

INVENTORY MANAGEMENT

Non-Classical Views

Edited by
MOHAMAD Y. JABER



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INVENTORY MANAGEMENT

Non-Classical Views

Industrial Innovation Series

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Dedication

To the soul of my father, and to my wife and sons

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Preface

Inventory is perhaps the most interesting and most researched topic of production and operations management. Inventory is important since it affects our lives; it is everywhere as household inventory, social inventory, and business inventory. Inventory provides flexibility, but it comes at a cost. Fortunes are tied up in inventory and managing it properly is vital for the success of an enterprise.

The earliest scientific inventory management approach dates back to the second decade of the past century (F. W. Harris. 1913. How many parts to make at once? *Factory: The Magazine of Management* 10(2), 136–152), with its golden era in the 1950s and 1960s. The models and concepts viewed inventory as an asset, one that can be converted to cash. This is the view of the classical school of thought. The classical paradigm aims to minimize the total cost of inventory. As markets become more dynamic and competitive, companies are pressured to remain responsive and efficient. In response to these pressures, companies have been making changes to their production and inventory systems. This includes the introduction of new technologies and philosophies, such as just-in-time (JIT), that advocates inventory is a waste and must be reduced. This is the view of the modern school of thought. Despite the differences between the two schools of thought, they both try to answer the two fundamental questions, which are how much to order and when to order. These inventory decisions are usually based on cost parameters that are misleading. Although the classical paradigm, which characterizes both schools of thought, has been successful for years, the question of whether its assumptions are still valid has yet to be answered. In addition, the classical paradigm focused on developing and analyzing inventory models with no regard to the confluence of managerial factors that may affect it directly or indirectly. Furthermore, the emergence of supply chain management and reverse logistics as tools that provide sustainable competitive advantages for companies, and changes in the economy and business activities, require researchers to think outside the classical box of inventory management.

The dire need for a new paradigm has been noted by Professor Attila Chikán, the first vice president and secretary general of the International Society for Inventory Research (ISIR); as well as by other researchers (e.g., Professors M. Bonney and L. G. Sprague). In a recently published paper based on 20 years of ISIR symposium papers, Chikán (2007. The new role of inventories in business: Real world changes and research consequences. *International Journal of Production Economics*, 108(1–2), 54–62) concluded that inventory cannot be managed independently of other company functions, nor can it serve as a buffer between functions and processes, and that cost alone is a misleading performance measure. Recently, the eighth ISIR Summer School organized by Professor Lucio Zavanella and held at the University of Brescia, Italy, had the general theme: “New and Classic Views in Inventory Management:

Advances in Research and Opening Frontiers.” The aim was to encourage contributions focusing on emerging trends in inventory studies. The idea to have an edited book on nonclassical views in inventory management, therefore, comes at an appropriate time to feed this emerging interest.

This edited book is unique in collecting emerging works on nonclassical inventory management that feed into the new paradigm. It makes a suitable reference for graduate students and researchers in the areas of inventory theory and management, and supply chain and logistics management.

This book consists of nine chapters.

Chapter 1 introduces and tests a new paradigm of the role of inventories in the operation of business enterprises.

Chapter 2 examines the coverage of inventory issues and concepts in the most popular finance/financial management textbooks.

Chapter 3 examines the relationships between inventory and the environment and discusses how inventory planning could help to alleviate some of these environmental effects.

Chapter 4 aims at showing how energy is related to stocks (and vice versa) and how it may influence them.

Chapter 5 focuses on supply chain management issues from the perspective of the hospital.

Chapter 6 focuses on developing an inventory management strategy for a warehouse supporting a complex emergency relief operation.

Chapter 7 explains how viewing inventories as queues provides a new cause and effect analysis of what creates excessive inventories in industrial systems.

Chapter 8 provides a review of the application of fuzzy set theory in inventory management.

Chapter 9 reviews and discusses the models that use thermodynamic reasoning to model inventory systems.

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Editor

Mohamad Y. Jaber is a full professor of industrial engineering at Ryerson University, Toronto, Canada. He obtained his Ph.D. in manufacturing and operations management from the University of Nottingham, United Kingdom. His research expertise includes modeling human learning and forgetting curves, workforce flexibility and productivity, inventory management, supply chain management, reverse logistics, and thermodynamic analysis of inventory systems. His research has been supported by the Natural Sciences and Engineering Research Council (NSERC) and the Social Sciences and Humanities Research Council (SSHRC) of Canada. He has published more than 60 articles in internationally refereed journals, including *Applied Mathematical Modeling*, *Computers & Industrial Engineering*, *Computers & Operations Research*, *European Journal of Operational Research*, *Journal of Operational Research Society*, *International Journal of Production Economics*, *International Journal of Production Research*, and *Production Planning & Control*. His industrial experience is in construction management. He is an area editor for *Computers & Industrial Engineering* and is on the editorial boards of the *Journal of Operations and Logistics*, *Journal of Engineering and Applied Sciences*, and *Research Journal of Applied Sciences*. He continues to serve as a member of the program/advisory committees for the *Annual International Symposium on Supply Chain Management* and the *International Symposium on Logistics*. He is a member of the *European Operations Management Association*, *Decision Sciences Institute*, *International Institute of Innovation, Industrial Engineering and Entrepreneurship*, *International Society for Inventory Research, Production & Operations Management Society*, and *Professional Engineers Ontario*.

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1 A New Inventory Paradigm *Conceptual Basis and Survey Results**

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* This article is an integrated, extended, and advanced version of three earlier papers by the author: Chikán (2007), Chikán (2008), and Chikán (2009). Parts of the text of these papers are used here with permission of the editor of *International Journal of Production Economics*.

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1.1 OVERVIEW

This chapter introduces and tests a new paradigm of the role of inventories in the operation of business enterprises. It starts out from the fundamental research results of the 1950s, and analyzes the traditional paradigm formulated in this period, called the golden age of inventory research. However, changes in the economic and business environment led to the emergence of the need of a different approach. The proposed new paradigm is introduced and its relation to the traditional one is outlined. Two surveys were conducted among Hungarian managers to test the validity of the new paradigm—one survey among manufacturing managers and another among logistics managers. The results are supportive, showing that managers' thinking mostly corresponds to the logic of the new paradigm. There are a lot of further research opportunities stemming from the paradigm proposition.

1.2 INTRODUCTION

History of researching inventories shows a very interesting pattern. There are peaks and drops both in time and by functional areas, and one can meet extreme stand-points about their importance in the economy and in business.

This chapter puts down the foundations of a new paradigm for researching inventories. We have enough information about the turn of the century changes in enterprise management to put business inventories in a new perspective, getting them out of the passive role assigned to them for decades and including them as an active part of company strategy. The increasing interest in practical inventory management (measured for example by the number of downloads of inventory-related items on the Internet) and in inventory research (see the growing number of participants at inventory conferences and sessions) clearly express the importance of a revival of the best traditions when some of the best minds of economics and management research focused at least part of their interest on inventories.

Our starting point is the golden age of inventory research in the 1950s. We will discuss the paradigm that served as a foundation of research in this era. This traditional paradigm was based on the characteristics of economic and managerial thinking of the time, and served its function very well for decades. However, as the economic and business environment changed, the need for a new paradigm has emerged. This chapter describes the changes in the environment and introduces the elements of a proposed new paradigm.

It is explicitly stated in the exposition of the new paradigm that it has to be validated in practice. Managers' views are tested in two surveys, results of which are summarized in the second part of the chapter. One of the surveys was completed among manufacturing managers, the other one among logistics managers. The survey results support the new paradigm, but further research is necessary for its full elaboration.

1.3 THE TRADITIONAL PARADIGM OF INVENTORY RESEARCH

I think everyone agrees that the golden age of inventory research was in the 1950s. This was the time when both conceptual and mathematical models of inventories were first formulated, following the sometimes interesting but basically very simple approach of earlier decades (Sprague 2000). Whitin (1957) had a truly classic conceptualization of inventory management, but even operations research (OR) hardliners contributed to conceptual clarification (the article most referred to is probably Ackoff [1956]). The fact that some of the best minds in economics and OR joined inventory researchers helped both conceptualization and mathematical formulation of the inventory problem, with the most important contributions coming from Stanford University (Arrow, Karlin, and Scarf 1958; Scarf, Gilford, and Shelley 1963). A summary and analysis of this age is in Girlich and Chikán (2001). A rich collection and analysis of the classical models can be found in Chikán (1990). The most quoted book on managerial applications is Silver and Peterson (1979 and further editions).

It is interesting that economists contributed to development of models that we would now call OR models; very little attention to inventories is attributed to mainstream economics. Perhaps there are understandable reasons for this continuing negligence of inventories in economic research. However, attempting discovery of these reasons is beyond the scope of this chapter. Here I concentrate only on business-level approaches, with reference to some cross-effects between the two study fields.

1.3.1 PILLARS OF THE TRADITIONAL PARADIGM

The traditional paradigm of inventory research is based on three pillars:

1. Inventories can be handled and optimized independently of other managerial circumstances (such as logistics, operations, or financial resources). This assumption made it possible to treat inventories as a single, controlled variable of a feedback control system, where demand is the diverting variable and the order placed is the regulating variable. All are within the inventory system and independent of other fields of company operation. Classical inventory models are mostly based on these control principles. It is worth mentioning that even though models were interpreted mostly on the SKU (stock-keeping unit, i.e., "item") level, this concept can be extended to the company level, handling total inventories of the company as an unstructured volume.

2. The main role of inventories is to serve as a buffer to be used to
 - a. smooth business processes, most of all production and sales; and
 - b. maintain a flexible connection between the various organizational units (e.g., shops, factories, depots, etc.) of the company.

The first role is connected to the actual physical processes going on within the company, whereas the second role refers mainly to the managerial (control) processes. These two roles are obviously connected, but they can be clearly distinguished.

3. The performance measure of operation of the inventory system is the level of total cost associated with the sum of holding and replenishing inventories and to handling shortages. In this concept the independency paradigm is reflected, based on the *ceteris paribus* principle. It is assumed that all other things being equal (which assumption can be valid in the case of the subsystems), inventory management can contribute to the increase of profit (the objective of the company as a whole) if it keeps its costs as low as possible. This approach is justified by defining holding cost so that it includes the opportunity cost of inventory investment, for example, by calculating with the average (or, depending on company policy, the marginal) return-on-investment ratio of the company.

1.3.2 EVALUATION OF THE TRADITIONAL PARADIGM

The traditional inventory paradigm was a consequence of some fundamental assumptions about the operation of the business enterprise. These assumptions came primarily from the economics literature. The most important ones are:

- The profit maximizing company, which made the cost-based decisions justified and did not allow the use of noncost measures
- The economies of scale principle, which made use of the independency principle possible by considering inventory decisions as solely volume-dependent and not seeking economies of scope
- The conventional linear organization structure (the existence of functional silos), which again supported the independency principle by making coordination with other functional areas possible and necessary only at the highest level of the hierarchy

The traditional paradigm played a key role in inventory research of several decades after the 1950s. Some of the most important consequences of its application are:

- We learned a lot about item-level inventory systems; by the 1970s we knew practically all we know today about their operation, management, and decision problems.
- There were only few attempts to synthesize this knowledge. Two books of the 1960s must be mentioned: *Analysis of Inventory Systems* (Hadley and Whitin 1963) and *Inventory Systems* (Naddor 1966) are probably the most often cited works. Both are excellent books, but they deal with special classes of inventory models.

- The new management concepts of the period were very negative toward inventories; they handled them only as residua, that is, consequences of managerial decisions focusing on other issues like sales, production, or distribution. Both material requirements planning (MRP) and just-in-time (JIT)—in the extreme—led to the zero inventory illusion or at least to a business atmosphere where inventories were considered as a (not so) necessary evil.

The diffuse character of inventory research and the lack of synthesis are well reflected in the survey made by the International Society for Inventory Research (ISIR; see Chikán [2002a, 2002b]), where respondents were asked to name the most influential papers or books in their research area. There were fourteen items listed by the respondents to this question, and no work was mentioned twice.

A large number of mathematical models was published in this period, but during this time there were very few notable publications about actual managerial issues and business approaches. This led to a situation in the 1970s–1980s when there was a growing and gradually more deeply perceived gap between theory and practice.

Studies of the golden age of inventory research almost totally neglected inventory problems beyond item-level optimization. The ruling paradigm, and especially the assumption that inventory can be managed independently of other functions, did not make it necessary to examine cross-effects of item-level decisions and their relationship with other decisions regarding production, marketing, and so forth; it seemed to be enough to refer to the *ceteris paribus* principle. Classical works of the time did not even refer to the overall inventory problem of the company; adding the item-level optimums was considered to fulfill the job of company-level optimization. However, this common understanding was more or less implicit. The literature barely referred to the potential problems caused by cross-effects of inventories. (The logic used in the OR literature was analogous to the one used by economists who assumed that the model-company's behavior can be extended to the economy as a whole. This logic is reflected in Carzo [1958]). Researchers accepted that item level models express company behavior, however it has not been shown to be an optimal aggregate inventory management rule (Whybark 1994).

It should be noted that the business framework for analyzing the role of inventories was also missing. In the 1970s there were few new results in the “theory of the firm,” and even less in something that could be called the “theory of business.” However, many of the classical works that we consider fundamental for understanding the general theoretical background of business were published in the period being discussed. Readers may refer to Putterman (1986) and Foss (1997) for a review.

In the same period, several new management concepts and methods were introduced. The most important ones were MRP and JIT, of which at least a side effect should have been reductions in inventories. However, studying inventory data of the period shows that although these methodologies proved successful in many individual company cases, they did not reduce inventories at the level of national economies (Chikán 1994; Bivin 2006). This indirectly suggests that there had been processes going on in the economy since the 1980s–1990s that counterbalanced inventory

reduction efforts. This can be considered as a sign of a need for a new business paradigm of inventories, which takes over the old cost-minimizing, inventory-reducing approach.

1.3.3 CONCEPTUALIZATION AND INCORPORATION OF BUSINESS CHANGES BY ACADEMIC RESEARCH

It necessarily took some time before the research community could have conceptualized these changes. There is a special relationship between business practice and research, which is not common in most areas of academic studies. The essence of this relationship is that new, innovative business practices mainly come from actual business life—they precede and not follow research results. The reason for this is that business is under so much pressure to innovate that practitioners are far faster in seeking and introducing new ways of doing things than any other segment of society. The common order of events is:

1. A company introduces a new approach, some innovation that corresponds to the requirement of the changing environment. The need to fit the environment is a fundamental thesis of organization theory (for the contingency approach, see Lawrence and Lorsch [1967]).
2. The new ideas spread rather fast; companies learn from one another in their everyday connections, at business conferences, and so forth. Companies jump on copying the innovations (frequently with the help of consultants, who are among the first to notice new developments and trigger changes). Further developments may follow one of three ways, depending on the actual success of the new approach in practice:
 - a. After some time it may turn out that the new idea is a fad, not leading to serious results.
 - b. The overall results may be mixed: a new approach can result in good practice at some companies and may prove useless or even harmful at other companies. This is because very frequently the initial application of a new approach is not connected to a prudent analysis of the actual conditions under which a new approach can be successful.
 - c. The third case is when a new approach proves to be so successful in such a wide range of cases that business accepts it practically as part of common knowledge.
3. Academic research explains and generalizes empirical research: in case of a fad or a full success it explains why they happened; in case of mixed results it identifies the conditions of successful application.

This approach can be argued. Even though it is supported by long-term observation of business developments, I am sure that there are a lot of exceptions. To illustrate: From among innovations widely known by people dealing with inventories, I would consider BPR in the first, JIT in the second, and MRP in the third category (see a, b, and c above) calling attention again to possible exceptions.

In the aforementioned process, there is an accumulation of knowledge that indicates two things:

- a) As the application of new approaches spreads over a given field of management (like marketing, human resources [HR], and inventory management), after some phases, the new approaches may integrate into a new paradigm. A new paradigm for me means a fundamentally new way of thinking about the given management field, which includes different actual principles and practices as well. (The classical reference to paradigm shifts is Kuhn [1996].)
- b) Academics have a special role in the process. Compared to businesspeople, they are certainly slow-moving individuals. In business research, academics are more followers than path breakers. However, academics still play a crucial role in business innovation in two respects:
 - They actually explain the developments, help to find the answer to whether a given new idea is a fad or a really useful new idea, and whether the idea is generically beneficial or its usefulness is connected to some special conditions or circumstances.
 - Academic research is indispensable in carrying out the integration of new knowledge into a new paradigm. It does the job of conceptual analysis and generalization; and tests views via empirical studies. Without these two steps no meaningful statement about paradigm changes can be formulated.

1.3.4 EMERGENCE OF THE NEED OF A NEW PARADIGM

As mentioned, the positive effect of the existence of the “old” paradigm was that for the end of the 1960s–beginning the 1970s we knew a lot about the nature and structure of the item-level problems as negative feedback control systems; just in time to give way to a new era that was made necessary by the appearance of MRP systems, with explicit reference to the dependent demand inventories and company-level (or at least product-line-level) optimization. Of course, research on the item-level problems did not disappear, especially since MRP systems actually were in need of models to support lot-sizing decisions.

The appearance and success of MRP systems was mainly a result of the development of information technology and information systems (for the roots and development of MRP systems, see Chikán and Sprague [2008]). MRP was followed by MRP II and distribution requirements planning (DRP), making it even clearer that inventories do not just stand alone but are closely and complexly connected to other company functions. (This idea has already been analyzed by the duly famous Holt et al. book [1960], which was a forerunner of the new approach. A recent exposition of the interfaces between inventories and other functions is given in Stenger [2008].)

The emergence and spread of the JIT concept was a final nail in the coffin of the dominance of the item-level approach in management of inventories. Since JIT simply questioned the fundamental common understanding that inventories are

valuable assets of the company, it became explicit that inventories are dependent on the organization of the company as a total entity, and that they can be reduced by the efficient organization of interaction of purchasing, logistics, production, and distribution—practically the whole “real sphere” or “material sphere” of the company. It is common that some authors of that time (e.g., Babbar and Prasad [1998]) practically identified the inventory problem with JIT issues. This seemed to support the practice-based view already known from earlier times that inventories are not managed at all; they are simply residuals of managerial decisions in other fields (mainly in sales and production). There is a lot of anecdotal evidence to support this view, which is 180 degrees different from the classical paradigm of inventory decisions. However, I could not find any research that should have proven that. Instead I believe that Sprague and Wacker (1994) and Whybark (1994) had it right: calling attention to the difference in hierarchy of those who make company-level strategic decisions and those who control actual inventories at a much lower hierarchical level. This duality leads to the appearance of two different approaches: a rather definite inventory reduction approach at the executive level, and a more balanced view at the tactical control level. The former bases its approach mainly on financial return considerations and because inventories, at least at first glance, show slow return on investments (since they mean inactive tying up of capital), it is a natural policy requirement to keep them low. However, the interest of low-level managers is completely different. They do not care much about company-level financial return; they are concerned about service levels, production disruptions, shortages of supply, and so forth, and they are actually accountable for these. Therefore, their concept of “optimal” level of inventories is very different than that of their high-level bosses.

Of course there is a trade-off between the two approaches, which can be expressed by balancing the advantages and disadvantages of holding inventories at the two levels described—the strange thing is that there was little, if any, said about that in the inventory literature. Instead there appeared numerous articles and books on “zero inventory,” which is a nonsense concept even if the authors in most cases do not mean it literally.

The above reasoning supports the need of a new inventory paradigm that takes into account the built-in duality of inventory management and makes it necessary to examine both levels and their interactions. There must be room in this new paradigm for both quantitative, mathematical models and approaches, and qualitative, organizations-oriented research.

The traditional paradigm provides a sound basis for the former; unfortunately, we have much less historical background for conducting organizational studies of inventory management.

Most companies cannot afford the talent of sophisticated inventory control systems: neither the well-researched and -developed forecasting techniques, nor the performance measures, which would connect the company level and the tactical management level, are affordable at an average company. As Bonney (1994) puts it: “But successful inventory reduction appears likely to be limited to the relatively small number of organizations which can provide the commitment to improving their whole systems.” Also, despite the development of information technology

(IT) companies use unsophisticated inventory accounting, which prevents the meaningful connection between the physical and monetary approach to inventories. (I think this is an important component of the macroeconomic “mystery” that interest rates do not influence inventories; see Blinder and Maccini [1991].) Lean inventory management is a nice slogan. Unfortunately, this approach far too often loses sight of the fact that anybody can reduce inventories. The question is the price of this reduction, the often hidden costs of not having inventory on hand. As Sprague and Wacker (1994) put it: “firms do not want inventories ‘per se’ but want the benefits that inventories can bring.” That is why I strongly agree with the practitioner’s view: “smart, not lean inventory management will define leaders” (Lawton 2003). It is exactly this smart management that needs the support of a new inventory paradigm. Indeed there are more and more signs of the appearance of this need. This is expressed quite clearly by Miller and Deis (2007). They are consultants with extensive practitioner experience who conclude their paper on aggregate inventory management by saying: “Inventory can be systematically managed.” Similarly, Barry (2007) starts his paper with the sentence: “Inventory management and forecasting are strategic issues.” These practitioners and consultants clearly indicate the need of a new inventory paradigm. Indeed, the elements of this can be already found in their communication. What is needed is a systematic, scholarly formulation of this paradigm. This is explicitly requested in Invatol (2008): “Despite the many changes that companies go through, the basic principles of Inventory Management and Inventory Control remain the same. Some of the new approaches and techniques are wrapped in new terminology but the underlying principles for accomplishing good inventory management and inventory activities have not changed.”

The new paradigm formulated in this chapter may put down the foundations of an appropriate approach. The interest of practitioners can be clearly seen by the huge number (sometimes thousands) of clicks on the inventory management sites of the Internet.

1.4 FUNDAMENTAL CHANGES IN THE GLOBAL ECONOMY

There is very rich literature on changes in the global economy over the past several decades; it is not the purpose of this chapter to discuss this in detail. I only summarize those dimensions of changes that, according to my view, have had the most important influence—directly or indirectly—on inventory management.

1.4.1 TODAY’S ECONOMY

The following characteristics of today’s economy are useful for discussion of the new inventory paradigm:

- *Service economy*: The requirements of today’s customers are not simply to buy some products and services, but to obtain “solutions” to their problems. This means that companies must offer a combination of products and services.