A NOTE ON SIMULTANEOUS PROCESSING

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ABSTRACT

In this paper the logistic and informational consequences related to the simultaneous processing/production of products are systematically studied based on a classification of production situations where one or a number of processes are, or can be, executed simultaneously for one or a number of copies of one or a number of products (article codes). Special attention is paid to production situations where one can choose with respect to the above. An overview is given of the pro's and con's of simultaneously processing in the latter case.

INTRODUCTION

In many production situations a number of (different) products may, or have to, be produced partly together. Although in literature some attention has been paid to how to plan and control in the above situations, see for instance (Bookbinder, 1986), (Fandel, 1987), (Kimball, 1987), a systematic study concerning the (potential) pro's and con's of simultaneously processing/producing several copies of one or a number of different products is still missing however. This paper tries to fill part of this gap.

SIMULTANEOUS VERSUS SEQUENTIAL PROCESSING

In this paper materials, parts, products are "simultaneously" processed/produced if they are processed/produced at the same time by the same set of resources. Thereby the "same set of resources" denotes a specific man/machine/tool combination. In the above definition processing and producing are distinguished. Processing stresses the material input aspect of an operation, whereas producing is output oriented. These two aspects may coincide, as holds for instance with respect to the simultaneous baking of different types of pottery in one oven at the same time.

The above is a rather restricted definition of simultaneously processing/producing. Resources may be looked upon from a technological point of view, concerning the set of activities they may take care of, or from an organisational point of view, dealing with the responsibility for the functioning of the resources. Examples of the latter production units are a company, a department, a Group Technology cell, an assembly line, a single man/machine combination. Taking this broader point of view, single-model, multi-model and mixed-model production by assembly lines, involving a number of (different) work stations (Wild, 1972), may be classified as simultaneous processing/production too. That's because different copies of the same or different models are processed simultaneously by different consecutive work stations, together making up the set of resources "line". Other, strongly
related, examples concern the, simultaneously, parallel-wise execution of the same process by a number of man/machine/tool combinations of the same type, or different types, for a number of copies of the same or different products, or the overlapping processing of a given number of parts/given quantities of materials by consecutive work stations. See also Note 2.

CLASSIFICATIONS

In this section situations where processing/production steps are executed simultaneously are considered in more detail.

SINGLE PRODUCT VERSUS MULTI PRODUCT

As will be clear from the pottery example given above, simultaneous processing/production may concern a number of copies of one product (article code), which holds e.g. for the production of bread, or one or several copies of a number of different products (article codes), which applies e.g. to the production of blister cards, where different types of final products are combined on one offset printing plate, or to the slitting of jumbo rolls of paper into a variety of slit widths. For further details concerning these examples as well as other examples see e.g. (Olhager and Oestlund, 1990) and (Kimball, 1987).

Another wellknown example of simultaneous processing concerns the (partly) simultaneous transport of different products.

FREE CHOICE VERSUS FORCED

There are all kinds of reasons why products are (partly) processed/produced simultaneously. Thereby simultaneous production is forced by the technology used, whereas simultaneous processing usually can be decided upon freely from a technology point of view.

Many times different products have to be produced together due to the way inputs are delivered and the processing technology and machines and tools used. This holds e.g. with respect to the processing of crystal wavers in the semi-conductor industry, where slices often have to be processed as a whole, whereas the processing of one waver usually gives rise to a number of products having different characteristics (Campbell, 1988). Other examples, like the processing of shrimps and the processing of raw oil, can be found in (Duncan, 1983). Which products are produced together in these cases is largely determined by the values of the process parameters used.

A different example concerns the meat industry, where animals are "disassembled" into a number of different parts, see e.g. (Duvall and Hoffman, 1983) and (Noghabai, 1989).

There are also many situations where one doesn't have to process different products simultaneously from a technology point of view but by doing so (revenues - expenses) may be increased both in the short and the long run. Revenues are related to throughput, whereas expenses concern both operating expenses and expenses related to inventories, see e.g. (Goldratt and Cox, 1986). Both throughput and inventory expenses are directly related to lead times.
The total "production" lead time for a given quantity of a given product concerns the (lead) time required for procurement, pre-production, production and distribution activities. Thereby one should not only take into account the times directly related to the material flows, but also the times required for the generation and processing of data and decision taking!

Lead times are made up of set up time, processing time and time for waiting.

By simultaneously producing a number of products it is possible to reduce one or more of these components of the lead times of the operations that are executed simultaneously for a given mix and volume of products. For an overview of the (potential) advantages that may be realised by lead time reductions, see e.g. (Wouters, 1991).

The production of a given quantity of a given material, part or product requires, apart from time, a number of resources like materials, machines, tools, operators, information. Operating expenses are directly related to the availability and the usage of resources required for all the above mentioned activities.

By simultaneously processing it might be possible to reduce for a certain mix and volume of products

- processing resource requirements, due to a reduction in the total set up and processing time,
- materials requirements, and/or
- resources required for administration and control,

which may lead to reductions in the operating expenses.

In order to estimate the latter, it usually doesn't satisfy to consider only the lead times and resource requirements for the operations that are or may be executed simultaneously for a number of products. That's because the partly simultaneous production of a number of (different) products often also has consequences for the durations of and the resources required for the operations that have to be executed before and after the operations that are executed simultaneously. See e.g. (Bookbinder and Higginson, 1986) for a critical note on using material reductions as a starting point for simultaneously producing.

In order to be able to process different materials/parts/products partly simultaneously, these materials/parts/products have to be available at the same time, as is required for the execution of assembly activities.

With respect to the set of operations succeeding the operations that are executed simultaneously for a number of different products it has to be mentioned that the latter operations always have to be followed by separating/sorting operations (Fandel, 1987).

The effects of the above mentioned consequences of simultaneous processing on throughput and expenses have to be taken into account as well in order to get a real insight into the (dis)advantages of simultaneous processing.

In the remaining part of this paper attention will be focussed on the partly simultaneous processing of different products which hasn't be forced by technological restrictions related to the execution of the different
In order to estimate the consequences of simultaneously executed processes for their logistical control, it is important to know the position of these processes relative to all the other operations that have to be executed for a given volume and mix of products.

In general a number of different situations can be distinguished with respect to the position of the operations that are/may be executed simultaneously for a number of different products relative to the other operations that have to be executed for these products. In order to simplify things without violating the essence of the problem and the generality of the here presented approach, these situations are indicated hereafter in case only two different products, called A and B, are produced. Thereby the arrows marked by A, B and A/B denote the (network of) operations that are, or may be, executed respectively separately and simultaneously for A and B.

A
----->
A/B /    \ B
----->

FIGURE 1A : SIMULTANEOUS OPERATIONS IN THE BEGINNING OF A LOGISTIC NETWORK

Examples:
- Disassembly of e.g. animals, raw oil, old cars etc.
- Processing of crystal wavers for the production of semi-conductors.

A
----->
\ A/B    / B
----->

FIGURE 1B : SIMULTANEOUS OPERATIONS AT THE END OF A LOGISTIC NETWORK

Examples:
- Assembly of parts
- Mixing of different substances, like in the production of cheese etc. (process industry)
- Combined transport to a customer
- Packing of different products (or a number of copies of the same product) together, like sets of cups and plates (Kotowski and Sygit, 1987).

Ab          Aa
----->      ----->
\ A/B       /  \ A/B
----->      ----->
Bb          Ba

FIGURE 1C : SIMULTANEOUS OPERATIONS SOMEWHERE IN A LOGISTIC NETWORK
In Fig. 1C the subscripts b and a are introduced in order to distinguish between the operations on A and B before and after their simultaneous processing.

Examples:
- "Baking" of different pottery in an "oven"
- Heat treatment of metal parts in an oven
- "Printing, cutting" of "sheets" filled with a number of (different) products (including the separation and sorting of these products).

\[
\begin{array}{c}
A \\
\text{-----} \\
\text{-----} \ A/B \\
\text{-----} \\
B \\
\text{-----} \\
\text{-----}
\end{array}
\]

\[
\begin{array}{c}
A \\
\text{-----} \ A/B \\
\text{-----} \ B \\
\text{-----} \\
\text{-----}
\end{array}
\]

FIGURE 1D : SIMULTANEOUS OPERATIONS AT A NUMBER OF PLACES IN A LOGISTIC NETWORK

Examples:
- All the examples mentioned with respect to Fig. 1C followed by simultaneously executed packing/transport activities.

Clearly many other situations can be sketched by combining a number of Figs. 1A and 1B. With respect to their characteristics to be considered in this paper they are similar to the situation sketched in Fig. 1D.

Apart from the situations symbolically depicted in Figs. 1A up to 1D one of the following situations may occur as well.

\[
\begin{array}{c}
A/B \\
\text{-----}
\end{array}
\]

FIGURE 1E : COMPLETELY SIMULTANEOUS PRODUCTION/PROCESSING

\[
\begin{array}{c}
A \\
\text{-----}
\end{array}
\]

\[
\begin{array}{c}
B \\
\text{-----}
\end{array}
\]

FIGURE 1F : COMPLETELY SEPARATE PRODUCTION/PROCESSING

Theoretically there are a number of alternative ways to cope with each of the above situations from a production order point of view. In Table 1 these are indicated for the situation sketched in Fig. 1C. In case a field isn't filled in this table, the production order indicated left from this field in the same row is used for triggering and controlling the progress of the operations indicated in the head of the column.
Case | Preceeding operations | Simultaneous processing | Succeeding operations
---|---|---|---
1 | single-product | multi-product | single-product
2 | single-product | multi-product | multi-product
3 | single-product | multi-product | multi-product
4 | multi-product | multi-product | single-product
5 | multi-product | multi-product | multi-product
6 | multi-product | multi-product | multi-product
7 | multi-product | multi-product | multi-product
8 | single-product | single-product | single-product
9 | single-product | single-product | multi-product
10 | single-product | single-product | single-product
11 | single-product | single-product | single-product
12 | multi-product | single-product | single-product
13 | multi-product | single-product | single-product
14 | multi-product | single-product | single-product

TABLE 1: ALTERNATIVE COMBINATIONS OF PRODUCTION ORDERS FOR DEALING WITH THE GOODS FLOW SKETCHED IN FIG. 1C

MULTI-PRODUCT PRODUCTION ORDERS

Production activities are triggered and their progress is controlled via production orders.

According to the APICS Dictionary (APICS, 1991) a production order is

"A document, group of documents, or schedule identity conveying authority for the manufacture of specified parts or products in specified quantities".

In general production orders serve many different purposes. They are used as
- a unit for planning
- a "vehicle" for registering/controlling the progress of work
- a "vehicle" for registering the usage of resources
- a document containing operation instructions
- a document for registering quality information
- a document for lot traceability.

Via production orders non-material resources and materials are linked together. By production orders we do not only influence the flow of materials through our company but also the efficient usage of resources. The sizes of production orders play an important role with respect to our production flexibility.

In many production environments production orders are defined for single
products only. Thereby often demands from several internal and external customers for a given part (product) are combined. There are also a lot of production situations where production orders are defined for the production/processing of a number of different products. In the following the latter orders will be denoted by multi-product production orders, whereas the production orders mentioned before will be called single-product production orders. In order to trigger the (simultaneous) production of a number of different products, or simultaneous processing of a number of different materials or parts, both single-product production orders and multi-product production orders may be used. Which type of production order should be used isn't as clear as it may look like at first sight. This holds especially if the production of given parts (products) involve both operations that have to be executed simultaneously for a number of these parts (products) and operations that aren't or can't be. In (Kimball, 1987) some attention is paid to the logistic and informational consequences of using multi-product production orders ("gang orders") for triggering and controlling the progress of the simultaneous production of products or the simultaneous processing of materials, parts. In (Wight and Landvater, 1983) some attention is paid to the special provisions in logistic control information systems that are required to deal with the types of orders described in (Campbell, 1988) and (Duvall and Hoffman, 1983). A systematic study concerning the logistic and informational aspects of using multi-product production orders as well as an overview of the pro's and con's of these orders when compared with the usage of single-product production orders is missing however. As far as the author knows also no attention has been paid to the consequences of "simultaneously" using single and multi-product production orders for different groups of operations that have to be executed within the context of the production of a given mix and volume of products within a certain period of time. This paper tries to close parts of these gaps. Thereby we restrict ourselves to the following aspects concerning (the usage of) multi-product production orders

A. Their definition
B. Their release to a production unit
C. The control of their progress
D. Their (partial) receipt, and
E. Their usage with respect to the time-phased planning of production activities.

DEFINING MULTI-PRODUCT PRODUCTION ORDERS

Defining multi-product production orders requires the following questions to be answered

1. Which products to combine
2. For which operations?
3. Which due date and which lead time the order should have?
4. What should be the total order size?
It will be(come) clear that the above questions can't be answered completely independently.

Ad 1. Which parts/products to combine?

In general this decision requires insight into
a. the time-phased requirements for the different parts/products
b. the (alternative) way(s) products are (may be) produced
c. the specific properties of the products themselves (like color, shape)
d. the time-phased availabilities of the required resources (tools inclusive!)

where points a. and d. concern dynamical aspects of the situation, whereas b. and c. concern static aspects.

Ad a.
The first thing required is an overview of all products that have to be produced within a given period of time.

Ad b.
Next it has to be determined whether there exist technological possibilities to process or produce (different) products simultaneously. For this purpose an overview of the different operations and an overview of the resources available for the execution of these operations should be generated.

Next an overview of the products which routings include these operations should be generated. One should take care that also alternative routings and resources are taken into account.

Then the durations of the common operations and the required set ups of the resources should be compared. For instance in case of baking products using an oven, the temperature within the oven during processing usually has to be about the same for all products to be dealt with in one go as well as the time required for the baking process.

Each multi-product production order will have only one due date and one "lead time". Therefore, in order to forecome unnecessary stocks, the single-product requirements to be (partly) fulfilled by multi-product production orders, i.e. the single-product production orders combined by the latter, should not differ "too much" from each other with respect to their due dates and "lead times" of the operations dealt with via the multi-product production order. What is meant by "too much" depends upon the specific situation considered.

Ad c.
It may be that the routings of different products may be the same, the due dates and the lead times of the corresponding single-product production orders are the same, but it still isn't possible to process the different products simultaneously due to the combination of geometrics or colors, or due to e.g. the fragility of the products during the processes that may be executed simultaneously.

Ad d.
It may be that based upon the foregoing products might be processed simultaneously but that this requires special tools, specifying the number of copies of the (different) products that may be processed together.
If these special tools are relatively very expensive or if their production
takes a lot of time, one may be forced to use as much as possible available tools. Suppose there is a tool available for the simultaneous production of say one copy of product A and two copies of product B. If there are 10,000 products A and B demanded, one can either decide to (let) produce a new tool or to produce 10,000 products B extra. Which decision is best depends among others on the short term expected sales of product B. See also (Fandel, 1987).

Ad 2. For which operations?

Having decided upon which parts/products may be partly produced together, we have to decide upon the operations that are to be triggered and controlled by multi-product production orders.

An important question to be answered in this context is "Should multi-product production orders only be used for triggering and controlling the progress of operations where different products are processed/produced simultaneously, or should multi-product production orders also be used to take care of these functions for part of the other production/procurement activities for part or all of these materials/parts/products as well?"

In order to answer this question insight is required in
a. Where the Customer Order Decoupling Points (CODP) for the different products are positioned.
   (The CODP indicates up to where in the production network of a given product the production activities are started based upon concrete customer orders.)
   b. The resources required for the different operations.
   c. The lead times for the different operations.
   d. By which production units the different operations are executed.
   e. The position of operations that are/may be executed simultaneously for a number of different products relative to the other operations that have to be executed for these products and the number of these other operations.
   f. The number of operations that are simultaneously executed.

Ad a.
The operations that are triggered by one multi-product production order for a number of different products should for each individual product be situated at the same side of its CODP. The CODPs for the different products may differ however.

Ad b.
It may be that the resources (like hardware) used for the simultaneously processing are, or have to be, used for the directly preceding or directly succeeding production activities as well, or that the hardware used for the former operations is hard coupled with the hardware used for the latter activities, whereas it isn't possible to define buffers in between these activities. In these cases one seems to be forced to use either single or multi-product production orders for all these activities.
Ad c.
See under ad 2.b.

Ad d.
If (part of) the directly preceeding and succeeding operations are executed by the same production unit, like a Group Technology cell or a line, as the operations that are, or have to be, executed simultaneously, multi-product production orders may be defined for all these operations.

Ad e.
For concreteness' sake let us assume that we decided upon the partly simultaneous production of a number of copies of product A and B. How to deal with the operations on part A and B preceeding and succeeding the simultaneously executed operations from a logistic control (production order) point of view?

If these operations require completely different types of resources, it doesn't make sense to let these operations be triggered by one multi-product production order. In that case single-product productions orders should be defined for these.

If these operations require the same types of resources, e.g. forming part of the same Group Technology cell, multi-product production orders, so called pseudo series (Bertrand et al., 1990) may be used. It might be useful to let the multi-product production orders originally only defined for the operations where the different products are processed simultaneously include the (pre-)production operations for which the above holds as far as these immediately preceed or succeed the simultaneously executed processing steps!

What may be the disadvantages of using multi-product production orders as suggested above? The materials required for the production of all parts have to be available in order to release the multi-product production order. This usually will mean that some materials are ordered for earlier than strictly required, increasing the inventory expenses. How serious this effect may be depends among others upon the procurement strategy used. It may be for instance that the materials for the different parts are always ordered together due to reduction in procurement expenses (discounts, transportation) that may outweigh the extra expenses for inventory resulting from this policy. Lack of material for a specific product, like ink of a certain color in case of blistercards, means that the production of all products may be delayed. When single-product production orders are used there may exist some flexibility with respect to this. The production of one part may be started already, whereas meanwhile the materials required for the other part may become available. (Of course such a strategy may be realised as well by using multi-product production orders but this introduces a lot of extra synchronisation activities as would be the case when separate single-product production orders would have been used.)

How to trigger the operations following the operations that are to be dealt with simultaneously? Apart from the arguments presented above it is important to know as well whether or not (all) products A and B produced together up to here are required at the same time for transport to the (same) customer. If not, and the operations don't require the same set of resources having
the same setups, it seems better to trigger the succeeding operations via separate single-product production orders. If all upto here simultaneously processed products A and B have to be transported simultaneously, e.g. because they have to be delivered "simultaneously" to the same customer, and the resources required for the operations following the simultaneous operations are the same or make up part of the same production unit, then also these operations might be triggered by the same or a separate multi-product production order. The latter also depends upon the results of the simultaneously executed processing steps. If the yield from these steps varies a lot for the different products, it may be better to define single-product production orders for them.

The number of and types of operations succeeding the simultaneous operations may also play an important part in this discussion. What to decide if the simultaneously executed processes are followed by only one other production operation, which differs, or requires different resources, for the different products? Introduction of new production orders for this single operation may give rise to a considerable amount of extra administrative work, which may give rise to a (considerable) increase of the total "production" lead time. In that case it seems justified to include this final operation in the set of operations controlled by the multi-product production order defined for the foregoing operations.

Ad f.
In many production situations only one operation exists where a number of different products can, or have to, be processed simultaneously. This holds e.g. for the baking of products in ovens. Often there aren't many of these "ovens" because they are rather expensive. Thereby it usually takes quite a lot of time to set up these "ovens". Often products can only be "baked" simultaneously, if they require exactly the same "baking" temperature and time. Which products are actually processed simultaneously by resources like the above mentioned oven is often determined by the products available at the moment that the oven becomes available again. Then it may, and often does, happen that either products have to wait till the moment that "enough" products are available to fill "most" of the oven or that the oven is set up and the production started for a partly filled oven. Because of the above ovens are often bottlenecks.

Essentially we are dealing here with "imaginary" multi-product production orders for the production unit "oven", which are defined just before executing the processing. The baking operation forms as well part of the set of operations belonging to the single-product production orders defined for each of the different products.

Does it make sense to define multi-product production orders also in this case? What may be won by doing this? Multi-product production orders may be useful here, if they can be defined for the operations preceeding the "baking" operation. In this way one may better be able to take care of the synchronised arrival of quantities of different products at the "oven" than when single-product production orders are used. Of course the preceeding operations have to fulfil the general requirements stated under ad e for this.
Ad 3. What should be the due-date and the lead time of a multi-product production order?

It will be clear that the due-date of a multi-product production order should be based upon the set of due-dates derived for the different products that are processed together. In order that all these parts or products can be timely delivered to their customers the earliest due-date in the above mentioned set should be taken as the due-date for the multi-product production order.

With respect to the priority of the multi-product production order it may be required to give the multi-product production order the same priority as the single-product production order having the highest priority of the set of single-product production orders together making up the multi-product production order.

The lead time of a multi-product production order equals the longest lead time of the single-product production orders making up the multi-product production order.

Ad 4. What should be the total order size?

Having agreed upon which operations for which products may be executed simultaneously, we have to decide upon the quantities of the different products.

The size (product volume) of a multi-product production order is determined by
-its time-phased resource requirements
-the time-phased resource availabilities (tools inclusive) as applies to single-product production orders as well.

In literature extensive attention has been (and still is) paid to lot sizes and their relation with throughput, inventories and operating expenses. See e.g. (Goldratt and Cox, 1986) and (Wouters, 1991).

The lead time for the production of one copy of a single product is made up of
-waiting time for processing
-due to the sizes of other production orders
-related to the size of the production order itself
-set up time
-processing time
-production order completion waiting time after processing.

Clearly the order size depends upon the availabilities of the resources that are required for processing the multi-product order.

In case of simultaneous processing, the quantities of the different products may be mutually dependent due to the usage of a common tool that predescribes the number and types of different products that may be produced in one go, as applies e.g. for the production of blister cards due to a common cutting frame. The influence of such tools may increase when these tools are very expensive and require quite a lot of time to be produced, whereas eventually presently not required (quantities) of products may be sold later. See also (Fandel, 1987).

Also the set up times of the resources involved in the operations that may be executed simultaneously play an important role with respect to the size
of multi-product production orders. The more time is required for setting up these resources, the larger the size of the order tends to be. Note that often bottleneck resources are involved in the operations that are executed simultaneously for a number of products.

RELEASING MULTI-PRODUCT PRODUCTION ORDERS

Aspects to be dealt with in this context are
- Routing
- Resource availabilities.

Routing.

For each multi-product production order it should be possible to define a routing.
Clearly this may give rise to problems if a multi-product production order is defined for operations requiring different resources for the different products, because in that case we are essentially dealing with a network of production activities instead of a linear chain.
The above problem also holds in case these different resources form part of one group technology cell. This problem can't be overcome by denoting the cell as a "workcenter" in the routing, because the different resources within the cell may be required quite differently.

Resource availability.

Before a multi-product production order is to be released, it should be possible to check whether all required resources are or will be timely available.
The (detailed) capacity check should be based upon the multi-product production order as a whole.
It should be possible to pick the required materials together.
With respect to the above aspects multi-product production orders don't differ from single-product production orders.

CONTROLLING THE PROGRESS OF MULTI-PRODUCT PRODUCTION ORDERS

Aspects that have to be considered in this context are
- Progress registration
- Overlapping execution of operations
- Splitting of multi-product production orders for parallel processing
- Rescheduling.

Progress registration.

In case of simultaneously processing it might be that processing problems involving multi-product production orders might have different consequences for the different products making up the order. In that case it should be possible to register the results for a multi-product order per operation per individual product. The latter certainly holds for single-product production orders that are processed sequentially within the context of a multi-product production order.
In the above cases the usage of multi-product production orders has no advantages over the usage of a set of single-product production orders as far as this aspect is concerned.
It should be possible to register the planned and realised set up and processing times per multi-product order if the underlying single-product production orders are processed simultaneously. If the latter are dealt with sequentially, registration should be possible for the individual single-product production orders.

Overlapping execution of operations.

With respect to this aspect multi-product production orders don't differ from single-product production orders. In case of sequential processing, the single-product production orders underlying the multi-product production order may correspond with the unit of overlap.

Splitting of multi-product production orders for parallel processing.

The above remarks also hold with respect to this aspect.

Rescheduling.

It is important to keep in mind that rescheduling a multi-product production order means the rescheduling of all the underlying single-product orders.

RECEIVING PARTS OF MULTI-PRODUCT PRODUCTION ORDERS
(LINKING SHOP FLOOR CONTROL AND GOODS FLOW CONTROL)

Partial receipts.

Because customers demand quantities of specific products, it should be possible to register the (partial) receipt of individual parts or products, notably after the separating/sorting operation. With respect to this aspect the usage of multi-product production orders doesn't differ from the usage of separate production orders for single products.

Closing.

It should be possible to register the completion of the complete multi-product production order within the context of WIP (work-in-process) registration.

MULTI-PRODUCT PRODUCTION ORDERS AND GOODS FLOW CONTROL

As mentioned before multi-product production orders are primarily introduced for reducing resource requirements and reducing the time that materials, parts, products have to stay within a company. Is it possible to make clear and use the advantages of simultaneous processing for goods flow control, i.e. for the time-phased planning of (critical) resources (like machines, operators, tools, materials, information) via multi-product production orders? It seems that this would require either to be able to define multi-product production orders at goods flow control level or to introduce correction factors to take into account that the processing of a number of products may be dealt with simultaneously more effectively.

Within this context it is important to know when the decision to process
different parts (products) together is taken. This may be done at the moment:
- the technology to be used is decided upon
- the resources like machines are chosen
- customer orders are received
- production orders are defined, or
- an operation has to be started.

The decision with respect to (partly) combining the production of different products depends strongly upon the customer orders that have to be dealt with during a given period of time. If customers always order products that can be processed simultaneously together in a fixed mix, we are dealing with a situation similar to the (forced) simultaneous production of by-products. Then we may use percentage bills or by-product bill structures to reflect this at the goods flow control level. (For a definition of these bills and some of their (dis)advantages see e.g. (Mather, 1987).) Such a customer behaviour may be stimulated by among others financial incentives. If it isn't possible to influence the ordering behaviour of the customers but it may be safely assumed that simultaneously produced products can always be sold, then one still may consider to use the above mentioned by-product or percentage bill structures.

The time-phased resource requirements for the simultaneous processing of products A and B according to the mix defined by "sheet" A/B (nA (nB) denotes the number of products A (B) per "sheet" A/B) may be generated based upon a BOM structure as shown in Fig.1.

**FIGURE 2 : BOM RELATED TO A MULTI-PRODUCT PRODUCTION ORDER FOR TWO DIFFERENT PRODUCTS**

The "lead times" to be used should be based upon the multi-product production order as a whole. From a goods flow control point of view one is interested in really existing materials, parts and products. So it seems that the single-product production orders related to the multi-product production order should be registered for the individual parts/products, as has been suggested before by e.g. (Kimball, 1987). The above means that in general the relationship between goods flow control production orders and shop floor control production orders becomes less clear. Only if the products which production are (partly) triggered and controlled by multi-product production orders are always delivered to a customer in a fixed mix that is also used in the multi-product production orders, such a registration may not be necessary.
If A and B may be produced separately as well, or in combination with other products, the above BOM structure is hardly useful for getting insight into future resource requirements for the production of A and B.

If some materials/parts/products are always (partly) processed simultaneously in a number of consecutive operations, rough cut capacity routings may be defined for the pseudo multi-product item "sheet A/B". The resource requirements may be partly directly related to the sheet itself, like the requirements for setting up machines, tools, and partly be based upon the requirements of the underlying single-product production orders, like the quantities of the different inks for printing in case of e.g. blistercards.

Multi-product production orders that are only defined for consecutive operations where products are processed simultaneously or serially by the same set of resources can be dealt with as single-product production orders for material resource planning.

If m-p production orders include operations that require different resources for different products, it is still easy to derive the (detailed) time-phased resource requirements. The rescheduling of these operations becomes more difficult however, because multi-product production orders correspond with non-linear networks in that case.

This makes clear that one should be very careful in including the above mentioned types of operations in m-p production orders.

If none of the above situations applies, it is hardly possible to take simultaneous production into account in forecasting time-phased resource requirements.

Then the usage of multi-product production orders may be considered when customer orders are received.

Sometimes the decision to produce different products simultaneously may have to be postponed till the moment that a resource becomes available for the processing of a new job, as may hold e.g. for the baking of different pottery in an oven. This may be due to an unreliable yield or unreliable durations of foregoing operations.

In that case it doesn't seem possible to take fully advantage of the resource requirement reductions that may be realised by means of multi-product production orders.

Having got some insight into the logistic consequences of using multi-product production orders, some attention will be paid to how the usage of multi-product production orders may be supported by an information system.

**INFORMATION REQUIREMENTS**

Hereafter some decision support systems are defined for using multi-product production orders. From the information requirements resulting from these systems the data structures required for these are derived.

For this purpose we go through the different aspects of multi-product production orders discussed in the foregoing section once more.
DEFINING MULTI-PRODUCT PRODUCTION ORDERS

1. Which products to combine?

Clearly a display of the planned orders and scheduled receipts by manufacturing family showing for each required item in the family the quantity scheduled per time period is required (Wight and Landvater, 1983, 0).

If the production of different products may be worthwhile to combine, information should be available with respect to which products might be combined for which (groups of) operations. This requires an overview of the routings of all products which processing requires a given resource, having a given set up, within a given period of time.

One possibility to indicate that products may be partly processed together might be via the coding of parts.

Product definitions in a CAD/CAM system might be helpful when the shapes of the products are important.

In order to reuse tools, like cutting frames for the production of cardboard boxes, made for a given combination of different products, it should be possible to relate a given product to all already available tools (cutting frames) involving (the geometry of) this product.

2. For which operations?

A useful decision support system for this purpose would be a system that order the outstanding production orders according to due date, sequence of operation/resource combinations including the required set ups of the latter.

3. Which due date and which priority the order should have?

The due date of a multi-product production order may be either generated by a sub system, based upon the formula

due date multi-product production order = minimum (due dates single product production orders involved)
or might be determined and filled manually.

It might be worthwhile to process production orders for one or more products a little bit later than planned. Therefore it always should be possible to change the due date manually.

Similar remarks hold with respect the priority of a given multi-product production order, where initially the priority multi-product production order may be set equal to the maximum {priorities single-product production orders involved}.

4. What should be the total order size?

As mentioned in the foregoing section, we have to define which quantities of which products will be processed together for which operations. For this purpose a time-phased detailed capacity plan should be available for all the resources required.
Besides it would be handy if the capacity requirements for a multi-product production order as a whole could be estimated automatically.

Summarising the above we arrive at the following data structure and data elements (attributes) for describing multi-product production orders

Data elements at multi-product production order level:
- Order identifier
- Due date production order (= min{due dates parts involved})
- Routing (*, @), where * denotes per part and @ denotes per sheet
  - Resources
  - Number of resource entities
  - Setup time (planned)
  - Processing time (planned)
  - Routing structure.

Data elements at sheet production order level:
- Part number (*)
- Quantity (*)

Data elements at single-product production order level:
- Part number
- Quantity
- Due date.

The above data structure shows that some of the operations may be related to the multi-product production order as a whole, whereas the remaining
operations may be related to the sheet production orders or to the individual single-product production orders.

RELEASING MULTI-PRODUCT PRODUCTION ORDERS

There should be a decision support system that gives an overview of the availability of the material requirements for the multi-product order as a whole based upon the combination of products. These material requirements may be related to the multi-product production order as a whole, the different sheet production orders or to the single-product production orders.

For each of these the following data elements should be defined

- Material identifier (*)
- Required quantity (*)
- Available quantity (*).

CONTROLLING THE PROGRESS OF MULTI-PRODUCT PRODUCTION ORDERS

Required data elements:

- Results of the operation
- Set up time (realised) (*)
- Variable processing time (realised) (*)
- Quantity (*).
- Status of the multi-product production order as a whole.

RECEIVING PARTS OF MULTI-PRODUCT PRODUCTION ORDERS

Here we are dealing with the interface between Shop Floor Control and Goods Flow Control.

Required data elements are

- Delivered quantity (*)
- Status single-product production order (*)
- Status multi-product production order as a whole.

MULTI-PRODUCT PRODUCTION ORDERS AND GOODS FLOW CONTROL

As mentioned before by (Wight and Landvater, 1983) and (Kimball, 1987) the rescheduling of a multi-product production order should automatically lead to a rescheduling of all related single-product production orders at goods flow control level.

ADVANTAGES AND DISADVANTAGES OF USING MULTI-PRODUCT PRODUCTION ORDERS

In this section the pro's and con's of multi-product production orders as compared with the usage of single-product production orders to trigger and control the processing of a given set of products are summarised.

Advantages.

- More efficient usage of resources
  (including a reduction in material handling activities depending on the
way materials and parts are picked for production orders
-Simple logistic control (less units of work to deal with)
-Less administrative work for releasing and controlling the progress of production orders.

Disadvantages.

-Extra information requirements and work for defining production orders
-Flexibility loss
-Raise in carrying costs due to a too early production of some of the products that are produced simultaneously.

Apart from the above mentioned structural disadvantages, the usage of multi-product production orders requires the implementation of the data elements and decision support facilities indicated in this paper.

Whether or not the above mentioned advantages outweigh the above mentioned disadvantages depends upon how the usage of multi-product production orders may influence operation and inventory expenses and sales. This clearly depends upon the specific situation to be controlled.

SUMMARY AND CONCLUSIONS

In this paper the consequences of using multi-product production orders for goods flow and shop floor control were systematically derived and discussed in detail, both from a logistic and an informational point of view. The paper indicates under what circumstances it may be worthwhile to use multi-product production orders and when not. By means of this paper we hope to stimulate managers to think anew about the types of production orders presently used by them.

NOTES

Note 1.

Strictly spoken operations of the types 1:1 and m:1 don't exist in reality. There is always more than one product at a time produced, because we aren't able to develop production technologies that don't give rise to waste.

Note 2.

Customer and purchase orders, containing order lines concerning different products that have to be delivered together, are multi-product orders too. In this paper we shall restrict ourselves to production orders however.

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REFERENCES


