Many steps towards zero inventory

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Theory and Methodology

Many steps towards zero inventory

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Abstract: Zero Inventory (ZI) and Just In Time (JIT) are two of the *buzz words* that pretend to offer entirely new concepts. Industrial and commercial companies, however, have always strived for stocks close to zero. Moreover, even JIT deliveries cannot cause stocks to disappear entirely—nor is that desirable. This paper describes how a large multinational company tried to reduce its stocks along the chain from raw materials to the distribution outlets. Zero Inventory has not been achieved, but neither was it aimed. A more realistic goal is MRI, the *Minimum Reasonable Inventory*.

Keywords: Inventory; manufacturing industries; practice; JIT; ZI

1. Introduction

Not only professional journals, but newspapers, weekly magazines and the like have paid ample attention to ZI (Zero Inventory). This manufacturing concept is based on the idea that inventory is caused by inefficiency and thus a sign that something is wrong. A closely related concept is Just In Time, commonly abbreviated to JIT, i.e. the arrival of materials and semi-finished products at workstations at the very moment of actual need. Control of a JIT factory is often achieved with the aid of Kanban, a method that came to the USA and Europe from Japan. Details of these subjects can be found in many

Table 1

Main characteristics of the Just In Time approach

Objectives. JIT aims to satisfy market demands, by:

- making the kind of products needed,
- of the required quality,
- when needed,
- in the amount needed (i.e. *really* needed, not planned weeks or months ago).

Implications. Unnecessary costs must be avoided, i.e. the cost price must be minimal. In order to realize this, production will as far as possible need to strive toward:

- zero stock (batch size one),
- zero rejection rate,
- zero set-up time,
- zero machine breakdown,
- zero transport,
- zero waiting time (no stock-piling in stores).

Results.

- short throughput time
 - great flexibility of product mix,
 - high delivery reliability,
 - 100% quality
 - low price.
-

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articles and books, e.g. Schonberger [24], Hall [14] and Zangwill [32]. Table 1 lists the main characteristics of the JIT approach.

As ZI and JIT are aimed at managing operations in an optimal way, one might expect that factory managers in Europe and the USA were eager to apply these new ideas quickly when they came to their attention and that the OR community would have stimulated them in this respect. Nothing is less true. Initially, the ideas were met with reserve, even ridicule, and put aside as 'typically Japanese'. They were considered as non-transportable to Western countries. The culture, mentality and work ethics in our part of the world were regarded as so different from those of the East that ZI, JIT and Kanban would not work here.

Matters have changed since those early days. First, ZI and JIT turned out to be useful in Japanese-managed factories with non-Japanese workers outside the Land of the Rising Sun. Later on, fully western companies in the USA and in Europe started applying ZI and JIT too, and with success! (See, e.g., Im and Lee [17], Jordan [18], Sohal [25], Voss and Robinson [29].) The Philips Group always has shown great interest in new concepts. In the field we are considering here, many of these new concepts were promoted by APICS (the American Production and Inventory Control Society). Consultants representing well known firms such as Arthur D. Little (logistics); Booz, Allan & Hamilton (logistics, management information systems); Brown (forecasting); Coopers & Leybrand (MRP); Goldratt (OPT, TOC); Howard (Markov decision theory) and McKinsey (strategic planning, logistics) have helped to implement these new concepts at many points in the company. Nevertheless, the success of JIT and ZI should not be overestimated. First of all, stocks never became really zero. 'JIT warehouses' were established in the UK. They are special firms that buy materials, put them in stock, sell them to factories and deliver them JIT (Wallbank [30]). These JIT warehouses have thus created a buffer between the factories and their original suppliers, not eliminating stock keeping costs but merely shifting them to another place. Furthermore, ZI and JIT are not universally applicable: mass production with stable demand patterns and suppliers at short distances seem to form the most favourable environment for suc-

cessful application of these new concepts. Clearly, most factories nowadays are faced with working circumstances that are far from this ideal situation. It was found in practice that: "Kanban control cannot cope with (deviations in the rate of production caused by deviations on the marketing side) because it requires constantly recurring production sequences", "(...) in job shop manufacturing the Kanban-system leads to long transport routes and is difficult to survey", "In contrast to MRP, Kanban can also not be employed, or at least not economically, in (...) the production of small series because (...) there are no (...) repeated production sequences", "Kanban (...) breaks down when the demand (...) is irregular" (Fandel, Dyckhoff and Reese [7]). And finally, in places where JIT is aimed at by using Kanban, the batch size is often larger than one, so that there inventory is present in the shape of production batches and transport batches.

Theoreticians have started to analyze ZI and JIT, attempting to place these concepts on a firm basis and indicating the conditions for their validity. Zangwill [32] even goes a step further: he shows that ZI can be erroneous in its claim that reduction of set-up time always leads to a drop in inventories. In our view, his point is valid but proved by wrong arguments. While we were preparing comments to justify this opinion, a critical review of Zangwill's article (see Gerchak [12] and Zangwill's rejoinder [33]) made that superfluous.

Advocates of ZI seem to suggest that no one had thought of reducing inventories before they came along. In reality, industrial and commercial companies have always tried to keep stocks as low as possible. In Sections 2 and 3 we will describe what the Philips Group has done to this end, and what results they have achieved so far. Such a history of successive and simultaneous measures illustrates the multi-dimensional character of any attempt to reduce inventories. It also is useful as a checklist for present and future improvement programs. We do agree with the advocates of ZI that only continuous effort will get inventories acceptably low.

Our views of the future are given in Section 4. These can briefly be stated by saying that ZI will not be achieved – but no one really wants to. It is more realistic to strive for MRI, i.e., a *Minimum Reasonable Inventory*.

Figure 1. OR trademark 1961

2. Stock reduction at Philips

2.1. The company

The Philips Group is diversified, but *high-tech* electronics is the common denominator of Product Divisions such as Lighting, Consumer Electronics, and Medical Systems. The company shows a high degree of vertical integration: it produces components from raw materials, manufactures intermediate products such as tuners, assembles TV and other sets, and installs complete systems (e.g. monitoring systems in hospitals and navigation systems for harbours and airports). Philips operates worldwide, selling its products in more than 60 countries.

Our story covers a period of some 30 years: from about 1957 to 1987. In that period, the company's turnover grew from less than \$1 billion to more than \$27 billion. Total stock as a percentage of annual turnover, fell from 35–40% in the years 1958–1964 to 23% in 1987 – thanks to a concerted effort of line and staff personnel from operations and management, from production, sales, logistics and EDP departments.

2.2. Paradise and paradigm

In the late fifties and early sixties, OR workers at Philips went through a period of *Sturm und*

Drang. Paradise was almost regained. With the enthusiasm of pioneers, they adopted Exponential Smoothing for forecasting [5] and adapted the HMMS rule for production smoothing [16], all with the OR trademark of optimality in mind (Figure 1). The optimization paradigm was prevalent, though nobody knew that term then.

In practice, however, OR ideas were implemented by a few 'lone wolves' only. When they moved on to another position, the OR application they had supported was gone. Institutionalization of OR implementation in industry and comparable types of enterprise was entirely lacking, as an overwhelming number of publications testify. Here we will only mention a couple by former pioneers of OR: Churchman and Schainblatt [6] and Ackoff [1]. Both outside and inside Philips, the cause was essentially the same: a cultural gap in combination with a practicality gap between OR and the business hindered the establishment of permanent OR groups and the assimilation of the OR approach by managers. At Philips, the situation was improved somewhat later by use of built-in algorithms for production and inventory control. At that time, the company's inventory level amounted to a sizable 35–40% of turnover. But nobody really cared: business was booming – at least compared to the turbulent years to come.

2.3. The difference that makes all the difference

The above-mentioned stock levels of 35–40% are expressed in terms of the annual turnover of the company as a whole. If however we express the stock level as a percentage of the 'costs of turnover', we get a different picture. The percentage stock levels for the early sixties then range from 42–47%. The difference between these figures and the above 35–40% 'makes all the difference' between profit and loss – in the sense that if these two percentages are equal, this is a sign that turnover equals costs of turnover, so that profit is zero. Even after tax, the remaining profit

Figure 2. Flow of goods

was large enough to make the company grow: new factories almost every month, extension of the product range, recruitment of new personnel, even of OR workers.

Times have changed. Costs, especially wages, have gone up. Competition has grown harder in saturating markets. Business has become more complex, e.g. as reflected in the growth in the 'vertical integration' of the flow of goods shown in Figure 2.

2.4. Two periods

The reduction of stocks at Philips was accompanied and stimulated by many new concepts and ideas that have been amply described in the literature. Some were tried out in succession; others were introduced while their predecessor was still in the experimental phase. We now describe some of them, with emphasis on the way they were interpreted in our company and worked out by the OR workers.

Up to 1979, most of the professional OR workers at Philips were concentrated in corporate staff departments. Attempts to get their ideas accepted in practice met with only moderate success. After 1979, many activities aimed at improving manufacturing efficiency were initiated at various points within the Philips organization. The OR workers, organized in departments such as the *Centre for Quantitative Methods* (c.f. Fortuin & Zijlstra [10]) then supported these actions as external consultants.

Our description of stock reduction at Philips is split into two parts: Section 3 covers the period up to the middle of 1979, while Section 4 deals with the '80s.

3. Different ways of managing complexity

3.1. Buffering: stocks as a symbol of wealth

'Vertical integration' as an economic term was definitely not equivalent to 'integral logistics' in the early sixties. And 'goods flow' often turned out to be a euphemism for stagnation. Goods were transported in a peristaltic way from one department to the next, with long halts between moves. Philips' organizational structure was firmly based on *business functions*, and control was exe-

cuted per *department*. Many of the thousand and one parts that went into a product of even moderate complexity, e.g. a bank terminal system, had to travel a long way: raw material entered the purchasing department, followed by: store → manufacture of sub-components (e.g. metal parts) → store → transport → manufacture of components (e.g. cathodes) → store → transport → store → assembly (e.g. picture tubes) → store → transport → store → final assembly → transport → commercial warehouse → transport → warehouse of National Sales Organization → transport → customer. Efficiency of operations *per department* was the main target at a time when (1) borders were real barriers, (2) effective means of fast communication were not available and (3) the complexity of big enterprises could only be managed by compartmentalization and introduction of slacks (Galbraith [11]) such as stocks and long throughput times. However, not only the primary production process but also the decision-making and planning processes were fragmented, in order to keep them manageable. It goes without saying that organizational hierarchies and bureaucracies resulted, increasing the throughput times still further.

High inventory levels between successive links in the production chain were a consequence. This situation resulted in long delivery times. Stocks almost became a symbol of wealth to production departments, who realized their plans and met their stock norms regardless of sales and market. Often, production was controlled by inventory levels: as soon as a stock decreased because of a delivery to the next department, the preceding department started production in order to compensate for the 'loss' of inventory.

3.2. Information processing: transparency

In 1967, the idea of 'transparency' started to circulate within Philips. If the manager of each department in a production chain were to know the future demand of all downstream departments, production could anticipate that demand so that delivery would be made just when it was needed. This concept was triggered by a few ideas.

– Intuitively, managers wanted to return to a situation in which the entrepreneur could survey his business at a glance. It was expected that

computers and communication could help create this situation, even though the result would be a *conceptual* space with electronic connections rather than a *physical* one (Naisbitt [20]).

– OR, particularly the analysis of stochastic processes, showed that feedback of information on stocks, sales and other variables right from the source of the goods flow to all departments involved would reduce most of the uncertainty that resulted from basing plans and norms on the internal demand only (Forrester [8]). However, such feedback must be based on use of conditional expectations rather than historical averages (Yaglom [31]) if it is to yield much benefit (Fortuin [9]).

– Later on, Galbraith [11] worked out the concept of lateral information systems, connecting units at the same hierarchic level in organizations with a long chain of command (Thompson [28]) – as opposed to vertical information systems

supporting functionally oriented hierarchies and intended as an alternative to slacks for the management of complexity.

In response to these ideas, Philips started up a project called IPSO (Initiating Production by Sales Orders) in the late '60s (Braat [4]). The objectives of this project were to design an integral computerized information system for the flow of goods right from the purchase of raw materials to the delivery of finished products to the customer, and to analyze the operation of this system, to find out to what extent such a *product-oriented* system could reduce costs as compared with *department-oriented* systems. The IPSO project, and related projects to follow, were supposed to realize the idea of 'managing complexity through transparency' by means of computerized information systems. In so doing, EDP (Electronic Data Processing) was turned into a weapon against stocks.

Figure 3. Functions of the information system 'IPSO' and the corresponding parts of the organisation

3.3. Planning and controlling

Not only EDP, but also certain, now well known, planning and control concepts, were implemented as computerized methods in this period. Material Requirements Planning (later known as MRP-I, see Orlicky [21]), for instance, had to fight the complexity due to products and production processes. In IPSO, MRP-I was combined with control concepts and OR techniques such as closed-loop scheduling, Exponential Smoothing (Brown [5]) as a forecasting method, HMMS (a decision rule named after the authors Holt, Modigliani, Muth and Simon [16]), simulation and optimization.

This attempt to control complexity had strange effects: its results became – entirely unintentionally! – an illustration of Ashby's famous statement: "Only variety destroys variety" [3]. Figure 3 gives an impression of the IPSO lay out; this picture serves to illustrate the enormous complexity ('variety' in Ashby's terminology) of an information system designed with the very intention of managing complexity.

3.4. Organization: materials management

All efforts to reduce stocks would have had little impact without the implementation of the materials management concept. This concept was much more product-oriented than the factory organizations of that time. The latter had a largely functional structure with departments for Pro-

curement, Receipt of Goods, Storage, Manufacturing, Packing and Forwarding, each having responsibility for only part of the goods flow. This flow then looked like a steeplechase with stocks as the hurdles. The materials management concept integrated these departments, thus creating an organizational complement to systems like IPSO.

3.5. Results up to the '70s

The use of concepts and ideas described in Sections 3.1–3.4 led to some decrease in stock levels. In the seventies, these levels were between 30 and 35% of the turnover, i.e. between 33 and 39% of the costs of turnover. This success was too moderate, because the company's profit was decreasing as well. In other words: the 'difference that makes all the difference' got smaller. Moreover, the amplitude of the fluctuations in stock level and in other economic performance indicators increased. At the end of the goods-flow chain, the machine factories, fluctuations were so strong that periods of rush work alternated regularly with periods of almost complete standstill (Figure 4). As a result, profit approached zero dangerously closely.

Thorough analysis of the internal business cycle, i.e. the fluctuation of performance indicators, resulted in a theoretical understanding of the phenomenon (see, e.g., Van Aken [2]). Then came oil crises and Japanese competition. With some exaggeration, we could compare Philips at this

Figure 4. The orders issued to the Philips Machine Works by the internal customers in index figures (the original measuring unit was the number of processing hours demanded by the orders) (from: van Aken [2])

Figure 5. The approach of the '80s

point to a lazy giant attacked by fierce, agile tigers. The organization of the company had become very complex, with more factories and warehouses than ever before. Clearly, something had to be done!

4. Crusades in the '80s

4.1. A revolution in logistics

The above-mentioned circumstances forced the company to think of logistics in *all* its aspects.

New points of view were discovered, old ones rediscovered; a kind of logistics revolution took place (de Kruiff [19]):

Organization. The final aim here is very strong product orientation, 'from first supplier to the ultimate buyer'. Development, production and marketing are combined into a *business unit*, under the management of a single person who is responsible for the results of all resources placed under his command. This implies:

- no sharing of resources (staff, factories, warehouses);
- worldwide rather than national accounting (since a given business unit will normally have resources situated in more than one country);
- little functionalization: staff departments are integrated into the line as far as possible.

The implementation of the necessary changes in procedures, systems, lines of command and in particular attitudes and organizational culture requires major effort and takes a long time. This process is still under way.

Production. Batch production is gradually being replaced by continuous flow production: the optimum batch size is reduced to one in the new situation (Figure 5). This could be achieved thanks to the use of new techniques, methods and con-

Figure 6. Five basic models define the range of structures for decoupling points (from: Hoekstra and Romme [15])

cepts such as: reduction of set-up times, Kanban, total quality control, flexible productions systems and group technology.

Information. Customer orders are penetrating further into the organization. The decoupling point (the point that separates the *order-driven* part of the goods flow from the *planning-driven* part, see Figure 6) used to lie downstream from the factory, so that the principle of 'ship to order' (with delivery from stock) was applied. The decoupling point has now moved a good way upstream; typically, a minimum quantity of modules is kept in stock and the desired final products are delivered via 'assembly to order' as soon as a customer order enters the factory. This is only practicable if throughput times are very short and flexibility is high. In order to achieve such conditions, organization and production have to be changed as indicated above. Product design, the control system and the people employed must also permit the required flexibility.

Product design. To permit the above approach, products are being given a *modular* design, i.e. they are composed of basic units (modules) which can be assembled in various ways to meet different customer specifications. Modular design is based on a careful analysis of the requirements of all 'stake-holders' in a product: the customer on the one hand, and the development and engineering, production, sales, services and logistics departments on the other. A distinction must be drawn here between *customer* modules and *production* modules. The former must be recognizable for (and usable by) the customer, and will be defined in terms of function. The latter are derived from the requirements of the technical realization of the customer modules; it follows that the production modules will often differ from the customer modules. To implement a modular design, one has to create interfaces between the modules involved, accept that these interfaces will take up more space inside the product and require relatively more expensive connectors. This means that initial development will generally take longer and be more expensive than the development of monolithic products. Product families, however, can be extended more quickly if a modular approach is used. However, modular design requires standardization. These facts and the procedures and guidelines needed to achieve modularity can delay the technological renewal process

trying to follow the changing wishes from the market as quickly as possible.

Control. The concepts of Manufacturing Resources Planning (MRP-II, a grown-up version of IPSO!), JIT, and even OPT (Optimal Production Technology), also called TOC (Theory of Constraints), have been propagated in successive campaigns. Successful implementation has been found to hinge strongly on motivation and training of the personnel.

People. Training and motivation go hand in hand. Games such as the 'JIT game', developed by Philips for internal use and subsequently made available commercially, have demonstrated on the one hand the devastating effects of isolated departments, large production series, and monolithic product design. On the other hand, they have shown how feedback of information, reduction of set-up times and above all cooperation along the product axis really can create a goods flow. We wish to emphasize that success in this field is not merely the result of constant effort to improve each single aspect of the production system. Synergy plays an important role too: computerization improves the integration of electronic components which improves computers; integration of electronic components permits more modularity; modularity decreases the need for complex control systems; communication through computers and reduced complexity permit integral management and strong market orientation.

4.2. *Some progress, but not enough*

All the effort and dedication of both line and staff employees, from operations and management, in production, sales, logistic and EDP departments, produced a big jump forward. The stock level dropped to 23% of turnover, or 24% of costs of turnover, in 1987. At the same time, lead times were reduced and the reliability of delivery improved considerably. Still, there is little reason for satisfaction. The 'difference that makes all the difference' is far too small. Besides, more than \$5 billion that could be used for *high-tech* activities are frozen in stocks. The number of tigers (from the Far East) has increased, technological change is accelerating even faster than before, currencies are 'feverish' and the balances in political and economic life are delicate, threat-

ened as they are by terrorism and stock exchange crashes.

4.3. What can be done?

In the first place, more of the same is needed, i.e. full-scale implementation of the measures described in Section 4.1. Secondly, these measures have to be intensified and improved as follows:

Organization. Extension of the product axis towards suppliers and customers, leading to co-makership, co-design and co-tradership. Co-makership means extending a kind of JIT control of the goods flow to external suppliers and/or customers. Co-design means that suppliers or customers are involved in the product design process. Formal contracts are needed here to cement the relationships made possible by EDI (Electronic Data Interchange) and other means of communication. Co-tradership, finally, means that certain tasks normally performed by the wholesaler or retailer are performed by the supplier instead; service through remote (computerized) diagnosis and repair is an example of this.

Information. Further customer-order penetration, leading to 'make to order' and even 'design to order' (Figure 6).

Product design. Further reduction of the number of components by ULSI (Ultra Large Scale Integration), till e.g. a video set (receiver plus recorder) ultimately consist of no more than six parts: display unit, motor, speaker, chip, housing, remote-control unit, the latter not only for the user's convenience but also because his or her non-miniaturized fingers are too big for direct manipulation of the minute controls.

Production process. Continued automation through CAM (Computer Aided Manufacturing) and robotization, with JIT clearing the way by rationalizing the production process.

Control. Using all concepts that fit the production situation. OR can play an important part here; see Striekwold [26].

People. Education permanente.

Last but not least, completely new measures must be taken:

1. Create organizations controlled by instant global communication, where marketing, development and manufacturing are synchronized and based on shared data and networks. Companies are forced to do this to survive the current climate of fierce worldwide competition, and are enabled to do so thanks to the availability of distributed information systems, especially EISs (Executive Information Systems). Such systems provide easy-to-use means for global business teams working with up-to-date internal and external information to communicate with one another and to direct one another's attention to important facts.

2. Create the practically operator-less 'factory of the future' by farreaching automation and minimization of the number of components, or even take a step towards factory-less 'operation of the future', by replacing hardware by software, since software does not need factories for its production. This type of replacement has already started; it needs much EDP technology. Such technology is also required for automation of the goods flow, together with much OR 'tools', e.g. algorithms for extrapolation, scheduling and quality control.

3. Employ people who are "in love with change" (Peters [22]), and realize that "change

Figure 7. Future flow of goods

must be added to death and taxes as inviolate certainties" (Synott [27]).

4.4. A daring scenario

Returning to the basic theme of this paper, the reduction of stocks at Philips, we can sketch the following likely picture:

Planned stocks will be zero, because the EOQ will become equal to one and flexible manufacturing systems will make safety buffers superfluous, except from some stocks on the co-trader's shelf.

Stocks in the pipeline will only be enough to satisfy a few days' demand. In the case of a global marketing strategy, further reduction is unrealistic, as it would require an unacceptably high share of the available resources.

Work In Process will only be significant where added value is put into the products of the future. This will be especially the case in the fields of high-process technology (VLSI, chips) and high-systems technology (telecommunications). High-tech innovation is a way to gain a competitive advantage through product differentiation. Then the manufacturing process will be on the first part of the learning curve, and losses are inevitable due to limited process control.

A conservative estimate (i.e. one possibly erring on the high scale) of the throughput times for the future flow of goods is given in Figure 7. Taking into account the average value of the products in the chain from raw material to customer, we foresee a total stock level of 10% of the turnover or 11% of the costs of turnover in the year 2000. Since we expect the company's turnover to have reached the \$50 billion mark by that year, this difference is acceptable.

5. Concluding remarks

Cost leadership is one of the strategic options for a company that wants to achieve a strategic advantage (Porter [23]). Here ZI can be a great help. However, many companies are forced to apply a mixed business strategy: cost leadership in one field, product differentiation through high-tech innovation or global marketing in others. Today, the entrepreneur has to reconcile different goals, very carefully he has to allocate his scarce resources. In case of a global market, he will have to cope with 'work in transport'. Operating at the frontier of the IC-technology, he is faced with the inevitability of lengthy and partly uncontrollable manufacturing processes that exclude 'zero work in process'. There it may even happen that the manufacturing process leads to products with specifications that have to wait for future customers.

Table 2 recapitulates the steps by which we expect Philips to reach not ZI but what we like to call MRI (Minimum Reasonable Inventory). This name implies that efforts to decrease stocks below this level will not be worth their while, given the strategic situation of the company. Other challenges will have much impact on life in industry. For instance complexity (see Grünwald and Fortuin [13]), of which we seem to have lost sight, will become a problem of immense importance. Global communications, shared computer networks and shared data, more sophisticated algorithms as a basis for management decisions, penetration of co-makers and co-traders into the organization (JIT on a global scale), are but a few of the "hot items" characterizing this issue. Fighting complexity is both a challenge and an opportunity for the systems approach, which OR will undoubtedly have taken up by the year 2000.

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Table 2
Steps towards a Minimum Reasonable Inventory

Era	Turnover (T%)	Turnover Costs (C%)	Ratio (C / T)
1958–1964	35–40	42–47	0.84
1970–1985	30–35	33–39	0.90
1987	23.9	24	0.95
2000	10	11.2	0.91

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