load report!

In the future, we're going to see more emphasis on the type of report shown in Figure 2–an input/output report for a work center. Here the planned input is shown in terms of standard hours. Note that it is planned at 270 standard hours per week. The actual input is then monitored week by week. In the first week, we put in 270 hours. If this were a starting work center, such as screw machines or presses, this input could be controlled to smooth it out. If this were an intermediate work center, monitoring the input would be useful to see if we're getting the right flow of work into the work center. Note that the planned output for 3 weeks is higher than the planned input. The obvious intent here is to bring down the in-process backlog. The cumulative deviation shows us how the input is going in comparison with the plan and how the output is going in compar[illegible] with plan.

One rule that is used with an input/output report is: don't put in more than is taken out the previous week. This can't be done in exact figures, because the amount put in usually has to be rounded out to lot sizes, but this approach shows how much is put in, how much is taken out. This enables us to hold backlogs in production control, but show capacity deficiencies in the factory without having to put a lot of work out on the floor that will have to be expedited. Input/output control is a far more useful tool for controlling production than machine loading, because it tries to control the cause of lead time.

INPUT/OUTPUT

	w1	w2	w3	w4
INPUT				
plan	270	270	270	270
actual	270	265	250	
dev.		-5	-25	
OUTPUT				
plan	300	300	300	270
actual	305	260	280	
dev.	+5	-35	-55	

FIGURE 2

Another classical approach to production and inventory control is the economic order quantity, or EOQ. Few people claim profitable results from EOQ; mainly due to misunderstanding the technique. You don't use EOQ by running numbers through a formula - you've got to compare what you're doing today with what you intend to do, pinpoint where the profits are going to come from, and make sure you get them. Much of our classical production and inventory control is unsound. There's information around on modern approaches to production control, and I encourage you to understand them thoroughly before implementing a system.

ELEMENT NO. 3: DESIGNED FOR THE USER

Systems have to be designed for the user; the system is merely a tool to help him make better decisions. Let the user control the information. He should be able to control the exceptions he gets from the system and be able to go into the computer again at least once a day whenever he needs further information that wasn't planned in the original exception reports. One item on an exception report can easily lead to needing information on three or four more items that were not printed out, based on the original exception rules.

Make the logic obvious. It's easy to program logic into a computer, but remember that the user is going to have the responsibility for operating with this information. If he doesn't understand it, he'll have one of two choices: ignore it completely or follow it blindly. Systems people are often fascinated with the things that they can program into the machine and baffled at the lack of success of their system.

Pt 17534	OQ=35	SS=17	LT=5					
		w1	w2	w3	w4	w5	w6	w7
Req't		12	4	14	1	0	21	4
On Hand	33	21	17	38	37	37	16	47
On Order				35				35
Planned Order		**						

FIGURE 3

Figure 3 shows a requirements plan for Part No. 17534, of which there are 33 units on hand. Requirements have been exploded down from the assemblies that use this part, and they total 12 in Week 1, giving a projected on hand balance of 21 at the end of Week 1. At the end of Week 2, there will be 17; at the end of Week 3, the requirement of 14 would leave a balance of 3 on hand, but here's an open order for 35, so the new projected on hand would be 38. In Week 4, it would be 37; Week 5, 37, and the requirement of 21 in Week 6 would take the projected on hand balance down to 16. This is one below safety stock. The computer, then, counts off backwards for 5 weeks, since this is the lead time. It indicates that in Week 1 we'll have to release a planned order (indicated by the asterisks in Period 1). But the computer also looks ahead and notes there is an order open for 35 that's due in Week 7.

Should we actually plan to order in Period 1 or should we reschedule the 35 from Week 7 into Week 6? For that matter, since we're only going to be one below safety stock, is there any need to reschedule at all. Imagine programming this type of decision into a computer–letting the computer automatically reschedule based on the percentage safety stock, the quantity of the order, the weeks the open order has to be rescheduled by, how far along it is in progress, etc! This could be a systems man's dream and a user's nightmare, as the computer automatically told him to reschedule an order, and he hadn't the faintest notion why. If we do program that kind of logic into the computer, the responsibility for the rescheduling lies with the man who designed the system. Often the user can't decipher why the computer did or didn't reschedule.

This is why the logic must be obvious. People should make the significant decisions which don't take time. The thing that takes time is getting the information needed to make a reasonable decision. One problem that bothers people is how to train a new user on the system. In this day of personnel turnover, it's easy to put a lot of effort into a system and then find that the new user simply doesn't like it. So keep the system simple and flexible, then the new user will be more likely to recognize it as a good, basic production and inventory control system, rather than as a highly specialized system that he doesn't understand and doesn't care to use. So another systems design rule is: eschew originality. We need a value analysis approach in developing systems. It's easy to come up with naively sophisticated techniques that don't really add much to the system, but make it a lot more complicated. Design the system so that the user will understand it and has control of it.

ELEMENT NO. 4: A CONTROL SYSTEM

A system should be designed not just to generate information but to generate the kind of information that will provide control. The elements of a control system are a norm, a tolerance, feedback, and action. A tolerance should also be established ahead of time; the amount of deviation that we will accept as being within range. We ought to *pre-determine* the level at which we will take action and *pre-determine* what that action will be. No system will really control if we don't decide what the norm is, provide some tolerance around it, and pre-plan the action that we're going to take when it is exceeded.

ELEMENT NO. 5: MODULARITY

Initial experiences with attempts at "totally integrated" information systems were very sad. Those that were integrated turned out to be impossible to modify without tearing the whole system apart and putting it together again. We can plug many systems into a common "Data Base" and draw on the same information through different systems, through one integrated system. Systems should be designed so that they can be modified.

ELEMENT NO. 6: INTEGRITY

One of the toughest things to show managers is the relationship between basic system integrity and results. Many managers, during a cost cutting period will reduce the number of people being used to maintain basic information, like bills of material. Later, they wonder why they can't get the right parts through to get the product out the door on time, and why so many people are spending time handling crises and exceptions that have occurred because the system doesn't function properly. One of the most difficult areas to get management interested in is stockrooms. In most manufacturing companies, stockrooms are a disgrace. Somehow, it's easier to program exponential smoothing than to put a fence around the stockroom. Why is it so hard to see the relationship between accurate inventory figures and performance, when a company that makes an assembled product knows that lack of one component can give the worst of all possible worlds. We'll have a high inventory of all the other components, yet low service, because we're not shipping the product. But people would much rather sit around drawing flow charts than get down to the nasty business of showing management what really needs attention, if systems are going to work properly. There are a number of techniques that can be used to generate systems integrity, but I think the best one is to get people to use the system. If foremen, for example, are actually using a dispatch report, they'll be a lot more interested in keeping the information on it accurate than if they don't use it.

ELEMENT NO. 7: RESPONSIBLE MANAGEMENT

Computers must be used intelligently, and a manager must recognize that this is the computer age and that we do need to manage with systems today. Many managers haven't yet learned to use systems to manage; firefighting is fun, and generates a great (false) sense of "being where the action is". Too often, managers look to outside consultants or computer companies to develop systems for them. This never seems to work very well. Consultants and computer companies can advise, but basically the company itself will have to develop what they're going to use. Management should be mature enough to look at systems as a way to manage better, rather than as a substitute for management. Systems don't run businesses; they help people to run businesses.

THE TOUGH JOB AHEAD

To summarize; the elements needed to develop a good information system are: a design team, a system that addresses the real problems, and is designed for the user; is a *control* system, is modular, and that has integrity. A pivotal element is management that takes a responsible attitude toward the system. The users - right down to the planner, expediter, and foreman level - need to be involved in the system. Giving them doses of formal education on how "our" system works, doesn't work.

There's a big payoff from the computer when it is used wisely in production and inventory control. When companies have reduced their inventories substantially, improved their service, and reduced product cost because of better parts availability through the use of computer systems, one can't help but be excited about the prospects. But responsibility for making the business more successful through use of the computer belongs to everyone: users, systems people, managers, consultants – and even computer salesmen. We've got to stop passing the buck, and start working together. It's going to take hard work to make computers really pay off, but don't be discouraged; we're still pioneers. We've only been at this for a little over ten years. Still, the time has come to change our ways. Systems are not toys for the technician; they're tools for the manager.

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DESIGNING AND IMPLEMENTING A MATERIAL REQUIREMENTS PLANNING SYSTEM

This talk was given over two sessions at the conference. George Plossl and Oliver Wight gave the talk together. The text is noted to indicate the sections each of them covered.

SESSION I

WIGHT: Inventory Management Using Material Requirements Planning.

It's a sign of the maturity of production and inventory control as a discipline that principles like the independent/dependent demand principle have been developed. This principle states that where demand is independent (finished goods items or service parts not used in current production) the order point technique is applicable. Where demand is dependent, as it is for all components and semi-finished inventory items that "go into" another inventory item, material requirements planning is a far more satisfactory technique. Certainly this isn't to say that some low value dependent demand items could not be controlled reasonably well with order point, but the service level required would have to be extremely high to give even reasonably adequate service, because an assembly can't be made unless *all* parts are available.

It has been rather amusing over the years to see all of the articles that have been written on statistical inventory control by people who obviously don't understand the practical application of statistics to manufacturing inventory management. Companies manufacturing most products from metal goods to pharmaceuticals are assembling a series of components in one manner or another. When this is true, even a very high service level on each of the individual components won't result in a very high service level for the assembly itself. A ten item assembly with a 95% service level on each item will have only a 56% chance of having all of the components available when required. But I find that a good many people don't understand this basic truth of statistics.

These people state that in their companies, even though service is not as good as it should be, even though they do have parts shortages, and even though they do have high inventories, they *do* get something shipped. If you were to believe the statistics, it would be virtually impossible to get all the parts together for a product with 100 components! Of course, the reason that they have trouble equating this example with their own experience is the fact that *most inventory systems in effect today don't really control the inventory.* Inevitably, if someone tells you that they are using order points to control dependent demand items like components that go into assemblies, you'll find that this inventory system tries to get the right things started in the plant or ordered from the vendors. This is the *formal system.* Then there is an *informal system* that consists of pulling parts out of the stockroom and trying to "stage" them well ahead of the time when they will be needed to meet the assembly schedule. By physically laying out the parts, shortages can be detected, hot lists can be written and expediting can swing into full force. In effect, we have a formal "push" system and an informal "pull" system. *The reason that the company is able to survive in the face of the overwhelming statistical evidence that the formal system can't possibly work is the fact that the informal system does most of the work in real life.*

We enthusiastically support the independent/dependent demand principle and consider it to be the single most significant inventory principle that has been developed. Certainly the ABC concept is significant. The idea of separating the vital few from the trivial many and concentrating our control effort on the "vital few". But this is a universal principle not necessarily confined to inventory management. The independent/dependent demand principle is an inventory management principle that helps to clarify the confusion about where to use order points and where to use requirements planning. One of the reasons that we feel very strongly about this principle is our own experience in many, many companies.

Some years ago when I was inventory manager at Raybestos, I had a very serious problem keeping brake shoe boxes fed to the assembly line. We kept a month's supply of boxes on hand

and based our ordering on past average usage. Unfortunately, this never seemed to work very well and it was a regular experience to have the brake shoe packaging foreman call up on Friday afternoon to complain that one of the items that was most urgently needed couldn't be made because we were out of boxes – *once again.*

The only solution that we could see to the problem was to carry more boxes in inventory. Unfortunately, we didn't have enough space to do that. A month's supply of cardboard cartons when you are turning out a product in very high volume takes up a tremendous amount of space. Finally, one of the supervisors came up with a bright idea. He suggested that instead of ordering boxes based on past average usage, we take the actual schedule, which covered about two weeks, plus a forecast of the schedule for the next two weeks, convert each part number to its box requirements and then summarize this by box part number. In effect, we were switching from an order point system to a material requirements plan and the results were very satisfactory indeed. With no increase in inventory, most of the box shortages were eliminated. In fact, boxes ceased to be a very serious problem from that day on.

Here is an excellent example of the value of a principle. If we know a principle, we can apply it to all kinds of applications no matter what product we are producing, no matter what company we are looking at. If we had known the independent/dependent demand principle back at Raybestos, it would have been a simple matter to recognize that the demand upon the box inventory is dependent: you only need boxes when you are making brake shoes. Thus we would have been directed toward a requirements planning system rather than an order point system.

End Item Master Schedule

	PAST DUE	WEEK									
		4	5	6	7	8	9	10	11	12	13
		—	—	600	—	—	800	—	—	400	—

Component Materials Plan

Lead Time 4 Weeks

	PAST DUE	WEEK									
		4	5	6	7	8	9	10	11	12	13
Projected Usage		—	—	600	—	—	800	—	—	400	—
On Hand		900	900	300	300	300					
Scheduled Receipts		—	—	—	—	—	500	—	—	400	—
Planned Order Release		—	500	—	—	400	—	—	—	—	—

Figure 1 – Assembly Requirements

Here we have a universal principle to help us in choosing between the two basic types of approaches to reordering. It is worth emphasizing also, that in spite of all the varieties of reordering techniques, there really are only two basic approaches. Material requirements planning calculates requirements for raw materials, semi-finished materials or components (parts, sub-assemblies) based on plans to make the item that these materials go into. Order point type systems, and these can include min/max, two-bin, periodic review, etc., all assume that an inventory item should be re-ordered based on average demand over lead time.

Let's take a look then at a typical material requirements plan. Figure #1 shows a master schedule for the "end item" and below it is the component material requirements plan. Let's imagine that the end item is a product like this projector that we are using today. We plan to make 600 projectors in week 6, 800 in week 9, and 400 in week 12. These requirements are posted against the component inventory record. There are 900 units of this particular component on hand. Let's imagine it to be a sub-assembly – the projector head. In week 6, we have a requirement for 600 projectors that will leave us a balance of 300 projector head assemblies available; in week 9, we have a requirement for 800 projectors. In the terminology of requirements planning, this is called a *gross requirement*. There are 300 units *available*. In week 9, you can see that there is a *net requirement* for 500 units. Since the lead time is 4 weeks, there will be a *planned order* to be released in week 5. This is called lead time offsetting, the planned order has to be backed off enough time periods so that it will be released at the beginning of the lead time. Note that in period 12 the gross requirement equals the net requirement since there is no material available.

The requirements plan makes a *time shift* as it moves from one period to another. In the example shown in Figure #1, each week an old week would be dropped and a new one added and any appropriate action would be taken by the computer. For example, as the time shift moved into week 5, the computer would generate a notice that an order for 500 units of the component should be released. If this order were not released because of a shortage of one of the parts, the following week that planned order release would show up in the "past due" column.

Note that in this over-simplified example there was no lot-sizing and that requirements were simply ordered in the same quantity as the net requirements. Obviously, in most instances in real life, this is not the case; some lot-sizing does take place. We will be talking about that later. Note also, that in this simple example, there is only one end use for this projector ahead. Actually, there could be many end uses in which case the projected usage would show the sum of all the requirements for projector heads based on the master schedules for different models of projectors.

The projector head requirements plan shows *planned orders* in it. There are two basic purposes for planned orders:

1. Planned orders generate material requirement at the next lower level;
2. Planned orders can be used to project capacity requirements.

If we were to imagine another inventory record for the lens in the projector head, we would need some way to project requirements for that lens. The planned orders for the projector head assembly would be used to generate these requirements. In the example we have been using, these would be a requirement for 500 lenses in week 5 (because we are going to *release* an order to assemble 500 projector heads in week 5), and 400 in week 8. Of course, there might be many other requirements coming from other projector heads that use the same lens. There might also be service requirements and these would be entered into the lens inventory record directly so that all requirements could be summarized. This is why I made the point above that order points should be used for service parts only when they have no assembly usage. When they are used in assemblies, as well as having an independent service demand, once again the time phased requirements plan is the more practical technique.

The planned orders can also be used to make a machine load *projection* periodically. This will enable production control to *forecast* load requirements, rather than trying to determine capacity requirements by looking only at released orders.

Requirements planning became practical with the advent of the computer. It was *possible* to make a material requirements plan manually or with punched cards, but keeping it up to date as schedules changed and component availability changed was never very practical. Requirements planning on a computer, however, in spite of all the complexity and jargon that has surrounded it in much of the literature, is basically a simple technique very much like we did it manually. There are two basic files (we'll talk later about some of the other files that are required). These files are usually called the *item master* record and the *product structure* record. In production control language, as opposed to the jargon of data processing, this simply means the *inventory record* and the *bill of material*. Picture an inventory planner trying to calculate parts requirements using a manual system. He probably had a Kardex record and a bill of material sitting on his desk. He'd look at the anticipated assembly schedule (the *master schedule*) and he would then check to see if he had the necessary sub-assemblies available to meet this schedule. If there was an insufficient quantity of one of the sub-assemblies and he needed to make more, he'd refer to the bill of materials to find out what components that sub-assembly took. He would then refer to the inventory records for those components to see if there were sufficient quantities of the components on hand so that he could release a sub-assembly order. This is exactly what the computer is doing. It is constantly cross-referencing between the item master record and the product structure records to determine parts availability to tell us when we need to order parts and also the dates when these parts will be due.

ON HAND QUANTITY	50
PLUS ON ORDER	150
MINUS GROSS REQUIREMENTS	300
EQUALS NET REQUIREMENTS	-100

Figure #2

The term *time-phasing* or *time-series* requirements plan is particularly significant. Figure #2 shows an inventory record with what might be called "requirements planning" information in it, but the information isn't time-phased. According to the information in Figure #2, 100 units are needed immediately. No one knows when the 150 that are on order are needed, but presumably they are needed immediately too. Figure #3 shows the gross requirements broken out into time periods. 50 units are needed on January 3rd, 30 on February 14th and so forth. The first thing that becomes apparent, looking at the requirements in their proper time periods, is the fact that the 150 that is on order is going to be needed by February 14th and *that* is one of the significant values of time-phased requirements planning. It not only tells us that we need to order material, it tells us when it is needed and by recalculating our requirements plan, the formal inventory management system will change the priorities on items; thus we don't have to depend on informal back-breaking expediting to do it.

Gross Requirements	Date To Be Assembled
50	Jan. 3
30	Feb. 14
70	Mar. 4
100	Mar. 27
50	Apr. 25

Figure #3

Let's assume, in this example, that the lead time is four weeks and that this is the beginning of the new year – January 2nd. Actually, the 100 that Figure #2 indicated had to be ordered immediately doesn't really need to be ordered until the last week in February. The requirements for 50 on January 3rd will be covered by the material on hand. The material on order will cover all of the requirements for February 14 and March 4th and half of the requirements for March 27th. A new order will have to be released to cover the balance of the requirements on March 27th and requirements on April 25th.

This example illustrates the fact that time-phasing not only helps with rescheduling but also puts proper order release dates on items. And this is a significant difference between material requirements planning done on a computer and old manual methods of requirements planning as well as order point techniques improperly used on dependent demand items. The material requirements plan changes the responsibility of inventory control from just ordering material to ordering material, putting the proper priority date on it, and *maintaining* the proper priority date.

To do this effectively, a requirements plan needs to meet a bare minimum specification. The example in Figure #2 could be called "Requirements Planning" but it is not a material requirements plan by today's standards anymore than a 1903 Oldsmobile would be considered an automobile by the average driver today. We feel that the bare essentials for a requirements plan are as follows:

1. *The time period must be no greater than one week* or the formal system will not be able to put usable relative priorities on items. When a foreman is told what material he needs to make in a given month, his first response will be *"that's fine, but which ones will you need this week"*.
2. The requirements plan should be recalculated – partially or completely – at least weekly so that it can reflect the latest changes in requirements as well as component availability.

This point about component availability is probably worth commenting on since a requirements plan should be revised if any particular component is absolutely not going to be available. For example, if a casting is scrapped and after turning heaven and earth and exerting all the pressure possible to get the vendor to deliver the casting, the best promise he can give is 6 weeks, the assembly master schedule should be revised to reflect this. If it's not revised, parts will be coming through production to an incorrect due date. In any company where fabrication capacity is reasonably well regulated to need, it stands to reason any time parts that are not needed are being made, parts that are needed will be pushed aside. In real life, this is an intolerable situation and overstated requirements and false priorities of this type only lead to a breakdown in the integrity of the requirements plan itself since the informal system will soon demonstrate the old adage "the truth will out".

So much for the mechanics of requirements planning, now let's discuss some of the actual techniques.

PLOSSL: Updating the Plan

There are two basic approaches to updating a material requirements plan: the first, called "regeneration", involves literally throwing away the previous plan and starting over with a new master schedule. The second is called "Net Change" and reworks the plan, introducing into the master schedule only those changes which have occurred since the last plan was made. Obviously, regeneration requires considerably more computer time and is also much less specific in identifying the immediate effects of master schedule changes on computer requirements.

Net change permits identification of the particular effects of individual customer orders on parts inventory and shortages. However, it requires considerably more discipline in handling changes in lead times, bill of material structure, and other parameters of the system. For example, regeneration will purge the system of all planned orders which appear in the wrong time bucket because lead times have been changed. Regeneration will also restore the proper requirements and eliminate unnecessary orders when items are added to or omitted from bills of material. Such changes usually have to be made by manual alteration in a net change plan.

Companies using material requirements planning usually start with a regeneration system. As they learn how to handle changes, they switch to net change to gain the benefits of reduced computer time and more specific information. In his presentation, Dr. Joseph A. Orlicky predicted that the systems of the future will be predominately net change systems.

A company having relatively few schedule changes or forecast revisions and many levels in their bills of material would benefit substantially from getting into net change at the earliest possible moment. On the other hand, a very few inventory levels and a widely varying forecast or master schedule resulting from major sales promotions would indicate that a regeneration system might continue to be needed.

LOT-SIZING

There are many techniques available for lot-sizing with material requirements planning. Figure #4 summarizes these. The familiar Camp Square-root approach has application for end products and some high-level subassemblies but it's use is questionable for most components of assemblies. Let's refer back to Figure #1 to illustrate one of the more serious limitations. The quantity of 900 on hand at the beginning of the plan resulted from running an economic lot size based upon the square-root formula. The balance of 300 left after week 6 is not sufficient to meet the requirements for 800 in week 9 so it is necessary to bring a new lot into stock. This balance of 300 obviously was not "economical", it was carried for quite a long period of time in inventory with no benefits. The square-root approach does nothing to order components in the sets required for assemblies. Another major limitation is the questionable validity of the assumption made in deriving the square-root formula that the usage will be uniform and the average inventory therefore, equal to half the order quantity.

Discrete lot-sizing techniques make no assumption of uniform usage and do order parts in sets as they are required for assemblies. Several techniques are listed in Figure #4. These techniques determine the proper lot size to run to fill non-uniform net requirements such as are illustrated below. Their objective is to determine how many of the period requirements should be combined into a single lot.

SQUARE ROOT E.O.Q.

DISCRETE LOT SIZING:

- LEAST TOTAL COST (PART/PERIOD BALANCING)
- LEAST UNIT COST
- PERIOD ORDER QUANTITY
- LOT-FOR-LOT
- WAGNER/WHITIN

FIXED QUANTITY

Figure #4 – Lot Sizing

The Least Total Cost approach assumes (like the square-root formula) that the total costs related to the lot-size decision will be a minimum when the ordering costs are equal to the inventory carrying costs. The trial and error solution in Figure #5 illustrates how this technique works. The net requirements and the weeks in which they are needed are taken from

DISCRETE REQUIREMENTS

Week 4	50	Week 6	100	Week 8	1050
Week 5	1050	Week 7	100		

the discrete requirements shown above. Net requirements are totalled and the cumulative carrying costs calculated until their total is *most nearly equal* to the set-up cost. In the example in Figure #5 this occurs for a cumulative lot-size of 1300 pieces.

PART NO. AB 2741 | INVENTORY COST = 0.4% PER WEEK

UNIT COST = $4.00 EACH | SET UP COST = $30.00

NET REQ'T	WEEK REQ'D	CUMUL LOT SIZE	EXCESS INVENT	WEEKS CARRIED	CARRYING COST UNIT	CARRYING COST CUMUL	SET UP COST
50	4	50	0	0	0	0	$30.00
1050	5	1100	1050	1	$16 80	$16.80	$30.00
100	6	1200	100	2	$3.20	$20 00	$30 00
100	7	1300	100	3	$4 80	$24.80	$30 00
1050	8	2350	1050	4	$67.20	$92 00	$30 00

Figure 5 – Discrete Lot Sizing

The IBM PICS Requirements Planning Package utilizes this basic technique with some modifications to the mathematics under the title "Part Period Balancing". It also has refinements called "Look-ahead" and "look-back" attempting to develop more economical lot-sizes using a longer horizon of net requirements. The value of these refinements is questionable, particularly in a dynamic business where requirements are chaning significantly. Part Period Balancing is, however, basically the Least Total Cost approach.

Another discrete lot-sizing technique called "Least Unit Cost" attempts to determine the economical lot-size based upon the cost per piece. The cumulative carrying cost and the set-up cost in Figure #5, would be added and the total divided by the number of pieces in the lot to get a "Unit Cost". The lot-size would be set at that quantity which gave the lowest unit cost. In the example in Figure #5, the lot-size calculated this way would be 1200 pieces compared to 1300 for the Least Total Cost approach, however. Tom Gorham, in his first article "Dynamic Order Quantities" published in the First Quarter 1968 issue of *Production and Inventory Management*, the APICS Journal, analyzed the two approaches and discussed simulations which indicated that the Least Unit Cost approach was not as economical as Least Total Cost. In many cases, its use resulted in either excess set-up costs or excess carrying costs. The results of Gorham's investigations have been confirmed by Black & Decker in simulations comparing these two techniques. We do not recommend the Least Unit Cost approach.

The Period Order Quantity technique is a very simple approach which achieves the bulk of the benefits with a minimum of effort. In this technqiue, the square-root formula is used to determine how many weeks supply would be ordered. This would be calculated by using the Camp formula to determine an order quantity, dividing this into an annual demand to determine the frequency of ordering, and then expressing this frequency as "weeks of supply". The material requirements planning program adds together the net requirements to order that many weeks supply. Using Figure #5, for example, a Period Order Quantity of "four weeks" would mean a lot size of 1300 pieces, the sum of the net requirements in periods 4, 5, 6 and 7.

For assemblies, sub-assemblies, and components with very little set-up cost, setting the lot size equal to the quantity required in each time bucket has several advantages. Called "Lot-for-Lot", this approach tends to minimize the lumping of requirements on lower level components which helps to develop more level loads on manufacturing facilities. It also minimizes inventories of components which can be scheduled to match higher level requirements and probably will never really be made for stock. It also reduces the amount of calculations needed in the requirements planning program.

A highly sophisticated mathematical approach called the Wagner/Whitin Algorithm uses the full material requirements planning horizon and explores the various alternatives in setting ordering quantities to minimize the total costs over the full period. This technique has had little application. It may find use in "fine tuning" a system in the future when its potential economies warrant the extra complexity.

A fixed lot-size is frequently the most sensible answer where tool life equipment capacity and other "real-life" limitations influence the decision. Forging dies, blanking dies, heat treating furnace and curing oven capacity may dictate a lot-size which is significantly different from that calculated by any of the above techniques. Minimum purchase order quantities have a similar effect. Since the cost penalty for departing from the economic order quantity is relatively small, particularly for larger lot sizes, these overriding factors should set the lot sizes.

SAFETY STOCK

As with the order point/order quantity system, safety stocks are necessary in material requirements plans to protect against demand variations for the end products and against supply variations for components. A sound approach is to carry safety stocks at the top level in end products and at the bottom level in raw material. This provides shelf stock to meet normal demand variations for the finished products and orders raw material to permit releasing manufacturing orders early to level production on the plant and to react quickly to unexpected scrap losses or unusually high finished goods demands. Safety stocks might also be carried on semi-finished components which can be converted quickly into a wide variety of higher-level items. This approach, combined with reduced part manufacturing lead times, results in the greatest flexibility to meet changing demand with minimum inventories.

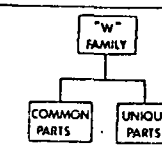
More theoretical work remains to be done to develop a rational basis for setting safety stocks on dependent demand items similar to the statistical approaches used for independent demand items. The definitions of "Customer service" and "forecast error" are yet unclear when applied to dependent demand items. There are three different ways now used to get safety stocks in materials requirements planning. These are shown in Figure #6.

1. SAFETY TIME
2. INCREASE MASTER SCHEDULE
3. FIXED QUANTITY

Figure #6 – Safety Stock

Adding Safety Time involves bringing a component or raw material into stock earlier than the requirements plan indicates it will be needed. The safety stock is actually the material left on hand when the new lot is received into stock. Obviously, this quantity can vary considerably depending upon the lumpiness of demand and may or may not be adequate to meet requirements for the higher-level items it is intended to cover. Safety Time has the additional disadvantages of inflating the planned lead times, thus tending to increase work in process, and distorting the true priorities of work. Applied to raw materials, however, two or three weeks of safety time would make material available if it were desired to start work on an item early in order to level load the plan. Problems of inflated lead time and distorted priorities would be minimal for such materials.

Safety stocks would be provided in the top-level items of the inventory if the quantities in the Master Schedule were increased. This tells the system we would like to have sets of parts in excess of those we really want to assemble. Care should be exercised, of course, to avoid providing excessive safety stocks. The problem arises when the product line contains families of items which have many common components and is illustrated by Figure #7.



	WEEKLY FORECAST		SAFETY STOCK	
MODEL	AVERAGE	ERROR	UNIQUE PARTS	COMMON PARTS
W1001	10	3	3	—
W1002	20	7	7	—
W1003	15	5	5	—
W1004	30	8	8	—
TOTAL	75	23	23	12

PROB MAX (FAMILY) $= \sqrt{(3)^2 + (7)^2 + (5)^2 + (8)^2}$

$= \sqrt{9 + 49 + 25 + 64} = \sqrt{147}$

= 12 SETS OF COMMON PARTS

Figure 7

The bills of material for the four individual models in this family of "W" products contain many common parts as well as components which make the models unique. Based on a weekly forecast, the average demand is projected to be 75 total assemblies but this, of course, could be higher if customers ordered the maximum possible in any one week. Maximum figures for any model could be determined by statistical analysis of the demand pattern and the level of customer service desired. For example, the forecast error for the W1001, based on past demand history, indicates that three additional units would cover the demand 95% of the time. Obviously, the sets of unique parts required for each model must be sufficient to cover the maximum demand to be satisfied for the model in which they are used.

However, in any week it is extremely unlikely that customers would order the maximum *for all items* in the family. Consequently, a safety stock of 23 sets of common parts would obviously be excessive. The probable excess demand for the family of finished models would be given by the square-root of the sum of the squares[1] of the excesses for the individual models. As shown in Figure #7, 12 sets of common parts would provide for the same 95% service level on the family of products. The safety stocks of common parts need be only 50% of the 23 sets which the material requirements plan would have generated had the maximum quantities of each model been used in the Master Schedule.

Companies having components common to many finished goods models should try to structure their bills of material to recognize common parts and thus avoid pyramiding safety stocks. Data-Control Systems in Danbury, Connecticut estimated they reduced safety stocks for their product line by 40% using the square-root technique described above with properly structured bills of material.

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[1]The technique is familiar to quality control people analyzing tolerance build-ups and is used also in reliability studies of complex assemblies like aircraft and missiles.

For many dependent demand items, an estimated fixed quantity is the only approach available for setting safety stocks. This could, for example, be the estimated maximum demand for higher-level assemblies or parts likely to occur in any one time period. Such an amount of safety stock would guarantee that enough of the component would be on hand to meet requirements if it were desired to start assembly or manufacture one week earlier than planned.

There are two ways safety stock computations can be handled in material requirements planning. One of these is illustrated in Figure #8 where the 200 pieces of safety stock are deducted from the "On Hand" balance of 1500 before the plan is made. The plan then shows net requirements when the projected "On Hand Available" figure drops to zero. An alternative would be to show net requirements when the projected "On Hand Available" figure has hit the safety stock quantity. In effect, this would add 200 to each of the projected "On Hand" figures shown in Figure #7, but the orders would still be generated in the same time periods. The IBM PICS package and other computer makers' software programs use the former approach because it is easier to handle in the computer. In either case, engineering changes which permit using up the balance of inventory of an item would require altering the usual planning program to be sure the safety stocks were consumed.

When manufactuirng orders are released for an item at one level, it is desirable to allocate the components of this item at lower levels. This earmarks or reserves the necessary quantities of these components for this order so that they will not be considered available to meet other demands.

IN STOCK – 1500 SAFETY – 200 ALLOCATED – 600

10314 SWITCH		PERIOD 1	2	3	4	5	6	7	8
PROJECTED REQUIREMENTS		100	450	100	100	1050	100	100	1050
SCHEDULED RECEIPTS					1000	1000			1000
ON HAND	700	600	150	50	-50 950	-100 900	800	700	-350 650
PLANNED ORDER RELEASE			1000	1000			1000		

REQTS: WEEK 2 – Y3L 350 WEEK 5 – Y3L 350 Y2L 600 WEEK 8 – Y3L 350 Y2L 600

Figure 8

Figure #8 shows one way of handling such allocations. The quantity of 600 for an order for a higher-level assembly using the switch has been deducted from the available "On Hand" balance before the plan is started. This is the approach adopted in the IBM PICS package. When this is used, care should be taken not to release orders for sub-assemblies, assemblies, or higher-level components too soon, since this would reduce the available quantities of lower level components, trigger new orders, and initiate other requirements earlier. This may distort the true priorities and

cause limited capacity to be devoted to the wrong items. Black & Decker, Data-Control Systems, and other companies with experience in requirements planning have a separate line in the plan for "Allocated" quantities. They can time-phase allocations for export or other customer orders with future delivery dates. This shows the planner known commitments for specific orders, but avoids the troubles of allocating too far in advance.

Figure #8 also indicates the use of the technique known as "pegging". This identifies for each component, the specific item or order at the next higher-level which cause the requirement. For example, the quantity of 1050 for a projected requirement in Week 5 can be traced upward to 350 required for the Y3L socket and 600 required for the Y2L socket. (The other 100 are for service requirements.) This permits a planner to trace upward through the product structure to find the source of demand when he must make rescheduling decisions. Pegging can also be used for identification of allocated quantities. Pegging may be as simple as identifying only the higher-level components which have generated requirements for the part or as complex as identifying each time period's requirement or allocation with the specific higher-level item and order which initiated it.

WIGHT: Aplications of the Technique

Material requirements planning is certainly one of the most universally applicable techniques in production and inventory control. It is the proper inventory management technique to use in controlling the following types of material:

1. Components.
2. Raw Material.
3. Service parts also used in current production.
4. Semi-finished material.
5. Branch warehouse inventory feedback.
6. Lumpy "independent" demand.

The application of material requirements planning to components has been discussed in the examples above. Raw material is also, of course, a *dependent* demand item, since raw material is not needed until the part that is made from the raw material is going to be started. Since the part is usually made in some kind of a lot size, once again the timing of the delivery of the raw material is the crucial question and material requirements planning works better than order point type techniques.

OP = DLT + SS
LT = 4
D = 100
SS = 250

OP = 650
OH = 1000
ORDER – WK4

Figure #9 – OP System

In the examples above, we talked about using material requirements planning where service parts were also being used in current production. It is worth also pointing out that, while order points cannot show the time phased relationship, therefore, they cannot be used where requirements planning is the proper technique; *the time phased material requirements planning format can be used to express an order point.*

Figure #9 shows an example using an order point. The order point, of course, consists of an estimate of demand over lead time plus safety stock. The lead time in this example is four weeks. The demand is forecast at 100 units per week. The safety stock is 250 units. The order point, therefore, is 650. If there were 1000 units on hand at the present time and usage actually was 100 per week, a replenishment order would be placed in week 4. Let's look at that same example shown in a time-phased format in Figure 10. Once again, the safety stock is 250 units, the forecast is 100 per period, the lead time is 4 weeks and there are 1000 units on hand. In week 8, the projected on hand balance would be below safety stock; the lead time offset tells us, then, that a planned order release should take place in week 4. This is exactly the same thing that the order point told us and illustrates the fact that order points can be expressed in a time-phased format. In fact, there are several advantages to doing this, not the least of which is the rescheduling capability in the time-phased format. As

SS = 250 FORECAST = 100/PERIOD LEAD TIME = 4 WEEKS

		PERIOD							
		1	2	3	4	5	6	7	8
PROJECTED REQUIREMENTS		100	100	100	100	100	100	100	100
SCHEDULED RECEIPTS									
ON HAND	1000	900	800	700	600	500	400	300	200
PLANNED ORDER RELEASE					←				

Figure 10 – The Order Point - Time Phased

requirements change, it tells the planner that he should revise due dates on open orders. Thus, the inventory system can be used to keep the priorities up to date.

Semi-finished material, such as the door hinges that a hardware manufacturer would keep in inventory unpainted, also has dependent demand. The hinges could be plated in many different finishes. By projecting the finished goods inventory requirements against the order points, the planned orders could be projected and these could be posted in the inventory record for the unfinished hinge to indicate when its supply would need to be replenished.

The more we see applications of material requirements planning, the more obvious its advantages become and the more universal its application becomes. Inventory items that are maintained in a factory warehouse to be supplied to branch warehouses are really dependent demand items. You don't need to have them until a demand from the branch warehouse is generated. Usually these orders from branch warehouses come into a central inventory as complete surprises, just as service parts branch inventories usually create havoc back at the main plant, since they come in without warning and usually they require fairly short lead time. By using the time-phased format, both at the branch warehouse and back at the central inventory location, planned orders can be projected and the main location can see much more clearly not only when future requirements *will be* coming, but also what the up to date priorities really are. This, of course, is a by-product of the rescheduling capability built into the time-phased requirements planning approach. In short, requirements planning provides the ability to get "visibility" from one level of inventory into another.

One of the most interesting examples of the application of time-phasing we have seen was on independent demand items that had lumpy demand. Picture an item in finished goods inventory that has two streams of demand, one is fairly continuous series of orders and the other is occasional, very large requirements for export or for promotions. How can these large requirements be shown with an order point system? This has always been a dilemma. If they are entered into the inventory system right away, that would generate replenishment orders even though the lumpy demand might not be required for some time in the future. On the other hand, if they are not entered into the system right away, how can we be sure that we will have the

components, raw materials, etc. that are needed to handle this large demand.

The answer, once again, is to show the order point in a time-phased format. The demand forecast that is used in the order point might be 100 units per week. An export order might call for 1000 units in week 8. By showing the order point in a time-phased format, this requirements could be entered methodically and we would be sure that it would generate – via planned orders – requirements for any lower level components at the right time.

As Dr. Orlicky pointed out, we probably will see a greater and greater trend to using the time-phased format, both for requirements planning and order point items, in the future because of its far greater flexibility.

It is interesting to note that the number of pages written on independent demand type inventory systems outnumbers the number of pages written on requirements planning by well over 100 to 1. The number of items in inventory that can best be controlled by material requirements planning outnumbers those that can be controlled effectively by order point in about the same ratio. It is a sign of the adolescence of our field that the literature available is in the inverse proportion to the applicability of the techniques.

When exponential smoothing and statistical order point first came along, we were among the first to use these techniques, and quite successfully. We are not in any way denying the validity of statistical order point concepts. The development of these concepts had helped us to refine our ability to handle independent demand inventory items and control inventories more successfully than we could with the old "hunch" type order points. Nevertheless, the professional should recognize where techniques apply and where they don't apply. He should be knowledgeable about all of the techniques and should not misapply good techniques since the results will inevitably be very disappointing.

SESSION II

WIGHT: Forecasting and Bill of Material Structuring

One of the most frequent objections that people present against using requirements planning as opposed to order points is the fact that they don't know how to forecast well enough to do requirements planning. Certaily the volume of the forecasting can't be the problem, since requirements planning approaches use forecasts for sub-assemblies and assemblies rather than parts. By definition, there are far fewer assemblies than parts to forecast. Sometimes the fact that an order point system has an assumed forecast – even if it is just some kind of average past usage – built in for each part that has an order point, is overlooked.

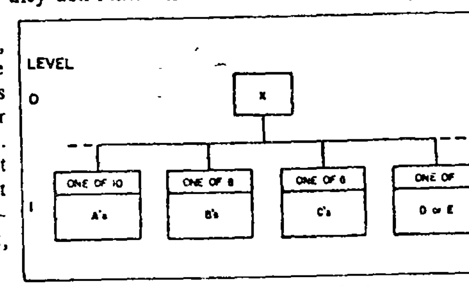
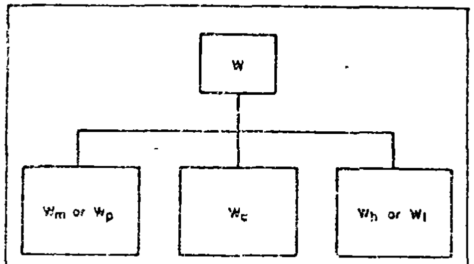


Figure 11 – Forecasting Options

More often than not, though, particularly with the type of product that is beoming more and more common in most companies, the forecasting problem lies in the structure of the bill of materials. Figure #11 shows this kind of problem. Imagine this to be a chain hoist, for example, that can be made up of one of ten different pulley sizes (Module A), one of eight different motors (Module B), one of six different gear boxes (Module C) and two different choices of hoisting assemblies. Let's assume, for the sake of this example, that any one of the motors can be used with any one of the pulley, gear box, and hoist assemblies, the forecasting problem even in this simple example quickly begins to get out of hand. Ten pulleys times eight motors times six gear boxes times two hoist assemblies gives a possible 960 different final configurations of product. Forecasting each of these final configurations is going to be almost impossible. But the lead times to assemble these modules together is quite short and the real problem is forecasting the parts that go into the modules rather than forecasting the final configuration of the product. As a consequence, it makes a great deal more sense to forecast at level 1 rather than level 0. In other words, instead of forecasting the final product itself, we will forecast each of the modules. This is the way that the automobile industry has done its forecasting for years. You couldn't possibly imagine anybody trying to *forecast* the final configuration of each automobile that is sold.

We can learn something from the automobile industry and some of the other companies that have recognized the modularity in their product and structured their bills of material this way. They don't carry bills of material that completely define the product, but instead they carry modules and assemble them together when they get an order for the product. Before looking at an example of this approach, let's look at Figure #12 which shows a further extension of this concept. Many bills of material consist of a group of common parts that show up on many other bills of material plus a few unique parts. Once again, the concept would be to break bills of material apart, so that there is one bill of material for common parts that go with each W type assembly and then bills of material for those parts that are unique to the assembly. Obviously, at some point in time, the bills of material will have to be assembled together again to make up the actual bill of material required for a specific product.



ASSEMBLY	PARTS COMMON	PARTS PECULIAR
W 1001	W_c	W_m W_h
W 1002	W_c	W_m W_i
W 1003	W_c	W_p W_h
W 1004	W_c	W_p W_i

Figure 12 – "W" Bill of Material Variations

The concept here really revolves around the computer's ability to index bills of material quickly and pull them together. We don't have to maintain the bills of material within the computer in the format in which we are going to use them, since we can get them out in just about any format that we want. By the same token, we don't even have to maintain complete bills of material on the computer. Thus, we can take partial bills of material and assemble them to suit our own needs.

Fisher Controls in Marshalltown, Iowa makes an extensive line of fluid control devices. They had a very serious problem with their bills of material, not only in being able to forecast end items which could take on almost an infinite number of variations, but also in coping with the sheer volume of the bills of material. Since there were so many combinations, their chances of having a bill of material available when an order was received from a customer were only about one in three. This meant each time an order was received, they had to go to engineering, have one bill of material modified with adds and deletes, etc., to come up with a suitable bill to specify the particular order. It seemed the harder they worked, the lower the percentage of actual orders they were able to specify with an existing bill of material! No matter how fast they captured the bills of material and got them on the computer, the engineers, marketing people, and customers were always thinking up new variations. And just one variation -- perhaps the addition of a teflon seat valve option – could double all the bills of material required for a product line. They were working against a geometric progression!

ITEM A – COMMON PARTS

SIZE	
1 INCH	(1)
2 INCH	(2)
3 INCH	(3)
4 INCH	(4)

ITEM B – VALVE

SIZE	1 INCH	2 INCH	3 INCH	4 INCH
30% CAP.	(1)	(2)	(3)	(4)
50% CAP	(5)	(6)	(7)	(8)
70% CAP	–	(9)	(10)	(11)
100% CAP	(12)	(13)	(14)	(15)

EM 110 x 1 A 2 B 9 C ___ D ___ E ___ F ___

Figure 13 – Type 310 Gas Regulator

Fisher decided to go to the modular bill of material. Figure #13 shows part of their order entry form for a type 310 gas regulator. When an order is received from a customer, this order entry form is filled out, a card is punched up that goes into the computer to tell it which modules to call out to generate a bill of material for *this* customer order. This bill of material may be

unique and it may never be repeated again. The history of demand for each module, of course, will be captured within the system.

At the bottom of Figure #13, we have started to fill in the order entry form. The "2" filled in behind Item A indicates that this order will require common parts that go with the two inch valve. The "9" filled in behind Item B indicates that the parts associated with the 70% capacity two inch valve will be required. These codes are used to retrieve the bill of material modules required to "custom assemble" a bill of material for this order.

What has this approach done for Fisher? Well, certainly it has put them in a position where they can forecast much more readily than they could when they were trying to forecast the final configuration of each product. With the product indicated in the example, the 310 gas regulator, the number of bills of material has been reduced from 760 to 60. More important than that, the number of product structure records in the computer has been reduced from a potential 24,300 to a maximum of 260, since common parts are not repeated over and over again in many bills of material. There are other advantages such as reduction in maintenance of bills of material and the ability to keep a meaningful history on the usage of each bill of material module. But the important ability is the ability to forecast better for the requirements plan. By the way, the information that I have used here about Fisher Controls was drawn from the article titled, "Stop: Before You Use The Bill Processor. . ." by Dave Garwood of Fisher Controls that appeared in the *Production & Inventory Management* Journal, Second Quarter 1970. The article is well worth reading.

MASTER SCHEDULING

The master schedule is the most important consideration in requirements planning. This is the schedule that goes into the computer to tell it what assemblies are going to be pulled from the stockroom on what dates so that the computer will convert this to "due in stock dates" for the components required for the assembly. The master schedule hasn't received much attention in the literature and yet it is the most important consideration in requirements planning. The master schedule is quite different from company to company. It is the element of requirements planning that needs the most tailoring to the individual company.

Some companies make up a master schedule strictly from their order *backlog*. A machine tool company, for example, with an order backlog that is extended out beyond their total lead time, would decide on the various "lots" of finished machines they were going to make and firm up their master schedule many months in advance. This would then go into the computer and start the requirements planning process rolling. This master schedule would be modified from time to time as particular machines were rescheduled or as lots of machines were rescheduled because of parts availability, capacity constrictions, changing customer needs, etc.

Other companies develop a master schedule strictly from a forecast. One of the power tool manufacturers, for example, has a master schedule that is first proposed by the marketing department who actually control the finished inventory. The manufacturing people then modify this master schedule based on their ability to produce. In other words, they are doing a rough *capacity plan* before they actually firm up the master schedule. There is no sense scheduling twice as many power tools in one month as the next, since it won't be possible to get the parts through to satisfy this type of schedule nor would it be realistic to expect this type of assembly capacity to be available. This master schedule, then, is a forecast supplied by the marketing department based upon the finished goods inventory position. It is modified from time to time as the forecast is revised. The master schedule is expected to be firm, however, for the next eight weeks since this company feels that they can't do very much to change theparts that are coming through in that short lead time. Obviously, if one of their die castings were scrapped and couldn't be replaced, the manufacturing people would have to adjust the master schedule to reflect the reschedule. Beyond the eight week horizon, there is another period of time when marketing can shift timing but not shift quantities. For example, if they have forecast that they are going to make a lot of 10,000 seven inch saws they can change the *timing* of that lot to move it up a week or back a week without too much difficulty. Once they start changing the quantity, this could seriously disrupt production since many of the components have already been started in lots of 10,000. Beyond this second horizon, timing *and quantities* can be changed. Obviously, the second horizon is out near the end of the total accumulated lead time down through the product structure levels. The reason for forecasting out beyond that period is to provide capacity planning information.

So here are two examples, one making a master schedule from a backlog, another making it from a forecast. A third and perhaps the most common approach of all is a combaintion of backlog and forecast. For many companies, the delivery lead time to the customer gives them just barely enough time to pull modules out of the stockroom and assemble them. They need to forecast component requirements long before they have an order on hand. For this type of

		PERIOD							
		1	2	3	4	5	6	7	8
FORECAST		X	X	150	150	150	150	150	150
ACTUAL ORDERS		X	50	180	110	180	140	250	110
OLD MFG. PLAN				500				500	
NEW MFG. PLAN				500			500		200

Figure 14 – Master Schedule Product No. 2031

company, the master schedule is a combination of forecast and backlog. Well out on the horizon, the master schedule could be entirely forecast. There would be an intermediate period when it would be a combination of forecast and some known backlog. Over a short horizon, the master schedule would consist of actual customer orders. Each week, the master schedule would be generated, reviewed in the light of changing component availability, changing customer requirements, and reinserted into the computer to generate a new requirements plan.

Figure #14 shows a master schedule for product 2031. Imagine that this master schedule has just been generated and the planner is making up the "new manufacturing plan" based on the latest customer requirements and the latest component availability. Note that actual orders are running well ahead of forecast. The orders for week 1 have all been released to the stockroom to be pulled for assembly. There are some 50 actual orders that should be pulled out of the stockroom in week 2, but they haven't been released, probably because some parts are not yet in stock. Last week's manufacturing plan called for an order for 500 units of product 2031 to be released to the stockroom in week 3. Note that this will not cover actual customer requirements through week 7 when the next order was originally planned to be released. Checking component requirements, assembly capacity, etc., the planner moves the order for 500 up into period 6. A little quick addition will show that he still hasn't covered all of the commitments that have been made to the customers. A disturbing situation, but undoubtedly more normal than theoretical for most companies. It looks like somebody here is making customer promises and accepting orders a little bit optimistically. It also looks like the forecast in this case has not been very accurate. Nevertheless, as is always the case in production and inventory control, we have to cope with the realities. The planner looks down through some of the requirements plans for key components and perhaps he has a lot of 500 scheduled several weeks out. In checking component availability, he decides that he can move 200 of that lot up into week 8. His new manufacturing plan (the hand written numbers) then reflects the very best he can do to meet the commitments that have been made on actual orders. This new manufacturing plan will go into the computer as the master

schedule (when he gets through doing this planning, he ought to go talk to the people who are doing the forecasting and also making commitments on customer orders since they put him in a very serious position; nevertheless, note that he tried to put into the master schedule the *truth* to the best of his knowledge).

A few key points are worth nothing about the master schedule:

1. The requirements plan indicates due dates into stores for all components. The master schedule then indicates the date that these components are to be pulled from stores. Note that the master schedule does not really represent either the assembly schedule nor does it represent the shipping schedule.
2. The master schedule was reviewed and revised *before* the regular run of the requirements plan. Major revisions might only be made monthly and minor revisions to reflect component availability, etc. would be made more frequently.
3. Everything in requirements planning starts with a master schedule. The master schedule must be told the truth or component priorities will not be maintained properly by the requirements plan.

Too often people misunderstand the function of the master schedule: they see it as some kind of performance commitment rather than as the "program" that makes material requirements generate realistic requirements. As a result, they will not reschedule items in the master schedule even when there is no possibility of making them on the date originally planned. This results in unrealistic component priorities and a material requirements plan that doesn't really work as well as it should. The moral is very clear:

TELL THE MASTER SCHEDULE WHAT YOU ARE REALLY GOING TO MAKE.

PLOSSL: The Files Required

Material requirements planning requires four basic files of data. The first is the "Item Master Record" – this contains the data usually shown on Kardex inventory records such as part number, description, unit of measure, balance on hand, receipts, issues, etc. Application manuals published by computer manufacturers for their software packages contain sample files showing the items that should be considered for inclusion in this important basic file.

In addition to the items usually covered, however, several others can be useful. To help level input into the factory, the file should include set-up times, running times, and the key machine groups where each item begins its processing. A planner seeking to level input to critical work centers like screw machines, turret lathes, die casting machines, presses, etc., can then easily pick out items representing significant loads which are approaching a reorder condition. If these data are identified in the item master file, it is unnecessary to search the routing files. Significant set-up savings can be obtained if items in a family which require only minor modifications to the set-up can be run together. Such family identification can also be part of the item master file so that the planner can see which items should be ordered together.

The second major file required is the "Product Structure Record" – really the bill of material linking the various components of the product together. As Dr. Orlicky emphasized, material requirements planning is product oriented and requires accurate, up-to-date knowledge of how the product is made from its components. The bill of material, therefore, is a vital part of the planning system. It is not just a parts list. The way it is structured can improve very considerably the ability to translate a Master Schedule into component requirements.

A third file is the "Open Order" file showing all open manufacturing and purchase orders. This important file is one of the most difficult to keep accurate; the problem is determining when an order is really complete and when a small balance really represents material still due.

A fourth file required is the "Master Schedule" showing the weekly requirements for end items which will generate the whole requirements plan. This schedule is derived from the forecast or the backlog of open customer orders, but it should not represent quantities of product desired for shipment or for delivery into inventory. It should be *the sets of parts desired to be sent to* *assembly in each ti... period.* It seems almost impossible for practitioners to resist the temptation to develop a master schedule using the quantities they *would like* to put together rather than the quantities they *actually believe* will be assembled. "Lying to the system" orders material which will not be used. This not only inflates inventories but distorts the real priorities.

An optional file showing "Allocations" in the future time periods would be of importance to companies with customer orders on the books requiring future delivery. A real problem is determining whether such orders represent a portion of the forecast or whether they will be additions to forecast quantities. Some companies, including Twin Disc, use the rule that the Master Schedule will be based on forecast or actual orders, whichever is larger. This guarantees that enough material will be on hand to meet the maximum requirement in any time period. The approach should be used very carefully, however, to avoid inflation of inventories.

RECORD ACCURACY

A fundamental requirement for successful application of material requirements planning is file integrity, essential if the company is to be operated *with the system* instead of *in spite of the system.* Accurate data is the foundation upon which good planning is built. It is as necessary as a good foundation under a manufacturing plant, and like that foundation, its development is dirty, time consuming, and expensive. When safety stocks, early delivery into stores, and other cushions are eliminated from the component inventories, record errors become more critical. If records are not accurate, the inevitable result will be the setting up of expediting sub-systems to cope with assembly shortages instead of depending upon the material requirements planning system to insure having the right components at the right time.

The first step in improving record integrity is, of course, to measure how bad the records are now. Few companies have specific knowledge of how many errors there really are or how much these errors are costing. Error measures should be based upon cycle counting and should show both the percentage of items having a "significant" error and the average percentage of error. For items counted by weighing scales, errors of less than 2% would probably not be significant; low-value, commercial hardware items may be considered under control when actual quantities are within 5% of record figures. "A" items would have a significant error if records differed from actual counts by more than a few pieces.

The development of a program to improve record accuracy will involve several departments, a large number of records, and many other activities. Like any management problem, the best attack is determining the important few *causes* which are creating the bulk of the errors. Component stockrooms where the majority of transactions occur are probably the greatest source of potential errors. We know of no company with accurate records that does not have a locked storeroom. "Point of use" storage is very attractive to reduce material handling costs, but it is extremely destructive of accurate records. There are always objections to locking the stockroom – usually based on the misconception that the basic objective is to prevent theft and pilferage. It isn't. Locks don't keep out thieves; they just make it more challenging to get in. The real purpose in locking the stockroom is to *establish measuring points* to insure that data flowing to the information system parallels the material flowing through the process. If the system is to be used to control, there must be specific means for it to know when and how much material really has moved.

Techniques built into the system like double counting, use of hash totals, and checking digits, and "reasonableness" checks (particularly good to catch unit-of-measure errors) can help to improve the accuracy of the data. However, the need for auditing records by actual counts will never be eliminated. Cycle counting keeps records accurate throughout the year, uses experienced personnel to the best advantage, and provides checks of record accuracy which can be related to the frequency of transactions on the items.

True record integrity requires a management policy intolerant of errors. A zero defects approach is necessary. It is frequently argued that the wage scales of storekeepers, receiving clerks, etc. are not high enough to get people capable of highly accurate work. Their wages, however, are usually higher than those of bank clerks. Bank precision is a result of the *climate of accuracy* maintained. Accurate records require that management establish such a climate and provide the necessary tools. How can people make good counts without accurate counting scales, orderly

storerooms, a minimum variety of shop containers in good repair, etc.? Don't overlook the importance of identification. When a count is in error, one record is wrong, but when identification mistakes are made, two records are wrong.

ENGINEERING CHANGES

The vital importance of the bill of material in planning requires that it, too, be accurate. Any component not included in the bill of material will not be ordered. Engineering change control is vital. Engineering changes can be made effective on the date existing components will be used up, altering the bill of material in the system after that date. They may also be phased in when a given quantity of a component is left. This quantity might cover the requirements for spare parts. Twin Disc has an ingenious method for timing engineering changes. If Item C is to replace Item B, they set C up in the bill of material immediately, but as a component of B. When B has been used up, the system calls out C, giving the signal to change the bill of material. This approach eliminates the need to estimate when available parts will be used up. The use of "block changes" grouping many engineering changes to be made at the same time can minimize the problems of control of bill of material accuracy.

INSTALLING THE SYSTEM

Installing the material requirements planning on a computer can be speeded up greatly by using software programs available from most computer manufacturers. Many of the techniques of lot-sizing, file maintenance, allocation, pegging, etc. are common to requirements plans for all companies using them and there is no need for each to write his own program. The present software packages, typified by the PICS programs available from IBM, are modular programs which permit a company to select from a variety of options to build its own custom-tailored system. This is analogous to selecting pre-fabricated windows, doors, and even bathrooms rather than building your own house from scratch. The pre-fabricated components can be assembled in a variety of ways to build a structure most useful to the owner.

In addition, software packages provide a variety of analysis routines which are useful in studying the effects of changing the system of ordering. These permit investigating the impact of lot-sizing decisions on aggregate inventories and studying the effect on component inventories of the introduction of requirements planning compared to order point/order quantity systems. Such analysis routines also provide educational tools to help people understand how the system will function.

The best approach to getting running is to use a pilot approach. Pick a product line with as few parts interchangeable with other product families as possible. Limiting the scope of the program means fewer problems to cope with. The bills of material should be checked, rechecked, and checked again to insure the highest accuracy. This can be improved by using bills of material as pick lists from which the storeroom issues sets of parts to assembly lines. All unplanned transactions (covered by hand written requisitions) should be checked in detail; the sources of errors will show up and bills of materials can be corrected.

The number of changes introduced at the same time as requirements planning should be minimized. It is sound to make as few changes in lot-sizing and in planned lead times as possible in the early stages to minimize the effects on the plant. In converting to requirements planning, the greatest problem will undoubtedly be the need to reschedule purchase and manufacturing orders already released. Other ordering systems usually generate orders far in excess of real requirements No company will want to cut off suddenly and dramatically the flow of orders to vendors or its own manufacturing facilities and plans should be made in advance to cut back gradually.

The need for education of those using the plan cannot be overemphasized. As Dr. Orlicky commented, material requirements planning replaces a clerical routine with order analysis. This requires understanding by planners of the variety of actions available to them. The system simply informs the planner of data relating to the decisions. He should understand where the information comes from and what alternatives are available to him. Starting to use requirements planning should be done very carefully – like a father holding his new baby.

BENEFITS

Few projects have more potential today for improving a company's profits and operations than the installation of computerized material requirements planning. Figure #15 summarizes the benefits, indicating some typical figures achieved by companies with successful systems.

REDUCED COMPONENT INVENTORIES:
- UP TO 50%
- FREQUENTLY 30%

IMPROVED CUSTOMER SERVICE:
- UP TO 90% FEWER LATE ORDERS
- UP TO 75% LESS STOCKOUTS

LOWER MANUFACTURING COSTS:
- UP TO 10% LESS ASSEMBLY LABOR
- UP TO 5% MORE PRODUCTIVITY OVERALL

FEWER INDIRECT EMPLOYEES:
- UP TO 25% LESS
  - STOREKEEPERS
  - EXPEDITERS
  - TRUCKERS
  - CLERKS

Figure #15 – Benefits of Requirements Planning

The greatest payback comes from reduced component inventories resulting from the elimination of safety stocks on dependent items and the timing of receipt of components to coincide more closely with assembly requirements. A reduction of 50% in such inventories is not unusual; very frequently, a 30% reduction is experienced.

Since the well-designed and managed system plans components to meet assembly requirements, customer service almost inevitably improves dramatically. Sub-systems are eliminated, upsets are minimized, and assemblies are put together the way they were designed. These result in lower manufacturing costs. With less inventory and fewer upsets, a company can reduce its indirect employees, particularly storekeepers, expediters, and truckers.

It is easy to justify all project costs involved in implementing such a program. The savings due to reduced inventories and the improved customer service alone are usually enough. However, many significant potential savings may be overlooked if a detailed analysis is not made. Specific savings must be identified and plans made to capture them or they will not be achieved.

The production control manager of a mid-West manufacturing firm, now operating a very successful requirements planning system, told recently of an additional benefit not listed in Figure #15. He testified that he can now spend the bulk of his time *planning for the future* instead of *reacting to the crises* caused by the mistakes of the past.

WIGHT: Diagnosing the Ineffective Material Requirements Plan

The minute computers became available for manufacturing companies and, indeed, even back in the days of the punched card equipment, the idea of requirements planning was very appealing as a payoff application It is the kind of thing that can hardly be done manually and, obviously, can be done well with the computer.

Yet very few companies today are doing material requirements planning successfully. We have probably worked with more of the successful ones that anybody else around and we've also had the chance to see a great many of the unsuccessful ones Frequently, people tell us that they have tried the requirements planning that we and other people like Romey Everdell have been talking about, but they certainly haven't gotten anything like the potential results. In fact, the odds are very staggering against a company succeeding with requirements planning, if present experience is any indicator. Nevertheless, the reasons for lack of success are very few and very easy to identify. Let's look at them briefly. The following is a diagnosis checklist based on observing many companies that have been unsuccessful with requirements planning and a few that have had the kind of success that is possible with this technique These are the areas where problems arise

1. Inventory record accuracy.
2. Bill of material structure.
3. Bill of material accuracy.
4. Degree of user control.
5. Master schedule.

We've already talked about inventory record accuracy and it needs little further elaboration. Isn't it interesting, however, how much time we put into some of the more esoteric areas of system development and how little effort so many companies have put into maintaining the basic inventory records accurately! You can do third order exponential smoothing or net change requirements planning against an inventory record that is inaccurate, and all you've got is garbage as a result.

The problem of bill of material structure is usually indicated by the symptom "We can't forecast our product requirements" or "We've got far too many bills of material to even put in the computer". The modular bill of material is usually the answer.

Bill of material accuracy is, of course, essential. With an order point system, each item is ordered whether it is needed or not. With the requirements planning system, only those parts that are needed as indicated by the master schedule are ordered. If they don't show up on the bill of material, they cannot be ordered.

Someplace, somebody got the impractical idea that computers were going to control inventory. Not that many people have the guts to actually let computers order inventory, but usually when the systems design starts, this is the concept. The more systems designers try to capture the logic for ordering inventory, the more they realize that it is highly fluid, depending upon strikes, capacity bottlenecks, which customer recently hollered the loudest, etc. It is certainly not a well-structured problem. We *always wind up, then, having people checking the computer* recommendations for releasing orders.

Most of the time, a system hasn't been designed to let the user do this conveniently and most of the time there is a great deal of naive sophistication built into the system so that the user doesn't feel like he really has control over it. The user must have the control over the system and useless sophistication must be eliminated from the system to make it as understandable and "transparent" to the user as is humanly possible.

Another aspect of user control that is critical and can contribute to his understanding of the system is having the user responsible for the design of the system. We have yet to see a requirements planning system work when systems people took the initiative for systems design. Only the user can be held responsible for results. Only he can assume the responsibility for specifying what the system should be. Obviously, he is going to need a lot of help from systems people, but the user *must assume responsibility for systems success.* He must always be able to retain control of the system to understand what it is doing, if we are to hold him responsible for results. Nobody has yet succeeded in holding a computer responsible for results.

The master schedule is, of course, one of the key items and usually the place where requirements planning falls down. Overzealous users trying to catch up on all of their past due schedules at once tend to dump into the master schedule an unrealistic plan that couldn't possibly be attained. One company we know manufactured about 4000 machines a month. When they put in their requirements planning system, they were introducing a new product, consolidating some product that had been made in another plan, and preparing for a strike. In the first month, they couldn't resist putting 19,000 units into the master schedule. The computer faithfully went through its calculations and generated a component past due list that was monumental. Faced with the information generated by the formal system that told them everything was late, both purchasing and manufacturing people immediately reverted to the informal system. Hot lists and expediting became the order of the day and the requirements planning system was certainly not successful. We judge success by the degree of operating improvement that has been achieved, not whether or not this system runs on the computer.

In fact, this company provides a very interesting example because putting a requirements planning system in the hands of people who have never had this powerful a tool can sometimes be dangerous Obviously, when then put 19,000 machines into their master schedule, the computer proceeded to generate floods of orders for components. Since they were bringing in more components than they were using in assembly, the inventory went up. Since the master schedule was overstated, all components were shown as late and priorities became meaningless. As soon as priorities became meaningless, they were back in the old situation of having most of the parts for all of the products rather than the situation that a good requirements plan should generate – having *all* of the parts for most of the products. This powerful tool can react so quickly that it can actually put a company in more serious trouble than they could get into with an unresponsive order point type of system. This is, of course, true with any tool. A power saw can do a better job than a hand saw, but it can also be far more dangerous. A scalpel is a very effective tool in the hands of a surgeon. We can make an excellent case for replacing a Boy Scout knife with a scalpel, but that doesn't make its owner a surgeon.

Perhaps the most significant problem we have, then, with requirements planning is strictly psychological. Back when we did requirements planning manually, we couldn't really put proper priorities on items. Manual requirements plans or punched card requirements plans couldn't be recalculated frequently enough to keep these priorities up-to-date. Order point systems, of course, never even put the right priorities on in the first place, and had no means of keeping them up-to-date to tell us what parts we really needed and when.

As a result, each company had its formal system and its informal system. With the advent of computerized requirements planning, we have something unique. An inventory system that *can* tell us the truth! But most companies have a big challenge ahead of them in making the transition from living with a veneer of formal system on top of a foundation of informal system to managing with a system.

Many people, for example, ask whether it is necessary to have more accurate inventory records with requirements planning. Since the technique is supposed to be better than order point techniques for dependent demand items, shouldn't they be better off even with their admittedly poor inventory record accuracy? The answer is "NO!" In fact, they probably won't see any difference at all since the informal system will continue to control the business and all they will have changed is the formal system veneer which probably never meant much anyway. Check in the typical plant and you will see many, many late shop orders that nobody is looking for and, if you ask the foreman how he can possibly run this way, he will tell you the truth, "When they really want it, they'll send an expediter around".

Do we really need to go to the trouble of making the transition from managing with the informal systems to managing with systems? This probably depends upon the company, but there are very few companies today that don't have the problem of a more and more complex product with more and more product variety and greater turnover among the people who used to help run the business "in spite of the system". And, in most companies, the symptoms are the same. Inventory is going up, service is not increasing. Slowly each year, you can see the business getting more and more out of control. The correlation between those companies that are showcase examples of good material requirements planning and high profits and growth is extremely high.

So, before you start in with the expense and trouble of developing requirements planning systems, try to get your people to face up to this problem of learning to manage with a system. Just putting this kind of system on a computer won't generate results; in fact, it may give people more powerful tools to get themselves in trouble. When the requirements planning system is developed and used properly, it can provide an excellent tool to help control the business better.

Requirements planning, of course, is the gateway to other applications. Capacity planning is a natural offshoot of requirements planning and, without capacity planning, there is no capacity control; without capacity control, there is no control over lead time. Requirements planning also provides the updating of priorities so that dispatch lists showing the latest priorities can be generated. Many companies have tried to put in shop floor control systems before putting in requirements planning and have only managed to give themselves better means for executing a plan when they didn't have any real plan to execute. Material requirements planning comes first.

Here we have a technique with *extremely broad application*. Practically every company has dependent demand inventory items. It is a system *that can be implemented*. There are fairly standard approaches to implementing it and we encourage the use of standard programs like the IBM PICS program. It is far better to take a standard approach and tailor it to your individual requirements than it is to invent your own. The ability to maintain this system and have it understood by users as well as the shortened development and installation lead time are most important considerations that make standard approaches very worthwhile.

We also have, for the first time, an inventory control technique *that can tell the truth.* If people want to face the challenge, they can now have a formal system that will take a lot of chaos, confusion, expediting, and just plain bull work out of production and inventory control. Some companies have made the transition from running primarily with an informal system to running with a formal system. For many, it is the most important challenge they face in the near future.

We sat the other evening thinking about this talk, thinking about the tremendous application potential of this tool that we've seen. There have been a number of highly successful companies. We were also thinking about the great number of companies that haven't really been able to use the tool effectively and we came to this conclusion: *It's easy to see how companies can manage poorly with requirements planning, but it is hard to see how they can manage well without it.*

SEMINARIO DE ACTUALIZACION EN ADMINISTRACION DE PRODUCCION E INVENTARIOS

TEMA: LA CONFECCION DE OBJETIVOS PARA LA ENSEÑANZA.

ING. ROBERT F. MAGER.

MAYO DE 1978.

La Confección de Objetivos para la Enseñanza

Robert F. Mager

Material adjunto al texto
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INDICE

INTRODUCCION

Todo el mundo habla de definir los objetivos educativos, pero casi nadie hace nada al respecto. Los libros sobre educación frecuentemente hacen hincapié en los objetivos; los manuales de programación enumeran el "definir los objetivos" como primer punto; y los materiales de enseñanza, tales como las películas y tiras fílmicas, frecuentemente contienen una descripción de los "objetivos". Pero, ¿con qué frecuencia se confeccionan las unidades educativas, sean grandes o pequeñas, en respuesta a las siguientes preguntas:

1. ¿Qué es lo que debemos enseñar?
2. ¿Cómo sabremos si lo hemos enseñado?
3. ¿Qué materiales y procedimientos darán mejor resultado para enseñar lo que deseamos enseñar?

No solamente deben ser contestadas estas preguntas para poder enseñar de manera eficaz, sino también es importante el orden en que se respondan. La primera pregunta debe ser contestada antes que las otras dos. La razón probable por la cual casi siempre se enumeran pobremente los objetivos es que son pocas las personas que saben cómo hacerlo. Esto no es una sorpresa, porque se ha escrito muy poco sobre la confección de objetivos—muy poco para los maestros. El trabajo de la enseñanza en sí ocupa todo su tiempo, y hace que el maestro estime que tiene sus objetivos bien "proyectados", y que no es necesario ni posible ser más específico.

La Confección de Objetivos para la Enseñanza constituye un punto de arranque para la descripción de cómo precisar los objetivos. No se propone que sea la última palabra acerca del problema. Por el contrario, es algo así como la primera palabra. Pero el salto de adelanto es grande y real. El libro no solamente proporciona un enfoque valioso de la tarea de especificación de metas, sino que también proporciona una **orientación** que concibe la especificación de metas como un problema práctico e inevitable que necesita soluciones prácticas. Este es un paso importante.

Robert Mager ha visto la necesidad de ofrecer instrucción específica en cuanto al enunciado de los objetivos, y ha trabajado sobre este problema. El éxito de sus esfuerzos será determinado, en parte, por los resultados que usted obtenga en la prueba de examen incluida en el libro. Sin embargo, el valor fundamental del libro depende del grado de inspiración que derive usted para expresar sus propios objetivos didácticos.

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PREFACIO

Había una vez un caballito marino que reunió siete piezas de a ocho y salió a galope a encontrar su fortuna. No había transcurrido mucho tiempo cuando se encontró con una anguila que le dijo:

"Psst. Oye, socio: ¿Adónde vas?"

"Voy a encontrar mi fortuna," contestó orgulloso el caballito marino.

"Estás de suerte," dijo la anguila. "Por cuatro piezas de a ocho te doy estas rápidas aletas, y así podrás llegar mucho más rápido."

"Qué bien," dijo el caballito marino, pagó el dinero, se puso las aletas y se deslizó a una velocidad dos veces más rápida. Al poco rato se encontró con una esponja, que le dijo:

"Psst. Oye, socio: ¿Adónde vas?"

"Voy a encontrar mi fortuna," contestó el caballito marino.

"Estás de suerte," dijo la esponja. "Por una suma pequeña de dinero te daré mi moto de propulsión a chorro, para que puedas viajar más rápido."

El caballito marino compró la moto con el dinero restante, y salió a través del mar a una velocidad cinco veces más rápida. De pronto se encontró con un tiburón, que le dijo:

"Psst. Oye, socio: ¿Adónde vas?"

"Voy a encontrar mi fortuna," contestó el caballito marino.

"Estás de suerte. Si tomas este atajo," le dijo el tiburón, apuntando para su boca, "ahorrarás mucho tiempo."

"Muchas gracias," le dijo el caballito marino, entrando rápidamente en el interior del tiburón, para ser devorado.

La moraleja de esta fábula es que si no se está seguro acerca de dónde uno se dirige, se puede ir a parar a otro lugar sin saberlo.

Antes de preparar la enseñanza, antes de escoger el material, la máquina, o el método, es importante poder exponer claramente cuáles son las metas. Este libro versa sobre los objetivos de la enseñanza. En el mismo trataré de mostrar cómo exponer los objetivos que mejor resulten en la comunicación de sus propósitos a otras personas. El libro **no** trata sobre la filosofía de la educación, ni sobre quién debe seleccionar los objetivos, ni sobre qué objetivos deben ser seleccionados.

Se supone que los lectores estén interesados en confeccionar una enseñanza eficaz, y que hayan enseñado, estén enseñando, o se estén formando para enseñar. Se supone también que estén interesados en comunicar ciertas habilidades y conocimientos a sus alumnos, y comunicárselos de tal forma que éstos puedan demostrar el logro de los objetivos didácticos trazados. (Si usted no está interesado en demostrar el logro de sus objetivos, acaba de terminar la lectura de este libro.)

Robert F. Mager

Palo Alto, California,
Noviembre de 1961.

NOTA

La mayor parte de este libro ha sido confeccionada en forma distinta a la de la mayoría de los libros que usted ha leído. En muchas de las páginas se le hará una pregunta. Cuando esto suceda, seleccione la mejor respuesta y remítase al número de esta página que se indica al lado de la respuesta. De esta forma, el material se ajustará a sus propias necesidades, y podrá continuar el estudio sin ser interrumpido por explicaciones innecesarias.

Debido a que las páginas de este libro no se leen consecutivamente, sería de gran ayuda utilizar un marcador para que pueda señalar el lugar donde está.

Remítase a la página 13

CAPITULO 1

OBJETIVOS

Una vez que el maestro decide enseñar algo a sus alumnos, tendrá que realizar varios tipos de actividades para tener éxito. El maestro debe decidir primeramente las metas que espera lograr al final de su curso o programa. Entonces debe seleccionar los procedimientos, el contenido, y los métodos que son apropiados a los objetivos; debe causar una acción recíproca entre el estudiante y la materia adecuada, de acuerdo con los principios del aprendizaje; y, finalmente, debe medir o **evaluar** el rendimiento del estudiante **de acuerdo con los objetivos o metas** seleccionados originalmente.

El primero de estos puntos, la descripción de objetivos, es el tema de este trabajo. Si usted está interesado en preparar una enseñanza que le ayude a alcanzar sus objetivos, primeramente debe estar seguro de que sus objetivos están expuestos clara e inequívocamente. Usted no puede entrar a analizar el problema de seleccionar la ruta más eficiente para llegar a su meta hasta que no sepa cuál es su meta.

Específicamente, los objetivos de este libro son tales que, si se logran, usted podrá realizar las siguientes tareas:

1. Dado uno o más objetivos docentes, usted podrá seleccionar aquéllos que se expresan en función del rendimiento.
2. Dado un objetivo didáctico bien confeccionado, usted podrá identificar la porción del mismo que define el mínimo rendimiento aceptable.
3. Dado uno o más ítems de examen para medir el rendimiento, usted podrá seleccionar aquéllos que

resultan adecuados para la evaluación de los objetivos.

Cuando se haya adentrado más en el libro, usted comprenderá por qué razón no se ha señalado el "saber cómo confeccionar objetivos" como uno de los objetivos de este libro.

Para ayudar a alcanzar estas metas, describiré algunas de las ventajas que se derivan de la especificación cuidadosa de los objetivos didácticos, describiré las características de los objetivos expuestos, proporcionaré alguna práctica en cuanto a reconocer las metas bien expuestas, proporcionaré cierta práctica en cuanto a seleccionar los ítems de examen adecuados para la evaluación de un objetivo, y, finalmente, le proporcionaré a usted la oportunidad de comprobar si he tenido éxito.

Al final de cada capítulo encontrará usted ciertos **Materiales Auxiliares.** Se trata de puntos complementarios que usted podrá considerar interesantes, informativos o útiles, pero que no son esenciales para alcanzar los objetivos enumerados anteriormente.

Tres de los términos que serán utilizados necesitan definición:

Conducta .... se refiere a cualquier actividad observable realizada por un alumno.

Conducta terminal... se refiere a la conducta que usted desea que el alumno demuestre cuando usted termine su enseñanza.

Criterio............. es una norma o prueba mediante la cual se evalúa la conducta terminal.

A través del libro, las palabras "maestro" y "programador" serán utilizadas indistintamente, ya que no hay diferencia alguna entre el aula y el programa de autoenseñanza en cuanto a la importancia de especificar los objetivos.

MATERIAL AUXILIAR

He aquí un ejemplo de cómo, si no se enuncian claramente los objetivos, las actividades del aula pueden obstaculizar al alumno en un esfuerzo por lograr un objetivo.

En un importante centro de enseñanza dirigido por el gobierno, se ofreció cierta vez un curso en el cual los estudiantes debían aprender a manejar y reparar un sistema electrónico grande y complejo. El objetivo del curso fue planteado de manera simple: **Poder manejar y mantener el Sistema Electrónico XYZ.**

Debido a que era imposible proporcionarle a cada estudiante un sistema electrónico para las prácticas (debido al costo exorbitante), se decidió aumentar el número de discusiones diagnósticas que hacía el estudiante durante el curso, dándole alguna "práctica" tanto en el aula como en el laboratorio.

Durante los ejercicios de diagnóstico en el aula, el maestro presentaba varios problemas para que sus alumnos los resolvieran. Así, señalaba un componente de uno de los muchos diagramas esquemáticos del equipo y preguntaba: "¿Qué sucedería si este tubo tuviera algún desperfecto?" Los estudiantes buscaban a través de los circuitos (en el papel), en un esfuerzo por pronosticar los síntomas que aparecerían como resultado del problema hipotético planteado por el maestro. Se le daba un problema al estudiante y se le pedía que indujera los síntomas.

Este procedimiento, sin embargo, era exactamente lo opuesto a lo que se esperaba del alumno en el examen final o en el trabajo, donde se le mostraría un **síntoma** característico y se le pediría que localizara el **problema.** Los maestros esperaban que el alumno corriera hacia adelante, enseñándole a correr hacia atrás.

Por lo tanto, por falta de un enunciado específico de los objetivos, los estudiantes no sólo estaban aprendiendo lo que no era, sino que los hábitos que estaban desarrollando en el aula estaban en contradicción con los que se esperaba que utilizaran en el trabajo.

CAPITULO 2

POR QUE NOS INTERESAN LOS OBJETIVOS

Un objetivo es un **propósito** expresado en un enunciado que describe el cambio propuesto en el alumno —un enunciado de cómo debe ser un alumno cuando haya terminado exitosamente una experiencia de aprendizaje. Es la descripción de un patrón de conducta (rendimiento) que queremos que el alumno demuestre. Según expresó cierta vez el Dr. Paul Whitmore, "el enunciado de los objetivos de un programa de enseñanza debe señalar los **atributos mensurables que se pueden observar** en un graduado del programa; de lo contrario sería imposible determinar si el programa logra o no sus objetivos".

Cuando se carece de metas claramente definidas, se hace imposible evaluar eficazmente un curso o programa, y no existe una base sólida para seleccionar los materiales, el contenido, o los métodos didácticos adecuados. Después de todo, un mecánico no escoge su herramienta hasta que no sepa qué operación va a realizar. Tampoco un compositor hace el arreglo de la partitura hasta que no sepa los efectos que desea lograr. De igual forma, un maestro de obras no selecciona sus materiales ni especifica un programa de construcción hasta que no tenga en sus manos los planos (objetivos). Muy a menudo, sin embargo, uno escucha a los maestros discutir sobre los méritos relativos de los libros de texto u otros materiales auxiliares del aula en oposición al laboratorio sin especificar nunca qué meta ha de ayudar a lograr el material auxiliar o el método en cuestión. No es posible hacer demasiado hincapié en el hecho de que el maestro trabaja a ciegas hasta que no sepa lo que quiere que hagan sus estudiantes al final de la enseñanza.

Otro motivo importante para enunciar claramente los objetivos tiene que ver con la evaluación del grado en que un alumno es capaz de actuar en la forma deseada. Las pruebas y exámenes son como puntos indicadores a lo largo del camino del aprendizaje, y son los que deben indicarle al maestro y al estudiante el grado de éxito que han tenido ambos en el logro de los objetivos del curso. Pero si las dos partes no tienen una idea clara y firme de las metas, las pruebas son, en las mejores circunstancias, engañosas; en las peores circunstancias, son inaplicables, injustas, o inútiles. Para que sean útiles, tienen que medir **el rendimiento en función de las metas.** A no ser que el propio programador tenga una visión clara de su propósito didáctico, no podrá seleccionar los ítems de examen que reflejen claramente la capacidad del estudiante para poner en función las habilidades esperadas, o que reflejen hasta qué punto puede demostrar el estudiante su adquisición de la información esperada.

Una ventaja adicional de los objetivos claramente definidos es que al estudiante se le proporcionan los medios para evaluar su propio adelanto en cualquier lugar a lo largo del camino de la enseñanza, y puede entonces organizar sus esfuerzos en actividades apropiadas. Con objetivos claros en mira, el estudiante conoce cuáles son las actividades que son apropiadas para lograr el éxito, y ya no le es necesario "descifrar" al maestro. Como usted sabe, frecuentemente se invierte una cantidad considerable de tiempo y esfuerzo por parte de los estudiantes en el aprendizaje de las idiosincracias de sus maestros; y, desafortunadamente, casi siempre este conocimiento le es muy útil al estudiante con discernimiento. Este tipo de estudiante puede pasearse a través de un curso, armado de artimañas confeccionadas para darle al maestro lo que éste quiere.

Antes de empezar a discutir lo que quiero decir con "objetivo significativamente enunciado", sería bueno asegurarnos acerca de qué entiende usted que es un objetivo. Lea el siguiente enunciado y después responda la pregunta a continuación. **Verifique su respuesta remitiéndose a la página que se encuentra al lado de la respuesta que usted seleccione.**

> Un estudio general de la organización y administración de las bibliotecas en las escuelas primarias y secundarias, con énfasis en los métodos de desarrollo de la biblioteca como parte integral de la escuela. Incluye funciones, organización, servicios, equipo y materiales.

¿Qué representa este enunciado? ¿Se parece más al objetivo de un curso, o se parece más a la descripción de un curso?

Al objetivo de un curso...... remítase a la página 23

A la descripción de un curso.. remítase a la página 27

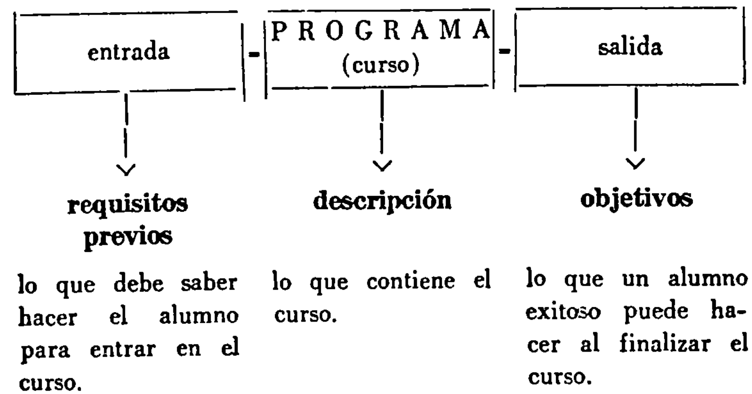
¡Caramba! No ha seguido las instrucciones. En ninguna parte de este libro se le indica que se dirija a esta página. Cuando se le haga una pregunta, debe seleccionar la alternativa que usted considere correcta o apropiada, y remitirse a la página indicada al lado de esa alternativa.

Estoy tratando de ajustar mis comentarios a sus propias necesidades, pidiéndole que responda a algunas preguntas en el transcurso de la lectura. De esta forma, no será necesario aburrirle con explicaciones adicionales cuando una sola es suficiente.

Regrese a la página anterior y lea nuevamente las instrucciones.

Usted dijo que el enunciado era un objetivo del curso. Aparentemente no me hice entender al principio, así que trataré de nuevo.

Una **descripción** del curso le dice algo sobre el contenido y los procedimientos de un curso; un **objetivo** del curso describe un resultado esperado de un curso. Quizás el esquema aclare la distinción:



Mientras que un objetivo plantea cómo debe ser el alumno como resultado del aprendizaje, la descripción del curso plantea solamente de qué trata el mismo.

Esta distinción es importante, porque una descripción del curso no explica qué será aceptado como logro adecuado; no le comunica al alumno las reglas del juego. Aunque puede que la descripción del curso diga al alumno qué posición él va a jugar, no le dice dónde están las líneas de **foul**, dónde están situados los postes de la meta, o cómo sabrá cuándo ha anotado.

Es útil poder reconocer la diferencia entre un objetivo y una descripción; por lo tanto, pruebe con otro ejemplo.

¿Cuál de los siguientes enunciados se parece más a un **objetivo**?

Ser capaz de explicar los principios necesarios para desarrollar la disposición para la lectura en los grados primarios... remítase a la página 25.

Discusión de los principios, técnicas y procedimientos en el desarrollo de la disposición para la lectura en los grados primarios... remítase a la página 26.

Usted dijo que "Ser capaz de explicar los principios necesarios para desarrollar la disposición para la lectura" era el enunciado de un objetivo.

¡Está usted en lo cierto! Este enunciado describe un objetivo en vez de un curso. No es lo mejor que se pudiera esperar, pero por lo menos trata de describir la meta en vez del proceso.

Vamos a continuar.

Remítase a la página 28

¡Vamos, vamos! La colección de palabras que le trajeron a esta página es parte de la descripción de un curso, y no muy buena por cierto. Espero que no se haya equivocado debido al hecho de que los catálogos universitarios están compuestos por frases parecidas. No es un enunciado de los resultados esperados del aprendizaje, y no tiene que ver con lo que nos interesa aquí.

Déjeme tratar de explicar la diferencia de esta forma: La descripción de un curso describe varios aspectos de un PROCESO conocido como "curso". El objetivo de un curso, en cambio, es la descripción de un PRODUCTO, de lo que el alumno debe ser como resultado del proceso.

Regrese a la página 23 y lea de nuevo el material.

Usted dijo que el enunciado era la descripción de un curso. ¡Y está usted en lo cierto! Estoy seguro de que reconoció el enunciado como una descripción de curso extraída de un catálogo universitario.

Antes de continuar, un último planteamiento sobre las descripciones de curso. Aunque a veces una descripción nos dice bastante sobre lo que contiene un curso, no nos da los **logros esperados** del curso. Aún más importante, no nos dice cuándo se han alcanzado los logros esperados.

Por eso, aunque la descripción de un curso puede ser algo perfectamente legítimo, con un verdadero valor aquí SOLAMENTE estamos interesados en los objetivos del curso.

Va bien; continúe, remitiéndose a la página 28.

MATERIAL AUXILIAR 1

Hace pocos años, el director de un curso militar de 32 semanas de duración notó un hecho muy peculiar: los alumnos estaban obteniendo resultados pobres en cada **tercer** examen. Los resultados eran bajos en el cuarto y altos en los próximos dos, y así sucesivamente. debido a que los resultados eran bajos y después altos incluso con los alumnos más aventajados, el director llegó a la conclusión de que esta peculiaridad no se debía al grado de inteligencia de los alumnos. Entonces decidió que, debido a que él mismo estaba tan involucrado en el curso, era probable que los árboles no le dejaban ver el bosque, y decidió consultar con asesores.

Durante el análisis de la situación estos consultores notaron que el curso estaba dividido en cinco subcursos; y, durante cada subcurso, se le hacían tres exámenes al alumno. Descubrieron que los alumnos obtenían un resultado pobre en la primera prueba porque no se les decía qué debían esperar; tenían que utilizar la primera prueba como un medio para descubrir lo que el maestro esperaba de ellos. Una vez que aprendían cuáles eran los objetivos, el resultado mejoraba mucho en los próximos dos exámenes de ese subcurso. Pero después venía otro equipo de maestros. Creyendo que los exámenes serían similares a los del primer equipo, los alumnos se preparaban para esto, sólo para descubrir que las reglas habían cambiado sin su conocimiento. Debido a esto el resultado era pobre en la cuarta prueba (la primera prueba del nuevo equipo de maestros). Y así continuaba a través del curso. Los objetivos eran imprecisos, y a los alumnos nunca se les dijo qué debían esperar.

Una vez que estas condiciones fueron puestas en conocimiento del director, el problema se resolvió fácilmente.

MATERIAL AUXILIAR 2

Si usted ha confeccionado un enunciado explícito de los objetivos para su propio curso, estará en una excelente posición para evaluar la idoneidad de los programas producidos comercialmente, comparando los objetivos enunciados por el productor del programa con los suyos propios. Si el productor del programa no ha enunciado los objetivos de su programa, la regla debe ser "cuidado antes de comprar", porque estará usted en la situación de comprar un producto cuyas características y cualidades tienen que ser adivinadas.

Seguramente, si la enseñanza programada triunfa en cuanto a modificar a los alumnos, es razonable pedirle a los productores de programas que nos digan **cómo** cambiarán nuestros alumnos como resultado del estudio del programa, **cuál** debe ser el requisito previo de conocimientos por parte de nuestros alumnos, qué naturaleza tenía la población en la cual se desarrolló y se probó el programa, y qué naturaleza tiene la población para la cual ha sido confeccionado el programa.

CAPITULO 3

LAS CUALIDADES DE LOS OBJETIVOS SIGNIFICATIVOS

Ya usted conoce que el enunciado de un objetivo describe el estado deseado en el alumno. También conoce que un objetivo se logra con éxito cuando el alumno puede demostrar su llegada a este estado. ¿Pero cómo confecciona usted el objetivo para elevar al máximo la probabilidad del logro del mismo? ¿Cuáles son las características de un objetivo significativamente enunciado?

Fundamentalmente, un objetivo significativamente enunciado es aquel que logra comunicar al lector el propósito didáctico del autor; es significativo según logre transmitir a otros una imagen idéntica a la imagen que el escritor tiene en mente sobre cómo será un alumno exitoso. Debido a que el enunciado de un objetivo es una colección de palabras y símbolos, está claro que pueden ser utilizadas varias combinaciones para expresar un propósito dado. Lo que usted debe buscar es aquel grupo de palabras y símbolos que comunique su propósito exactamente como USTED lo entiende. Por ejemplo, si usted le da un objetivo a otro maestro, y él enseña a sus alumnos para que actúen en una forma tal que concuerde con lo que usted tenía en mente, entonces usted ha comunicado su objetivo de manera significativa. Si, por otro lado, usted no está de acuerdo con que estos alumnos sean capaces de actuar de acuerdo con sus propósitos, si entiende que "tenía algo más en mente", o que su propósito fue "mal interpretado", entonces su enunciado ha fracasado en la comunicación adecuada.

Un objetivo significativamente enunciado, entonces, es aquél que logra comunicar su propósito; el mejor enunciado es el que excluye el mayor número de alternativas posibles para la meta. Desafortunadamente, existen muchas palabras "cargadas", palabras de amplia interpretación. Según el grado en que usted utilice SOLAMENTE tales palabras, se expone usted a la posibilidad de una mala interpretación.

Considere los siguientes ejemplos de palabras:

PALABRAS CON MUCHAS INTERPRETACIONES	PALABRAS CON MENOS INTERPRETACIONES
saber	escribir
conocer	exponer
entender	explicar
entender **verdaderamente**	identificar
apreciar	diferenciar
apreciar **completamente**	resolver
captar el significado de	construir
disfrutar	enumerar
creer	comparar
tener fe en	contrastar

¿Qué es lo que usted quiere decir cuando dice que desea que un alumno "conozca" o "sepa" algo? ¿Quiere decir que usted desea que el alumno pueda exponer, resolver, o construir? Decirle simplemente que usted desea que él "conozca" le dice muy poco; la palabra puede significar muchas cosas.

Aunque se pueden incluir palabras tales como "entender" y "apreciar" en el enunciado de un objetivo, el enunciado no es lo suficiente explícito como para ser útil hasta que usted no indique cómo piensa probar el "entendimiento" y la "apreciación". Hasta que usted no describa lo que estará HACIENDO el alumno cuando demuestre que él "entiende" o que "aprecia", habrá descrito muy poco. Por eso, el enunciado que mejor comunica el propósito es aquel que describe bastante bien la conducta terminal del alumno, para evitar cualquier mala interpretación.

¿Cómo puede usted confeccionar objetivos que describan la conducta deseada en el alumno? Bueno, puede haber un buen número de maneras de hacerlo, pero ya se sabe que el método descrito en las próximas páginas da resultado, y este es el método que yo he encontrado más fácil de utilizar.

Primero, identifique la conducta terminal por su nombre: usted puede especificar el tipo de conducta que será aceptada como muestra de que el alumno ha alcanzado el objetivo.

Segundo, trate de definir la conducta deseada, describiendo las condiciones importantes bajo las cuales se espera que se realice la conducta.

Tercero, especifique los criterios de actuación aceptable, describiendo cómo debe actuar el alumno para que su rendimiento se considere aceptable.

Aunque cada uno de estos puntos puede contribuir a que el objetivo sea más específico, no será necesario incluir los tres en cada objetivo. **La meta** es confeccionar objetivos que comuniquen el propósito; las características descritas arriba sólo son guías para ayudarle a saber cuándo lo ha logrado. No es el caso que se trabaje sobre un objetivo hasta que tenga estas características; más bien, se trabaja sobre el mismo hasta que comunique claramente uno de los resultados educativos esperados—y uno puede confeccionar tantos enunciados como sean necesarios para describir **todos** los resultados esperados.

Usted puede comprobar si un objetivo define claramente un resultado esperado, si puede contestar "sí" a la siguiente pregunta:

¿Puede otra persona competente seleccionar a los alumnos exitosos con respecto al objetivo, de manera tal que usted, el que confecciona el objetivo, concuerde con las selecciones?

Los capítulos siguientes describen en detalle cómo se puede lograr esto.

Remítase a la próxima página.

MATERIAL AUXILIAR

No hay por qué considerarse un total ignorante por utilizar palabras como "apreciar" y "entender" en el enunciado de los objetivos, siempre y cuando se explique lo que uno quiere decir con ellas. Una forma de hacer esto es el incluir en el propio enunciado lo que uno quiere decir con la palabra. Otra forma es el utilizar el vocablo en un objetivo **general**, meramente con vistas a identificar la materia adecuada, y confeccionar después tantos enunciados específicos como sean necesarios para comunicar el propósito.

CAPITULO 4

IDENTIFICACION DE LA CONDUCTA TERMINAL

El enunciado de un objetivo es útil en la misma medida en que especifique lo que el alumno ha de HACER o REALIZAR cuando esté demostrando su dominio del objetivo.

Como nadie puede determinar el conocimiento de una persona mirándole el cerebro, sólo se puede determinar el estado del intelecto o habilidad del alumno por medio de la observación de algunos aspectos de su conducta o actuación (el vocablo "conducta", según se usa aquí significa **acción abierta**). Ahora bien, la conducta o actuación del alumno puede ser verbal o no verbal. Se le puede pedir que responda a las preguntas oralmente o por escrito, para demostrar su capacidad de efectuar cierta habilidad, o de resolver ciertos tipos de problemas. Pero cualquiera que sea el método utilizado, usted (el programador) sólo puede inferir el estado o condición del intelecto del alumno a través de la observación de su actuación.

Por eso, la característica más importante de un objetivo útil es que **identifica el tipo de actuación** que será aceptada como muestra de que el alumno ha alcanzado el objetivo.

Por ejemplo, considere el siguiente enunciado de un objetivo:

> Alcanzar una comprensión crítica del funcionamiento de la Pizarra de Localización de Blancos.

Aunque este puede ser un objetivo importante de lograr, el enunciado no dice lo que estará haciendo el alumno cuando esté demostrando que ha alcanzado el objetivo.

Las palabras que más se acercan a describir lo que el programador desea que el alumno pueda HACER son "comprensión crítica", y es dudoso que dos personas concuerden en cuanto al significado de esta expresión. Ciertamente, esta expresión no le dice al alumno cómo organizar sus esfuerzos para poder alcanzar el objetivo.

A continuación tenemos un ejemplo de un objetivo enunciado más adecuadamente:

> Cuando el alumno termine el programa de enseñanza, será capaz de identificar por su nombre cada uno de los controles situados al frente de la Pizarra de Localización de Blancos.

¿Qué palabras nos dicen lo que estará haciendo el alumno cuando demuestre su logro del objetivo? Las palabras "identificar por su nombre". El objetivo le comunica al alumno el tipo de respuesta que se espera de él cuando se ponga a prueba su dominio del objetivo.

La forma de confeccionar un objetivo que cumpla con el primer requisito es, por tanto, confeccionar un enunciado que describa uno de los propósitos educativos, y después modificarlo hasta que responda a la pregunta.

¿Qué estará HACIENDO el alumno cuando demuestre que ha logrado el objetivo?

Vamos a aplicar esta prueba a varios ejemplos. ¿Cuál de los siguientes objetivos está enunciado en términos conductuales o de actuación?

Desarrollar una apreciación
por la música.............remítase a la página 39

Poder resolver ecuaciones
de segundo grado..........remítase a la página 40

Aunque puedo entender por qué usted dijo que "Desarrollar una apreciación por la música" está enunciado en términos de actuación, está usted equivocado.

Vamos a hacer la pregunta clave con respecto a este objetivo. ¿Qué estará HACIENDO el alumno cuando demuestre que ha alcanzado este objetivo? ¿Qué estará haciendo cuando "aprecie" la música? Usted puede ver que, tal como está enunciado ahora, el objetivo no da la respuesta. Debido a que el objetivo no excluye ni define ninguna conducta, será necesario aceptar cualquiera de las siguientes conductas como muestra de que el alumno aprecia la música:

1. El alumno suspira y se extasía cuando escucha a Bach.
2. El alumno compra un tocadiscos de alta fidelidad y $500.00 de discos.
3. El alumno responde correctamente 95 preguntas de selección múltiple sobre historia de la música.
4. El alumno escribe un ensayo elocuente sobre los significados de 37 óperas.
5. El alumno dice: "Oye, socio, esto es lo duro. ¡Está riquísimo!"

Recuerde, no estoy sugiriendo que "desarrollar una apreciación por la música" no sea un objetivo importante de lograr. El problema es que con un objetivo tan vago como éste, nadie puede tener la menor idea del propósito del que seleccionó el objetivo. Puede ser un objetivo meritorio, pero, tal como está enunciado arriba, no logra comunicar su propósito.

Ahora regrese a la página 38 y seleccione la otra respuesta.

Usted dijo que la **deducción** de ecuaciones no podría ser una muestra efectiva de capacidad en la **resolución** de ecuaciones; si esto fue lo primero que usted escogió, va bien.

¡Absolutamente correcto! El objetivo planteaba la conducta de **resolución** de ecuaciones, y no mencionaba la conducta de **deducción.** Si usted quisiera impartir la habilidad de deducir ecuaciones, debería comunicar esta meta confeccionando otro objetivo.

Si usted confecciona el objetivo en términos significativos (útiles), invariablemente llenará varias páginas para cubrir el curso completo. Mientras más objetivos incluya, más éxito tendrá en comunicar su propósito. En todo caso, no sería honesto pedirle a sus alumnos que aprendan a **resolver** ecuaciones, y después **examinarlos** con preguntas completamente distintas. La forma de evitar el convertirse accidentalmente en un "maestro voluble" es el aclarar sus propósitos docentes, tanto para usted mismo como para sus alumnos.

Vamos a probar otro ejemplo. ¿Cuál de los siguientes objetivos está enunciado en términos de actuación?

Poder reparar un radio.....remítase a la página 43.

Saber cómo funciona un amplificador.............remítase a la página 44.

Usted dijo que "Poder reparar un radio" está enunciado en términos conductuales. ¡Muy bien! Este objetivo cumple el primer criterio de un enunciado útil, porque plantea **lo que estará haciendo el alumno** cuando demuestre el logro del objetivo. Estará "**reparando** un radio".

Vamos a probar solamente un ejemplo más. ¿Cuál de los siguientes está enunciado en términos de actuación?

Poder confeccionar un resumen de los factores que condujeron a la depresión de 1929.......remítase a la página 45.

Comprender las reglas de la lógica..............remítase a la página 46.

Conocer las reglas del balompié.............remítase a la página 47.

Usted dijo que "Poder resolver ecuaciones de segundo grado" es un objetivo enunciado en términos conductuales.

Correcto. Este objetivo nos dice lo que el alumno estará haciendo cuando demuestre que ha alcanzado la meta. Estará resolviendo ecuaciones de segundo grado.

Imagínese que el alumno pueda demostrar que él puede deducir una ecuación de segundo grado. ¿Demostraría este tipo de actuación que el alumno ha alcanzado el objetivo?

Sí lo haría................remítase a la página 41

No lo haría...............remítase a la página 42

Usted dijo "Sí lo haría". Usted estima que si el alumno logra demostrar que puede deducir una ecuación de segundo grado, ha alcanzado el objetivo. Vamos a observar de nuevo el objetivo, y fíjese con cuidado cómo está enunciado: Poder resolver ecuaciones de segundo grado.

El enunciado no dice nada sobre **deducir** ecuaciones, ¿no es así? Ahora, si usted estima que el alumno debe poder deducir una ecuación en particular, así como resolverla, entonces debe confeccionar otro objetivo que defina lo que quiere decir con **deducir,** o ampliar el que ya tiene, incluyendo la deseada habilidad de deducir ecuaciones. Pero tal como está enunciado, el objetivo no incluye la conducta de **deducir** entre las actividades que usted puede aceptar como evidencia de que el alumno ha cumplido los requisitos del objetivo.

No tiene usted que preocuparse por el hecho de que el objetivo enunciado abarque tan pequeña proporción de las habilidades y conocimientos que usted espera impartir durante el curso completo. Simplemente confeccione un objetivo que abarque **cada** clase de habilidad o de conocimiento que usted quiere que el alumno adquiera. Mientras más enunciados de este tipo tenga, mayor éxito tendrá en comunicar su propósito educativo.

Ahora regrese a la página 40 y seleccione la otra respuesta.

Usted dijo que "Saber cómo funciona un amplificador" está enunciado en términos de actuación. Pero ¿qué estará **haciendo** el alumno cuando demuestra que SABE cómo funciona un amplificador?

Supóngase que yo le diera clases sobre amplificadores y, que para demostrarme que **sabe** cómo funcionan, usted dibuja un diagrama de un amplificador. Y suponga que le suspendo, diciendo que el hecho de poder dibujar un objeto no significa que usted REALMENTE conoce cómo funciona. Entonces, suponga que usted se consigue una colección de piezas y algunas herramientas, construye un amplificador que funciona, y que yo le suspendo de nuevo porque afirmo que **construir** un amplificador no significa que REALMENTE se conoce cómo funciona. Seguramente que a estas alturas ya usted querría ahorcarme, y con mucha razón. Me parece que ya entiende lo que le quiero decir. La palabra SABER no es "incorrecta" —excepto que cuando se utiliza como único término explicativo en el enunciado de los objetivos, no logra explicar mucho. No logra comunicar.

Ahora, el saber cómo funciona un amplificador puede implicar la capacidad para dibujarlo, para construirlo, para describir el objetivo de cada uno de sus componentes, etc. Cada uno de éstos puede ser un buen objetivo en sí, pero no está totalmente claro CUAL de ellos será sobreentendido en la palabra SABER.

Regrese a la página 42 y seleccione la otra respuesta.

Usted dijo que "Poder confeccionar un resumen de los factores que condujeron a la depresión de 1929" estaba enunciado en términos de actuación.

¡Aboslutamente correcto! Aparentemente, aplicó la pregunta clave al analizar este objetivo, y determinó correctamente que el alumno debía estar "confeccionando un resumen". El alumno no estaría recitando un resumen, o reconociendo los factores en una lista de factores, ni siquiera dictando un resumen. El alumno sabría que para demostrar el logro de su objetivo tendrá que confeccionar un resumen de factores.

Y hablando de resúmenes, remítase a la página 48.

Usted dijo que "Comprender las reglas de la lógica" está enunciado en términos de actuación.

Bueno, vamos a efectuar la pregunta clave al analizar este enunciado. ¿Qué estará HACIENDO el alumno cuando esté **comprendiendo** las reglas de la lógica? ¿Estará recitándolas? ¿Estará enumerándolas? ¿Estará solucionando problemas de lógica? Si es así ¿qué tipo de problemas? Este objetivo no lo dice. Usted debe decidir qué es lo que aceptará como evidencia de "comprender", y entonces describir esta intención en el objetivo.

Regrese a la página 43 y seleccione otra respuesta.

Usted dijo que "Conocer las reglas del balompié' está enunciado en términos de actuación.

Bueno, una vez más, vamos a formular la pregunta clave con respecto a este enunciado.

¿Qué estará HACIENDO el alumno cuando demuestre que ha logrado este objetivo? ¿Estará recitando las reglas? ¿Estará confeccionando una lista de reglas? ¿Estará jugando el juego sin romper ninguna de las reglas? ¿Estará mirando a otros jugar, señalando los errores según los detecta? El objetivo no nos lo dice.

Ahora regrese a la página 43 y seleccione otra respuesta.

PRIMER RESUMEN

1. Un objetivo didáctico describe un resultado **esperado**, en vez de una descripción o resumen de contenido.
2. Una característica de un objetivo eficazmente enunciado es que está formulado en términos conductuales o de actuación, términos que describen lo que el alumno estará HACIENDO cuando demuestre el logro del objetivo.
3. El enunciado de objetivos para un programa completo de enseñanza consta de varios enunciados específicos.
4. El objetivo que esté definido con mayor eficacia será el que mejor comunique el propósito docente de la persona que selecciona el objetivo.

Remítase a la próxima página.

MATERIAL AUXILIAR 1

Suponga que yo le ofrezco venderle un carro en $500, y suponga que yo mantengo que el auto está en excelentes condiciones", pero no le permito verlo. ¿Lo compraría?

Suponga que yo le ofrezco enseñarle a sus hijos a PENSAR LOGICAMENTE por $1,000. Si logro hacerlo, tendría usted una ganga. ¿Pero estaría de acuerdo con semejante trato sin decirle yo de antemano, explícitamente, lo que pienso lograr y cómo podríamos medir el resultado? Espero que no.

En cierto sentido, un maestro establece un contrato con sus alumnos. Los alumnos acuerdan hacer una cierta inversión a cambio de ciertas habilidades y conocimientos. Pero, casi siempre, se espera de ellos que paguen por algo que nunca se define o describe cuidadosamente. Se les pide que compren (con sus esfuerzos) un producto que no se les permite ver y que está descrito vagamente. El maestro que no especifica claramente sus objetivos didácticos, que no describe lo mejor posible cómo piensa que cambie el alumno después de su enseñanza, se está aprovechando indebidamente de sus alumnos.

MATERIAL AUXILIAR 2

Quizás usted haya tenido experiencias profesionales similares a esta. Durante las sesiones de clase de un curso de álgebra para séptimo grado, el maestro orientó muy bien la enseñanza de la solución de ecuaciones simples, y se aseguró de que cada alumno tuviera la práctica suficiente para darle confianza en su propia capacidad. Sin embargo, cuando llegó el momento del examen, las preguntas eran fundamentalmente problemas enunciados con palabras, y el rendimiento de los alumnos fue pobre. La justificación que le da el maestro a este "cambio de prueba" es que los alumnos no "entenderían realmente" el álgebra si no pudieran resolver problemas expresados con palabras.

Quizás el maestro tenía razón. Pero la habilidad de resolver ecuaciones es considerablemente diferente a la habilidad de resolver problemas expresados con palabras; si el maestro quería que sus alumnos aprendieran a resolver los problemas expresados con palabras, debería haberlos enseñado a hacerlo.

No espere que un alumno muestre la habilidad B simplemente porque usted le ha dado práctica en la habilidad A.

CAPITULO 5

DE LA CONDUCTA TERMINAL UNA DEFINICION MAS AMPLIA

Cuando usted haya confeccionado un objetivo que identifique la conducta que espera que sus alumnos muestren cuando terminen con éxito el programa, habrá confeccionado un objetivo menos equívoco que la mayoría de los utilizados actualmente. En vez de esperar que sus alumnos adivinen lo que usted tiene en mente cuando utiliza palabras tan ambiguas como "comprender", "saber", o "apreciar", habrá por lo menos identificado para él (y para usted mismo) el tipo de actividad que será aceptado como evidencia del logro. Y más importante, quizás, habrá comenzado a especificar sus objetivos de manera tal que le permitan seleccionar el contenido apropiado para la enseñanza, y que le proporcionará una base para evaluar la enseñanza confeccionada por otros.

Puede que no sea suficiente el simple hecho de especificar el acto terminal para evitar que sea mal entendido. Por ejemplo, un objetivo tal como "poder correr los 100 metros planos" probablemente está enunciado con suficiente detalle como para evitar equivocaciones serias. Pero un enunciado tal como "poder computar un coeficiente de correlación" es otro problema distinto. Aunque este último objetivo nombra un acto terminal, existen serias limitaciones en el enunciado; hay varias formas importantes en que el alumno puede interpretar mal el propósito. ¿Qué tipo de correlaciones se espera que compute el alumno? ¿Es importante seguir un **procedimiento** específico, o solamente se considera importante una **solución** correcta? ¿Se le proporcionará al alumno una lista de fórmulas, o se espera que él trabaje sin ninguna referencia y sin medios auxiliares para el cálculo? La respuesta que se dé a cada una de estas preguntas conllevará una diferencia importante en el énfasis y el contenido del programa, en la exactitud con que el alumno podrá dirigir sus esfuerzos, y en la situación de examen adecuada para el objetivo.

Para enunciar un objetivo que comunique con éxito su propósito educativo, tendrá a veces que definir la conducta terminal más ampliamente, enunciando las condiciones que usted impondrá sobre el alumno cuando esté demostrando su dominio del objetivo. A continuación relacionamos varios ejemplos:

Dado un problema de la siguiente clase...
Dada una lista de...
Dada cualquier referencia sobre la selección del alumno...
Dada una matriz de intercorrelaciones...
Dado un juego típico de herramientas...
Dado un equipo en buen funcionamiento...
Sin la ayuda de referencias...
Sin la ayuda de la regla de cálculo...
Sin la ayuda de herramientas...

Por ejemplo, en vez de especificar simplemente "poder resolver problemas de álgebra", podemos mejorar la calidad de comunicación del enunciado al redactarlo más o menos así:

Dada una ecuación algebraica de primer grado con una incógnita, el alumno debe poder hallar la incógnita sin la ayuda de referencias, tablas, o dispositivos de cálculo.

¿Cuán específico debe ser usted en su definición de la conducta terminal? Debe usted ser lo suficientemente específico como para asegurar que la conducta perseguida sea reconocida por otra persona competente, y lo suficientemente específico como para que otras conductas posibles no sean confundidas con la conducta deseada. O sea, debe ser lo suficientemente específico como para que otras personas entiendan su intención tal como USTED la entiende.

A continuación relacionamos algunas preguntas que se puede hacer usted mismo sobre sus objetivos, como una guía para identificar aspectos importantes de las conductas terminales que desea desarrollar:

1. ¿Qué se le proporcionará al alumno?
2. ¿Qué se le negará al alumno?
3. ¿Bajo qué condiciones se espera que el alumno efectúe la conducta terminal?
4. ¿Existen algunas habilidades que usted está tratando específicamente de NO desarrollar? ¿Excluye el objetivo tales habilidades?

Para ver si me he dado a comprender, observe el siguiente objetivo, y remítase a la página indicada debajo de la parte de la oración que usted crea que dice algo sobre las condiciones en las cuales debe efectuarse la conducta terminal.

Dada una lista de factores que condujeron a importantes hechos históricos.... remítase a la página 54.

el alumno debe ser capaz de seleccionar por lo menos cinco factores que contribuyeron a la depresión de 1929............ remítase a la página 55.

Usted seleccionó **"Dada una lista de factores que condujeron a importantes hechos históricos"** como las palabras que describen las condiciones o situación bajo las cuales debe efectuarse la conducta seleccionada.

¡Muy bien! Estas palabras nos dicen que no se espera que el alumno halle los factores buscando en una biblioteca, o en un ensayo sobre historia, o en su memoria. Se le dice al alumno que se le proporcionará una lista, y que se espera que él **reconozca** en vez de **recordar.**

He aquí otro ejemplo de un objetivo. ¿Contiene palabras que describan las condiciones bajo las cuales debe ocurrir la conducta esperada?

Dada una lista de 35 elementos químicos, el alumno será capaz de recordar y escribir las valencias de por lo menos 30.

Sí.......................remítase a la página 56.

No.......................remítase a la página 57.

Usted dijo que la frase "el alumno debe ser capaz de seleccionar, etc." describe las condiciones bajo las cuales se espera que ocurra la conducta seleccionada. Quizás todavía está pensando en la primera característica de un objetivo eficaz, la que requiere la identificación de la conducta terminal. Si es así, me alegro que todavía lo recuerde. Pero en estos momentos estamos buscando palabras que describan las situación o las condiciones bajo las cuales se evaluará la conducta terminal. Quizás le ayude a reconocer tales palabras en un objetivo la formulación de la siguiente pregunta: "¿Con qué o sobre qué cosa está haciendo el alumno aquello que está haciendo?"

Regrese a la página 53 y seleccione la otra alternativa.

Usted dijo que el enunciado el enunciado sí nos dice algo sobre las condiciones bajo las cuales recordará el alumno las valencias de los elementos. ¡Correcto! El enunciado nos dice que se le dará una lista de elementos. Hay otro rasgo muy interesante en este objetivo, así que vamos a examinarlo otra vez.

Dada una lista de 35 elementos químicos, el alumno será capaz de recordar y escribir las valencias de por lo menos 30.

Fíjese que el enunciado también nos dice algo sobre el tipo de conducta que permitirá el "aprobado". Nos dice que 30 valencias correctas de un total de 35 es la **habilidad mínima aceptable.** (Si usted estima que esto se refiere a otra característica de un objetivo claramente enunciado, ha acertado de nuevo. Tendré más que decir al respecto en el Capítulo 6, "Especificación del Criterio.")

Ahora pase a la página 58.

Usted estima que el anunciado NO contiene palabras que describan la situación de prueba. Observemos nuevamente el enunciado.

Dada una lista de 35 elementos químicos, el alumno será capaz de recordar y escribir las valencias de por lo menos 30.

Es claro que el enunciado cumple el primer requisito y describe lo que el alumno estará haciendo cuando demuestre su capacidad de "aprobar" el objetivo: estará **escribiendo las valencias de distintos elementos.** ¿Nos dice también algo el enunciado sobre las referencias que se les permitirá utilizar a los alumnos, o los materiales que se les dará para trabajar mientras recuerdan? Sí, ¿no es verdad? Dice que se le dará al alumno una lista de elementos para trabajar con ellos.

Regrese a la página 54 y seleccione la respuesta correcta.

Muy frecuentemente, una manera muy buena de explicarle al alumno las condiciones bajo las cuales se espera que actúe consiste simplemente en enseñarle algunos ejemplos de problemas de examen. Muchos maestros tienen la costumbre de enseñarle a los alumnos, al principio del curso, por lo menos una página de ejemplos de examen para que los alumnos tengan una visión clara de las condiciones bajo las cuales serán evaluados.

Cuando se utilizan los problemas de examen como parte del enunciado de la meta, se pueden utilizar diversos procedimientos. Uno puede enunciar, por ejemplo, que:

> El alumno será capaz de resolver el siguiente tipo de ecuación:
>
> $$ax^2 + bx + c = 0$$

o también,

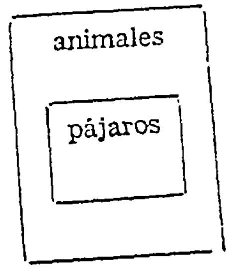
> El alumno debe demostrar comprensión con respecto a las normas del Estado sobre el plan de estudios, contestando correctamente a preguntas del siguiente tipo:
>
> A continuación se presenta un programa detallado de las actividades incluidas durante el día en una escuela primaria hipotética. Indique cuáles de estas actividades son ilegales según las normas del Estado, y agregue las actividades exigidas por las leyes del Estado y que no han sido incluidas en el programa. (El programa de actividades se incluye a continuación.)

o también,

> El alumno será capaz de demostrar su comprensión de las reglas de la lógica, solucionando correctamente problemas del siguiente tipo:

¿Cuál de los siguientes enunciados está ilustrado por el diagrama de Venn que aparece más abajo?

1. Todos los animales son pájaros.
2. Algunos pájaros son animales.
3. Todos los pájaros son animales.
4. Ningún pájaro es animal.



Independientemente de cómo usted decida presentarlo, su especificación del objetivo definirá la conducta con mayor precisión si contiene palabras que describan la situación (condiciones dadas, autorizaciones, restricciones) bajo la cual se espera que el alumno demuestre su logro del objetivo.

Antes de resumir este capítulo y pasar a la última guía para la confección de objetivos útiles, he aquí un método para comprobar la claridad con que un objetivo describe la conducta terminal deseada.

Dado un objetivo y una serie de problemas de examen, **acepte** o **rechace** cada problema de examen sobre la base de si es cierto o no que el objetivo define (incluye) la conducta requerida en el problema. (Este procedimiento es análogo al análisis de un contrato para ver qué situaciones están "abarcadas" por el contrato y cuáles no lo están.) Si usted se ve obligado a aceptar todo tipo de problemas de examen como adecuados, el objetivo necesita ser más específico. Si el objetivo le permite aceptar aquellos problemas que se propone utilizar, y le permité rechazar aquellos que no considera pertinentes o adecuados, el objetivo está enunciado con suficiente claridad para ser útil.

A modo de ilustrar este procedimiento, le proporcionaré un objetivo y algunos problemas de examen. Escoja usted el problema adecuado al objetivo, cuyo problema debe ser considerado **justo** porque representa el propósito descrito en el objetivo.

He aquí el objetivo:

> Cuando se le formule una pregunta en francés, el alumno será capaz de demostrar su comprensión de la pregunta al contestar, en francés, con una oración adecuada.

Ahora, ¿cuál de las siguientes situaciones de prueba será adecuada al objetivo?

Traduzca las siguientes oraciones del francés.......remítase a la página 62.

Traduzca las siguientes preguntas del francés.......remítase a la página 63

Conteste, en francés, las siguientes preguntas.......remítase a la página 64.

Usted escogió "Traduzca las siguientes oraciones del francés." Quizás no fui claro con respecto a lo que usted debe hacer. Debe usted tratar de identificar aquellos problemas o situaciones de prueba que son adecuados para un objetivo, y que digan algo con respecto a si un alumno ha logrado efectivamente el objetivo que se ha enunciado. Si usted comprende lo que debe hacer y a pesar de ello seleccionó esta página, entonces está equivocado. El objetivo define claramente la situación que será aceptable como evidencia de "comprensión", y esa situación **no** es aquella en que el alumno **traduce**.

Regrese a la página 61 y observe bien el objetivo antes de seleccionar otra respuesta.

Usted estima que la traducción de preguntas del francés al español nos dirá si un alumno puede responder en FRANCES a una pregunta hecha en francés. ¡Vamos, vamos! Este problema de prueba no es adecuado al objetivo enunciado. El objetivo especifica claramente el tipo de conducta que demostrará la aptitud del alumno y **no** es una conducta de **traducir.**

Regrese a la página 61 y lea el objetivo con más cuidado antes de seleccionar otra respuesta.

Usted dijo que "Conteste, en francés, las siguientes preguntas" ayuda a medir hasta qué punto el alumno ha logrado el objetivo enunciado.

¡Correcto! Absolutamente correcto. El objetivo enuncia claramente que la "comprensión" se verá demostrada cuando el alumno responda, en francés, a las preguntas formuladas en este mismo lenguaje.

Ahora pruebe este otro objetivo:

> Poder resolver una ecuación simple de primer grado.

¿Cuál de los siguientes problemas es adecuado a este objetivo?

1) Despejar X:

   $2 + 4X = 12$........... remítase a la página 65.

2) Si siete martillos cuestan siete pesos, ¿cuánto cuesta un martillo?...... remítase a la página 66.

¡Excelente! Usted comprendió que la única forma de saber si un alumno ha entendido cómo resolver ecuaciones es pedirle que resuelva algunas ecuaciones.

Ahora vamos a ver lo que sucede cuando se aplica este procedimiento a un objetivo pobremente enunciado. He aquí el objetivo:

> Desarrollar un conocimiento de la historia de Estados Unidos.

Y la pregunta es ésta: ¿Puede alguno de los siguientes problemas de examen considerarse **inadecuado** para medir si un alumno ha logrado el objetivo?

1. Discutir el significado de tres acontecimientos importantes cualesquiera de la historia de Estados Unidos.
2. Decir los nombres de los generales que comandaron las tropas estadounidenses durante la Segunda Guerra Mundial, la Guerra Civil, y la Guerra de Independencia.
3. Decir tantos acontecimientos como sea posible que ocurrieron en la historia de Estados Unidos entre 1850 y 1950, y decir la fecha de cada acontecimiento.

Sí........................ remítase a la página 67

No........................ remítase a la página 70.

Usted dijo que para evaluar un objetivo que pide una conducta de **reparación** podemos pedir una conducta de **localización.**

Vamos a ver nuevamente el objetivo. Dice:

> Dado un motor DC de diez o menos caballos de fuerza que tiene sólo **un** funcionamiento defectuoso, y dada una caja de herramientas y las referencias, el alumno debe reparar el motor en un período de 45 minutos.

Ahora bien, "reparar el motor" significa hacerlo funcionar. Por eso, HACERLO FUNCIONAR es la conducta deseada. El problema de examen, sin embargo, solamente le pide al alumno "localizar" un defecto en el funcionamiento. Por eso, el problema solamente prueba una porción de la conducta especificada por el objetivo. Este problema es incompleto para poder evaluar la conducta enunciada en el objetivo. Para poder considerar este problema como adecuado, es preciso que haya otros problemas adicionales para evaluar los restantes aspectos del objetivo.

Regrese a la página 67 y lea el material otra vez. Entonces seleccione la respuesta correcta.

Usted dijo que el problema no es adecuado al objetivo. ¡Correcto! El objetivo especifica la conducta de **reparar,** y no la conducta de **localizar.** Y no es justo que yo le pida una de estas conductas después de haberle pedido que desarrollara la otra. Si el objetivo no hubiera sido tan específico, usted no hubiera sabido exactamente qué tenía que aprender, y habría desperdiciado gran parte de su tiempo, debido a la falta de información específica, tratando de hallar el tipo de examen que yo pondría, tratando de determinar mi gusto y de encontrar otros indicios sobre cómo aprobar.

Cuando usted confeccione el contenido didáctico **sin tener** objetivos específicos, puede dejar de proporcionar información y práctica con respecto a las propias habilidades que más interesado esté usted en desarrollar. Incluso puede caer en la trampa de igualar la dificultad de enseñar un concepto con la importancia del concepto.

Ahora regrese a la página 65 y trate de contestar correctamente.

¡Muy bien! Usted comprendió que cualesquiera de los problemas tendría que ser considerado como justo, o aceptable, o adecuado, de acuerdo con la forma en que está enunciado el objetivo.

Por tanto, el procedimiento de evaluar los problemas de examen sobre la base de su adecuación a los objetivos es muy útil para comprobar la precisión del propio objetivo. Si se enuncia el objetivo en forma tal que incluya todas las posibles situaciones de prueba que tienen que ver con la materia, entonces el objetivo está enunciado en forma demasiado vaga para comunicar sus propósitos al alumno. Si, por otra parte, está enunciado en forma tal que incluye las situaciones de prueba que usted piensa utilizar, y que excluye aquéllas que usted entiende que son inadecuadas, entonces el objetivo probablemente está enunciado con suficiente claridad como para comunicar su propósito.

Pase a la próxima página.

SEGUNDO RESUMEN

1. Un objetivo didáctico es un enunciado que describe el resultado esperado de la enseñanza.
2. Un objetivo es significativo en la misma medida en que comunique un propósito didáctico al que lo lea, y esto se logra en la misma medida en que describe o define la conducta terminal esperada del alumno.
3. La conducta terminal se define:
   a) Al identificar y nombrar el acto observable que se aceptará como demostración de que el alumno ha alcanzado el objetivo.
   b) Al describir las condiciones (elementos dados, restricciones) que son necesarias para excluir aquellas actuaciones que no se aceptarán como demostración de que el alumno ha alcanzado el objetivo.

Pase a la próxima página.

MATERIAL AUXILIAR 1

En una organización industrial se hizo necesario enseñar a algunos empleados a "poder leer contadores eléctricos". Ya que este enunciado general implica varias habilidades, y debido a que se quería que el alumno pudiera utilizar este enunciado de objetivos como un medio para evaluar su propio aprovechamiento, el enunciado final contenía un objetivo que definía cada habilidad de la forma siguiente:

1. Dado un contador, el alumno será capaz de identificar el valor indicado por la posición de la aguja, con toda la precisión que permita el tipo de contador.
2. El alumno será capaz de identificar el valor indicado por la aguja en contadores longitudinales, no longitudinales, inversos, y bidireccionales.
3. Dado un contador de una sola escala y un conmutador de gamas, el alumno será capaz de identificar el valor indicado por la aguja para cada una de las distancias mostradas por el conmutador de gamas.
4. Dado un contador con varias escalas y un conmutador de gamas, el alumno será capaz de identificar la escala que corresponda a cada posición del índice del conmutador de gamas.

Espero que esté usted de acuerdo en que con este enunciado de objetivos el alumno tendrá una mejor idea de lo que se espera de él, que si se le proporcionara un enunciado en que simplemente se dijera "poder leer contadores eléctricos".

MATERIAL AUXILIAR 2

Si usted se ha documentado bien en cuanto a la teoría de la conducta, podrá apreciar que lo que aquí se llama "condiciones" podría definirse con mayor precisión como **descripción de la conducta.** Indudablemente, "calcular con una regla de cálculo" es una conducta diferente a "calcular con una máquina de sumar". De manera similar, "resolver una ecuación" requiere conductas diferentes cuando se efectúa con ayuda de referencias y cuando se efectúa sin la ayuda de refrencias.

Aunque admito que toda actividad observable de un organismo se puede denominar como conducta, y aunque admito la precisión técnica de una afirmación tal como que "escribir con un lápiz largo requiere una conducta distinta a la de escribir con un lápiz corto", mantengo que la diferencia obstaculiza más que lo que ayuda en lo que respecta a la confección de objetivos didácticos. Si usted se sienta a definir todos los aspectos de la conducta que piensa desarrollar, pronto se verá envuelto en una tela de araña de especificaciones triviales.

Para contribuir a identificar aquellos aspectos de la conducta terminal que merecen ser mencionados, debe usted describir suficientes condiciones para que el objetivo implique claramente el tipo de problemas de examen adecuados para evaluar la conducta que usted está interesado en desarrollar.

CAPITULO 6

ESPECIFICACION DEL CRITERIO

Ahora que ya usted ha descrito lo que quiére que el alumno sea capaz de hacer, puede entonces elevar el nivel de comunicación de un objetivo, al decirle al alumno COMO usted quiere que lo haga. Esto se logra si se describe el criterio de actuación aceptable.

Si usted puede especificar al menos la mínima actuación aceptable para cada objetivo, tendrá una norma de actuación con la cual podrá evaluar sus programas didácticos; tendrá un medio para determinar si los programas tienen éxito en el logro de sus propósitos didácticos. Lo que usted debe tratar de hacer, por tanto, es indicar en su enunciado de los objetivos lo que será considerado como actuación aceptable, al añadirle palabras que describan el criterio de éxito.

Indique la afirmación que mejor describe su actitud en estos momentos.

Enséñeme cómo describir la mínima actuación aceptable. . remítase a la página 76.

Muchas de las cosas que enseño son intangibles y no pueden ser evaluadas. . . . . . remítase a la página 79.

Dado un receptor de TV que por lo demás funcione adecuadamente, de entre los siguientes modelos (aquí se inserta una relación de los modelos adecuados) el alumno debe ser capaz de ajustar el captador de iones.

¿Se describe o indica en este enunciado el criterio de una actuación aceptable? ¿Contiene las palabras que dicen cuándo se considerará que el alumno ha logrado el objetivo?

Sí.......................remítase a la página 80.

No.......................remítase a la página 81.

Bueno, está bien... pero si está usted enseñando habilidades que no pueden ser evaluadas, está usted en la difícil situación de no poder demostrar que está enseñando algo en primer lugar.

Aunque es cierto, en general, que mientras más importante sea un objetivo más difícil será el enunciarlo, se puede mejorar grandemente con respecto a lo que se ha hecho hasta ahora en cuanto al enunciado de objetivos. Y estoy convencido de que pronto podrá hacerlo mucho mejor de lo que lo ha hecho hasta ahora. Cada vez que usted avance aunque sea una pequeña distancia hacia la especificación adecuada de un objetivo, obtendrá todo el provecho y evitará todos los peligros que han sido señalados en este libro.

Así que vamos a ver hasta dónde llega usted, aunque no podrá hacer todo lo que quiera, aun pasado mañana.

Vaya directamente a las páginas 76 y 77.

Usted dijo que el enunciado describe o indica el criterio de una actuación aceptable. Bueno, en cierta forma tiene razón. Sin duda alguna el enunciado nos plantea lo que estará haciendo el alumno cuando demuestre que ha logrado el objetivo (ajustar el captador de iones), y nos plantea que recibirá un aparato de cierto modelo, en buen estado de funcionamiento, para realizar el ajuste. Y por OMISION, nos plantea que CLALQUIER tipo de conducta de ajustar captadores de iones será considerada como satisfactoria. Ya que no se fijan límites en la actuación, tendrá que aceptar como aceptable cualquier cosa que muestre el alumno con relación a la conducta de ajuste.

Regrese a la página 78 y seleccione la otra alternativa.

¡Correcto! Usted comprendió que el enunciado no describe o indica un criterio de actuación aceptable.

Existen por lo menos dos formas en que se puede mejorar este objetivo. La primera es el incluir palabras que describan qué aspecto tendrá el receptor cuando se realice el ajuste adecuado. La segunda es el incluir palabras que definan el tiempo límite dentro del cual debe efectuarse el ajuste. Si le agrega estas mejoras al objetivo, éste quedará de la siguiente manera:

> Dado un receptor de TV que por lo demás funcione adecuadamente, de entre los siguientes modelos (aquí se inserta una relación de los modelos adecuados) el alumno debe ser capaz de ajustar el captador de iones para lograr un "raster" uniforme dentro de un período de cinco minutos.
>
> (Nota: "Raster" es el término utilizado para describir una pantalla encendida, pero sin imagen.)

Una de las formas de definir una actuación aceptable, por tanto, es el indicar un tiempo límite—cuando se proyecte tener un tiempo límite.

Otra forma de indicar el criterio de una actuación exitosa es el especificar la cantidad mínima de respuestas correctas que usted aceptará, la cantidad de principios que deben ser aplicados en una situación dada, la cantidad de principios que deben ser identificados, o la cantidad de palabras que deben ser escritas correctamente. Por ejemplo:

> Dado un esqueleto humano, el alumno debe ser capaz de identificar correctamente y rotular por lo menos 40 de los siguientes huesos; no se restarán puntos por adivinar (aquí va una relación de huesos).

La habilidad mínima aceptable está especificada de acuerdo con la cantidad de huesos a identificar. El alumno tiene que identificar correctamente por lo menos 40, y se le alienta a adivinar. Hay otro rasgo interesante en este objetivo que debe dar respuesta a una de las preguntas que probablemente le ha preocupado a usted a lo largo de este capítulo, ¿cómo se puede indicar precisamente cuáles son los criterios de evaluación **sin** insistir también en que cada alumno actúe exactamente de la misma forma que el resto de los alumnos? La respuesta se encuentra en el enunciado del objetivo dado. Todos y cada uno de los alumnos deben identificar correctamente **por lo menos 40** de los huesos del esqueleto. El límite mínimo de actuación aceptable se especifica, pero cada alumno puede superar ese límite actuando en forma distinta al resto de los alumnos.

Una alternativa para indicar la **cantidad** es el indicar el **porcentaje** o la **proporción**. En tal caso, si es adecuado, se puede indicar que:

> El alumno debe contestar en francés gramaticalmente correcto a un 95% de las preguntas que se le formulen en francés durante el examen.

O se puede especificar:

> El alumno debe escribir correctamente por lo menos un 80% de las palabras que se le dicten durante el período de examen.

O se puede especificar:

> El alumno debe escribir los nombres y direcciones de por lo menos tres quintas partes de los médicos de Nueva York que recomiendan los ingredientes de la marca X.

Otra forma de describir la conducta deseada es el definir las características importantes de la precisión de actuación. En el ejemplo sobre el ajuste de captadores de iones en receptores de TV, se planteó que el

ajuste se consideraría satisfactorio cuando el alumno lograra un "raster uniforme". En este caso no es muy importante si existe alguna discrepancia sobre lo que pueden entender diferentes personas en cuanto a qué es un "raster uniforme". El aparato funcionará bien aunque haya un poquito de sombra aquí o allá en la pantalla. Pero existen momentos en que sí es importante lograr una actuación más precisa, y entonces es importante definir con más detalles la calidad de la actuación aceptable.

Por ejemplo, una de las habilidades que debe desarrollar un mecánico de cohetes es el ajuste de una pantalla redonda de TV, llamada PPI. En la pantalla hay un marcador de recorrido, producido electrónicamente; uno de los trabajos del mecánico es ajustar ese marcador hasta que esté **redondo.** Pero, ¿qué cosa es lo **suficientemente redondo?** ¿Cómo podemos decirle al alumno qué precisión debe alcanzar antes de considerar satisfactorio su trabajo?

Bueno, en este caso es importante que el marcador esté **muy redondo.** Usted podrá observar claramente que las palabras "muy redondo" no logran comunicar mucho, y por eso se debe buscar una mejor forma de describir su propósito con respecto a la calidad de actuación que usted busca. Una forma de hacerlo sería el definir la cantidad de **desviación aceptable** a partir de alguna norma. Se pudiera poner un patrón redondo en la pantalla, y decirle al alumno que el marcador será lo "suficientemente redondo" cuando en ningún lugar se desvíe más de un octavo de pulgada del patrón. El objetivo podrá ser algo así:

Dado un sistema de radar XX-1 que esté funcionando adecuadamente, y un juego tipo de herramientas, el alumno debe ajustar el marcador de recorrido del PPI hasta alcanzar una redondez aceptable, en un período de 45 segundos. La redondez aceptable se define como una desviación de un octavo de pulgada o menos a partir del patrón.

Quizás los siguientes casos sean ejemplos más comunes con respecto a la forma en que a veces se especifica la precisión de actuación:

...y para considerarla correcta, la solución del problema debe ser exacta hasta el número entero más cercano.

...el alumno debe utilizar la balanza de química lo suficientemente bien como para pesar los materiales con exactitud, llevándolos al miligramo más cercano.

...y cuando se calcula con las escalas C y D de la regla de cálculo, los cómputos deben ser precisos al nivel de tres cifras significativas como mínimo.

Cuando usted trate de confeccionar objetivos que satisfagan los requisitos discutidos en este libro, sin duda encontrará otras formas de especificar la calidad de actuación que usted se propone aceptar como muestra del éxito del alumno. Una forma muy buena de empezar es el revisar los exámenes que usted utiliza; ellos le dirán lo que usted **YA ESTA** utilizando como norma de actuación, y así podrá mejorar los objetivos al exponer estas normas por escrito. Una vez que haga esto, puede formularse usted mismo las siguientes preguntas para probar la claridad y calidad de los objetivos:

1. ¿Describe el enunciado lo que estará haciendo el alumno cuando demuestre que ha alcanzado el objetivo?
2. ¿Describe el enunciado las condiciones importantes (los datos dados, o las restricciones, o ambas cosas) bajo las cuales se espera que el alumno demuestre su capacidad?
3. ¿Indica el enunciado cómo será evaluado el alumno? ¿Describe al menos el límite mínimo de actuación aceptable?

Si en alguna ocasión se encuentra usted imposibilitado de decidir si una frase que ha confeccionado debe ser considerada como una restricción o un criterio, pregúntese si la frase dice algo sobre la calidad de actuación que se espera del alumno. Si es así, se trata de un criterio. Si todavía no està seguro de qué se trata, tranquilícese. Después de todo, lo importante no es el nombre que se le dé, sino el grado en que cumpla con la función para la cual se confeccionó.

Un comentario más antes del resumen final: Solamente se han utilizado ejemplos de objetivos de contenido para familiarizarle con la estrategia de confección de objetivos. Pero, claro está, usted frecuentemente tratará de alcanzar objetivos diferentes a los que sólo se relacionan con el contenido o la materia. En aquellos casos, por ejemplo, donde se espera que el alumno desarrolle cierto grado de "confianza" en su dominio de la materia, o donde se espera que adquiera ciertas "actitudes críticas", es adecuado decidir qué se aceptará como muestra de "confianza" o de "actitudes críticas", y describir estas conductas en objetivos separados. Los enunciados de objetivos deben incluir **todos** los resultados **propuestos**, ya estén relacionados o no con el contenido; sólo cuando se logre esto tendrá usted una base sólida para seleccionar las experiencias de aprendizaje que serán incluidas en un programa docente.

Una vez equipado con objetivos claros, y teniendo presente el propósito de demostrar su logro, se encuentra usted listo para pasar al próximo paso en el diseño didáctico—la confección del examen de comprobación.

Pase a la próxima página.

RESUMEN FINAL

1. El enunciado de un objetivo docente es una colección de palabras o símbolos que describen uno de los **propósitos** educativos.
2. Un objetivo comunicará adecuadamente su propósito en el mismo grado en que describa lo que el alumno estará HACIENDO cuando demuestre su aprovechamiento, y cómo usted sabrá cuándo lo ha alcanzado.
3. Para describir la conducta terminal (lo que el alumno estará HACIENDO):
   a) Identifique y describa el acto total de conducta.
   b) Defina las condiciones importantes bajo las cuales debe realizarse la conducta (condiciones dadas, o restricciones, o ambas cosas).
   c) Defina el criterio de actuación aceptable.
4. Confeccione un enunciado separado para cada objetivo; mientras más enunciados tenga, mejor oportunidad tendrá de hacer explícito su propósito.
5. Si le entrega a cada alumno una copia de los objetivos, probablemente no tenga usted que hacer mucho más.

Pase a la próxima página.

MATERIAL AUXILIAR . 1

No hay razón alguna para que el enunciado de un objetivo esté contenido en una sola oración: al contrario, usted encontrará distintas ocasiones en que se necesiten varias oraciones para comunicar claramente su propósito. Esto es generalmente cierto, por ejemplo, cuando se describen objetivos que requieran una conducta de síntesis o una actividad creativa por parte del alumno. A continuación se expone un ejemplo de este tipo:

> El alumno debe componer una pieza musical con una sola base tonal. La composición debe tener por lo menos 16 rayas y 24 notas. El alumno debe demostrar su comprensión de las reglas de una buena composición, al aplicar por lo menos tres de ellas en el desarrollo de su partitura. El alumno debe terminar su composición en menos de cuatro horas.

A continuación damos otro ejemplo, tomado de un curso de relaciones humanas:

> El alumno debe confeccionar un análisis de cinco cualesquiera de los diez estudios de casos que le son dados en el examen. Estos análisis deben ensayar una discusión de los casos de acuerdo côn los principios desarrollados durante el curso, y el alumno debe mostrar que ha considerado cada problema a partir de los puntos de vista de, por lo menos, dos de los participantes, al exponerlos con sus propias palabras. Se pueden utilizar referencias y notas, y se puede tomar un máximo de 24 horas para la confección de los cinco análisis.

MATERIAL AUXILIAR 2

Para una mayor información sobre objetivos, los siguientes libros serán sumamente informativos:

Taxonomy of Educational Objetives
Handbook I: Cognitive Domain
Benjamín S. Bloom, Editor
New York, David McKay, Inc., 1956.

Taxonomy of Educational Objetives
Handbook II: Affective Domain
D. R. Krathwohl, B. S. Bloom and B. B. Masia
New York: David McKay, 1964.

BENJAMIN S. BLOOM
Taxonomía de los Objetivos de la Educación
La Clasificación de las Metas Educacionales
Biblioteca: Nuevas Orientaciones de la Educación
Editorial "El Ateneo"
Buenos Aires, Junio de 1971
Traducción de **Marcelo Pérez Rivas**
Prólogo de la Edición en Castellano:
Profesor **Antonio F. Salonia**

Estos libros tratan sobre los diferentes tipos de objetivos que puede usted escoger y proporcionan muchos ejemplos sobre situaciones de examen adecuadas para cada tipo.

No siempre es posible especificar un criterio con toda la precisión deseada, pero esto no debe impedirle el que trate de comunicarse en la medida de lo posible con el alumno y con otras personas. Seguramente usted podrá encontrar alguna forma de evaluar cualquier punto que usted estime lo suficientemente importante como para invertir una cantidad significativa de tiempo en enseñarlo. Si usted encuentra algo que está seguro de no poder evaluar, el esfuerzo se debe centrar en encontrar la forma de evaluarlo.

CAPITULO 7

AUTOEXAMEN

En las páginas siguientes encontrará un breve autoexamen mediante el cual puede comprobar su capacidad para determinar si los objetivos dados manifiestan o no las características discutidas en este libro. Responda a todas las preguntas y después busque las respuestas correcta en la página 101.

Para que el autor haya logrado sus objetivos (enunciados en la página 13 y 14) sólo puede usted cometer 7 errores, como máximo, en las 44 preguntas.

1. ¿Están enunciados los siguientes objetivos en términos de actuación (conductuales)? ¿Nombra cada uno de ellos un acto que el alumno realizará cuando demuestre que ha alcanzado el objetivo?

	SI	NO
a) Comprender los principios del arte de vender	——	——
b) Ser capaz de relacionar tres ejemplos de la falacia lógica del tipo X ...	——	——
c) Ser capaz de comprender el significado de la Ley de Ohm	——	——
d) Ser capaz de nombrar los huesos del cuerpo humano	——	——
e) Ser capaz de enumerar los principios de administración de escuelas secundarias	——	——
f) Conocer las obras de Shakespeare	——	——
g) Comprender verdaderamente la ley del magnetismo	——	——
h) Ser capaz de identificar los objetivos docentes que indican lo que el alumno estará haciendo cuando demuestre que ha alcanzado el objetivo	——	——

2. A continuación están dadas dos características de un objetivo docente:

A. Identifica la conducta que será demostrada por el alumno.

B. Indica una norma o criterio de actuación aceptable.

¿Están presentes cada una de estas características en cada uno de los siguientes objetivos? Para cada objetivo, verifique si cada una de estas características están presentes.

	A	B
a) El alumno debe comprender la teoría de la evolución. La demostración de comprensión estará dada por la redacción de un ensayo sobre la evolución	——	——
b) El alumno debe completar un examen de selección múltiple de 100 preguntas sobre biología marina. El límite mínimo de actuación aceptable será el responder correctamente 85 preguntas, en un período de 90 minutos	——	——
c) El alumno debe nombrar correctamente cada objeto representado en cada uno de una serie de 20 modelos	——	——
d) Para demostrar su capacidad para leer un modelo de montaje, el alumno debe confeccionar el objeto representado por el modelo entregado en el examen. Se le permitirá a los alumnos utilizar todas las herramientas del taller	——	——

e) Durante el examen final, y sin referencias, el alumno debe redactar una descripción de los pasos a seguir en la confección de un modelo	——	——
f) El alumno debe sacar su revólver y disparar cinco veces, desde la cadera, en un período de tres segundos. A 25 yardas de distancia, los primeros cinco disparos deben hacer blanco en la silueta; a 50 yardas, por lo menos dos de los cinco disparos deben hacer blanco	——	——
g) El alumno debe conocer bien las cinco reglas cardinales de la investigación de homicidio	——	——
h) El alumno debe ser capaz de llenar el informe normal de accidente ...	——	——
i) El alumno debe ser capaz de redactar un ensayo coherente sobre el tema "Cómo Confeccionar Objetivos para un Curso de Comprensión del Derecho". El alumno puede utilizar todas las referencias mencionadas durante el curso, asi como las notas de clase. El alumno debe redactar su ensayo en el papel proporcionado por el examinador	——	——

	A	B
j) Junto a cada uno de los siguientes principios psicológicos, el alumno debe ser capaz de nombrar los autores de los experimentos en los cuales se basan los principios (a continuación sigue la lista de principios)	——	——
k) Dada una lista de objetivos, el alumno debe ser capaz de evaluar cada uno de ellos	——	——
l) Enumerar las características importantes de los programas autodidácticos lineales y ramificados	——	——
m) El alumno debe ser capaz de nombrar y dar un ejemplo de cada una de las seis técnicas de programación útiles para elicitar una respuesta correcta. Para considerarlas como correctas, las técnicas enumeradas por el alumno deben aparecer en el folleto "Técnicas de Programación", distribuido por el maestro durante el curso	——	——
n) Desarrollar enfoques lógicos para la solución de problemas de personal.	——	——

3. A continuación se muestra un objetivo pobremente enunciado:

El alumno debe ser capaz de comprender las leyes referentes a los contratos.

Indique si las siguientes situaciones de prueba tendrían que ser consideradas como adecuadas para evaluar si este objetivo ha sido logrado.

Situaciones de prueba	**Adecuada**	**No adecuada**
a) Se le pide al alumno que nombre a cada uno de los jueces de la Corte Suprema	——	——
b) Dado un contrato con ciertos términos legales encerrados en un círculo, se le pide al alumno que confeccione una definición de cada uno de tales términos ...	——	——
c) Dado un contrato legal y una lista de leyes sobre contratos, se le pide al alumno que indique cuál de las leyes, si es que hay alguna, se viola en la redacción del contrato	——	——
d) Se le pide al alumno que conteste 50 preguntas de selección múltiple sobre el tema de los contratos legales	——	——

4. ¿Cuáles de las siguientes situaciones de prueba serán adecuadas para elicitar el tipo de conducta mediante la cual se pueda determinar si el alumno ha alcanzado el objetivo?

Objetivo: Dado un audiómetro de cualquier modelo, en buen funcionamiento, el alumno debe ser capaz de hacer los ajustes y cambios de control necesarios para realizar una prueba normal de audición.

Situaciones de prueba	**Adecuada**	**No adecuada**
a) Enumere los pasos, en el orden correcto, para el montaje y posterior utilización de un audiómetro	——	——
b) Vaya al audiómetro de la mesa número 5 y ármelo para que se pueda utilizar en la realización de una prueba normal de audición	——	——
c) Describa los pasos que se siguen en la realización de una prueba normal de audición	——	——
d) Analice el papel del audiómetro en el laboratorio de audición	——	——

Pase a la página 101.

NOTAS

DIRECTORIO DE ASISTENTES AL CURSO SEMINARIO DE ACTUALIZACION EN ADMINISTRACION DE PRODUCCION E INVENTARIOS (DEL 8 AL 13 DE MAYO DE 1978)

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