MANAGING SERVICE INVENTORY IN THE SUPPLY CHAIN

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MANAGING SERVICE INVENTORY IN THE SUPPLY CHAIN

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Christopher Allen Boone graduated from Dyersburg High School in 1989. He enlisted in the United States Air Force in 1990 and served for five years as a military public health technician. During this time, he earned an Associate of Science degree in Environmental Medicine from the Community College of the Air Force and graduated with honors from Faulkner University in Montgomery, Alabama, with a Bachelor of Business Administration degree in 1993. In 1995, he was commissioned a Second Lieutenant in the United States Air Force. Over the next four years, he held several positions at locations in California and Tennessee. In 1999, he attended the Air Force Institute of Technology's Graduate School of Engineering and Management in Dayton, Ohio. He was a distinguished graduate, earning a Master of Science Degree in Logistics Management. Upon graduation, he was assigned to the Air Force Logistics Management Agency where he conducted research aimed at improving logistical support for wartime and peacetime military operations. In August 2003, he began pursuit of his Doctorate degree, entering Graduate School, Auburn University. Upon graduation, he will be assigned to the Defense Energy Support Center.

DISSERTATION ABSTRACT

MANAGING SERVICE INVENTORY IN THE SUPPLY CHAIN

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Services have become an increasingly important part of the U.S. economy. This move has forced many companies to shift their focus from simply improving product manufacturing and product delivery to improving product service and customer satisfaction. The effective and efficient repair of a failed system or product is one important way of improving service and satisfying customers. To provide the necessary repair, managers must ensure the availability of the right service parts at the right points within the supply chain. Thus, the management of service parts is becoming increasingly important and has already grown into a nearly $700 billion a year business, representing approximately 8% of the gross domestic product of the United States.

This dissertation research effort incorporates three distinct yet related research efforts, each exploring a different aspect of the evolving role of service parts inventory management in today's supply chain environment. The first effort utilizes a field-based comparison of a system approach to service parts inventory management and a traditional item-based approach to service parts inventory management. Results suggest that a system-based approach to service parts management is more effective in reducing the number, duration, and magnitude of service part related disruptions than the more traditional item-based approach. The second effort relies on a Delphi panel of service parts experts to highlight the most critical challenges of service parts management. Consensus was achieved amongst the panel members regarding the ten most critical challenges and opportunities for future research were proposed. The final effort relied on a grounded approach to identify the challenges and objectives of service parts management and resulted in the development of two descriptive models. Each model presents a broad perspective and provides a basis upon which future research can build.

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I would like to express my deepest love and gratitude to my wife and our two children for their unending support and encouragement throughout this process. I thank God daily for blessing me with such an amazing family.

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Like most significant milestones in one's life, the completion of this dissertation represents the culmination of countless influences and endless encouragement from family, colleagues, and professors. I owe special thanks to Mr. Bernie Smith for his unending support and friendship. I also want to thank the other members of my dissertation committee, Dr. Brian Gibson and Dr. Anand Nair, for their helpful suggestions. Finally, I want to thank the United States Air Force for providing me the opportunity to pursue a dream.

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CHAPTER 1

INTRODUCTION

Researchers and practitioners continue to face the age-old challenges associated with inventory level setting and replenishment. However, the realities of the environment in which these challenges must be met, is evolving. The popular cliché, that the competitive battleground is shifting from organization vs. organization to supply chains vs. supply chain, is now perceived to be a reality (Srinivasan, Srinivasan, & Choi, 2005). Effective supply chain management has become a prerequisite to gaining and retaining a competitive advantage (Moberg, Cutler, Gross, & Speh, 2002; Power, Sohal, & Rahman, 2001).

As researchers and practitioners move from the traditional view of enterprises as separate, independent entities towards more collaborative models (Singh, 2005), the management of inventory increases in importance. The planning and control of inventories and related activities are vital to managing a supply chain (Jones & Riley, 1985). This is especially true for service-based supply chains.

Services have become increasingly important as the driving force in the U.S. economy (Ellram, Tate, & Billington, 2004). Worldwide competition, declining finished good sales, and dwindling profit margins have forced many companies to shift their focus from simply improving product manufacturing and product delivery to improving product service and customer satisfaction (Vigoroso, 2005).

One important means for keeping customers satisfied is to provide quick repair of a product or system that has failed. While customer service may not be the principal way to attract customers, it is frequently a reason for losing them (Sandvig & Allaire, 1998). To provide the necessary repair, enough parts, often referred to as "spare parts" or "service parts", have to be available at appropriate points within the supply chain to guarantee the desired service level (Botter & Fortuin, 2000). Thus, the management of service parts is becoming increasingly important (Pfohl & Ester, 1999). Service parts has already grown into a nearly $700 billion a year business representing approximately 8% of the gross domestic product of the United States (Patton & Steele, 2003).

The objective of this dissertation research effort is to investigate the evolving role of service parts inventory management in today's supply chain environment. To facilitate this effort this dissertation will follow a publication-style format. The publication-style format serves two main purposes. First, it is well suited for students who intend to pursue academic careers soon after completion of the dissertation. The format allows for more timely transition from dissertation completion to journal submission. Second, the publication-style format provides an opportunity to complete multiple efforts within a single program of research.

This dissertation has a total of five chapters. However, the contents of each chapter vary from that of a traditional dissertation. Chapters 2, 3, and 4 of this dissertation represent three distinct yet related efforts centering on inventory replenishment in the supply chain. Each chapter is intended to stand alone and includes its own introduction, literature review, study description, analysis, and opportunities for future research. Chapter 5 will conclude the dissertation by summarizing this research effort and its contributions to the field.

The first portion, "Measuring the Impact of a Systems Approach to Service Parts Inventory Management on Supply Chain Disruptions: A Field Experiment." is a direct response to the need for empirical evidence supporting the adoption of a system-focused approach to service parts inventory management (Lee & Billington, 1992). Most traditional approaches to inventory management rely on simple formulas to balance inventory costs while setting levels for individual items (Sherbrooke, 1992). This item-level approach lacks a system perspective, which is a key component of the supply chain philosophy (Mentzer et al., 2001). The study uses a series of field experiments to examine the impact of a system-focused approach to inventory replenishment on the number, duration, and magnitude of supply chain disruptions.

The second portion, "Critical Challenges of Inventory Management in Service Parts Supply Chains: A Delphi Study," uses a web-based Delphi panel of inventory practitioners to identify the most critical challenges of service parts management. The objective of this effort is to use the important and pragmatic perspective of practitioners as a guide for researchers seeking to contribute to the knowledge and understanding of service parts management.

The final portion, entitled "Exploring the Dynamics of Service Parts Management: A Grounded Approach", builds on the results of 18 semi-structured interviews with senior managers from commercial and government organizations involved in service parts management. The research provides insight into the dynamics of service parts management. Specifically, the paper uses a grounded approach to develop a set of models describing both the diverse challenges and interconnected objectives associated with service parts management. These models act as broad frameworks and will serve as guides for future research endeavors.

Together, the three components represent a unified body of research providing valuable new insights into the practice of service parts inventory management.

CHAPTER 2

MEASURING THE IMPACT OF A SYSTEMS APPROACH TO SERVICE PARTS INVENTORY MANAGEMENT ON SUPPLY CHAIN DISRUPTIONS: A FIELD EXPERIMENT

Abstract

Service parts management is becoming increasingly important, having already grown into a nearly $700 billion a year business. A failure to effectively manage service parts can create disruptions and have a detrimental impact on the entire supply chain. Despite this growth in value and importance, many organizations continue to rely on simple, item based approaches to service parts inventory management. Item based approaches are often ill suited for situations in which strategic or service focused objectives, like those associated with service parts management, are sought. A more holistic or system based approach to inventory management is needed.

Using a quasi-experimental design, this exploratory field study empirically investigates the performance of two different approaches to inventory management within a service parts supply chain. The study uses field data to assess the performance of a system based approach to service parts inventory management. Results from nine test locations and one control location suggest that the system approach investigated is effective in reducing both the number and duration of supply chain disruptions.

Introduction

Effective supply chain management has become a prerequisite to gaining and retaining a competitive advantage (Moberg et al., 2002; Power et al., 2001). As a result, the planning and control of inventories and related activities has grown in importance and is now a key to effectively managing a supply chain (Jones & Riley, 1985). This is especially true for service-based supply chains. The service sector now accounts for more than 80% of total employment in the United States (Fitzsimmons & Fitzsimmons, 2006). Worldwide competition, waning finished goods sales, and shrinking profit margins have forced many companies to seek service-based revenue models, shifting their focus from simply improving product manufacturing and product delivery to improving product and service and satisfaction (Vigoroso, 2005).

While customer service is not the only way to attract customers, it is frequently a reason for losing them (Sandvig & Allaire, 1998). Customers are slow to forget when a major system or piece of equipment sits idle due to the lack of a service support (Sandvig & Allaire). Further, it has been shown that superior after sales service can increase both first time and repeat sales (Cohen & Lee, 1990).

To provide the necessary after sales service, enough parts, often referred to as "service parts," have to be available at appropriate points within the supply chain to guarantee the desired service level (Botter & Fortuin, 2000), forging a link between service part availability and a reputation for good customer service (Ashayeri, Heuts, & Jansen, 1996). Service parts management is therefore becoming increasingly important (Pfohl & Ester, 1999). Service parts have already grown into a nearly $700 billion a year business, representing approximately 8% of the gross domestic product of the United States (Patton & Steele, 2003).

The management of service parts inventories presents some unique challenges when compared to the management of manufacturing inventories (Kennedy, Patterson, & Fredendall, 2002). Service parts are typically expensive, demand for them may be erratic, and delivery times are often long and stochastic (Botter & Fortuin, 2000). Failure to overcome these challenges and effectively manage service parts can create disruptions and have a detrimental impact on the entire supply chain (Zsidisin, Ellram, Carter, & Cavinato, 2004). The cost of disruptions due to unscheduled downtime created by a lack of spare parts can range from $1,700 an hour in a paper and plastic production plant (Sandvig & Allaire, 1998) to over $50,000 an hour in a semiconductor manufacturing plant (Cohen, Zheng, & Wang, 1999).

Despite this growth in value and importance, many organizations continue to rely on simple, item based approaches to service parts management (Thonemann, Brown, & Hausman, 2002). Under these traditional item approaches, inventory managers rely on simple inventory models to balance inventory costs while setting levels for individual items (Sherbrooke, 1992). Lenard and Roy (1995) suggest that such item based approaches are ill-suited for situations in which strategic or service focused objectives, like those associated with service parts management, are sought. Instead, a more holistic or system based approach to inventory management is needed (Lee & Billington, 1992) to achieve maximum inventory performance (Closs, 1989) within a supply chain environment.

The objective of this exploratory study is to investigate the performance of a system approach to service parts inventory management in a field setting. The remainder of the paper is organized into five sections. Additional motivation for the research is discussed, followed by a description of the research design and research setting. The final two sections will include the results of the study as well as a discussion of its implications.

Motivation for Research

Traditional views of service parts inventory management tend to focus on inventory at the item level and to be reactive in nature, often seeking to optimize inventory performance at a single location at the expense of the overall system (Closs, 1989). Under these traditional approaches to inventory management, inventory levels for an item are determined by simple formulas that balance inventory holding, ordering, and stockout costs (Sherbrooke, 1992). Inventory levels for each individual item are then set to achieve some predetermined criterion (Thonemann et al., 2002). Such an approach is considered simpler due to a lack of sophistication (Closs) and because decisions on the individual inventory item levels are often made without considering other items (Sherbrooke).

However, simpler is not necessarily better. Lee and Billington (1992) suggest that more rigorous inventory techniques should be used because simplistic inventory stockage policies within a supply chain setting often lead to substantial inefficiencies. They go on to identify the use of simplistic inventory stocking policies as one of the common pitfalls of supply chain management (Lee & Billington).

The traditional item approach also appears inconsistent with a key underlying theory of supply chain management. Though theories from many disciplines have contributed to the development of the supply chain philosophy (Stock, 1997), few have been as influential as systems theory. Within the context of supply chain management, a systems theory based approach is one in which decisions are not made based on individual functions or activities alone because of their complex inter-relationships with other functions or activities (Optner, 1965). Instead, decisions are made based on the desired final outcome (Gregson, 1977). The requirements of the supply chain subsume the activities of its individual parts (Christopher, 1971).

A systems view of the supply chain is one of the three distinguishing characteristics of the supply chain philosophy (Mentzer et al., 2001). As an essential component of any supply chain, inventory management should also take a systems view. Sherbrooke (1992) suggests that a systems view, in which all parts in the system are considered when making inventory level decisions, is necessary to achieve the overall desired system performance. Closs (1989) also calls for a system view of inventory, suggesting that strategic adjustments to existing inventory policies are necessary in order to achieve enhanced system performance.

Research by Singh and Vrat (1984), Cohen, Kleindorfer, Lee and Pyke (1992), Sherbrooke (1992) and many others has recommended system approaches to service parts inventory management. Further, many argue that the underlying assumptions of most inventory models proposed by researchers in the academic literature are unrealistic (Ashayeri et al., 1996). Others argue that the inventory models often fail to recognize the real world complexities associated with inventory management (Zanakis, Austin, Nowading, & Silver, 1980), especially those associated with service parts inventory management (Botter & Fortuin, 2000; Sandvig & Allaire, 1998).

Therefore, though seemingly well-suited for solving the complex problems associated with supply chain problems, the systems perspective remains insufficiently developed in most organizations (Holmberg, 2000). Thonemann et al. (2002) suggest that the delayed adoption of a systems focused approach to inventory management is because such an approach can prove time consuming and costly. The implementation of a systems approach can therefore only be justified if it is expected to have a significant positive impact on performance.

One means for demonstrating the potential impact of a systems approach to inventory management on supply chain performance is through the assessment of its impact on supply chain disruptions. In its simplest form, the goal of supply chain management, and more specifically inventory management, is to match supply and demand (Cachon, 2004). Supply chain disruptions can then be viewed as an indicator of supply and demand mismatches.

Recent work by Hendricks and Singhal have established the negative impact of disruptions on shareholder wealth (2003), operating performance (2005a), and long-term stock price (2005b). Supply chain disruptions can also negatively impact customer service, damage a firm’s reputation, impact the productivity and utilization of assets, and lead to decreased net sales (Hendricks & Singhal, 2005a). Knowledge of these detrimental impacts has highlighted the need for practices that can prevent disruptions.

Juttner, Peck, and Christopher (2003) call for research that develops approaches for minimizing the risk of disruptions in specific supply chains or industries. One obvious approach to dealing with the risk of disruption, especially in service parts supply chains, is through alternative approaches to inventory management (Zsidisin & Ellram, 2003). However, it is not yet clear which of these approaches may prove to be most helpful in preventing disruptions.

The lack of and evident need for "real world" evidence related to the use of a system approach to service parts inventory management, especially as a means for addressing supply chain disruptions, served as the motivation for this field-based study.

Research Design

To address the needs described above, this exploratory study relies on a set of field-based experiments. The following sections provide insight into the research design by describing the research setting, the measures of performance, and the research methodology employed.

Setting

The experiments took place at ten different field locations. Each of the ten locations is part of a U.S. based aerospace organization with operations in the U.S. and abroad. Each location is independently responsible for managing a consumable service parts inventory to facilitate local aircraft maintenance activities in support of its assigned operational activities. Table 2.1 provides additional insight into the typical monthly activity at each of the test locations.

Table 2.1

Description of Monthly Field Location Activity

Location #	Geographic Location	# of Distinct Line Items On-hand	Value of On-hand Inventory	# Monthly Transactions
1	Midwestern U.S.	1,087	$605,300	1,500
2	Northwestern U.S.	4,121	$830,400	6,000
3	Asian Pacific	3,709	$838,000	4,500
4	Northern Europe	706	$77,639	370
5	Asian Pacific	1,516	$316,400	1,200
6	Midwestern U.S.	1,360	$182,000	910
7	Southwestern U.S.	3,589	$846,581	3,400
8	Southeastern U.S.	3,326	$810,000	4,000
9*	Central Europe	1,867	$485,440	2,900
10**	Central Europe	1,983	$471,478	2,000

*Test location included as part of non-equivalent control group
**Control location included as part of non-equivalent control group

Though the types and number of consumable service parts vary by site depending on the make, model, and number of aircraft assigned, all sites rely on a single wholesale parts supplier. Figure 2.1 depicts the supply chain-operating environment for all of the field locations.

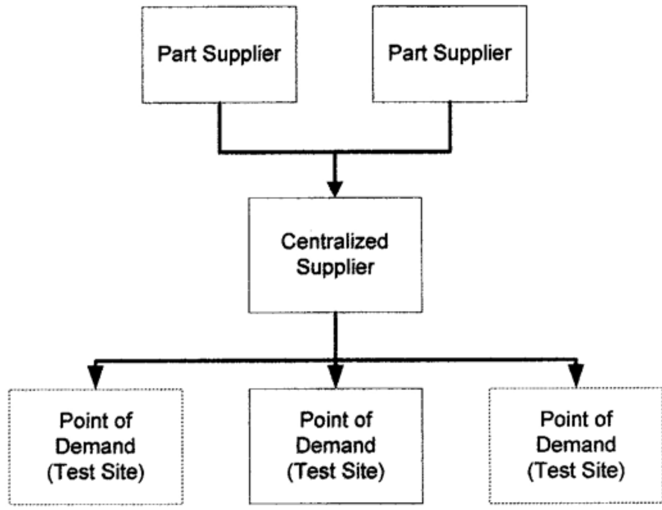

Figure 2.1. Supply chain environment

Methodology

Each field location or point of demand, is charged with providing the best possible customer support subject to organizationally assigned fiscal constraints. Thus, each of the locations studied must allocate inventory investment across a large set of service parts to best meet demand and maximize overall performance. At the time of this study, nine locations were testing an alternative approach to inventory level setting. The legacy approach is an EOQ based approach that has been in place for over thirty years. The alternative approach takes a more systematic view of inventory level setting. Both are described in more detail below.

Traditional approach. Each of the test locations has traditionally relied on an economic order quantity (EOQ) based level-setting model. Harris first introduced the EOQ model in a paper published in 1913 in *Factory, The Magazine of Management* (Erlenkotter, 1990). In his article, *How Many Parts To Make at Once,* Harris described a mathematical model, EOQ, which allows managers to determine an order size that minimizes total cost (Harris, 1990). The goal of using this mathematical equation is to find the order quantity, which produces the proper balance between inventory carrying cost (holding cost) and the production set-up or ordering cost of an item (Weiss, 1990)

The traditional approach under investigation computes the inventory level for an item using an economic order quantity and a reorder point (ROP), which consists of average demand and a measure of the variance of demand (VOD) during the order and shipment lead-time.

EOQ based models are not without criticism. Much of the criticism of the EOQ model revolves around its often unrealistic assumptions like a known and constant demand rate and zero replenishment lead-time (Silver, Pyke, & Peterson, 1998). Other criticisms of the model target the total cost equation upon which the EOQ model is based (Woolsey, 1988). EOQ models focus on short-term variable inventory costs (Ramasesh, 1990). Even calculating the variable holding and ordering costs is often difficult because they are not typically accounted for by financial accounting measures and must be reconstructed by management accountants (Selen & Wood, 1987). Miscalculations of these parameters can lead to disappointing and potentially disastrous results (Adkins, 1984). However, studies have found that though many of the underlying assumptions were not met, many firms, like the test locations in this study, continue to use EOQ based inventory systems (Osteryoung, Nosari, McCarty, & Reinhart, 1986).

Systems approach. Closs (1989) defines a systems view of inventory management as one that seeks to improve the information upon which allocation decisions are made, seeks to reduce demand placed on the inventory system, and accurately assesses organizational requirements and capabilities so that inventory procedures are consistent with system goals and objectives. The approach investigated in this study is a move towards just such a systems approach to inventory management, incorporating additional information into the leveling decisions while aligning the system objectives with the organizational objectives. Though the model itself was not available for reasons of confidentiality, a description is provided.

Aligning with organizational objectives. The purpose for developing the system-focused approach to inventory management was to minimize the total number of expected backorders (EBOs) subject to a fiscal constraint. The hope for the system is that it will allow for improved overall customer support without an increase in inventory cost. To achieve its objective, the model first computes the EBOs for each inventory item. The EBO is a function of historical demand for the item and the expected delivery lead-time as forecasted by the item supplier. The calculation of the EBOs relies on Deemer, Kaplan, and Kruse’s (1974) established approach to projecting the number of stock-outs for an inventory system. The calculation includes a variety of data, including the item’s demand rate, variability of demand, and expected delay time from the wholesale supply organization.

Improving information availability. Recognizing that information sharing is vital to both the systems approach and to improving supply chain performance in terms of costs and service level (Zhao, Xie, & Zhang, 2002), the inclusion of expected support levels from the supplier is seen as a key benefit. The forecasted supplier lead-times enables the system-focused model to better address one of the major contributing factors to poor inventory performance, uncertainty in the order cycle (Closs, 1989).

The marginal analysis process, shown in Figure 2.2, begins by setting the inventory of all items to zero. The model then begins an iterative process by which it computes the EBOs and a sort value for each item. This sort value is the models method of ascertaining the potential reduction in EBOs per the required investment for each item.

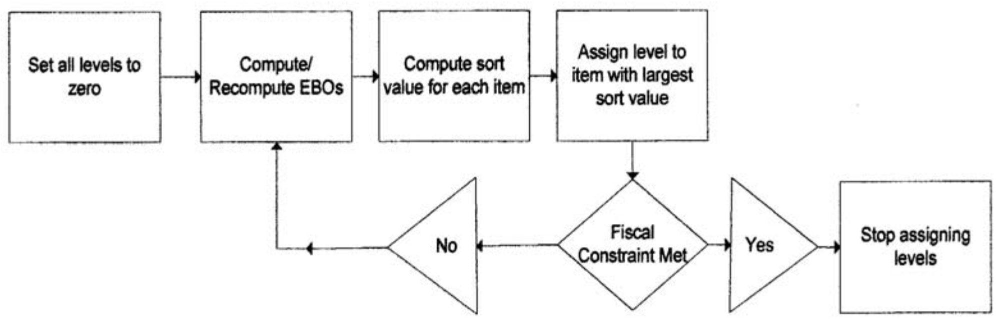

Figure 2.2. System approach

Phrased differently, the sort value answers the question, "if I add one to the inventory level for this item, what is the reduction in EBOs per dollar spent?" The item with the highest sort value represents the item from which the system would receive the most benefit per dollar spent. The model assigns a level to the item with the highest sort value and then repeats the process of allocating levels based on the highest sort value until the allotted funds are exhausted.

Data Collection

Transaction data from one year prior to and one year after the implementation of the system approach was collected for nine test locations and one control location. Data for each location was collected from a central database. The database is updated monthly and contains inventory and transaction data for each of the test locations. Full access to the data was provided through the organizations database administrator. The data base administrator also had an active role in managing and monitoring the field tests and provided invaluable insights into the data.

This level of access and depth of data allowed for the identification of the total number of inventory flow disruptions (backorders) and their duration, measured in number of days, for all ten of the selected locations. The data base also allowed for the identification of the number and duration of operational disruptions via a code assigned by the organization that identified disruptions resulting in a process shutdown or delay.

The data was divided for use in two sets of analysis. Data was collected from five U.S. based test locations, two Asian Pacific locations, and a European location in order to conduct the pretest-posttest comparisons. Data from two additional Central European locations was collected for use in the non-equivalent control group test.

Performance Measures

In order to compare the performance of an item approach to that of a system-focused approach to service parts management, a set of supply chain focused performance measures is needed. Traditional measures of inventory performance were deemed inappropriate for this comparison, as they lack a system focus.

The emerging emphasis on supply chain disruptions (Hendricks & Singhal, 2003, 2005b; Svensson, 2004; Zsidisin, 2003; Zsidisin & Ellram, 2003; Zsidisin et al., 2004) provides an interesting lens through which to view inventory performance. By definition, a supply chain disruption is any unplanned event which might affect the normal flow of materials (Svensson, 2000). Disruptions can take many forms, including transportation delays, port stoppages, natural disasters, operational issues, and part shortages (Craighead, Blackhurst, & Handfield, 2006).

The fact that part shortages continue to be a major source of supply chain disruptions is especially interesting since inventory has historically been one of the most common methods used to prevent or buffer the effects of disruptions(Craighead, Blackhurst et al., 2006). However, this does present an opportunity to investigate the performance of alternative approaches to inventory replenishment in terms of their impact on supply chain disruptions. Within this disruption context, the key measures of inventory performance then become the number, duration, and magnitude (Craighead, Blackhurst et al.) of the disruptions resulting from a lack of inventory. As shown in Figure 2.3, the first opportunity to measure the impact of inventory approach on supply chain disruption is the number of initial inventory flow disruptions (backorders) generated under each system.

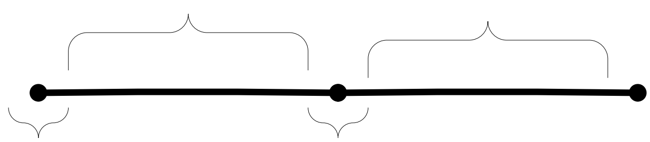

Figure 2.3. Performance measures

Once an initial inventory flow disruption occurs, the duration of the disruption (as measured by the difference between when the item was backordered and when the backorder was filled) becomes a key measure of performance (Kiesmuller & Kok, in press), because the duration of the unavailability of parts is a major area of concern (Fortuin & Martin, 1999).

Thus far, the measures have focused on the number and duration of inventory flow disruption. The remaining two measures provide insight into what Craighead, Blackhust et al. (2006) refer to as the “domino phase” of disruption recovery and are intended to provide additional insight into the impact of inventory approach on the magnitude of disruptions. They explain that as the disruption continues in time, the negative impact of the disruption increases. A continued disruption can result in severe operational impacts such as lost sales or process shutdowns(Craighead, Blackhurst et al.). Disruptions resulting in such severe operational impacts due to their duration or due to the criticality of the part causing the disruption are henceforth referred to as operational disruptions.

Research Method

Yin (2003) defines a case study as research that takes an empirical approach to investigating a contemporary phenomena without isolating it from its real life context. Case study research designs are considered appropriate when there is little prior knowledge about a phenomenon of interest (McAfee, 2002) and the dynamics of a situation are important (Dobson, 2001). This is certainly the case when seeking to provide a field based assessment of a systems approach to inventory management.

Typically, case studies are qualitative (McAfee, 2002). However, case studies can take on many different forms. Case research can use qualitative methods, quantitative methods, or a combination of both (Cavaye, 1996). This research effort is fundamentally quantitative, seeking to measure the impact of a system approach to inventory management on supply chain disruptions in a field setting. Such an effort dictated the use of two experimental designs. This study used both the one group pretest-posttest design and the non-equivalent control group design. Each design will be briefly discussed.

Field study: Pretest/posttest design. The one group pretest-posttest design is one of the more frequently used designs in organizational research and is illustrated in Figure 2.4 below (Cook & Campbell, 1976).

	Pretest Performance Measure	Treatment	Posttest Performance Measure
Test Group	O	X	O

Figure 2.4. Pretest/posttest design

This design allowed for the assessment of the impact of the system approach on operational performance at nine locations by comparing pretest performance which occurred under the traditional approach to inventory management with posttest performance which occurred under the system focused approach. Although uniquely insightful, this design is limited, due to its inability to account for external factors and is susceptible to both external and internal threats to validity. In field-based research, the factors not considered can have a far-reaching impact on the observed data patterns and the generalizability or external validity of the results (Campbell, 1957; Campbell &

Stanley, 1963; Cook & Campbell, 1979). To help address these threats an additional level of analysis was added, using a non-equivalent control group design.

Field study: Non-equivalent control group design. Lynch (1992) suggests that research in which the background factors are held constant, results in enlightened data analysis of high statistical power. In an attempt to control for these factors in a field setting, the research design selected for this study is considered a quasi-experimental design. More specifically, Campbell and Stanley (1963) have described the type of research design selected for this study as a nonequivalent control group design. This design is regarded as controlling for many of the threats to validity and is appropriate when random assignment of the treatment is not possible (Campbell & Stanley). Figure 2.5, provides a graphical depiction of the nonequivalent control group design. The test location represents the experimental or test group. The implementation of the system-focused approach is considered the treatment (X). An additional location, not utilizing the system approach serves as the control group.

	Pretest Performance Measure	Treatment	Posttest Performance Measure
Test Group	0	X	0
Control Group	0		0
	T^1		T^2

Figure 2.5. Non-equivalent control group research design

The more similar the experimental group and the control groups are, the more effective the control becomes (Campbell & Stanley, 1963). The control group selected was as similar as possible in terms of the geographic location, type of aircraft supported, number of inventory items managed, typical value of on-hand inventory, and typical number of inventory related transactions. By selecting such similar locations, the study controls for many of the factors that could potentially influence the outcome of the performance measures such as the types and amounts of inventory, demand patterns, and costs associated with the inventory at each location

Analysis and Results

This section provides a description of the comparisons between the traditional and system approaches to service parts management. Comparisons are made using pre-implementation (item based approach) and post-implementation (system based approach) measures at nine locations using the following measures: (1) the number of inventory flow disruptions (number of backorders), (2) the duration of the inventory flow disruptions (average number of days per backorder), (3) the number of operational disruptions (number of severe backorders), and (4) the duration of the operational disruptions (average number of days per severe disruption). Comparisons are also made between the differences in pre-implementation and post-implementation measures of inventory performance at a control location.

A test of difference between two proportions was used to account for changes in the volume of transactions when testing for differences in the number of disruptions and the number of severe disruptions. Univariate analysis of variance was then used to test for differences in the mean duration of initial disruptions and severe disruptions.

Pretest and Posttest Measures

An assessment of the impact of the system approach on the number of disruptions relied on the comparison of the proportion of disruptions under the traditional approach with the proportion of disruptions under the system approach. As shown in Table 2.2, six of the eight test locations showed a significant reduction ($p < .05$) in the proportion of inventory flow disruptions experienced after implementation of the system approach. The average reduction in the proportion of inventory flow disruptions was 6.8%, with a high of 12.8% and a low of 1.9%. Location 3 experienced no significant change in the proportion of disruptions, while location 2 actually experienced a significant increase in the proportion of inventory flow disruptions. Though no explanation for the increase was given, members of the test organization attributed the increase in disruptions to an increase in demand, highlighted by an additional 8,000 transactions compared to the previous year.

Table 2.2

Inventory Flow Disruptions

Location #	Pretest # Transactions	Pretest # Bos	Pretest Proportion	Posttest # Transactions	Posttest # Bos	Posttest Proportion	Z	P-Value
1	17,028	5,122	30.1%	18,623	3,692	19.8%	22.419	0.000
2	67,340	9,275	13.8%	75,619	12,661	16.7%	-15.551	0.000
3	54,535	7,156	13.1%	52,476	6,900	13.1%	-0.131	0.552
4	4,071	1,225	30.1%	4,690	811	17.3%	14.146	0.000
5	10,475	1,765	16.8%	17,496	2,621	15.0%	4.161	0.000
6	10,002	3,386	33.9%	11,812	2,917	24.7%	14.869	0.000
7	37,001	8,691	23.5%	45,247	9,016	19.9%	12.366	0.000
8	43,968	10,758	24.5%	50,784	10,937	21.5%	10.710	0.000

An assessment of the impact of the system approach on the number of operational disruptions (OpDisr) again relied on a comparison between the pretest proportion of operational disruptions (Traditional Approach) and posttest (System Approach) proportion of operational disruptions. As shown in Table 2.3, all of the test locations experienced a significant reduction ($p < .05$) in the proportion of operational disruptions. The average reduction in proportion of operational backorders was 0.66% with a minimum reduction of 0.18% at location 3 and a maximum reduction of 1.61% at location 7. A look at the raw data reveals a reduction of over 1,100 operational disruptions across all eight locations despite an increase of over 32,000 transactions. It is also interesting to note that the systems approach was able to reduce the number of operational disruptions at location 2, negating much of the adverse impact of the increased demand and increased number of inventory flow disruptions discussed previously.

Table 2.3

Operational Disruptions

Location #	Pretest # Transactions	Pretest # OpDis	Pretest Proportion	Posttest # Transactions	Posttest # OpDis	Posttest Proportion	Z	P-Value
1	17,028	174	1.02%	18,623	56	0.30%	8.495	0.000
2	67,340	480	0.71%	75,619	354	0.47%	6.063	0.000
3	54,535	517	0.95%	52,476	401	0.76%	3.260	0.001
4	4,071	53	1.30%	4,690	19	0.41%	4.637	0.000
5	10,475	110	1.05%	17,496	106	0.61%	4.108	0.000
6	10,002	176	1.76%	11,812	152	1.29%	2.859	0.002
7	37,001	1,025	2.77%	45,247	526	1.16%	16.863	0.000
8	43,968	1,187	2.70%	50,784	994	1.96%	7.600	0.000

Univariate analysis of variance allowed for the assessment of the impact of the system approach on the mean duration of the inventory flow disruptions. The analysis considered the differences in the mean duration of the disruption under the traditional approach and the system approach. As shown in Table 2.4, all eight of the test locations experienced a significant reduction ($p < .05$) in the mean duration of inventory flow disruptions. The average reduction in mean disruption duration was 9.72 days with individual locations experiencing reductions ranging from 2.71 days to 18.02 days.

Table 2.4

Inventory Flow Disruption Duration

Location #	Pretest Mean Disruption Days	Pretest S.D	Posttest Mean Disruption Days	Posttest S.D.	Delta	F	P-Value
1	38.74	71.20	20.72	36.80	-18.02	198.270	0.000
2	29.01	58.66	17.52	29.41	-11.49	361.400	0.000
3	30.62	55.62	25.54	34.60	-5.08	41.932	0.000
4	42.43	53.73	32.70	47.59	-9.73	17.507	0.000
5	28.92	50.70	21.76	34.63	-7.15	30.800	0.000
6	19.54	44.76	16.83	32.63	-2.71	7.323	0.007
7	31.69	60.37	14.69	28.11	-17.00	583.274	0.000
8	33.17	60.07	26.55	57.72	-6.62	68.454	0.000

As shown in Table 2.5 additional univariate analysis of the mean difference in the duration of operational disruptions (SevDisr) revealed that five of the test locations experienced a significant reduction ($p < .05$) in the mean duration of operational disruptions. Those locations experiencing a significant reduction experienced an average reduction in the length of the operational disruptions of over 71 days, with reductions in duration ranging from 46 days at location 2 to 111 days at location 7.

Table 2.5

Operational Disruption Duration

Location #	Pretest Mean OpDisr Days	Pretest S.D	Posttest Mean OpDisr Days	Posttest S.D.	Delta	F	P-Value
1	117.19	353.00	26.04	70.35	-91.15	3.670	0.057
2	87.16	309.20	40.77	97.31	-46.39	7.426	0.007
3	73.85	261.73	21.63	65.83	-52.22	15.214	0.000
4	120.00	323.87	19.37	66.67	-100.63	1.791	0.185
5	72.27	260.05	55.64	117.36	-16.63	0.362	0.548
6	86.25	289.28	11.46	45.12	-74.79	9.947	0.002
7	163.65	10.68	52.23	14.91	-111.42	36.919	0.000
8	146.52	8.94	67.20	9.77	-79.33	35.876	0.000

Non-equivalent Control Group Research Design

The non-equivalent control group portion of the analysis also relied on the comparison of proportions and means. Data from both the test and control location was used to further assess the impact of the system approach on the number, duration, and magnitude of disruptions. As shown in Tables 2.6 and 2.7, the system approach seems to have had no clear significant effect on either the number of inventory flow disruptions or the number of operational disruptions at either the test or the control location. However, as shown in Table 2.6, both the test and control location experienced a significant increase in the number of inventory flow disruptions.

Table 2.6

Inventory Flow Disruptions for Test and Control Sites

Location #	Pretest # Transactions	Pretest # Disruptions	Pretest Proportion	Posttest # Transactions	Posttest # Disruptions	Posttest Proportion	Z	P-Value
9 (test)	34,829	3,931	11.3%	36,396	4,629	12.7%	-5.874	0.000
10 (control)	27,634	2,644	9.6%	20,010	2,237	11.2%	-5.725	0.000

However, as shown in Table 2.7, the analysis of the proportion of operational disruptions revealed that both the test and control location experienced a significant reduction in the proportion of operational disruptions.

Table 2.7

Operational Disruptions for Test and Control Sites

Location #	Pretest # Transactions	Pretest # Disruptions	Pretest Proportion	Posttest # Transactions	Posttest # Disruptions	Posttest Proportion	Z	P-Value
9 (test)	34,829	346	0.99%	36,396	200	0.55%	6.790	0.000
10 (control)	27,634	141	0.51%	20,010	26	0.13%	6.932	0.000

During the univariate tests comparing the mean inventory flow disruption duration, the test location was found to have experienced a significant reduction in the mean duration of disruptions under the system approach. As shown in Table 2.8, the control location experienced no significant change in mean duration of inventory flow disruptions.

Table 2.8

Inventory Flow Disruption Duration for Test and Control Sites

Location #	Pretest Mean	S.D.	Posttest Mean	S.D.	Delta	F	P-Value
9 (test)	35.66	61.28	19.61	34.13	-16.05	232.74	0.000
10 (control)	33.70	61.05	35.79	60.41	2.10	1.44	0.230

As shown in Table 2.9, the comparison of the duration of operational disruptions revealed a significant reduction in mean duration at the test location, while the control location had no significant change. In fact, the control location experienced an increase in the mean duration of operational disruptions that would be considered significant at a .10 level of significance.

Table 2.9

Operational Disruption Duration for Test and Control Sites

Location #	Pretest Mean	S.D.	Posttest Mean	S.D.	Delta	F	P-Value
9 (test)	97.64	313.00	31.81	81.00	-65.83	8.47	0.004
10 (control)	22.89	86.51	61.50	119.46	38.61	3.85	0.052

Discussion and Implications

This research was motivated by the need for evidence to support the benefits of a system approach to inventory management. As shown in Table 2.10, the overall results of this exploratory study suggest the effectiveness of a system approach to service parts inventory management in a supply chain. Using both a pretest-posttest design and a nonequivalent control group design, results from tests of differences between proportions and analysis of variance tests supported the effectiveness of a system approach in reducing the proportion and duration of both flow disruptions and operational disruptions in a service parts supply chain.

Table 2.10

Consolidated Results

Test Location #	Porportion of Flow Disruptions	Duration of Flow Disruptions	Porportion of Operational Disruptions	Duration of Operational Disruptions
1	↓	↓	↓	↔
2	↑	↓	↓	↓
3	↔	↓	↓	↓
4	↓	↓	↓	↔
5	↓	↓	↓	↔
6	↓	↓	↓	↓
7	↓	↓	↓	↓
8	↓	↓	↓	↓
9 (Test)	↑	↓	↓	↓
10 (Control)	↑	↔	↓	↑

↓ Significant Reduction
↑ Significant Increase
↔ No Significant Change

Thus, the results of this exploratory study contribute to the body of knowledge related to system-focused approaches to service parts inventory management in several key ways. First and foremost, this effort provides a much needed field based investigation of a system approach to inventory management within a service parts supply chain. Despite its potential to solve complex supply chain problems, the system perspective has generally been insufficiently developed (Holmberg, 2000), leaving limited opportunities to compare traditional and system based approaches to inventory management (Thonemann et al., 2002). Also, though historically a frequent topic of interest among researchers, inventory problems in general, have received less attention in recent years (Lenard & Roy, 1995). This is especially true in the often overlooked areas of service parts and aftermarket support (Farris, Wittman, & Hasty, 2005).

In addition, this effort provides direct support for two of the three strategic adjustments described by Closs (1989) as necessary to constitute a systems approach to inventory management. First, by incorporating expected response times from suppliers, the system approach investigated in this study provides support for the benefits of information sharing and improvements in the information upon which inventory decisions are made. Though qualitative and anecdotal evidence suggest information sharing can improve overall performance, limited empirical evidence exists indicating the magnitude of its impact (Closs, Roath, Goldsby, Exkert, & Swartz, 1998) or quantifying its benefits (Lee, So, & Tang, 2000). Past research has been varied (Sahin & Robinson, 2005) and often times inconclusive (Cachon & Fisher, 2000). Based on the reductions in both the number and duration of disruptions experienced at the field locations, these research results support the expectation of improved performance from information sharing and answers the call for research that quantifies the value of supplier information in improving supply chain performance (Van der Duyn Schouten, Van Eijs, & Heuts, 1994).

By utilizing a marginal analysis approach to allocate available inventory investment in a manner that minimizes expected backorders, the investigated system approach incorporates what Closs (1989) refers to as internal operational adjustments. These internal adjustments allowed the investigated organization to focus on objectives that were more representative of its capabilities and requirements. As a service parts organization, disruptions, brought on by poor inventory management, can have significant negative impact. It is logical then in terms of time, money, and resources to adapt processes in such a way as to avoid disruptions (Giunipero & Eltantawy, 2004). In this investigation, the internal adjustments, along with the incorporation of supplier information, resulted in a reduction in both the number and duration of disruptions and represents a move towards a true system approach to inventory management.

As is the case in most exploratory investigations, there are several opportunities to improve upon and extend this research. For example, the availability of only one control location limited the number of comparisons. The data was also limited in that it only covered one year prior to and one year after implementation of the system focused approach. Research over a longer duration may provide additional insight.

Despite these limitations, this exploratory effort represents a unique field investigation of two approaches to inventory management and has implications for both researchers and managers. For both, this research provides evidence of the benefits of a system approach to service parts inventory management. This study addresses the lack of empirical evidence to support the many qualitative and anecdotal research efforts touting the benefits of information sharing and a system approach to inventory management. Finally, this research enhances the understanding of a system approach to inventory management as a means for combating the occurrence and impact of supply chain disruptions.

CHAPTER 3

CRITICAL CHALLENGES OF INVENTORY MANAGEMENT IN SERVICE PARTS SUPPLY CHAINS: A DELPHI STUDY

Abstract

The effective planning and control of inventories is critical to successfully managing a supply chain. The academic community has an important role to play in helping industries remain competitive through inventory management. However, many have suggested that inventory research often fails to meet the needs of practicing inventory managers. This is of particular concern in the increasingly important area of service parts management. A series of structured interviews with senior service parts mangers was used as input for a web-based Delphi study seeking to identify a set of critical service parts inventory challenges. The identified challenges serve as a guide for researchers seeking to contribute to the service parts body of knowledge.

Introduction

While inventory problems are literally as old as history itself (Hadley & Whitin, 1963), the future of inventory management is certain to present new challenges. The planning and control of inventories and related activities is critical to the success of supply chain efforts (Jones & Riley, 1985). Managers must continuously seek reliable and effective inventory practices and systems to remain competitive (Closs, 1989). This is especially true for service-based supply chains.

The service sector now accounts for more than 80% of employment in the United States (Fitzsimmons & Fitzsimmons, 2006), with many companies shifting their focus from simply improving product manufacturing and product delivery to improving product service and customer service (Vigoroso, 2005). To provide the necessary after sales service, enough parts, often referred to as service parts, have to be available at appropriate points within the supply chain to guarantee the desired service level (Botter & Fortuin, 2000). Service parts management is therefore becoming increasingly important (Pfohl & Ester, 1999) and has already grown into a $700 billion a year business (Patton & Steele, 2003).

One might expect the seemingly infinite stream of inventory theory related research to be a key resource for managers seeking to gain a competitive advantage through inventory management. However, some have suggested that managers who turn to inventory theory research may find it to be of little significance (Krautter, 1999) or that it has little to offer in terms of enhancing inventory practices (Wagner, 2002). This has led many to suggest a gap exists between inventory theory and practice (Lenard & Roy, 1995; Silver, 1981; Wagner, 1974, 2002; Zanakis et al., 1980).

While the varied solutions offered to bridge this gap represent valuable research, input from practitioners is noticeably absent. Therefore, an empirically derived agenda founded on practitioner-identified issues, is needed. The objective of this effort is to use input from a panel of practicing service parts inventory managers from a variety of industries and government agencies to identify a set of critical inventory related challenges. These challenges will serve as the foundation for future research aimed at improving our understanding of service parts management and aid in addressing the pressing challenges within the field. In the sections that follow, additional motivation for the paper is provided along with a description of the research design and methodology. Analysis of the results and implications are then presented.

Motivation for Research

According to the Council of Supply Chain Management Professionals 16th Annual State of Logistics Report (Wilson, 2005), the movement towards global supply chains has led to an increase in the value of business inventories every year since 2001. In 2004, business inventories were valued at a record high $1.63 trillion. Managers, now more than ever before, need reliable and effective inventory management practices and systems in order to reduce costs and remain competitive (Closs, 1989).

Supply chain researchers should seek solutions to the evolving challenges of inventory management. In one of the earliest assessments of the operations management field, Buffa (1980) calls for operations management to have a strong relationship with the practicing world. Similarly, Mentzer and Flint (1997) suggest that a business discipline like supply chain management should evolve in such a way that it becomes more rigorous and increasingly relevant to practitioners.

Recent reviews of operations management and logistics research echo the calls for rigorous research that is also relevant to practitioners. Craighead, Hanna, Gibson, and Meredith (2006) note the applied nature of logistics research and the need for research that adds value to both academicians and practitioners. A similar review of operations management literature concluded by pointing to the critical importance of operations management research to academia as well as industry and society (Craighead & Meredith, 2006).

The question then becomes how inventory researchers can best address the challenges faced by inventory managers. Many alternative approaches have been suggested. Zanakis et al. (1980) suggest that educators and researchers should obtain more practical, field experience and that they should direct more research to realistic problems whose solutions would benefit practitioners. Similarly, Silver (1981) suggests researchers should focus on formulating models that provide a good, accurate model rather than an impractical, optimal one. Lenard and Roy (1995) suggest models should include a multi-criteria and multi-item approach, so that the models are less dependent on unrealistic assumptions and more sensitive to the need of inventory managers to manage hundreds or even thousands of items simultaneously. Wagner (2002) suggests models should incorporate and account for dirty demand data and that these models should be able to operate within a supply chain environment.

Although these suggestions represent potential improvements in inventory research, input from practitioners remains noticeably absent. Practitioners provide a pragmatic perspective that is invaluable in highlighting areas of limited or incomplete knowledge (Malhotra, Steele, & Grover, 1994). Gibson, Mentzer, and Cook (2005) extol the need for both academics and practitioners to play an active role in the maturation of the supply chain discipline. Malhotra et al. suggest that the academic community has an important role to play in making industries more competitive, stating that:

> The tremendous amount of resources and expertise that exists within the academic community offers an opportunity for significant contributions. This is true from both the research and teaching standpoints. However, the contribution of the academic community in enhancing productivity growth can only be obtained by understanding what issues managers believe are important (1994, pg. 190).

The growing importance of the service parts industry, the need to understand the challenges of service parts management, and the need to identify challenges that academics can address served as the motivation for this study.

Research Design

As shown in Figure 3.1, the study began with the solicitation of input from a panel of practicing service parts inventory mangers regarding the challenges of facing service parts. The study then called upon service parts managers to reach consensus regarding the importance of the identified issues. Identified issues not adequately addressed within the existing body of literature represent opportunities for research and serve as a guide for future researchers seeking to contribute to the knowledge of service parts management.

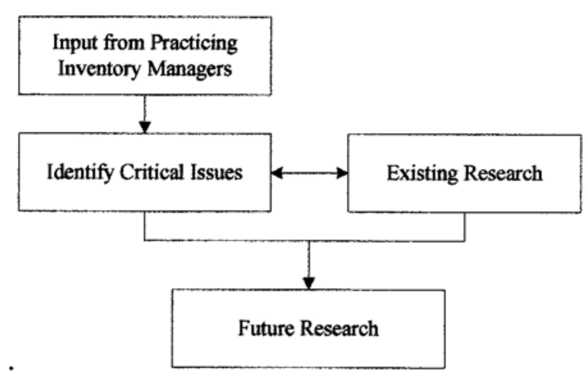

Figure 3.1. Study description

Methodology

A modified Delphi approach was chosen as the best approach for gaining practitioner insight into the challenges of service parts management. The Delphi method was developed by Rand in the 1950s (Linstone & Turoff, 1975) as an alternative means for eliciting opinions from groups of experts (Martino, 1983). The Delphi method creates opportunities to gain valuable insight from practicing managers and to identify topics that academics can address (Malhotra et al., 1994).

The Delphi is an appropriate methodology (Cook & Frigstad, 1997) when insight from a panel of experts is sought (Lummus, Vokurka, & Duclos, 2005; MacCarthy & Atthirawong, 2003). Examples of the use of the Delphi method are available in several supply chain related fields. Benson, Hill, and Hoffman (1982) used a panel of American Production and Inventory Control Society (APICS) members to gain insight into the future of manufacturing systems. Brancheau and Wetherbe (1987) used the Delphi method to identify the most critical issues facing information system (IS) executives. McDermott and Stock (1988) used the Delphi method to gain insight into the short-term, intermediate, and long-term trends and events facing logistics managers. To identify key strategic and tactical manufacturing issues, Malhotra et al. (1994) relied on a Delphi panel of manufacturing vice-presidents. More recently, MacCarthy and Atthirawong used a Delphi approach to investigate factors affecting production location decisions while Lummus et al. used the Delphi method to identify and rank characteristics of a flexible supply chain.

As shown in Figure 3.2, the Delphi is an iterative process and requires multiple phases. Each of these phases is discussed further in the following sections.

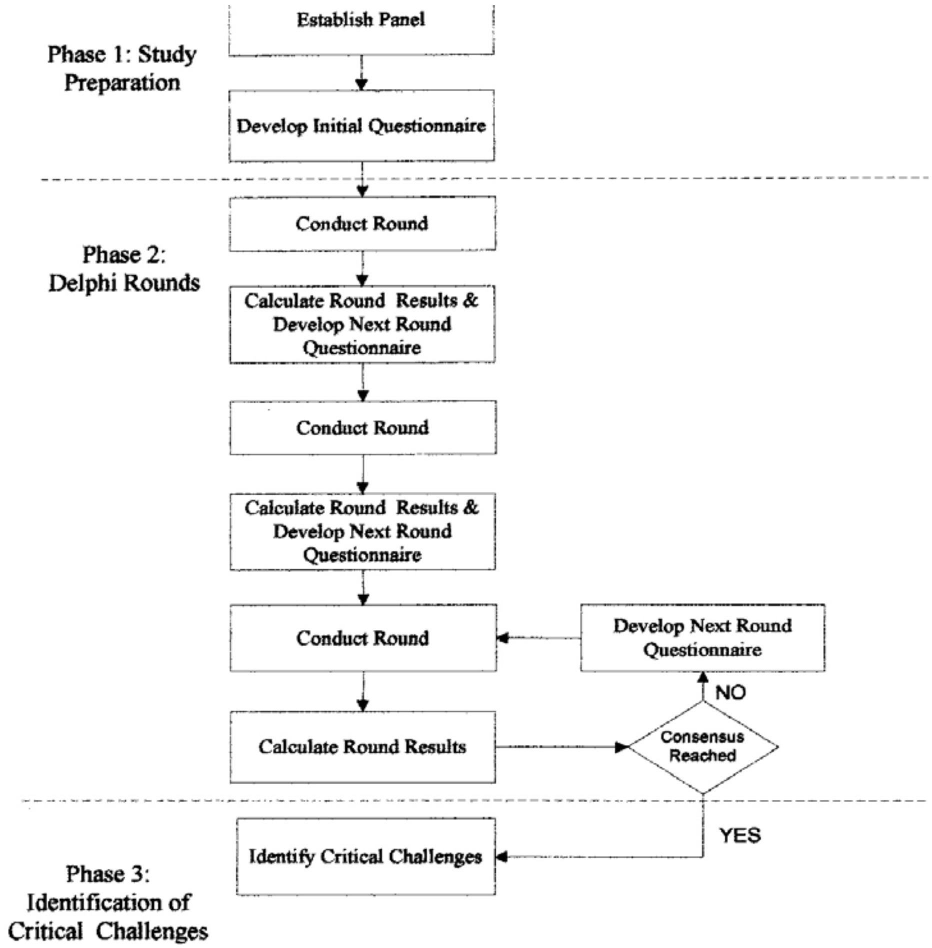

Figure 3.2. Overview of research methodology

Phase 1: Study preparation. Phase 1 consists of two distinct steps: establishment of the Delphi panel and development of the initial questionnaire. The first step in the Delphi process requires the identification and solicitation of panel members with the knowledge and background necessary to address the issues under consideration (Malhotra et al., 1994). The number of panel members is limited only by the time and resources available (Mitchell, 1991). However, studies have found little is gained from excessively large panels (Dalkey & Helmer, 1963). Recommendations for the minimum panel size vary, ranging from eight members (Elliot, 1986) to fifteen (Mitchell, 1991) members, with groups of at least ten providing the best performance (Brockhoff, 1975).

The next step in Phase 1 is the development of the initial questionnaire. The initial questionnaire is traditionally open ended (Lummus et al., 2005). However, this traditional approach may prove troublesome to both panel members and researchers due to its lack of structure (Martino, 1983) and ambiguity (Sackman, 1974). One method for addressing this weakness is to use semi-structured interviews to provide an initial set if issues. Semi-structured interviews are said to provide more meaningful information on issues of interest (Story, Hurdley, Smith, & Saker, 2001) and present opportunities to benefit from the elaborations of panel members. The use of the interview to establish an initial list of issues is also desirable (Van Dijk, 1990) as it can increase panel member commitment to the study and improve overall response rates (Mitchell, 1991).

Once the initial questionnaire is developed, it can be delivered to panel members via paper or the web. Web-based questionnaires are a viable alternative to printed questionnaires (Boyer, Olson, Calantone, & Jackson, 2002) and provide capabilities not available with other self-administered questionnaires (Dillman, 2000). Web-based questionnaires have also been shown to reduce turnaround and response times while lowering data processing costs (Lummus et al., 2005).

Phase 2: Delphi rounds. The initial questionnaire becomes the first in a series of linked questionnaires. Subsequent questionnaires provide panel members feedback from the preceding questionnaires and ask for further information (Brancheau & Wetherbe, 1987). The process continues until consensus is reached among panel members. The number of rounds needed to reach consensus can vary from 2 to 4 (Martino, 1983).

However, The number of rounds needs to be as few as possible, to avoid panel fatigue and attrition (Mitchell, 1991).

Phase 3: Identification of critical challenges. Consensus among panel members has been measured in various ways, including graphically (Ogden, Petersen, Carter, & Monczka, 2005) and statistically (Schmidt, 1997; Schmidt, Lyytinen, Keil, & Cule, 2001). Another method for judging consensus is to evaluate the percentage of panel members ranking a challenge as one of the ten most important (Doke & Swanson, 1995; Murry & Hammons, 1995). Though the literature offers little guidance on the percentage of responses necessary to constitute consensus (Murry & Hammons), there is precedent for concluding consensus for those challenges being ranked in the top ten by at least 60% of the panel members (Doke & Swanson).

Data Collection

The implementation of the study was a multi-phased process. The study began with the establishment of the Delphi panel and the identification of the initial set of issues. Identification of the initial set of issues allowed for the development and pilot testing of the initial questionnaire. Responses from the initial questionnaire were used to provide feedback to the panel members via a second round questionnaire. The study concluded after the second round as a sufficient level of consensus was reached regarding the ten most critical challenges facing service parts inventory managers. Each of these phases is discussed further in the sections that follow.

Panel Selection

In order to identify a set of challenges that would prove applicable to a wide range of service parts industries, a diverse panel of experts was sought. Senior service parts managers from a variety of industries and U.S. military organizations, as well as third party service parts support providers, were identified through personal contacts, referrals, and professional association listings and contacted regarding their willingness to participate. While 20 experts agreed to participate in the Delphi portion of the study, only 18 were able to participate in the interview process due to restrictions levied by their employer. The 20 panel members had a combined total of 351 years of experience, with the average panelist having 19.5 years of service parts experience. As shown in Table 3.1, the panel possessed experience in managing a service parts in a wide variety of industries.

Table 3.1

Background of Panel Members

Industry
Manufacturing
Aerospace/Aviation
Heavy Equipment
Technology/Computers/Network
Utility
Automotive
Telecommunications
Medical
Maritime

Identifying Issues

Eighteen semi-structured interviews were conducted either by phone or face-to-face with each of the available panel members. During the interview, each panel member was asked to provide six responses to the following research question: *What are the most critical challenges of service parts inventory management*? Some researchers suggest limiting the number of responses from each panel member (Couger, 1988). However, Schmidt (1997) suggests each panel member be asked to provide at least six responses, because of the likelihood of repeated responses. This process resulted in a total of 114 responses being provided by the panel members. Related responses were then consolidated to create the set of 18 critical challenges shown in Table 3.2.

Table 3.2

Challenges of Service Parts Management

Issue	Service Part Challenges
1	Planning for new product introduction
2	Planning for the service requirements of ageing products and the repair of ageing parts
3	Satisfying regulatory and legal requirements
4	Maintaining repair cycle process discipline
5	Lack of a system or holistic perspective
6	Maintaining accurate configuration management and product revision data
7	Understanding the criticality or essentiality of each service part
8	Lack of service focused performance metrics
9	Lack of accurate service parts usage data
10	Lack of system integration among suppliers, repairers, customers, and service providers
11	Inaccuracy of service parts forecasts
12	Planning the location and physical distribution of service parts
13	Lead time variability
14	Minimizing embedded costs associated with service parts management
15	Fulfilling fiscal and budgetary requirements
16	Acquiring, developing, and maintaining a knowledgeable service parts workforce
17	Minimizing service parts obsolescence
18	Service Parts Sourcing

Questionnaire Development and Testing

A questionnaire, containing each of the challenges and its description, was developed and prepared for submission to the panel via the internet. The questionnaire was then pilot tested. The lack of pre-testing questionnaires has been a common criticism of past Delphi studies (Sackman, 1974). Vagueness or over specification in the questionnaire can reduce the information produced by the panel members (Linstone & Turoff, 1975). Thus, the initial questionnaire was pre-tested by 10 knowledgeable colleagues (Dillman, 2000) to ensure the clarity of each question and to help ensure reliable results (Mitchell, 1991).

Round 1. On the first day of Round 1, the 20 panel members received an email explaining the importance of his or her participation and a link to the web-based questionnaire (Appendix A). The instructions for Round 1 included:

> Eighteen challenges were identified during a series of interviews with practicing service parts inventory managers from various industries as well as several branches of the United States armed services. A brief description, based on comments made by the interviewees, is provided for each challenge.

Panel members were asked to select and rank the ten most critical issues, with 1 being the most important. Round 1 of the Delphi study was open for 9 days with 18 of the 20 panel members responding for a 90% response rate. The mean responses and percentage of panel members who ranked each challenge in their top ten are shown in Table 3.3.

Table 3.3

Round 1 Responses by Mean Rank

Mean Rank	% Who Ranked in Top 10	Service Part Challenges
3.55	61%	Lack of a system or holistic perspective
3.88	89%	Inaccuracy of service parts forecasts
4.50	67%	Maintaining accurate configuration management and product revision data
4.83	67%	Lack of system integration among suppliers, repairers, customers, and service providers
4.91	61%	Minimizing service parts obsolescence
5.18	61%	Planning for new product introduction.
5.50	67%	Lead time variability
5.50	50%	Understanding the criticality or essentiality of each service part
5.63	44%	Acquiring, developing, and maintaining a knowledgeable service parts workforce
5.73	61%	Planning the location and physical distribution of service parts
5.82	61%	Planning for the service requirements of ageing products and the repair of ageing parts
5.92	67%	Maintaining repair cycle process discipline
6.11	50%	Lack of accurate service parts usage data
6.38	44%	Service parts sourcing
6.40	56%	Fulfilling fiscal and budgetary requirements
6.67	33%	Lack of service focused performance metrics
7.80	28%	Minimizing embedded costs associated with service parts management
8.83	33%	Satisfying regulatory and legal requirements

As shown, the top two challenges were the lack of a system or holistic perspective and the inaccuracy of service parts forecasts. The lowest ranked challenges were related to minimizing embedded costs (fuel cost, personnel cost, storage cost) and satisfying regulatory and legal requirements. In an effort to further refine the set of challenges;

those items not receiving one of the top ten mean ranks and not ranked as a top ten issue by a simple majority (Schmidt, 1997; Schmidt et al., 2001) of the panel members were removed. This resulted in the removal of four challenges: service parts sourcing, lack of service focused metrics, minimizing embedded costs, and satisfying regulatory and legal requirements.

Round 2. Five days after the conclusion of the first round, a second questionnaire was developed, pilot tested by 6 knowledgeable colleagues and sent to the 18 panel members who participated in the first round. Each of the panel members received another email explaining the importance of his or her continued participation and a link to the Round 2 questionnaire. Panel members received the following instructions:

> The objective of this round is to achieve consensus regarding the most critical challenges of service parts management. The challenges are listed below according to the level of criticality assigned by the panel members, with the item receiving the lowest mean rank (most critical) listed first. The mean group rank for each challenge as well as the percentage of panel members who ranked the challenge as one of the ten challenges is included for your review. In light of these first round results, please indicate your views by again selecting and ranking the ten most critical challenges

Presented with the summary results, the 18 panel members that responded to the Round 1 questionnaire were again asked to consider what they believe to be the ten most critical challenges and to again select and rank the ten most critical issues. Panel members were given 9 days to complete Round 2. At the close of the round, fifteen panel members had responded to the questionnaire, resulting in an 83% response rate (15/18).

As shown in Table 3.4, the lack of a systems approach and the inaccuracy of service parts again ranked as the two most critical challenges.

Table 3.4.

Round 2 Responses by Mean Rank

Mean Rank	% Who Ranked in Top 10	Service Part Challenges
3.00	80%	Lack of a system or holistic perspective
3.67	100%	Inaccuracy of service parts forecasts
4.13	53%	Lack of accurate service parts usage data
4.73	73%	Lack of system integration among suppliers, repairers, customers, and service providers
5.18	73%	Lead time variability
5.33	60%	Understanding the criticality or essentiality of each service part
5.71	93%	Maintaining accurate configuration management and product revision data
5.90	67%	Minimizing service parts obsolescence
6.10	67%	Planning for the service requirements of ageing products and the repair of ageing parts
6.44	60%	Fulfilling fiscal and budgetary requirements
6.70	67%	Planning for new product introduction
6.91	73%	Maintaining repair cycle process discipline
7.00	73%	Planning the location and physical distribution of service parts
7.33	60%	Acquiring, developing, and maintaining a knowledgeable service parts workforce

Study conclusion. Since not much is gained by iterating more than twice (Ford, 1975), and most convergence of panel members occurs between round one and two (Lanford, 1972), a decision was made to end the study after two rounds and proceed with the analysis and assessment of the identified challenges and their rankings. Dalkey

(1969) suggests that the responses to round two were typically the most accurate and that responses often became less accurate on subsequent rounds.

Another key in the decision not to conduct a third round was the convergence of the panel responses. Convergence in responses is a key criterion for terminating the study (Martino, 1983), and as will be discussed in the following section, the level of consensus among the panel members in this study was statistically significant and had leveled off (Schmidt, 1997).

Analysis and Results

The objective of this Delphi based study was to achieve consensus amongst a panel of service parts experts regarding the most critical challenges facing service parts inventory managers. Murry and Hammons (1995) suggest that consensus can be measured by the percentage of panel responses for an item. Following a similar approach as Doke and Swanson (1995), those challenges ranking as one of the ten most critical by greater than 60% of the panel members in both rounds of the Delphi were considered to have achieved consensus. As shown in Table 3.5, 10 of the identified challenges met the criteria.

Table 3.5

Percentage of Panel Members Ranking Issue in Top Ten

Issue #	Round 1 K=18 % Top Ten	Round 2 K=15 % Top Ten
*1	61%	67%
*2	61%	67%
3	33%	NR
*4	67%	73%
*5	61%	80%
*6	67%	93%
7	50%	60%
8	33%	NR
9	50%	53%
*10	67%	73%
*11	89%	100%
*12	61%	73%
*13	67%	73%
14	28%	NR
15	56%	60%
16	44%	60%
*17	61%	67%
18	44%	NR

The level of consensus was also measured after each round using Kendall's coefficient of concordance (W), as recommended by Schmidt (1997). Kendall's W provides a coefficient of agreement among raters (Kendall & Gibbons, 1990) based on the ranks assigned by the panel members and is a common method for measuring consensus in Delphi studies (Schmidt). As suggested by Schmidt, the formula for computing W was adjusted to account for the fact that each panel member only ranked 10 of the 18 challenges in Round 1 and 10 of the 14 challenges in Round 2.

According to Landis and Koch (1977), a Kendall's coefficient of concordance value of 0.11–.20 is considered slight agreement while values of 0.21–0.40 are considered to represent fair agreement. As shown in Table 3.6, Round 1 resulted in slight agreement amongst panel members (W=0.16, p<.001) regarding the importance of the initial 18 challenges, while fair agreement across panel members (W=0.22, p<.001) was achieved regarding the importance of the 14 challenges presented during Round 2.

Table 3.6

Panel Rankings of Challenges

	Round 1 K=18		Round 2 K=15	
Issue #	Mean Rank	D^2	Mean Rank	D^2
1	5.18	0.30	6.70	1.25
2	5.82	0.01	6.10	0.27
3	8.83	9.64	NR	
4	5.92	0.04	6.91	1.76
5	3.55	4.77	3.00	6.66
6	4.50	1.51	5.71	0.02
7	5.50	0.05	5.33	0.06
8	6.67	0.88	NR	
9	6.11	0.15	4.13	2.12
10	4.83	0.80	4.73	0.73
11	3.88	3.44	3.67	3.66
12	5.73	0.00	7.00	2.01
13	5.50	0.05	5.18	0.16
14	7.80	4.29	NR	
15	6.40	0.45	6.44	0.74
16	5.63	0.01	7.33	3.07
17	4.91	0.67	5.90	0.10
18	6.38	0.42	NR	
Totals	103.12	27.47	78.13	22.63
Grand Means	5.73		5.58	
	W	X^2	W	X^2
	0.16	48.408*	0.22	42.279*

*p<.001

From the significance of the measures of consensus, the general conclusion can be made that there is fair consensus among the panel members concerning the most critical challenges of service parts inventory as a whole.

While the level of agreement as measured by Kendall's W may seem low, the results were expected. The objective of this research was to identify a set of challenges that spanned all service parts industries, hence the diverse nature of the selected panel members. Comments from panel members even suggested that a number of the challenges were more prominent in some service parts industries than in others. Thus, the diversity of the panel combined with the diverse nature of the service parts industry, rendered the finding of an extreme level of agreement across all issues highly unlikely.

Discussion

Based on the results, the challenges shown in Table 3.7 represent the most critical challenges facing service parts inventory managers. These ten challenges serve as a guide for future researchers seeking to contribute to the broad area of service parts management.

Lack of a system or holistic perspective. During both rounds of the Delphi study, panel members ranked the need for a more holistic perspective of system performance as the most critical challenge facing service parts managers. A system perspective is vital to effectively fit together all of the complex pieces of the service parts supply chain (Patton & Steele, 2003). All efforts related to service parts, from the earliest stages of product development to the design of the product support system and customer support, should be based on a holistic perspective with system performance and customer satisfaction as the objective. Despite this potential to solve complex supply chain problems, the system perspective continues to be insufficiently developed (Holmberg, 2000).

Inaccuracy of service parts forecasts. The only challenge that was a unanimous selection by all panel members related to the inaccuracy of service parts forecasts. The old adage that the forecast is always wrong is especially applicable to service parts forecasts. Much of the demand for service parts is due to equipment or part failure, making demand for service parts sporadic and often highly variable, significantly complicating forecasting efforts.

Lack of system integration among suppliers, repairers, customers, and service providers. Panel members highlighted the lack of information system integration and information sharing among suppliers, repairers, customers, and service providers as one of the most critical challenges of service parts management. Several panel members described the difficulty of satisfying customer demands given their lack of information regarding the availability of parts at a supplier and or the status of parts within the repair process.

Maintaining accurate configuration management and product revision data. Panel members descried the importance of having accurate system configuration data. They explained that often times the service provider is unaware of configuration changes or revisions until a technician is on site (Patton & Steele, 2003). Such inaccurate configuration and revision data complicates service efforts and creates the need to keep additional service parts in stock (Fortuin & Martin, 1999), both of which increase overall costs.

Lead time variability. Variability in supplier or repairer lead times can have a significant impact on inventory levels and costs throughout a service parts supply chain. One panel member from a heavy equipment manufacturing and service organization declared that consistency, not velocity, of lead times was the key to efficient service parts planning and management. Inconsistent lead times result in the use of buffer inventories as a means for ensuring desired levels of customer support. Of course, this excessive inventory leads to higher financial costs and risks (Christopher & Lee, 2004).

Minimizing service parts obsolescence. One of the greatest risks associated with service parts management is the obsolescence of parts. With rapid changes in product introduction and design, panel members described the risk associated with stored service parts becoming obsolete as new or superior items supersede them. Other panel members detailed the risk associated with losing a service contract, rendering the inventory linked to that contract obsolete. The challenge for service parts managers is to limit the investment in parts subject to obsolescence, while maintaining required levels of service.

Planning for new product introduction. The introduction of new products or systems results in the need for new service parts. Panel members described the challenge of planning for service parts in this initial phase of the service parts life cycle. During this initial phase, very little is known about the failure behavior of the parts (Fortuin, 1980), complicating any efforts to forecast future demands. This is complicated by the fact that the initial phase is often the most critical phase of product life to those in sales, where negative perceptions can cripple a new product (Patton & Steele, 2003). Service parts managers are often forced to rely on their knowledge and experience (Fortuin & Martin, 1999).

Planning for the service requirements of ageing products and the repair of ageing parts. The end of product production presents a unique challenge for service parts managers. Many products, like heavy equipment and aircraft, may remain in service for decades after the end of production, but continue to generate needs for service. Panel members described the challenge as being multifaceted: determining the final buy of service parts, identifying and maintaining suppliers and repairers for ageing parts, and establishing policies for managing the repair and refurbishment of parts.

Planning the location and physical distribution of service parts. In many instances, service is accomplished where the end product is used (Patton & Steele, 2003). This makes the physical distribution and location of service parts (location, warehousing, material handling, packaging, and transportation) a key challenge. Panel members described the distribution decision as crucial to providing the necessary flexibility to meet customer demands and to achieve desired levels of customer service.

Maintaining repair cycle process discipline. The repair cycle is a complex process that begins with its removal or replacement, includes the repair process, and ends with it being replaced or returned to stock in a serviceable condition. To avoid excessive investment and cost, this process must be managed carefully. Panel members explained that the challenge with managing the repair is that the bulk of the responsibility for good repair cycle discipline lies with field service providers, repair organizations, and customers. Good repair cycle discipline is characterized by timely return of unserviceable parts by field service providers and customers as well as the appropriate prioritization of repair by the repair providers.

These ten challenges represent some of the most critical challenges faced by service parts managers. These issues also represent an agenda and serve as a guide for future researchers seeking to contribute to the increasingly important area of service parts management. In the section below, several specific opportunities for future research are presented.

Future Research

Subjects dealing with after market support, like service parts, are often overlooked and under investigated (Farris et al., 2005). Thus, each of the challenges described above represents numerous opportunities for investigation. However, there are some specific opportunities that warrant additional mention based on the importance assigned by the panel members.

System Approach to Service Parts Inventory Management. Despite the growth in value and importance of service parts management, and the recognized need for more holistic approaches to service parts management, many organizations continue to rely on simple, item based approaches to service parts management (Thonemann et al., 2002). These traditional item approaches rely on simple inventory models that usually seek to balance inventory costs (Sherbrooke, 1992). Such item based approaches are ill-suited for situations in which higher level or service focused objectives, like those associated with service parts management, are sought (Lenard & Roy, 1995). Instead, a more holistic or system based approach to inventory management is needed (Lee & Billington, 1992) to achieve maximum inventory performance (Closs, 1989) within a supply chain environment.

Thonemann, Brown, and Hausman (2002) suggest that the delayed adoption of a system focused approach to inventory management is because such an approach is perceived to be time consuming and costly and thus the implementation can only be justified if it is expected to have a significant positive impact on performance. Researchers should seek to provide empirical evidence of the impact of a services approach to service parts management on organizational performance.

Improving Service Parts Forecasts. As pointed out by the panel members, demand for service parts is difficult to forecast due to its lumpy nature. In general, the subject of lumpy demand has been largely ignored in the literature (Fortuin & Martin, 1999). In a recent review of service parts research (Kennedy et al., 2002), only Foote's (1995) effort which documented the implementation of a control based forecasting system and its impact on inventory effectiveness was identified. More recent efforts such as the study be Willemain, Smart, and Schwarz (2004) have begun to seek new and alternative approaches to service parts forecasting. However, further research targeting service parts forecasting and service parts forecasting related issues is needed.

Information Sharing in a Service Parts Supply Chain. Information sharing is believed to be vital to improving supply chain performance in terms of costs and service level (Zhao et al., 2002). Though qualitative and anecdotal evidence supports this belief, limited empirical evidence exists indicating the magnitude of its impact (Closs et al., 1998) or quantifying its benefits (Lee et al., 2000). Past research has been varied (Sahin & Robinson, 2005) and often inconclusive (Cachon & Fisher, 2000). Researchers should seek to quantify the value of supplier information in improving service parts supply chain performance.

Limitations and Implications

This study sought to engage practicing service parts managers in the identification of the critical challenges of service parts management. The study identified an initial set of 18 challenges through interviews with senior service parts managers. Then, using a modified Delphi approach, the study identified the ten most critical challenges. These challenges now serve as a guide for future researchers seeking to contribute to the increasingly important area of service parts management.

An obvious limitation for any research effort of this type is its cross-sectional nature. The information provided by the panel members were collected during a single point in time. Although there is no indication that the challenges presented will be resolved in the near future, the importance of the challenges may change over time. Future research efforts could seek to repeat this study and compare the challenges and their importance over time.

Another limitation may be the U.S. bias of the panel members selected. Although many of the organizations represented by the panel members are responsible for service parts management internationally, all of the organizations represented were U.S. based. Therefore, the results may not be fully generalizable.

Despite these limitations, this effort stands as a bridge between practitioners and researchers. Researchers seeking to contribute to the understanding of service parts management can use these challenges as the basis for their studies. Practitioners, looking to academia for assistance, will then find research that is both rigorous and relevant to the challenges they face.

CHAPTER 4

EXPLORING THE DYNAMICS OF SERVICE PARTS MANAGEMENT: A GROUNDED APPROACH

Abstract

Service parts inventory managers are playing an increasingly important role as many companies begin to shift their focus from simply improving product manufacturing and delivery to improving product service. Poor management of service parts can result in significant operational disruptions and loss of revenues. Thus, there is a need for a better understanding of the dynamics of service parts management. This exploratory study uses a grounded approach to investigate the key objectives and challenges of service parts management through the eyes of a diverse group of senior service parts managers. In doing so, this effort provides unique insights into service parts management and serves as a foundation upon which future related research efforts can build.

Introduction

The United States continues to evolve into a postindustrial, or service-based, society. The service sector now accounts for more than 80% of total employment in the United States (Fitzsimmons & Fitzsimmons, 2006). Many companies, faced with worldwide competition, declining finished good sales, and shrinking profit margins, have been forced to seek service-based revenue models, shifting their focus from simply improving product manufacturing and product delivery to improving product service and customer satisfaction (Vigoroso, 2005).

One important means for keeping customers satisfied is to provide quick repair of a product or system that has failed. To provide this repair, enough parts, often referred to as “service parts”, must be available at appropriate points within the supply chain to guarantee the desired service level (Botter & Fortuin, 2000). Thus, the management of service parts, as a part of after-sales service, is becoming an increasingly important competitive tool (Pfohl & Ester, 1999).

Service parts are already a nearly $700 billion a year business and represent approximately 8% of the gross domestic product of the United States (Patton & Steele, 2003). As such, service parts managers are playing an increasingly important role, with many businesses now profiting more from the sale of service parts than from the sale of finished goods (Patton & Steele). However, the management and control of service parts is an increasingly complex matter (Fortuin & Martin, 1999).

Therefore, companies moving towards or planning to move towards a more service oriented business model, need to understand the unique dynamics of service parts management. Similarly, supply chain researchers need to understand the unique dynamics associated with service parts and the challenges of managing a supply chain whose performance is dependent on effective service parts management. These needs serve as the motivation for this paper.

Building on a series of semi-structured interviews with senior managers from both commercial and government organizations involved in service parts management, this paper provides insight into the dynamics of service parts management. Specifically, the paper uses a grounded theory approach to develop a set of models generalizing both the challenges and key performance objectives of service parts management. The sections that follow provide additional background on service parts, describe the methodology, discuss the analysis and results, and present conclusions and opportunities for future research.

Background

Fortuin and Martin (1999) suggest that service parts managers, like other inventory managers must answer the fundamental questions of inventory management: which parts to stock, how many parts to stock, and where to stock them. However, there are some fundamental differences between managing service parts inventories and the management of manufacturing based inventories. Table 4.1 provides what Kennedy et al. (2002) describe as some of the key function and policy differences between service part inventories and traditional manufacturing inventories.

Patton and Steele (2003) go on to describe 21 different ways in which service parts inventories differ from manufacturing inventories. Chief among these are the challenges brought on by the distinct phases of product life. Patton and Steele (2003) suggest there are five distinct phases: preproduction, product introduction, normal life, post production, and termination. Fortuin and Martin (1999) describe three distinct phases of the life cycle of service parts: initial, normal, and final. Though they differ in the number of phases, both highlight the fact that manufacturing inventory related issues are limited to the first one or two phases of product life, while service parts inventory related issues continue until the final phase or termination of the end product (Fortuin, 1980). So, unlike manufacturing inventory managers, service parts managers must deal with issues related to ageing parts and systems, part repair processes, configuration changes, and long-term part sourcing (Patton & Steele, 2003).

Table 4.1

Comparison of Inventory Functions and Policies

	Work-in-Process Inventories	**Finished Product Inventories**	**Service Parts Inventories**
Function	Address variability in production flow brought on by changes in product mix, equipment breakdown, differences in production rates between different processes, material handling	Serve as a source of products for delivery to customers and addresses irregularities in lead time demand, differences in quality levels, differences in machine production rates, labor troubles, scheduling problems, differences between capacity and demand	Assist a maintenance staff in keeping equipment, systems, or products in operating condition in response to both Scheduled or unscheduled (due to product failure) maintenance
Policies	Policies can be adjusted to increase or decrease inventory by changing productions rates and schedules and improving quality	Policies can be adjusted to increase or decrease inventory by reducing lead times, changing production schedules, and improving quality	Policies are largely a function of how products are used and maintained

The consequences of failing to acknowledge these differences and to properly manage service parts inventory can be quite costly. Failure to effectively manage service parts can create disruptions and have a detrimental impact on the entire supply chain (Zsidisin et al., 2004).   Some have reported the cost of unscheduled downtime attributed to the lack of spare parts as high as $1,700 an hour (Sandvig & Allaire, 1998) to over $50,000 an hour (Cohen et al., 1999).

Farris et al. (2005) suggest that while after-sales support issues like service parts management are clearly important, they are often overlooked. Managers need simple but robust concepts and models that reflect practice and provide knowledge that can be applied to their circumstances (Eccles & Nohria, 1992). Despite a growing body of literature related to after-sales service and service parts management (Botter & Fortuin, 2000; Fortuin & Martin, 1999; Kennedy et al., 2002; Sandvig & Allaire, 1998), no effort was identified that sought to provide a generalizable model of the objectives and challenges associated with the service parts management. Researchers and practitioners need such models and should seek to develop models to describe the manner in which after-sales support is effectively provided (Farris et al.).

Methodology

The goal of this research is to provide a descriptive model of the performance objectives and challenges of service parts management using a grounded approach. The grounded approach was introduced in the 1960s by Barney Glasser and Anselm Strauss (Bryant, 2002). The advantage of the grounded approach is that it capitalizes on the richness of practitioner insight and data (Leonard & McAdam, 2002), making it one of the more influential paradigms for qualitative research in the social sciences today (Denzin, 1997).

Grounded theory approaches are so called because the results are generated not from existing theory, but grounded in data collected from one or more empirical studies (Gasson, 2004). Although traditionally associated with sociology (Goulding, 2005), the grounded approach has begun to appear more frequently in supply chain related research. For example, Carter and Dresner (2001) use a grounded approach to investigate the role of purchasing in environmental management while Flint, Larsson, Gammelgaard, and Mentzer (2005) utilized a grounded approach to explore innovation within a logistics context through the eyes of logistics managers. Similarly, this effort seeks to explore the objectives and challenges of service parts management through the eyes of practicing service parts managers.

The grounded approach relies on a systematic analysis of qualitative data (Goulding, 2005). The qualitative data is typically collected through interviews, transcribed, in preparation for analysis (Gasson, 2004). The analysis of the interview data consists of three coding phases: open, axial, and selective (Strauss & Corbin, 1998).

During open coding, the researcher categorizes the data into emerging themes or categories (Gasson, 2004) originating from the data rather than pre-defined assumptions from an outside source (Knapp, 2005). The researcher then seeks relationships between the identified categories during axial coding (Gasson, 2004). Axial coding involves the reduction of the original list of concepts (Glasser & Strauss, 1967) by relating the identified categories and developing a more consolidated and comprehensive scheme (Orlikowski, 1993). Finally, selective coding is the process of integrating and refining the categories (Strauss & Corbin, 1998) in order to focus on the core concepts (Gasson, 2004). In selective coding, the researcher develops a narrative that integrates the results of the axial coding (Crook & Kumar, 1998).

Data Collection

Data collection relied on a series of semi-structured face-to-face and telephone interviews with senior service parts managers. Diversity was sought among the panel members in terms of their experience and backgrounds in order to provide an expansive view of service parts management and to facilitate the development of a general yet robust model. Thus, senior managers from a variety of service part related industries and U.S. military organizations, as well as third party service parts support providers, identified through personal contacts, referrals, and professional association membership listings, were solicited regarding their willingness to be interviewed. Eighteen experts agreed to participate and were interviewed, with each interview lasting an average of 40 minutes. The initial interview guide is provided in Appendix B.

The study participants had a combined total ofr nearly 350 years of experience, with the average participant having over 19 years of service parts experience. As shown in Table 4.2, the panel possessed experience in managing service parts in a wide variety of industries.

Table 4.2

Background of Panel Members

Industry
Manufacturing
Aerospace/Aviation
Heavy Equipment
Technology/Computers/Network
Utility
Automotive
Telecommunications
Medical
Maritime

Research Results and Discussion

This effort served two primary purposes. The first dealt with identifying the underlying performance objectives of service parts management. The second sought to identify the challenges confronting managers seeking to achieve these objectives. Each is discussed further below.

Performance Objectives

When asked about the primary objective of their approach to service parts inventory management, the participants provided a variety of responses, that through open and axial coding, were classified into one of four concepts: maximize part availability, minimize cost of providing service parts, minimize the number of system disruptions, and maximize customer service and satisfaction. As shown in Figure 4.1, describing these concepts in isolation is difficult, thus each is discussed in relation to the other objectives.

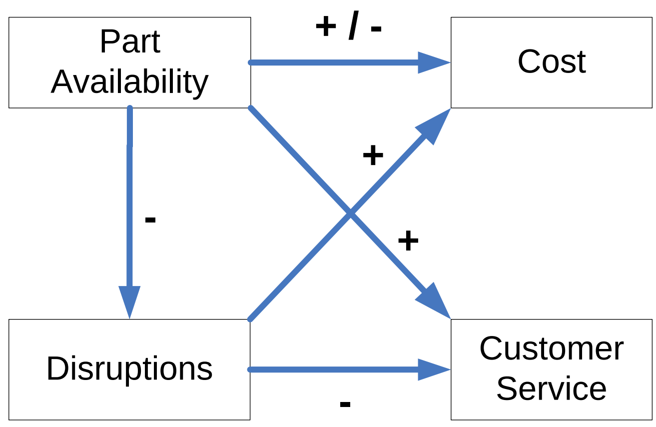

Figure 4.1. Performance objective model

Maximize part availability. At the heart of this complex interaction lies the objective of having parts available and accessible upon demand by customers. As demonstrated in the model above, an objective of increased part availability can significantly influence inventory cost, customer service, and system disruptions. Increased part availability is expected to reduce the total number of inventory related disruptions by having parts available when required for service and thus providing for improved customer service. However, an increase in availability typically requires an increase in on-hand inventory and thus an increase in overall cost of providing the service parts. However, the lack of available parts may also increase costs by necessitating the use of expedited processes to satisfy customer demands. This delicate relationship between availability and cost is what prompted many of the participants to indicate that their primary objective was to seek a balance between the two. According to one participant, the true challenge is to understand the cost to make the part available as well as the cost associated with not having the part available.

Minimize the number of system disruptions. Lack of a needed service part can prove very costly. Thus, many of the service parts managers described the need to focus on the essentiality and criticality of the parts they managed in an effort to reduce the number of disruptions of the systems they supported. This was especially important to those in the manufacturing, aviation, computer network, and utility industries. An increase in the number of disruptions in one of these industries can result in increased cost and lost opportunities (e.g. lost sales, cancellations, delays). A service parts manager from the utility industry estimated that the lack of a service part, which required a power unit to reduce power or shut down, could result in a loss of up to $1 million in revenues per day. A service parts manager tasked with supporting a large network provider estimated that for every one hour the network was down, the companies utilizing that network combined for a loss of nearly $80,000 in revenue per hour.

Minimize the cost of providing service parts. The participants indicated that controlling the costs associated with holding and managing inventory was an important objective of their service parts management efforts. There are many factors that influence the cost of providing service parts inventory. Participants pointed to rising costs in warehousing as a driving force behind the need to reduce storage space requirements. Another participant pointed to the cost of labor as a key driver of the cost of providing service. Still another pointed to the increase in fuel costs as a critical factor that must be considered. Of course the primary means for reducing costs is to simply reduce the amount of on-hand inventory. However, many of the service parts managers warned that manufacturing like efforts to "lean" service parts inventory must be entered into cautiously. The lack of service parts inventory can mean the complete shut down of an organization's operations.

Maximize customer service and satisfaction. Underlying all of the objectives listed above is a focus on customer service and satisfaction. Whether through the reductions in cost, availability of parts, or minimization of disruptions, the primary objective of service parts management is customer satisfaction. A number of the participants highlighted this with comments like: "our focus is always on the customer," "our primary goal is customer satisfaction," or "our sole objective is customer satisfaction."

Challenges

The second portion of this research effort focused on the challenges that service parts managers must overcome to achieve their objectives. When asked to consider the most critical challenges they faced as service parts managers, the participants again provided a wide range of responses. Through open and axial coding, these challenges were coded into one of three concepts: upstream challenges, downstream challenges, and knowledge and perspective challenges. Figure 4.2 presents these concepts relative to the service parts provider. Each is discussed further in the sections that follow.

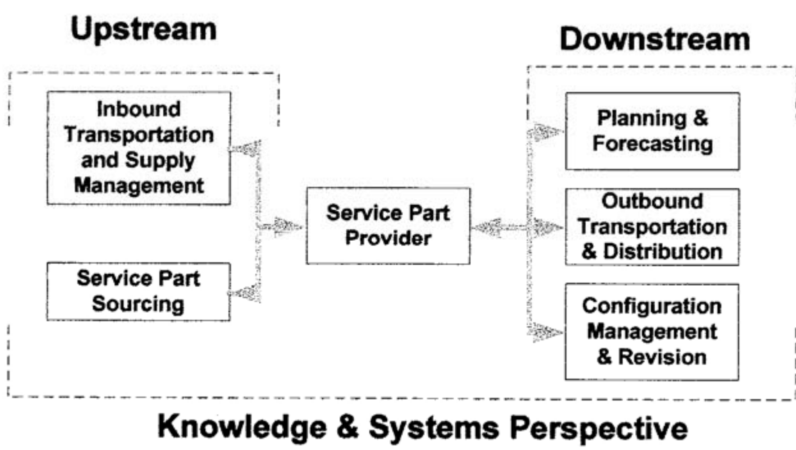

Figure 4.2. Challenges model

Upstream challenges. The concept of upstream challenges refers to those issues influencing the service provider's acquisition and receipt of parts. Chief among these upstream challenges is service part sourcing and inbound transportation and supply management.

While service parts managers must deal with many of the common challenges of inventory sourcing such as a lack of supplier visibility and lack of supplier integration, many of the challenges they face are unique due to the types of parts managed. One such challenge deals with the requirement to support ageing systems or assets. One participant with a military aviation background reported that the majority of the assets he supported were at least 18 years old with some assets nearing 40 years in age. Manufacturing of such systems has long ended and spare parts are often difficult to obtain, requiring the part to be manufactured if repair is not possible.

One of the manufacturing participants indicated that the large diversity of parts and the limited number of suppliers for many of the parts limited his organization's leverage with suppliers. The volume of parts from any one supplier was such that no price breaks could be negotiated. Other parts have such a limited number of suppliers to choose from that negotiation was again not helpful in reducing purchase cost.

Inbound transportation and supply management, though not unique to service parts, also warranted mention by the participants as being a key challenge of service parts management. Several participants highlighted the challenge of managing variability in shipping times and the variability of the quality of parts received. Variability on timing or quality has a direct impact on service parts managers' ability to plan and respond to demands for service.

Participants also highlighted the pressure to reduce the amount of on-hand inventory and the amount of required storage space. Excessive inventory and storage space both contribute to increased cost of service parts management. There is constant pressure to reduce both in order to reduce costs and to remain competitive.

Downstream challenges. The concept of downstream challenges refers to those challenges that influence the service provider's ability to forecast and satisfy customer needs. Three key areas emerged from the interviews: planning and forecasting, outbound distribution, and configuration and revision management. Each will be discussed in turn in this section.

Nearly every participant identified planning and forecasting as a challenge of service parts management. Planning and forecasting for service parts is inherently complex. Though some can be avoided through preventive or time-based maintenance, part and system failures drive demand for service parts. For new systems, accurate forecasts are difficult due to the lack of failure data. Similarly, it is difficult to plan service parts needs for ageing systems, whose failure rates grow increasingly unpredictable as the system ages. Forecasts for service parts in their normal use phase are only slightly less complex. Though demand data may be more readily available, forecasters and planners often lack visibility of asset usage, a key contributor of part failure.

Several challenges emerged regarding the distribution of service parts to customers. Principal among these was the challenge of being responsive to customer needs. In the case of medical equipment, service is often required in hours, not days. Such a level of service requires constant and careful consideration of service part locations and transportation options.

Responsiveness also requires the careful management of the repair cycle process, especially for those parts for which there is limited supply. The repair cycle is a complex process that begins with removal or replacement, includes the repair process, and ends with the part being replaced or returned to stock in a serviceable condition. The challenge for service parts mangers seeking an efficient repair cycle process lies in ensuring the timely return of unserviceable parts by field service providers and customers as well as the appropriate prioritization of repair by the repair providers.

Other common challenges associated with outbound distribution of service parts included the variability in distribution times and its potential negative impact on customer service. Some participants suggested that ensuring service parts were protected from damage during delivery to customers was often a challenge. Still others described the rising cost of labor and fuel as key challenges to efficient service parts distribution.

Several of the expert participants noted the challenge of maintaining accurate system configuration data. Several experts from technology dependent industries described the challenge of maintaining accurate part configurations due to the rapid rate at which products are revised and new versions introduced. However, experts from more conventional industries, such as aviation and manufacturing, also suggested the challenge with maintaining accurate part configuration data due to system or asset modifications was a key issue. Failure to maintain accurate configuration data can quickly lead to a situation in which the service provider is holding an abundance of obsolete inventory and unable to meet customer demands for new parts.

Knowledge and perspective challenges. The concept of knowledge and perspective challenges refers to two underlying challenges identified by the participants related to the availability of knowledgeable service parts workers and the need for a more holistic perspective when managing service parts.

Interestingly, several of the experts mentioned the challenge of acquiring, developing, and maintaining a knowledgeable service parts workforce. Participants perceived a general lack of mathematical skills and service parts related experience. With most inventory professionals coming from a manufacturing background, there seems to be a limited number of professionals that fully comprehend the fundamental differences between service parts inventory management and inventory management in a manufacturing environment.

One of the most frequently expressed challenges was that of achieving a systems perspective. Participants recalled numerous occasions where emphasis on individual functional performance without a broader focus on system performance led to sub-optimization. One aviation expert described an organizational effort to reduce transportation costs that would have resulted in the need for additional inventory and an overall increase system cost. Such efforts are common and often lead to sub-optimization.

Conclusions and Future Research

This research has studied service parts management through the eyes of a diverse panel of service parts experts. Using a grounded approach, this study has helped to increase our understanding of the complexity associated with service parts management by highlighting its key objectives and the challenges to achieving those objectives.

The objectives of service parts management were found to be highly interrelated. Managers of service parts must maintain a delicate balance between cost and availability. They must pay careful attention to the potential cost of disruptions caused by a lack of a service part and constantly seek to improve customer service.

However, there is a multitude of challenges service parts managers must overcome in order to achieve these objectives. The upstream challenges related to the difficulties associated with service part acquisition and receipt. The downstream challenges focused on the difficulties in predicting the need for service parts and the challenges of providing those service parts to customers. The final set of challenges highlighted the underlying need for more knowledgeable service parts workers and the need for a more holistic approach to service parts management.

In describing these objectives and challenges, this effort represents a unique opportunity for future researchers seeking to contribute to the knowledge of after-sales service and service parts management. Though the objectives and challenges were identified, no claims as to their relative level of importance or criticality was made. A clear understanding of the importance of the identified challenges would be useful in guiding future researchers to the most important issues. Research targeting any of the identified challenges would also prove beneficial.

CHAPTER 5

CONCLUSIONS

More and more (Ellram et al., 2004) companies are beginning to recognize the need to focus on product service and customer satisfaction. One important means for keeping customers satisfied is to provide quick repair of a product or system that has failed. To provide the necessary repair, enough service parts must be available at appropriate points within the supply chain to ensure the desired service level (Botter & Fortuin, 2000), placing an increasing level of importance on the management of service parts (Pfohl & Ester, 1999).

Service parts have now grown into a $700 billion a year business (Patton & Steele, 2003). Managers recognize that failure to manage these parts effectively can have potentially catastrophic effects on both revenues and customer satisfaction. This dissertation sought to explore this growing area of importance and value through three distinct yet related essays, each presented in a separate chapter of the dissertation. Each essay builds on this common theme in order to make a distinct contribution to the knowledge and understanding of service parts management.

The first essay, presented in Chapter 2, details a field-based test of an alternative approach to service parts inventory replenishment. The approach utilizes improved information and a system perspective, addressing two of the most critical challenges identified during the second essay. Using a quasi-experimental design, the field-based test provided empirical evidence to support the adoption of a system-based approach to service parts inventory management by comparing the performance of a traditional item based approach to service parts replenishment with that of a service based approach to service parts management. This effort provides a much needed field based investigation of a system approach to inventory management within a service parts supply chain.

In addition, this effort provides direct support for two of the three strategic adjustments described by Closs (1989) as necessary to constitute a systems approach to inventory management. First, by incorporating expected response times from suppliers, the system approach investigated in this study provides support for the benefits of information sharing and improvements in the information upon which inventory decisions are made. Though qualitative and anecdotal evidence suggest information sharing can improve overall performance, limited empirical evidence exists indicating the magnitude of its impact (Closs, Roath, Goldsby, Exkert, & Swartz, 1998) or quantifying its benefits (Lee, So, & Tang, 2000). Past research has been varied (Sahin & Robinson, 2005) and often times inconclusive (Cachon & Fisher, 2000). Based on the reductions in both the number and duration of disruptions experienced at the field locations, these research results support the expectation of improved performance from information sharing and answers the call for research that quantifies the value of supplier information in improving supply chain performance (Van der Duyn Schouten, Van Eijs, & Heuts, 1994).

By utilizing a marginal analysis approach to allocate available inventory investment in a manner that minimizes expected backorders, the investigated system approach incorporates what Closs (1989) refers to as internal operational adjustments. These internal adjustments allowed the investigated organization to focus on objectives that were more representative of its capabilities and requirements. As a service parts organization, disruptions, brought on by poor inventory management, can have significant negative impact. It is logical then in terms of time, money, and resources to adapt processes in such a way as to avoid disruptions (Giunipero & Eltantawy, 2004). In this investigation, the internal adjustments, along with the incorporation of supplier information, resulted in a reduction in both the number and duration of disruptions and represents a move towards a true system approach to inventory management.

The second essay, presented in Chapter 3, sought to engage practicing service parts managers in the identification of the critical challenges of service parts management. The study identified an initial set of 18 challenges through interviews with senior service parts managers. Then, using a modified Delphi approach, the study identified the ten most critical challenges relied on these identified challenges as the basis for a Delphi study. In the Delphi study, a panel of service parts experts selected and ranked the importance of the most pressing challenges of service parts management. The challenges are shown in Table 5.1.

Table 5.1

Ten Most Critical Challenges Faced by Service Parts Management

Service Part Challenges
Lack of a system or holistic perspective
Inaccuracy of service parts forecasts
Lack of system integration among suppliers, repairers, customers, and service providers
Maintaining accurate configuration management and product revision data
Lead time variability
Minimizing service parts obsolescence
Planning for new product introduction
Planning for the service requirements of ageing products and the repair of ageing parts
Planning the location and physical distribution of service parts
Maintaining repair cycle process discipline

By reaching a consensus on the ten most critical challenges, the effort provides a guide to both researchers and managers regarding the areas in which their efforts can make the most difference. The challenges now serve as a guide for future researchers seeking to contribute to the increasingly important area of service parts management.

The final essay, presented in Chapter 4, provided a grounded investigation of the primary objectives and challenges of service parts management. Through the eyes of a diverse group of service part experts, the researcher explored the primary objectives of service parts management and highlighted the delicate balance that must be maintained between cost, availability, service, and disruptions. Using the same approach, the researcher also explored the challenges that must be overcome to better achieve these objectives. From these investigations, models were developed. Each of these models represents a broad perspective of the dynamics of service parts management and serves as the foundation upon which to base future research endeavors.

Both independently and collectively, these research efforts have made significant contributions to the service parts body of knowledge. However, much work remains. All indications are that the value of service parts and their importance will continue to increase as customer demands for and reliance on them increases. Thus, managers and researchers should continuously seek to understand the dynamics of service parts and methods for improving their management.

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APPENDIX A

1ST ROUND QUESTIONNAIRE

Identifying The Most Critical Challenges of Service Parts Management

Introduction: You are one of a select group of individuals with experience in service parts management chosen to participate in this study. Thus, your continued participation is critical to the success of this research project and is greatly appreciated.

Study Description: This is the first of two, possibly three, rounds of questionnaires designed to reach a consensus regarding the most critical challenges of service parts management. Your responses to this and all subsequent questionnaires will remain confidential. Again, thank you for your support. It is greatly appreciated.

Demographic Data: Please provide the requested information to aid in administering subsequent questionnaires and describing the level of expertise of the participating members. Individual responses will remain confidential. Only aggregated results from the study will be released.

* Please enter your email in the space provided:

* Please enter your job or duty title in the space provided:

* How long (# of years) have you been involved with service parts management?

* Please select the industry below that best describes the industry within which you deal with service parts.

☐ Technology/Computers/Networks

☐ Manufacturing ☐ Aerospace/Aviation ☐ Heavy Equipment

☐ Utility ☐ Automotive ☐ Telecommunications ☐ Medical

☐ Maritime ☐ Rail ☐ Service Provider (e.g. third party, consultant)

Ranking the Challenges: The remainder of this questionnaire is designed to identify the most critical challenges faced by service parts inventory managers. Eighteen challenges were identified during a series of interviews with practicing service parts inventory managers from various industries as well as several branches of the United States armed services. A brief description, based on comments made by the interviewees, is provided for each challenge.

Research Question: What do you consider the ten most critical challenges facing service parts inventory managers?

* Please indicate your views by ranking the ten most critical challenges using numbers 1 to 10, where 1 indicates the most critical challenge. Please only rank the top ten issues using each number (1-10) once.

0	**Planning for new product introduction:** The introduction of new products or systems often results in the need for new types of service parts. Planning for these new services parts is often difficult due to the lack of historical demand and failure data.
0	**Planning for the service requirements of ageing products and the repair of ageing parts:** Service parts requirements become less predictable as the supported systems and the service parts both increase in age.
0	**Satisfying regulatory and legal requirements:** Regulatory and legal requirements often require organizations to provide service part support long after the production of the serviced item has ended.
0	**Maintaining repair cycle process discipline:** The repair cycle, including all stages through which a repairable item passes from the time of its removal or replacement until it is reinstalled or placed in stock in a serviceable condition, must be managed carefully to avoid excessive investment. Good repair cycle discipline is characterized by timely return of unserviceable parts by field service providers and customers as well as the appropriate prioritization of repair by the repair providers.
0	**Lack of a system or holistic perspective:** Emphasis on individual functional performance without a broader focus on system performance leads to sub-optimization. For example, a functionally motivated effort to reduce transportation costs could result in the need for additional inventory to meet customer demands, increasing overall system cost.
0	**Maintaining accurate configuration management and product revision data:** Planning for service parts is complicated by both the lack of accurate configuration data and revisions to the serviced item

0 **Understanding the criticality or essentiality of each service part:** Understanding the criticality and essentiality of each service part enables service parts managers to concentrate their attention on the parts that are most important to equipment or product operation and customer satisfaction.

0 **Lack of service focused performance metrics:** Common measures of inventory performance are often more applicable to a manufacturing setting than they are to service parts management. Service parts management requires an emphasis on service levels, responsiveness, and demand satisfaction.

0 **Lack of accurate service parts usage data:** Accurate part usage data would enhance the ability to plan and predict the need for service parts.

0 **Lack of system integration among suppliers, repairers, customers, and service providers:** Lack of information system integration and information sharing among suppliers, repairers, customers, and service providers inhibits strategic decision-making and diminishes overall system performance.

0 **Inaccuracy of service parts forecasts:** Demand for service parts is often sporadic and highly variable, which complicates efforts to forecast future demand.

0 **Planning the location and physical distribution of service parts:** The physical distribution of service parts (location, warehousing, material handling, packaging, and transportation) is a key to providing the necessary flexibility to meet customer demands and to achieve desired levels of customer service.

0 **Lead time variability:** Consistency and stability in service parts pipelines is necessary for accurate parts planning and ensuring desired customer service levels.

0 **Minimizing embedded costs associated with service parts management:** The embedded costs of providing service parts support, like the cost of fuel, cost of labor, and cost of storage space, must be considered by service parts managers.

0 **Fulfilling fiscal and budgetary requirements:** Service parts management organizations must often function under stringent budgetary or fiscal requirements. Requirements to exhaust an annual budget or to remain within established spend levels for a service contract can significantly influence service parts management decisions.

0 **Acquiring, developing, and maintaining a knowledgeable service parts workforce:** Many professionals come from a manufacturing background and must adopt an alternative approach or philosophy to succeed in service parts management. Thus, there are a limited number of professionals that comprehend the fundamental differences between service parts inventory management and inventory management in a manufacturing environment.

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Minimizing service parts obsolescence: Service parts may become obsolete because new or superior items supersede them or because they are no longer needed.

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Service Parts Sourcing: Service parts managers must often rely on multiple sources to obtain service parts, including the purchase of new parts and the repair of unserviceable parts. In other instances, service parts may no longer be in production, requiring a part to be manufactured to meet customer demands. In both cases, leverage with suppliers is often limited.

Please use the space provided to add any additional challenges not listed above. If additional challenges you added would be included in your top ten, please provide it's ranking and a brief description.

End of Round 1: This concludes the first round questionnaire. Upon receipt of all first round responses, a second questionnaire will be developed and sent to all study participants using the email address provided. This second survey will differ from the first in that it will include the average group ranking for each challenge. Presented with this additional information, participants will again be asked to select and rank the 10 most critical challenges.

APPENDIX B

SERVICE PARTS INVENTORY MANAGEMENT INTERVIEW GUIDE

Introductory Remarks: Your participation in this research effort would be greatly appreciated. I value both you knowledge and experience.

Purpose: The purpose of this research effort is to provide insight into the management of service parts inventory.

Your participation in this research is voluntary and your responses to these questions will be kept strictly confidential. Neither you nor your organization or company will be named in any output (e.g. summary reports, or publications) of this project.

Information about the Interviewee

Name:
Job title:
Primary functions of job:
How long have you been involved in inventory management (How many years experience)?

Interview questions:

1. What is the primary goal of your approach to service parts inventory management (e.g. cost reduction, maximize availability, customer service)?

2. What are your primary measures of service parts inventory performance (e.g. inventory turns, fill rate, # of back orders, on time delivery)?

3. What are the most significant/critical challenges related to managing service part inventory in your supply chain (please name at least 6)?