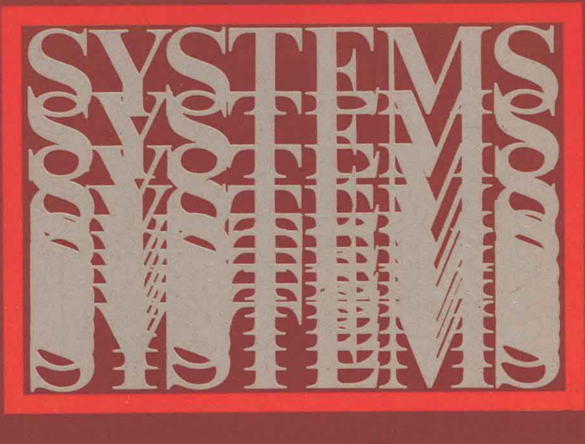
J. J. Verzijl

PRODUCTION PLANNING AND INFORMATION SYSTEMS



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Preface

The simultaneous production of several more or less complex commodities could not possibly be organised properly without using a great many systems competently and in proper balance, for instance systems of planning and information, estimating and post-calculation, rating, wage and salary information, work-structuring, training, career planning, co-ordination and costing. None of these is completely self-sufficient in the sense of being able to stand alone.

Planning systems can no more exist without information than fire without oxygen and are prone to fail whenever information is overdue or incomplete. Assuming that all the other systems involved are up to standard, the remedy lies in the efficient use of computers and business machines. However, since this study concerns only planning and information, the other systems will only be mentioned very briefly, as the occasion demands.

The principles and formulae on which to build systems of planning and information are shown to be no more complicated than the four 'simple' equations defining all the marvels of electricity and magnetism which are part of our daily lives and the source of all electrical equipment from electric lamps to space-craft, and from the hot-plate to the television receiver. Properly applied, these principles and formulae can go a long way towards ensuring a high standard of performance and good working conditions in any manufacturing department or factory.

Eindhoven, 1976 J. J. VERZIJL

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Introduction

Planning experts will be the first to admit that theirs is an unrewarding and intricate task, aimed at keeping control over situations usually involving an enormous variety of factors, as mentioned in the Appendix. As a swimmer avoids drowning by varying his style to suit conditions, so a planner achieves results by adopting whatever method best suits the situation for which he has to plan. Planning situations range from one extreme to another; for instance, from that of a football match played at tremendous pace with new plans being evolved, and if possible thwarted, first by one side and then by the other, so that a no-score draw denotes failure of all these plans, to that of a successful attempt to beat the world record for speed skating over 10 000 metres, which simply means that the skater has managed to pace himself perfectly throughout each of the 25 circuits. Where a factory's order book is full, any enquiry from a customer as to whether a new order can be delivered by such and such a date can only be met by a skilful search for whatever tiny bit of capacity can be spared to accommodate the order conveniently, without jeopardising other delivery deadlines.

In his book *Humanity in Flux**, Pierre Bertaux defines this kind of situation succinctly in such phrases as 'Rigid planning leaves no room for manoeuvre' and 'Whoever plans, reckons without the unknown' (or 'Man proposes, but God disposes').

In industry there is really a need for a separate term to distinguish between what passes for planning, but allows new orders to be accepted regardless of risk to those already in the pipeline, and true planning in the sense of ensuring that new orders rarely (if ever) jeopardise the due completion of work taken on earlier. That is the kind of planning we shall be studying.

* *Mutatie van de mensheid*, in Dutch, published by Scientific Publishing Company, Amsterdam, Holland.

1 Planning

1.1 Why Plan?

Planning systems are designed to:

(1) Foster good industrial relations.
(2) Reduce production costs to a minimum.
(3) Keep throughput times as short, and amount of work in progress as small as possible.
(4) Achieve a high standard of reliability of delivery.
(5) Ensure controlled and consistent growth of productivity.

Of all the different factors which govern good industrial relations, planning and information systems are the most crucial in that they control many of the variables inherent in other systems. In fact it is true to say that none of these other factors can possibly operate effectively if the planning and information system goes wrong. Without proper planning and information it is not possible to distribute the work fairly, or at any rate as fairly as circumstances allow, amongst the work force.

This particular study will be confined to points (2), (3) and (4), and will not consider point (5) because it would involve not only a broad discussion of cost–price structure, budgeting and prices and incomes policy, but also a knowledge of just what sectors of the economy should, or should not be encouraged to develop in order to bring about 'real growth'. Our problem would then have to be placed in some kind of consistent framework, as discussed in *To Each His Own*, by J. J. Verzijl.*

1.2 How to Plan?

1.2.1 Little strokes fell great oaks

A few per cent increase in orders inevitably causes uneven ordering intervals and a variation in order quantities incompatible with the

* *Ieder het zijne*, in Dutch, published by Koninklijke Van Gorkum & Co., Assen, Holland.

need to keep stocks small and lead times short. Simple formulae confirming this statement will be demonstrated in due course, beginning with a simple planning situation of continuous production by the supplier and continuous use by the customer, and proceeding by stages to the more difficult ones involving discontinuous production coupled with more critical loading and an expanding product mix. It will be seen that even a small additional order quickly adds enormously to stocks, lead times and demand on capacity, thereby tempting customers to place excessive orders and create a vicious circle.

1.2.2 Planning situations

Planning problems involve suppliers, customers and products alike. Their governing factors are prices, material supplies, reorder dates, delivery dates and production capacity. Let us begin with a simple planning situation: suppose that a product made in one operation is to be produced in quantity by a regular supplier on behalf of a regular customer. Four different situations are then conceivable, as shown in table 1.1. We need only consider the planning problems facing the supplier. There will be none, except perhaps a capacity problem, if he is able to count on *continuous* production (situations A1 and A2), since planning only presents a problem to the supplier when production is discontinuous, that is when the spare machine time has to be used to make one or more items for the same customer, or for others (situations A3 and A4). Whether a customer uses—or perhaps sells—his own products continuously or discontinuously is of no concern to the supplier.

Table 1.1

Situation	A1	A2	A3	A4
Continuous production by supplier	yes	yes	no	no
Continuous use by customer	yes	no	yes	no

Let us consider the planning problem arising in situation A3, i.e. discontinuous production by the supplier as against continuous production by the user. Because the investment in stock is substantial and the market 'uncertain', the customer splits his overall requirement

Table 1.2

Situation	B1	B2	B3	B4
Orders scheduled at regular intervals of so many working days	yes	yes	no	no
Same quantity ordered every time	yes	no	yes	no

into a number of order quantities, which can again be done in four different ways, as shown in table 1.2.

The outcome of situations A3 and B1 combined (regular ordering cycles and identical quantities per order) does not present a true planning problem of the kind which does arise where situations A3 and B2 coincide (orders at regular intervals of so many working days, but for varying quantities).

1.2.3 Stocks and order quantities

Example 1.1

Our first example illustrates the somewhat rudimentary planning situation of A3 and B1 combined. The customer uses 1000 items X a day whereas the supplier's daily output is 4000. Therefore the item only keeps the machine occupied for 25% of the time, during which the supplier's stock of item X builds up at the rate of $4000-1000=3000$ per day. Assuming that the customer orders 8000 every eight working days, this situation will only keep the supplier occupied for two days out of every eight. Moreover, it takes one day to set up the machine and six days to deliver the goods.

Supplier's output, customer's offtake and the combined stock level are perhaps best expressed in terms of how many days' consumption, or usage they represent. Thus, the customer of course absorbs one days' usage per day, amounting to 1000 units in the present case, whilst the supplier produces four days' usage per day, and the stock level rises at the daily rate of three days' usage. Because the frequency of orders is not necessarily cyclic, we shall refer to it in terms of the *number of days' demand.* Figure 1.1 illustrates the scheduling of orders—production, transport and usage as expressed in these terms.

The first order goes on record as soon as production begins, that is after the machine is set up. The stock of item X builds up to eight days' usage within two days, whereupon production is interrupted.

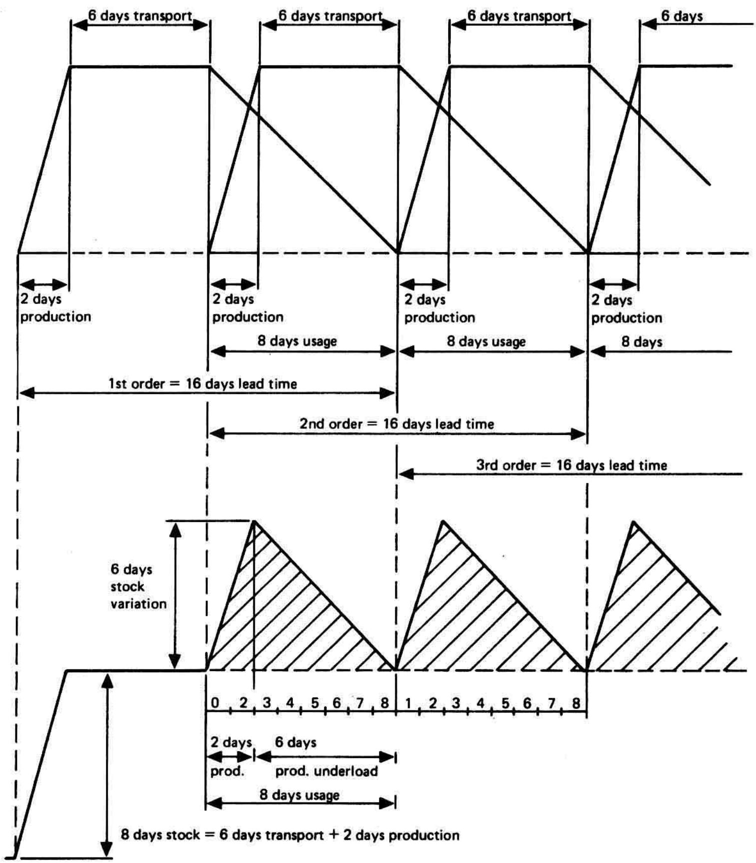

Figure 1.1 Course of stocks

Transport takes another six days, therefore usage, or perhaps sales, can commence on the ninth day and then continue for eight days in all. Because all the orders, including the first, require a lead time of 16 days, the need for continuous usage means that another batch will have to arrive on the 17th day, and go into production eight days earlier in order to provide this. Therefore, uninterrupted usage calls for the orders to run concurrently, simply because of the time it takes to produce and ship them.

Note that the base line of each triangle in the lower half of figure 1.1 spans as many days as it takes to use the 8000 units. The portion of this line on the left of the vertical spans two days, that is the supplier's production time, and that on the right of the vertical another six days which the supplier must fill as best he can with work from the same customer or from others, but at all events mainly in the interests of this regular customer. The vertical height represents the combined stock levels of supplier and customer, that is six days' usage in the present example. For all practical purposes, then, these triangles represent a situation in which transport takes no time at all and which is therefore ideal for keeping stocks as small as can be. They are very convenient for working out how stocks, production costs and risk of obsolescence are likely to be affected by increasing or reducing the batch size. The amount of stock resulting from transport time and frequency can be determined by simple addition; in the present case it is eight days' usage in all, i.e. two for production and six for transport. So much for planning situation A3, B1, in which the machine loading is dictated by the ratio of customer's usage time to supplier's production time plus set-up time.

In the present example the item only takes up 25% of the machine time, not including set-up time. The machine will have to be utilised more intensively than this to create a real planning problem. Suppose we want to start making one more item. The order for this will then have to satisfy two conditions, as follows (still referring to situation A3, B1):

(1) Allowing for set-up time, it must utilise enough of the machine time to make both items viable at prices acceptable to the customer(s).
(2) It must match the frequency of orders for item X.

To continue our example, item Y meets these conditions in that it is ordered at regular intervals of eight working days and used at the rate of 1000 items a day by the customer. Since the supplier's output is 2000 a day and $8 \times 1000 = 8000$ units are needed every eight days, it takes $8000 \div 2000 = 4$ days to produce these, with another day as set-up time. Figure 1.2 illustrates this schedule.

Example 1.2

For our second example we move from situation A3, B1 to the more fully fledged planning situation A3, B4, i.e. discontinuous production of varying quantities ordered at varying intervals. Suppose that the

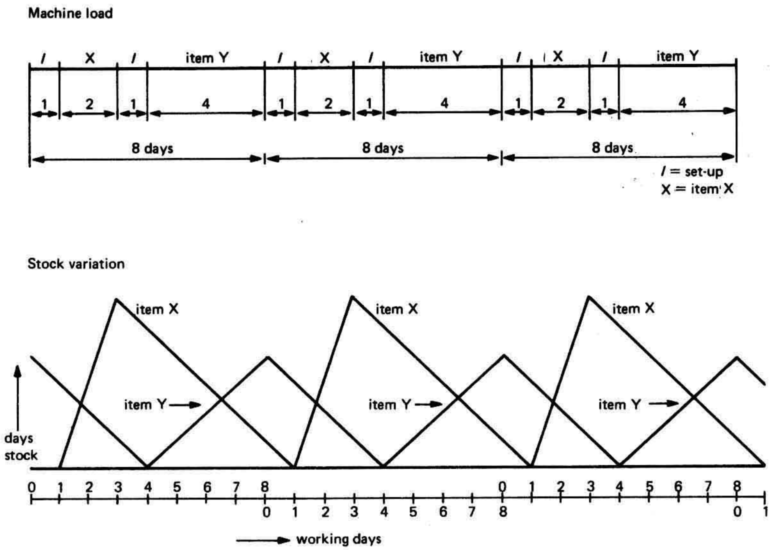

Figure 1.2 Machine utilisation and course of stocks

users, without having increased their daily usage (or sales) of items X and Y, nevertheless begin to view the future with rather more confidence and therefore ask for the batch size to be increased from 8000 to 12 000, or in other words from 8 to 12 days' demand. Out of every 12 days the supplier then devotes three to producing item X ($3 \times 4000 = 12\ 000$), six to producing item Y ($6 \times 2000 = 12\ 000$) and a day each, or two days in all, to setting up the two items, thus completing the regular orders in 11 days, i.e. with one day's capacity to spare. Because it would take that long to set up another item, this spare day counts as idle time. (How that affects the cost price will not be discussed here.)

1.2.4 Crucial formulae

It will be evident from these two examples that usage (or sales) by the customer, production by the supplier, stock fluctuation and customer's demand are interdependent. Given the customer's daily usage of units, these relationships can be defined in a few simple formulae, as follows:

$$Z = \Sigma I/(1 - \Sigma v) \tag{1.1}$$
$$V(X) = Z \times [1 - v(X)] \tag{1.2}$$
$$P(X) = Z \times v(X) \tag{1.3}$$

where Z is the demand in terms of days' usage; I is the time (days) it takes to set the machine up for the production of an item, supposing that every item made on the machine requires the same set-up time, so that $\Sigma I = n \times I$; n is the number of different items produced on a given machine during the demand period; ΣI is the total set-up time per demand period; Σv is the machine load factor stemming from all the items made in one demand period, less their set-up times; $V(X)$ is the peak stock level of item X in Z days' demand; $v(X)$ is the ratio of daily usage to daily output of item X; and $P(X)$ is the order quantity in terms of days' output of item X. (Note: these formulae are only valid where machine utilisation is 100%.)

Example 1.3

Suppose the customer manages to boost sales of item Y to 1300 a day, leaving those of item X at the original level of 1000 a day. Supplier and customer agree that the increased output must come from the same machine so as to avoid using extra tools and machines. This situation may be formulated as follows:

$v(X)$ remains at 0.25 $(1000 \div 4000)$
$v(Y)$ becomes 0.65 $(1300 \div 2000)$

So

$$\Sigma v = 0.25 + 0.65 = 0.90$$

and equations (1.1–1.3) give

$$Z = \frac{n \times I}{1 - \Sigma v} = \frac{2 \times 1}{1 - 0.9} = \frac{2}{0.1} = 20 \text{ days' demand}$$
$$V(X) = Z \times [1 - v(X)] = 20 \times (1 - 0.25) = 15 \text{ days' usage}$$
$$V(Y) = Z \times [1 - v(Y)] = 20 \times (1 - 0.65) = 7 \text{ days' usage}$$
$$P(X) = Z \times v(X) = 20 \times 0.25 = 5 \text{ days' production}$$
$$P(Y) = Z \times v(Y) = 20 \times 0.65 = 13 \text{ days' production}$$

In example 1.1 there were eight days' demand ahead with usage at the rate of 1000 items X and 1000 items Y a day, whereas now the demand period is 20 days and the daily usage 1000 items X and 1300

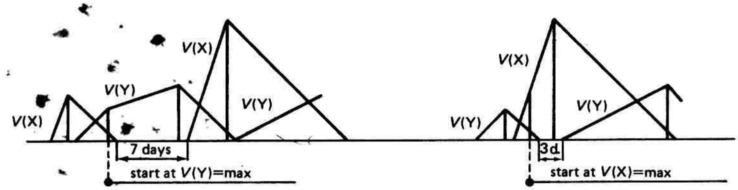

Figure 1.3 Course of stocks

items Y. In other words, the demand for both items has changed from 8 to 20 days' supply, which means that the order quantity of item X must also be drastically increased, although usage of this item remains unchanged. Moreover, figure 1.3 shows that the customer will run out of item X seven days too soon if the batch increase happens to coincide with production of item Y, or will have to wait three days for delivery of item Y if it occurs during production of item X.

1.2.5 Formulae produce amazing results

Example 1.4

Now assume that the customer wants a third item W to go into production on the same machine. In terms of hours the job is of little consequence, constituting a mere 5% of the total load. However, table 1.3 shows how much it affects the schedule. The consequences of this insignificant rise in production are amazing in that it extends the demand period from 20, to 60 days, while the supplier now finds

Table 1.3

Item	v			Demand (days)			Production (days)			Stock (days)			Price factor		
X	0.25	0.25	0.25	8	20	60	2	5	15	6	15	45	1.33	1.11	1.05
Y	0.50	0.65	0.65	8	20	60	4	13	39	4	7	21	1.33	1.11	1.05
W			0.05			60			3			57			1.05
ΣV	0.75	0.90	0.95												
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3

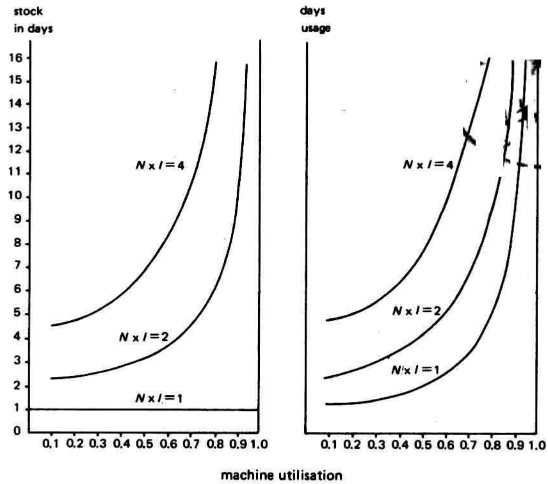

Figure 1.4 Machine utilisation against stock

that one of the items monopolises his production capacity for 15, instead of 5 days, and another for 39, instead of 13 days (three times as long). Moreover, a customer working with really minimal stock levels will initially have to wait up to 10 days for item Y, or up to 26

Table 1.4*

v	Value of Z (days)		
	$n \times I = 1$	$n \times I = 2$	$n \times I = 4$
0.2	1.25	2.5	5
0.4	1.66	3.33	6.66
0.5	2	4	8
0.6	2.5	5	10
0.8	5	10	20
0.9	10	20	40
0.95	20	40	80
0.98	50	100	200
0.99	100	200	400

* v, n, I and Z are defined on p. 9.