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An Overview of Inventory Management with Some Suggested Research Topics

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This paper presents an overview of inventory management. This includes a categorization, by a number of dimensions, of inventory problems and associated models. Relevant literature references are provided within the dimensions. The paper points out the continuing gap between theory and practice, followed by a number of suggested research topics to help bridge the gap.

Keywords: Inventory Management, History, Tutorial, Research Agenda

1. Introduction

The Editor, Dr. Ilkyeong Moon, asked me to prepare a paper on a topic of broad interest to the readership of this journal. I had earlier written a manuscript (Silver, 2008a) for a special issue of *INFOR*, on the general area of inventory management but with an emphasis on Canadian research and application accomplishments. With the permission of the Editor of *INFOR,* the current paper uses much of the material from the *INFOR* publication, but with the removal of most of the Canadian emphasis. Additional, more general, references have been introduced but the resulting list of references is still somewhat biased to the works of Canadian authors (including myself).

In the next section I limit my scope of coverage of inventory management. Some brief historical remarks are included in Section 3. Then, Section 4 deals with an overview of inventory management including the various objectives of, and constraints and relevant cost categories faced by inventory managers (and their advisors). Next, Section 5 provides a possible classification (by a number of dimensions) of inventory management problems and associated models. Subsequently, Section 6 is focussed on a critical issue that I have emphasized throughout my career, namely the continuing need to bridge the gap between theory and practice. This naturally leads into the topic of Section 7, specifically some suggestions regarding future research. Finally, the paper ends with a brief summary section.

2. Limiting the Scope of Coverage

Most organizations involved in the management of inventories are faced with making decisions for large numbers (1,000's, 10,000's or 100,000's) of individual items in the face of a diverse collection of factors (e.g., demand patterns, modes of shipment from suppliers, and methods of delivery to customers) and constraints (e.g., budget limitations, vendor restrictions, and desired customer service levels). The three key questions that inventory management attempts to answer on an item-by item basis are :

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i) How often should the inventory status be determined, that is, what is the review interval?
ii) When should a replenishment order be placed?
iii) How large should the replenishment order be?

Of course, an aggregate perspective is needed for top management e.g. across a population of items what are the projected total average dollars in stock, the average overall service level and the replenishment workload? There are also broader (system design) questions e.g. which items to stock at all (the so-called "assortment problem"-Agrawal and Smith 2003, Kok and Fisher 2007) and in a multi-location situation at which locations to carry stocks of specific items.

Inventory management problems often interact with other areas of operations or supply chain management. Examples include:

i) provision of raw materials for production scheduling,
ii) production of inventories of finished items constrained by aggregate output rates determined by medium range production planning,
iii) inventories needed for service activities,
iv) selection of the locations and capacities of warehouses,
v) the modes of transportation to be used for inbound and outbound shipping (Higginson and Bookbinder 1994, Henig *et al*., 1997),
vi) the effects of pricing, promotion and other marketing decisions, and
vii) the choice of suppliers.

An excellent reference on decisions in supply chain management is Pyke and Johnson (2000). Except for recognizing the constraints on inventory management implied by the above interactions, as well as bringing some of them into the classification scheme in Section 5, I shall not elaborate further on them in this paper. In particular, this means that the topics of MRP and production scheduling will not be covered. Moreover, no attempt will be made to treat demand forecasting, a subject that obviously interacts with inventory management.

3. A Brief History

One could argue that inventory management principles can be traced back at least to biblical times as evidenced by the story of Joseph interpreting the Pharaoh's dream as being seven years of plentiful harvests followed by seven years of crop failures and his associated advice to the Pharaoh to stockpile enough harvested grain during the plentiful years to ensure adequate food during the subsequent famine. In terms of published professional material probably the earliest article (laying out the principles of the economic order quantity) was by Harris (1913) as reported by Erlenkotter (1990). Military applications and the formation of associated research teams (e.g. the RAND Corporation in the USA and the Defence Research Board in Canada) led to considerable research and development work after World War II. In particular, all of K. J. Arrow, A. J. Clark, S. Karlin, H. E. Scarf, H. M. Wagner and T. M. Whitin were affiliated with RAND. One of the earliest papers in this era was Arrow *et al*. (1951). Other important publications in the 1950's, with at least elements related to inventory management, included Dvoretsky *et al*. (1952a, 1952b, 1953) Karr and Geisler (1956), Wagner and Whitin (1958), several articles in Arrow *et al*. (1958a, 1958b), Galliher *et al*. (1959), Simpson (1959), and Scarf (1959). From the 1960's onward there was a rapid proliferation of publications, some of which will be mentioned later, in a wide range of outlets.

Text books on inventory management began to appear in the 1960's. Early examples included Wagner (1962), Hadley and Whitin (1963), Naddor (1966) and Brown (1967). In addition, Eilon and Lampkin (1968) published a compilation of abstracts of papers that had appeared in the period 1953～1965.

My initial employment, after obtaining my doctorate from M. I. T., was as a member of the Operations Research Group at Arthur D. Little (ADL) Inc. (1963～1967). On my very first day on the job Robert Brown gave me a number of his working memoranda and convinced me to become involved in a major study related to the development of IBM's Inventory Management Program and Control Techniques (IMPACT) inventory system. Brown's pragmatism (including the use of heuristics) in solving real inventory problems had a major impact on the orientation of my entire career. Many of the research problems, on which I have worked, have stemmed from consulting studies both while at ADL and in later years. Another major source has been through workshops where, as part of the registration process, I have specifically asked the participants to list one or two problems of interest to them. (See Silver 2008b for further details regarding sources of research topics.) One of my colleagues at ADL was Harlan Meal, the co-author of what became known as the Silver-Meal heuristic (Silver and Meal 1969, 1973).

4. An Overview of Inventory Management

Of necessity there is considerable duplication here and in later sections of material that I have written in Silver (1981a) and contributed to the book Silver *et al.* (1998). Other recent textbooks have been authored by Axsäter (2006) and Zipkin (2000).

I'll first discuss objectives and constraints of interest to inventory managers, followed by relevant cost categories. Then, in the subsequent section, a classification (dimensions) of problems and associated models will be laid out.

4.1 Objectives and Constraints

The possible objectives of concern to inventory managers include:

i) Cost minimization (with or without discounting)
ii) Profit maximization (with or without discounting)
iii) Maximization of rate of return on stock investment
iv) Determination of a feasible solution
v) Keeping at an acceptable level the amount of human effort expended in the management and control of inventories
vi) Ensuring flexibility to cope with an uncertain future
vii) Minimizing political conflicts (in terms of the competing interests) within the organization
viii) Maximizing the chance of survival of the individual manager's position or of the firm itself

Most published modelling has focussed on only the first objective. The several possible constraints include :

i) Supplier constraints - minimum order sizes, restrictions to certain pack sizes, maximum order quantities (particularly under allocation schemes in times of tight supply), restrictions on replenishment times.
ii) Marketing constraints - minimum tolerable customer service levels, where service can be measured in a number of ways.
iii) Internal constraints - storage space limitations, maximum budget to be used for purchases during a particular period, maximum workload (number of replenishments per period), personnel involved (capabilities and attitudes).

As Eilon (1979) has remarked, there is often little difference between certain objectives and internally imposed constraints; for example, maximization of rate of return versus specifying a minimum acceptable rate of return. Realization of this point can have an important bearing on the modelling process as well as on the applicability of the solution obtained. Related to this point, later in the paper I shall suggest more frequent use of exchange curves that show the aggregate consequences (across a population of inventoried items) of using a particular inventory management strategy. The consequences are shown in terms of a tradeoff between two or more measures of interest to top management.

4.2 Relevant Costs

Basically there are four categories of costs relevant to inventory decision making, namely i) replenishment costs, ii) carrying costs, iii) costs of insufficient supply in the short run, and iv) system control costs. Again, from a managerial perspective these costs, aggregated across populations of items, are of more interest than on an individual item basis. (See Chapter 3 of Silver *et al.*, 1998 for a more complete discussion.)

4.1.1 Replenishment Costs

These are the costs incurred each time that a replenishment action is taken. It is convenient to express the costs as the sum of two parts : i) a fixed component, often called the setup cost, independent of the size of the replenishment; and ii) a component that depends on the size of the replenishment, in particular, including the cost of the material itself.

4.1.2 Carrying Costs

Having material in stock incurs a number of costs including : i) the cost of borrowing the capital tied up or foregoing its use in some other investment, ii) warehouse operation costs, iii) insurance, iv) taxes, and v) potential spoilage or obsolescence. Most models in the literature assume that these costs are proportional to the average inventory level (where the latter is often measured at only the end of each review instant in a periodic review situation.) However, in actual fact, certain components may be related to the inventory level in a more complicated fashion. For example, the cost of borrowing capital may be more a function of the *maximum* amount borrowed, particularly when revenues generated by sales cannot be used in the short run to pay off the debt.

4.1.3 Costs of Insufficient Supply in the Short Run
When inventory levels are insufficient to routinely satisfy customer demand, costs are incurred, whether or not they are explicitly measured. Unsatisfied demand leads to immediate costs of backordering and/or lost profit on sales. In addition, such poor service can have a longer range cost impact through loss of good will. Finally, many companies, in the short run, will take almost any possible action to avoid shortages, e.g., expediting, transshipment from another stocking location, procurement from a competitor, or substitution of a more costly item.

4.1.4 System Control Costs
This crucial category of costs has often been ignored in the inventory theory literature. It includes the costs of acquiring the data necessary for the adopted decision rules, the computational costs and other costs of implementation (including training and the possible adverse behavioural effects of a new system). The costs of changing plans (so-called system nervousness) also fit in this category (Yelig and Mackulak 1997).

It is relatively easy to list the categories of costs as has been done above. However, their measurement in practice is a different story. In particular, accounting costs, primarily developed for other purposes, are usually inappropriate for inventory decision making purposes. Shortage-related costs, often not even shown in accounting records, are particularly difficult to measure. This has led to the frequent use of a surrogate service level constraint, which only implicitly specifies a shortage cost. There are equivalencies between certain service measures and shortage costs (Boylan and Johnston 1994 and Silver *et al.*, 1998). Exchange curves (mentioned earlier) can be used to portray aggregate tradeoffs between measures of interest (e.g., average inventory level versus number of stockout occasions per year) as one varies the value of a so-called policy variable such as the implicit cost per unit short per unit time.

5. Dimensions of Inventory Management Problems and Associated Models

Any model is an abstraction of reality. The idea is to have the model capture the essence of the real world problem in a parsimonious fashion, i.e. the model should be both effective and efficient. The following classification (by some eight dimensions) of inventory management problems should be useful for research and application purposes. However, I recognize that such a scheme runs the risk of stimulating research of a very incremental nature in that there are such a large number of distinct combinations of assumptions regarding the various dimensions. I also mention that there is some overlap among the dimensions. Only some of the many possible references are provided, including my own work. In each case the references are listed alphabetically.

5.1 Single versus Multiple Items

Can each item be considered in isolation for decision making purposes? Item interdependencies (multiple item problems) can take on a variety of forms including :

- an overall constraint on budget or space used by a group of items. (Goyal 1975, Minner and Silver 2005, 2007, Moon and Cha 2006, Moon and Silver 2000, Silver and Moon 1999, Zhao *et al.*, 2007).
- coordinated control to save on replenishment costs. Possibilities here include group discounts, situations where a major setup cost is incurred if any member of a family of items is replenished, and circumstances where items share the same transportation mode (Atkins and Iyogun 1988a, 1988b, Goyal 1973, 1988, Iyogun 1991, Jackson *et al.*, 1985, Miltenburg 1987, Miltenburg and Silver 1984a, 1984b, Nilsson and Silver 2008, Silver 1965a, 1974, 1976a, 1981b, Thompstone and Silver 1975, Viswanathan 2002). Lee (2003) pointed out that one of the benefits of vendor managed inventory is

in the latter context.

- substitutable items - when a particular item is not in stock, the customer may be willing to accept a substitute product (Agrawal and Smith 2003, Kok and Fisher 2007, McGillivray and Silver 1978).
- complementary demand - certain products tend to be demanded together; in fact, the customer may not accept one without the other (Agrawal and Smith 2003, Brumelle and Granot 1993, Teunter 2006).

The discussion of another important type of interdependency, namely multiple stocking points, will be covered under a later dimension.

5.2 Time Duration

In some situations (e.g., style goods, newspapers) there is a relatively short selling season (or period) and remaining stock cannot be used to satisfy demand in the next season (or period). This decoupling effect simplifies the analysis compared with the multiperiod case. When the time horizon extends well out into the future and there is considerable uncertainty, a pragmatic approach is to use a rolling horizon implementation. At the start of each time period the current decisions are made only considering (the most recent) information for a relatively small number of periods in the future. These current decisions are implemented and the problem is resolved at the beginning of the next period (Alscher and Schneeweiss 1987, Bookbinder and H'Ng 1986, Martel *et al*., 1995).

5.3 Number of Stocking Points

Sometimes it is appropriate to treat a single stocking point in isolation. However, in many organizations inventories of the same item are kept at more than one location. In multiechelon situations (Bossert and Willems 2007, Cohen *et al*., 1990, Cohen *et al*., 1986, Gallego *et al*., 2007, Jackson and Muckstadt 1989, Martel 2003) the orders generated by one location (e.g., a branch warehouse) become part or all of the demand on another location (e.g., a central warehouse). In addition, one can have horizontal multiplicity, that is, several locations at the same echelon level (e.g., several branch warehouses) with the possibility of transshipments and redistributions. (Archibald 2007, Cao and Silver 2005, Jackson 1988, Jönsson and Silver 1987a, 1987b, Kutanoglu 2008, Minner *et al*., 2003). Supply chain management concepts, such as the pooling effects of centralized inventories (Benjaafar *et al*., 2005, Jackson and Muckstadt 1989, Tagaras and Cohen 1992), or delayed product differentiation (Caux *et al*., 2006, Graman and Magazine 2002, Lee *et al*., 1993, Silver and Minner 2005), are relevant here.

5.4 Information and Control

In multi-location problems (including a single stocking point, but incorporating the supplier(s) and/or customers) how much sharing of information (such as end-item demand, inventory status, and planned replenishments) occurs across and up/down the supply chain (He *et al*., 2002, Zhao 2002)? Is control centralized or decentralized (Axsäter *et al*., 2002)? What incentives (contractual and otherwise) are in place to facilitate collaboration?

As Lee (2003) has noted, e-business provides new opportunities in areas such as efficient procurement, the use of secondary and spot markets, auctions and mass customization (see also Bichler and Steinberg 2007). Here we see some overlap with revenue management considerations (McGill and van Ryzin 1999).

5.5 The Nature of the Product and the Type of Demand Process

Is the product consumable, perishable and/or recoverable/repairable? What generates the demand? Are there primarily external customers or is there internal usage? Is the item used as a spare part for regular maintenance and/or repair? References related to spare parts include Aronis *et al*., (2004), Cohen and Kamesan (1990), Cohen *et al*., (1989), and Kutanoglu (2008). Are we talking about an end item or a component of two or more other items? (Agrawal and Cohen 2001, Baker *et al*., 1986, Gerchak *et al*., 1988, Humair and Willems 2006, Jans *et al*., 2008, Jönsson *et al*., 1993, Jönsson and Silver 1989a, 1989b).

Are life cycle considerations important? Is it a new item, or is it in its growth phase, in its mature phase, or is it facing declining demand? In addition, what are important influences on the demand in a specific period? These can include marketing decisions (promotions, special pricing), competitor actions, general economic conditions, seasonal effects, and so on. Is the demand primarily from a captive market or is there a significant chance of losing sales/consumption when demands take place during an out-of-stock situation? Are there different classes of customers that have to be distinguished (Arslan *et al*., 2007, Wang *et al*., 2002)?

There are a number of possible choices in modelling the demand process. For simplicity in exposition I'll ignore most of the aforementioned issues and assume that demand is to be modelled as just a function of calendar time. The possibilities include :

- deterministic, level demand
- deterministic, but varying in a known way with time (Brosseau 1982, Goyal *et al*., 1996, Jans and Degraeve 2008, Silver 1979, Silver and Meal 1969, 1973, Silver and Miltenburg 1984)
- known stationary distribution with known parameters - commonly used distributions include the normal, gamma (Burgin 1975, Das 1976), Poisson and negative binomial (Agrawal and Smith 2003). There are also special cases such as slow movers (Cohen *et al*., 1986, Dolgui and Pashkevich 2008) intermittent demand (long periods with no demands - see Willemain *et al*., 2004) and erratic demand items (small size transactions mixed with occasional, much larger ones - the compound Poisson distribution can be useful here - Archibald and Silver 1978, Kukreja and Schmidt 2005, Silver 1970, Silver *et al*., 1971, Vincent 1985). The so-called "known" parameters are in fact usually estimated from sample data (Silver and Rahnama 1986, 1987, Strijbosch and Moors 2005).
- known stationary distributions but with parameters not assumed known - Bayesian methods can be used in this context (Aronis *et al*., 2004, Dolgui and Pashkevich 2008, Miltenburg and Pong 2007a, 2007b, Murray and Silver 1966, Silver 1965b).
- unknown stationary distribution - There are two possible approaches. One is to use distribution-free methods (see for example, Moon and Gallego 1994) while the other is bootstrapping which involves repeated sampling from limited historical data (see, for example, Bookbinder and Lordahl 1989, Willemain *et al*., 2004).
- non-stationary, probabilistic demand - Strictly speaking, most practical demand patterns are in this category, but associated mathematical models become very complicated in terms of data requirements, computational needs and user understanding (Bookbinder and H'Ng 1986, Bookbinder and Tan 1988, Brill and Chaouch 1995, Gelinas *et al*., 1995, Martel *et al*., 1995, Pujawan and Silver 2008, Silver 1978, Song and Zipkin 1993).

5.6 Procurement Cost Structure

The unit value of an item may depend upon the size of the replenishment. This may be a result of a supplier discount or it can come about through freight consideration, e.g., truckload versus less-than-truckload (Arcelus and Rowcroft 1992, Das 1990, Elhedli and Benli 2005, Hu *et al*., 2004, Sethi 1984). In some cases the so-called fixed cost of a replenishment may actually be semivariable. For example, if the dollar value of a replenishment is high enough, special contract regulations and approval procedures may be needed. Other complexities can include special procurement opportunities, on a one-time or repeating basis, (Arcelus and Srinivasan 1995, Aucamp and Kuzdrall 1989, Goyal *et al*., 1991, Moinzadeh 1997, Naseraldin and Silver 2007, Silver *et al*., 1993), as well as credit terms, i.e. non-zero payment periods (Arcelus and Srinivasan 1993, Carlson *et al*., 1996, Goyal 1985, Robb and Silver 2006, Silver and Costa 1998). In addition, costs in general can change over time, e.g. due to inflation (Buzacott, 1975) or process improvement (Moon 1994, Porteus 1986, Silver 1993).

5.7 Nature of the Supply Process

There is some overlap here with Sections 5.3 and 5.5. Also some of the supplier constraints were previously mentioned in Section 4.1. Repeating, the latter include minimum and maximum order sizes (Robb and Silver 1998), restriction to integral packs or truckloads, restrictions on available times at which replenishment requests can be processed, etc.

Another important factor is the replenishment lead time. Possible assumptions here parallel those related to the demand process, viz. :

- there is a known lead time associated with each replenishment
- a replenishment arrives after a random lead time - The type of probability distribution and its parameters may or may not be assumed known (Robb *et al*., 2007, Tyworth *et al*., 1996, Wang and Hill 2006).
- there may be seasonal effects on the lead time such as the impact of freezing and thawing on the movement of supplies to the Canadian far north (Silver and Zufferey 2005).
- can the lead time be affected by, for example, expediting actions (Duran *et al*., 2004)?

In addition, what happens at the end of the lead time? Is the entire requested amount or a randomly differing quantity received (so-called yield variability - Li *et al*., 2008, Parlar and Perry 1995, Sepehri *et al*., 1986, Silver 1976b, Wang and Gerchak 1996)? Also, there may be interruptions in supply such as weather-related, strikes, equipment breakdowns, scheduled downtimes, and so on (Parlar and Perry 1995).

The supplier may be severely capacitated, usually in a manufacturing context (Baker *et al*., 1978, Dixon *et al*., 1983, Dixon and Silver 1981, Jans and Degraeve 2008, Jönsson and Silver 1985, Wang and Gerchak 1996). In such a case can capacity be reserved ahead of time (Costa and Silver 1996, Jain and Silver 1995)? Is there more than one supply option (combination of supplier and transportation mode) available? If so, it may be profitable to simultaneously use two or more of these options (Kelle and Silver 1990, Mishra and Tadikamalla 2006).

Are used items returned, possibly in conjunction with demands for new (or refurbished) items (Craig and Silver 1972, Kelle and Silver 1989)? Can the returned items be resold or reused (e.g. containers) after possible minor adjustments/repairs? Here one is into issues of recycling, reverse logistics, conversion of units, etc. (Fleischmann and Kuik 2003, Guide and van Wassenhove 2006, Moon *et al*., 2006, Silver and Moon 2001a, 2001b, Teunter *et al*., 2004).

5.8 Shelf-Life Considerations

Obsolescence or deterioration of stock may be important considerations. Obsolescence represents the situation where the stock is still in appropriate physical condition but can no longer be sold at anywhere near its original price (usually due to the appearance of a new competing product such as in electronics). Deterioration or perishability signifies that for legal and/or physical reasons the stock can not be used for its original purpose after the passage of a certain length of time, an example being the distribution of whole blood (Abad 1996, Arcelus *et al*., 2006, Emsermann and Simon 2007, Silver and Costa 1998, van Donselaar *et al*., 2006).

Disposal of stock (possibly still generating some net revenue) becomes an option to prevent obsolescence or perishability. Even when the latter are not relevant, disposal may be useful to compensate for errors in forecasting, record keeping, order placement, and so on (Rosenfield 1992, Silver and Willoughby 1999).

6. Bridging the Gap Between Theory and Practice

Throughout my career in teaching, research and consulting, I have pointed out that a substantial gap exists between the theory and practice of inventory management and I have personally strived to help narrow it. A discussion of a number of reasons for the existence of the gap was presented by Zanakis *et al*., (1980). The following are some suggestions for bridging the gap :

i) More attention should be devoted by analysts to formulating an accurate model and obtaining a good solution rather than getting the optimal solution to a mathematically interesting, but possibly unrealistic, formulation of the practical problem. In this regard heuristic solution methods are worthy of more consideration. (For an overview of heuristic methods see Silver 2004.)

ii) More research should be focussed on transient, rather than steady state, conditions. The latter, although much more analytically tractable, are becoming less and less relevant due to shortening life spans of products as well as widespread implementation of continuous process improvements (Silver 1993).

iii) More emphasis should be placed on achieving consistency in decisions and on demonstrating improvements over current performance. An understandable decision rule that improves somewhat on current conditions is almost certainly better than the optimal solution that is neither understood nor accepted by management (Woolsey 2006).

iv) More attention should be devoted to the aggregate consequences of inventory decision rules. Top and middle managers, who are usually responsible for the go-no-go decision on a new system, are much more interested in the aggregate consequences than in the performance on an individual item basis. Exchange curves (Gardner 1987, Silver *et al*., 1998) are useful tools in this connection in that they show the tradeoffs between aggregate measures of interest (e.g., total safety stock versus total stockout occasions per year) for different possible decision systems.

v) There is a need for easily understood procedures, particularly in smaller organizations. Spreadsheets (Grossman 1999, Roy 1989) and other implementation aids, such as graphical and tabular displays (Das 1984, Silver 1991) should be more widely used.

vi) More attention should be given to the behavioural aspects of inventory management. A crucial phase of any effective OR study is convincing the decision maker and those providing the data that the decision system is aiding, not replacing, them and that it is in their interest to cooperate.

vii) More research effort should be directed to problems whose solution would be of significant benefit to practitioners. Some associated suggestions are presented in the next section.

7. Some Suggestions Regarding Research Topics

In this section I suggest a number of research topics in inventory management. For another, somewhat overlapping, perspective see Wagner (2002).

i) Dealing with what Wagner calls "dirty" demand data (caused by stockouts, promotions, unusually large customer orders, competitor actions, and so on) and limited lead time data from a non-stationary environment.

ii) Other non-stationary situations including the impacts of changing the givens and continuous process improvement.

iii) Coordinating decisions with those regarding depth of product line, vendor selection, transportation options, pricing, etc.

iv) Continued investigations in support of coordinated decision making (including contracts, incentives, and so on) in situations involving multiple (both vertical and horizontal) stocking points.

v) The impacts of e-business opportunities on inventory management (see the last paragraph of Section 5.4).

vi) Practical methods that incorporate recycling and conversion of returned or unused units.

vii) Dynamic realistic representation of the impact of commonality of components (modular design).

viii) Postponement (both form and location) opportunities.

ix) Inventory management as part of a coordinated response to a major disaster (health, weather- related, and so on).

x) Addressing the markedly increased ability to produce customized items to order - two examples are the use of digital technology and customer ordering via the Internet permitting production to order of software, reports, books, etc. (see, for example, OnDemandBooks.com) and nanotechnology providing the ability to build items (including spare parts) to demand.

8. Summary

In this paper I have provided an overview of inventory management, including a dimensional classification of inventory problems. Following a review of the continuing gap between theory and practice I suggested a set of research topics, the resolution of which, I believe, would have major impacts on the performance of organizations throughout the world.

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