INVENTORY MANAGEMENT: A TUTORIAL, CANADIAN PUBLICATIONS, PRACTICAL APPLICATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

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ABSTRACT

This paper first presents a tutorial overview of inventory management. This includes a categorization, by a number of dimensions, of inventory problems and associated models. Relevant Canadian contributions to fundamental and applied theory are listed within the dimensions. Then substantial evidence is provided of widespread Canadian applications of inventory management. 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, applications, research agenda

1. INTRODUCTION

As part of the Special 50th Anniversary issue of INFOR the special editor, Gilbert Laporte, invited me to prepare a paper on inventory management that included a tutorial overview, important Canadian contributions (with a requested emphasis on my own work), and some significant future research issues. Given the vast inventory management literature the preparation of the Canadian contributions (both research and applications) portion proved to be a daunting task. I have attempted to include the important work of Canadian residents (and a few individuals who, I believe, spent significant time in Canada but now reside elsewhere). My
reporting is obviously not all inclusive and I apologize to authors whose relevant work I have overlooked.

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. Canadian applications are the topic of Section 6. Subsequently, Section 7 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 8, 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:

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”) 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 (Berman et al, 1993)
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),
vii. 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 BIT OF HISTORY

Where this paper is part of a special issue to celebrate OR accomplishments over a number of years, I thought it appropriate to provide a little additional history in two senses. First, there is the history of inventory management, not restricted to the Canadian context. Second, I’ll briefly discuss some historical elements of my own career.

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
several articles in Arrow et al (1958a, 1958b), Galliher et al(1959), Simpson (1959), and Scarf
(1959). It is noteworthy that much of this activity occurred precisely during the period in which
CORS originated. 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.

Now I’ll provide a little bit of history regarding key events related to my involvement in
inventory management research, consulting and education. I learned about operational research
late in my undergraduate education in civil engineering at McGill and held an OR summer
position in 1959 (having nothing to do with inventories) with the Defence Research Board in St.
Hubert, Quebec. During my doctorate at M.I.T. I did take a course related to inventory
management, but my thesis topic was on Markovian decision processes.

My initial employment after graduation 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 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 (2008) for further
details regarding sources of research topics). One of the studies, in which I was involved while at ADL, was for the International Grenfell Association which at the time provided medical and welfare support for the communities in northern Newfoundland and Labrador. My role in the study was to provide guidance regarding the ordering and distribution of supplies. 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)).

I returned to Canada in 1969 as one of the founding faculty members of the Department of Management Sciences at the University of Waterloo. One of my first assignments was to develop a new graduate elective course whose contents included inventory control/management. That course and my consulting and research experiences led to the co-authoring of Peterson and Silver (1979). To give an indication of how long I have been involved in the field of inventory management, there was a significant period where programmable calculators played an important role (Silver (1979c)).

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 focused 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. 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.)

(a). 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.

(b) 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.

c) 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.

d) 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.

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 (Oral, 1981 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. 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. Many references are provided including my own work and that of other Canadian citizens/residents. In each case the references are listed alphabetically. I also wish to explicitly mention John Buzacott who has made major research contributions, primarily related to manufacturing situations (e.g. Buzacott and Shantikumar, 1993), but with inventory management implications.
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. (Dixon and Poh (1990), Goyal (1975), Minner and Silver (2005, 2007), Moon and Silver (2000), Silver and Kelle (1989), Silver and Moon (1999)).
- substitutable items – when a particular item is not in stock, the customer may be willing to accept a substitute product (McGillivray and Silver (1978), Parlar and Goyal (1984)).
- complementary demand – certain products tend to be demanded together; in fact, the customer may not accept one without the other (Mamer and Smith (1982, 1985)).

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 (Bell, 1978). When the horizon extends well out into the future and there is considerable uncertainty present, a pragmatic approach is to use a rolling horizon implementation. At the start of each period the current decisions are made only considering (the latest) information on a relatively small number
of periods (horizon) in the future. These current decisions are implemented and the problem is resolved at the beginning of the next period (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 (Atkins and Sun (1995), Cohen and Kamesam (1990), Cohen et al (1986), Gerchak and Gupta (1991), Goyal and Gunasekaran (1990), Goyal and Gupta (1989), Iyogun (1992), Iyogun and Atkins (1988), Jackson and Muckstadt (1989), Martel (2003), Pyke and Cohen (1990, 1994)), 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. (Cao and Silver (2005), Jackson (1988), Jönsson and Silver (1987a, 1987b), Minner et al (2003)). Supply chain management concepts, such as the pooling effects of centralized inventories (Jackson and Muckstadt (1989), Tagaras and Cohen (1992), Tyagi and Das (1998)), or delayed product differentiation, (Graman and Magazine (2002), 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 (end-item demand, inventory status, planned replenishments) occurs across and up/down the supply chain (He et al (2002), Jönsson and Silver (1987))? 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. Here we see some overlap with revenue management considerations (Bell, 1998).
5.5 The Nature of the Product and the Type of Demand Process


Are life cycle considerations important? Is it a new item, in its growth phase, mature, or 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 (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
- known stationary distribution with known parameters – commonly used distributions include the normal, gamma (Das, 1976), Poisson and negative binomial. There are also special cases such as slow movers (Cohen et al, 1986) intermittent demand (long periods with no demands) and erratic demand items (small size transactions mixed with occasional, much larger ones – the compound Poisson distribution can be useful here) (Archibald (1981), Archibald and Silver (1978), Presman and Sethi (2006), 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).

- known stationary distributions but with parameters not assumed known – Bayesian methods can be used in this context (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, 1994).
- 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)).

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 (Abad (1988), Arcelus and Rowcroft (1992), Bregman and Silver (1993), Das (1984, 1990), Goyal (1995), Hu et al (2004), Kuzdrall and Britney (1982), Parlar and Wang (1994), 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 (1986, 1989), Goyal et al (1991), 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 (1999), Silver and Costa (1998)). In addition, costs in general can change over time, e.g. due to inflation (Buzacott, 1975) or process improvement.
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 (Das (1975), Robb et al (2007)).
- there may be seasonal effects on the lead time (Silver and Zufferey, 2005)
- can the lead time be affected by, for example, expediting actions?

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 - Bar-Lev et al (1994), Gerchak et al (1988), Henig and Gerchak (1990), Parlar and Perry (1995), Sepehri et al (1986), Silver (1976b), Wong 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), Jönsson and Silver (1985), Millar and Yang (1994), Wang and Gerchak (1996)). In such a case can capacity be reserved ahead of time (Costa and Silver (1996), Jain and Silver (1995), Silver and Jain (1994))? 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).

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 (Silver and Moon, 2001a, 2001b), etc.
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), Jain and Silver (1994), Silver and Costa (1998)).

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 (Silver and Willoughby, 1999).

6. SOME CANADIAN APPLICATIONS

In this section I present evidence of substantial Canadian applications of inventory management. I apologize for not including other relevant material that was not brought to my attention or that I have inadvertently overlooked.

Several individuals responded to my request for examples of practical applications. For each I show the source of the information, by whom the (consulting) studies were carried out and an alphabetical listing of the client organizations:

i. W. J. Hurley (Hurley and Balez, 2008) – Canadian Army (ammunition requirements planning).

ii. Robert Lamarre (Gestion Conseil Robert Lamarre et Associés Inc.) – Abitibi Consolidated, Agence Métropolitaine de Transport, Alcan, Atlantic Ferguson, Association du Transport Urbain du Québec, Aur Ressources (Louvicourt), Autostock, Avon, Barrick Gold, Bombardier (I also served as a subcontractor on part of this work), Brewers Warehousing, Buro Plus, Cambior, Cantrex, Carling O’Keefe, Cascades, CDMV, Centre du Rasoir, CIBA Geigy (Novartis Pharma) Canada, CNR, Day & Ross,

iii. Russ McGillivray (KPMG Consulting and BearingPoint) – Canadian Bearings Inc., Grand & Toy, Future Shop, Ontario Ministry of Natural Resources (Forest Fire Management Program – study jointly done with Dave Martell), Royal Canadian Mint, United Farmers of Alberta, Van Waters & Rogers Canada.

iv. Rein Peterson (personal consulting) – Ciba-Geigy

v. Alan Saipe – Baxter Healthcare (KPMG LLP), Connaught Labs (internal study), Grand & Toy (Saipe & Associates), IBM (Stevenson & Kellogg), Kal Tire (KPMG Consulting), Lipton’s (Stevenson & Kellogg), Osram Sylvania (KPMG LLP), Rothman Benson & Hedges (Saipe & Associates), Schneider Electric (Saipe & Associates), Umbra (Saipe & Associates), Vincor (KPMG Consulting).


Another application, at Barber Ellis Fine Papers, was reported by Bookbinder et al (1989). Also two of the individuals who provided input, Robert Lamarre and Russ McGillivray (both former graduate students under my supervision), indicated that they had developed quite general software systems related to inventory management.

Besides assisting in the development of applications for clients, my own consulting experience has involved the presentation of in-house workshops on inventory management for a number of organizations including Bata Ltd., Canadian National Railways, Caremart Group of Independent Pharmacists, Department of National Defence, General Fasteners Ltd., and Novacor Chemicals Ltd.
There are two other sources of evidence of Canadian inventory management applications. Both are the consequences of annual activities of CORS, namely the Omand Solandt Award (presented to an organization) and the CORS Competition on the Practice of OR. In both cases the information available to me was very limited. For the Solandt Award I only had a listing of the organizations, while for the Practice Competition there was just a listing of the winners and the titles of their papers. Here are the Solandt winning organizations that are likely to have made use of inventory management models and systems: J.D. Irving (2005), Tigrsoft (2000), Dofasco (1999), Imperial Oil (1993), Consolidated Bathurst (1988), Suncor (1985), Department of National Defense (1984), and Canada Packers (1978). Similarly, the following are prize winning entries in the Practice Competition (with the associated year indicated) that almost certainly involved inventory-related issues:


7. 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 the gap. 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 void:
i. More attention should be devoted by analysts to formulating an accurate model and obtaining a good solution to it 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 lifespans 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. Diagnostic tools can be helpful in this regard (Saipe, 1979). 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 management, 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 (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), Raby et al (1991)) and other implementation aids, such as graphical and tabular displays (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.
8. 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. Impact of nanotechnology and the associated ability to build items (including spare parts) on demand.

9. SUMMARY

In this paper I have provided an overview of inventory management, including Canadian contributions to fundamental and applied theory, listed within a dimensional classification of inventory problems. Subsequently a broad range of Canadian applications were listed. 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 in Canada and elsewhere.

In summary, Canadians can be rightfully proud of their contributions in both research activities (that have led indirectly to advances in practice) and applications in the field of inventory management in the 50 year period since the founding of CORS. Exciting opportunities remain for future developments.

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