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# Warranty Management and Product Manufacture

With 83 Figures

 Springer

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Dedicated to our ever patient,  
supportive and loving wives,  
Jayashree and Carol

## Preface

In industrialized societies, new products are appearing in the marketplace at an ever-increasing pace. Their introduction is either market driven – a result of increasing customer expectations and needs – or technology driven – resulting from advances in technology. In addition, the complexity of products tends to increase with each new generation. A further complicating factor is that customers are uncertain about, and have no easy way to research, new product performance.

Two items that are becoming more critical and important in the customer purchase decision process are:

1. Pre-purchase services – including information regarding product performance, useful life, cost of operation, etc., and
2. Post-purchase support services – including training in product use, availability of spares, maintenance, assistance with problems, etc.

Customers want assurance that the product will perform satisfactorily during the useful life of the product. Manufacturers not only need to provide this assurance, but more importantly, need to ensure customer satisfaction as well. Without this, survival in a fiercely competitive global market environment would be impossible. Warranties play an important role in this context.

The use of warranties is widespread and they serve many purposes. These include protection for manufacturer and buyer, signals of product quality, assurance that the product will perform satisfactorily, providing a means of compensating buyers when a purchased item does not perform as promised, and resolving disputes between buyer and manufacturer. Many different types of warranties have been studied in detail from various points of view. A warranty of any type, since it involves an additional service associated with a product, will lead to potential costs beyond those associated with the design, manufacture and sale of the product. These costs, in fact, are unpredictable future costs and have a significant impact on the total profits for a manufacturing business. In most cases, these costs range from 1% to 10% of total sales, depending on the product and the manufacturer. At present, the North American automotive industry spends about 8.5 billion dollars on servicing warranty claims each year. The costs of warranty

depend on product reliability and warranty terms. Product reliability, in turn, is influenced by the decisions made during the design and manufacture of the product.

Warranty management deals with decisions with regard to product warranty. Warranty decisions must be integrated with decisions relating to technical issues such as design, development and manufacturing, and to commercial issues such as marketing, price, sales, revenue, etc. Warranty must be managed so as to ensure that the business objectives – profits, return on investment, market share, and so forth – are achieved, while at the same time providing adequate assurance to customers and ensuring customer satisfaction.

Unfortunately, most businesses view warranty as only providing the assurance, and warranty management as efficient administering of warranty claims. The focus is on monitoring claims to ensure that they are valid and to prevent loss through warranty fraud. This can be termed Stage-1 warranty management. Few businesses have moved beyond this to Stage-2 warranty management, where the focus is on improving business performance through actions that lead to warranty cost reduction and/or increase in customer satisfaction. This is achieved through changes to product design, production and warranty servicing logistics through a proper analysis of data obtained during the servicing of warranty claims. In both of these approaches to warranty management, warranty is viewed as an afterthought and warranty decisions are not linked to other product life cycle decisions. Stage-3 warranty management views warranty from a strategic perspective. This begins with a warranty strategy that is linked to the various technical and commercial strategies from the very start of the new product development process. The aim of warranty management is to achieve the overall business objectives by focusing on product performance assurance as well as ensuring customer satisfaction.

This book deals with Stage-3 warranty management and looks at both strategic and operational aspects. It is the third and final book in the warranty trilogy written/edited by the authors. The first two books are *Warranty Cost Analysis* (Marcel Dekker, 1990) and *Product Warranty Handbook* (Marcel Dekker, 1994).

The objective of the book is to provide a comprehensive, integrated framework for strategic warranty management. This requires an understanding of the role and impact of warranty on design, engineering, development and production of a product, as well as on quality assurance, marketing, and post-sale service. Each of these aspects of warranty is discussed in some detail in the book. The approach taken is conceptual, using few symbols and no mathematics, with some formulas and mathematical discussion given in footnotes for the interested reader, and references cited for details and further results. Finally, some accounting and legal aspects of warranty that are relevant for effective warranty management are briefly discussed.

The book is primarily intended for managers at all levels (senior, middle and junior) in manufacturing businesses. We recommend the following sequence for initial reading of the book:

*Senior Level Managers*

CEO: Chapters 1, 3, 4 and 14

Manager in charge of Design and Development: Chapters 1, 2, 3, 4, 5, 14

Manager in charge of Production: Chapters 1, 2, 3, 4, 5, 9, 14

Manager in charge of Marketing: Chapters 1, 3, 4, 5, 10, 14

Manager in charge of Post-sale Support: Chapters 1, 3, 4, 5, 11, 14

*Middle and Junior Level Managers*

All managers: Chapters 1 – 14

Managers at the middle and junior levels should supplement this by extra reading as indicated in the endnotes for the various chapters.

The book can also be used as textbook for a graduate level course in Business Management, Operations Management and Industrial Engineering programs as part of managing new product development.

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## Introduction and Overview

### 1.1 Introduction

In the purchase decision, buyers of a product typically compare characteristics of comparable models of competing brands. When competing brands are nearly identical, it is very difficult, in many instances, to choose a particular product solely on the basis of the product-related characteristics such as product price, special features, perceived product quality and reliability, financing offered by the manufacturer, and so on. In such situations, post-sale factors – warranty, parts availability and cost, service, maintenance, and so forth – take on added importance in product choice. Of these, warranty is one that is known (or at least potentially known) to the buyer at the time of purchase.

In the case of new products, another feature is that each new generation is more complex than the earlier generation it replaces. Often customers are uncertain about new product performance. Here warranties play an important role in providing product assurance to customers in the sense that the manufacturer will make provision for some remedial action should the product not perform satisfactorily over the warranty period. Many different types of warranties are offered, depending on the product, the manufacturer, and the buyer. As a result, product warranty plays an increasingly important role in consumer and commercial transactions.

The use of warranties is widespread and they serve many purposes. In the simplest terms, a warranty is a contractual agreement between the manufacturer and the buyer that requires the manufacturer to either rectify item failures or compensate the buyer for failures that occur within the warranty period subsequent to its sale. Purposes of warranty include protection for both manufacturer and buyer, signaling of product quality, and assurance to buyers that items will perform as promised. In addition, warranty terms are often an important element of marketing strategy. Warranties play an important role in the resolution of disputes that may arise between buyer and manufacturer. They also pose serious challenges to legislators in terms of formulating sensible warranty policy legislation that will protect the interests of both buyers and manufacturers.

The outline of the chapter is as follows. Section 1.2 traces the historical evolution of warranty from the twenty-first century B.C. to the present time. Following this, we discuss alternate theories of warranty. This provides the background for a discussion of warranty in the context of modern manufacturing, which is the topic of Section 1.4. In our discussion, we highlight the ways in which warranty impinges on the various stages of manufacturing and how warranty decisions must be made in a framework that integrates the different technical and commercial issues that are encountered in this context. Section 1.5 defines the scope and objective of the book and we conclude with an outline of the book in Section 1.6.

## 1.2 Historical Perspective

The origin of the word warranty is interesting. In a study of the origin and history of the concept, Loomba [1] states:

*The words warranty and guarantee, known to linguists as “doublets,” are derived from same original source but traveling to today’s English language by different routes. The origins of the word warranty can be traced back to the Old North French word warrant and warrantie, to the Old High German word werento meaning “protector”. During the Middle Ages, the original expressions used included hoc ex condicione, warrantizavit, promisit, and sub tali plevina.*

### 1.2.1 Pre-Industrial Revolution

The earliest record of warranty can be found in the Babylonian and Assyrian tablets of the twenty-first century B.C. Since then it has evolved over time and in many different societies. Some of the key milestones in this evolution were:

- i. Roman laws of the fifth century B.C.,
- ii. Bavarian laws at the start of the Christian era,
- iii. Jewish commercial laws of the second century A.D.,
- iv. Hindu religious laws of the fifth century,
- v. Islamic laws of the eighth century,
- vi. Egyptian formularies of a slightly later period,
- vii. Scattered Russian codes of the early tenth century, and
- viii. The customs of the church rule of medieval times and customs of the English borough.

It is clear that the concept of product warranty has maintained a significant position in trade practices of many societies through the ages. Warranty assumed a special role subsequent to the industrial revolution.<sup>1</sup>

### 1.2.2 Post-Industrial Revolution

The start of the Industrial Revolution in the sixteenth century brought a major change to manufacturing. Components were produced by different businesses and often no single entity was responsible for the product as a whole. The refusal of public authority, through public legislature and a formal judiciary system, to accord effective protection to the purchaser was reflected by the growing acceptance of *caveat emptor* or “let the buyer beware.” The expression *caveat emptor* appeared in print for the first time in the sixteenth century. Under the code of *caveat emptor*, buyers were not entitled to receive compensation for any problem associated with the product short of outright fraud on the part of the vendor, unless the vendor had explicitly guaranteed the item in question.

Until the first half of the nineteenth century, *caveat emptor* was the rule and sellers rarely offered any sort of formal warranty on their goods. In the late nineteenth century, warranties were treated as standardized contracts with extremely limited scope. Typical product warranty coverage usually excluded remedy for failed component parts, transportation charges, ensuing damages, and so forth. Manufacturers imposed one-sided standardized warranty terms as mechanisms to unilaterally limit their legal obligations to consumers. At the same time, deceit associated with the sale of goods, such as adulteration and misrepresentation, became widespread. Dishonest manufacturers offered warranties on products without any intention of discharging their obligations under warranty. As a result, consumers began to perceive a warranty of any sort as an indication of poor product quality.

Associated with these changes was the fact that businesses were becoming larger. In an effort to control the behavior of businesses, the Federal Trade Commission (FTC) was established in 1914 in the USA. The federal government formulated certain codes governing the sale of goods, enacted various Acts, and encouraged all states to adopt them in order to achieve consistency. Under one such act, the Uniform Sales Act, an express warranty is defined as

*... any affirmation of fact or any promise by the seller relating to the goods  
... if the natural tendency of such affirmation or promise is to induce the  
buyer to purchase the goods, and if the buyer purchases the goods relying  
thereon. [2]*

This definition illustrates the dual nature of the obligation of express warranty. The statute describes two kinds of express warranty, one that is promissory or

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<sup>1</sup> [1] Loomba traced the history of the warranty concept [1] from its ancient beginnings to the post-industrial era of consumerism and warranty legislation in the latter part of the twentieth century.

contractual in nature,<sup>2</sup> and a second, which is a non-promissory affirmation of fact.<sup>3</sup> It should be noted, however, that the implied warranties of quality and of title under the Uniform Sales Act were imposed by law and clearly were non-consensual [3]. The involved parties could potentially use their contractual power by means of a disclaimer to destroy a non-consensual warranty, but its creation in no way depends on their intentions [4].

During the twentieth century, consumer movements have had an impact on warranty. There have been three consumer movements. The first began in the early part of the twentieth century in reaction to marketplace excesses, which had their origins in the industrial revolution of the nineteenth century. The major consumer problems related to quality and safety of foods and drugs and came to an end with the onset of World War I.

The second consumer movement began after the end of World War I and the focus was on the shoddy performance of some of the consumer durables on the market. The courts offered very little warranty protection and implied warranties were unknown. This led to the creation of independent product testing organizations to curb such deceitful practices. Two of the most important such organizations were the Good Housekeeping Institute, run by *Good Housekeeping* magazine, which tested household goods; and Consumers' Research, a consumer-sponsored organization, which led to the publication of *Consumer Reports*. Approval from such organizations served as a symbol of acceptable product quality and gave credibility to a manufacturer's warranty. However the movement came to an end with the start of World War II.

The third consumer movement began after the end of World War II and gained momentum in the 1960s, paving the way for the additional consumer legislation mentioned previously. Because of growing concerns for buyers' protection, the notion of express warranty was augmented by another concept, "*implied warranty*," which basically states that a product must be capable of performing its intended function when used properly and under normal operating conditions. By 1952, every state in the United States except Louisiana adopted what is termed the Uniform Commercial Code (UCC). This code specifies the obligations of manufacturers, distributors, and any other vendors, with regard to both express and implied warranties. Several forms of legislation have been enacted during the past few decades to regulate warranties on various products, the most notable such legislation being the Magnuson-Moss Warranty-Federal Trade Commission Improvement Act of 1975. An excellent discussion of express and implied warranties, the Magnuson-Moss Act and related issues may be found in [5].

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<sup>2</sup> Analytically speaking, only the promissory express warranty and those affirmations of fact which constitute an implied-in-fact promise are consensual.

<sup>3</sup> Here, an actual agreement to a contract is not essential and the obligation is imposed by law, analogous to the implied-in-law promise.

## 1.3 Theories of Warranty

Through time, the perceived role of warranty in society has changed. As the notion of warranty became more complex and its use became more widespread, a number of theories of warranty were developed. We look next at three of these.

### 1.3.1 Exploitative Theory

The exploitative theory had its origins in pre-1950 legal literature on warranty. According to this theory, the terms of a warranty are developed for the manufacturer's benefit, while the consumer has few rights and bears the risks. Buyers who believe this theory often feel that if a product is sold, it should last a certain amount of time. The warranty is seen to serve the manufacturer by adding to the price of the product (i.e., by offering a service that should be provided anyway). These buyers reason that because a warranty is offered the manufacturer does not have confidence in the product.

Before 1975, consumers were still at the mercy of manufacturers. Warranties did not provide notice of consumer rights, disclaimers were couched in legal jargon, administration was confusing and ineffective, remedies for defective items were impractical, and excessive and unjustified claims often resulted from consumer frustration and hostility. The Magnuson-Moss Warranty Act (1975) aimed to provide consumers with information, improve the quality of warranties and provide procedures for consumer remedies. To some degree the Act succeeded. The readability of warranties has improved slightly, however the Act's standard of "simply and readily understood" is still an ideal that, for the most part, remains far from reality [6]. Another aim of the act was to ensure that warranty was a good indicator of the product's reliability, leading to the signal theory of Warranty.

### 1.3.2 Signal Theory

As products become more complex and less easily evaluated by consumers, warranties are used as signals [7] to indicate the product's performance and reliability. The product performance and warranty terms determine costs incurred by the manufacturer, so it follows that a longer warranty period results in higher costs unless product performance is of a correspondingly higher quality. This theory proposes that if a manufacturer offers a better warranty than a competitor, then the reliability of the product should also be better, to reduce costs associated with warranty claims.

Because of this signaling characteristic, warranty is an important product feature and can be used to promote sales. A market study in the *Journal of Consumer Research* concluded that for the consumer durables and motor vehicle markets "warranties were accurate signals of product reliability" [8]. A second study [9] found that for automobiles and some consumer durables, warranty was better at signaling product reliability after the Magnuson-Moss Warranty Act than before. Other studies have found that warranties were accurate signals both before and after the Act [6].

### 1.3.3 Investment Theory

More recently, warranty has been viewed as both an insurance policy and a repair contract. This gives rise to a third theory of warranty, the investment theory (more on this can be found in [10]). Under this theory, the buyer sees warranty as an investment that reduces the risk of costs due to early failure. Manufacturers are insured against having to rectify problems caused by inappropriate use, while the buyer is covered for repair costs of premature failures. The aim is to extend the useful life of the product by specifying responsibilities of the manufacturer and the buyer. By specifying a repair policy, the manufacturer aims to build a long-term relationship with customers, thereby retaining their business even after the warranty period expires.

## 1.4 Warranty and Manufacturing

### 1.4.1 Impact of Warranty

Modern industrial societies are characterized by (i) rapidly changing technologies, (ii) fierce competition between manufacturers whose products are often nearly identical due to common components and technology, and (iii) better educated and more demanding customers. This raises serious challenges for buyers, manufacturers and policy makers at national and regional levels.

The notion of post-sale support is becoming an important feature of most product sales. In this context, warranty (and extended warranty, which the consumer can buy at additional cost as opposed to the base or normal warranty that is an integral part of the sale) is an element of post-sale support and manufacturers need to view it as part of the post-sale service strategy. A warranty of any type, since it involves an additional service associated with a product, will lead to potential costs beyond those associated with the design, manufacture and sale of the product. These costs, in fact, are unpredictable future costs, which have typically ranged from 2% to as much as 15% of net sales [11], depending on the product and the manufacturer. According to D. F. Blumberg, total expenditures for repair and service in the USA is \$247 billion, about 10 – 12% (or roughly \$25 – 28 billion dollars) for goods under warranty. The market for stand-alone warranty/claims processing solutions in 2002 is \$194 million, with another \$110 million being spent on Internet-based warranty portals. The overall market, “still in infancy,” is experiencing a 19% annual growth rate [12]. In the North American automotive industry, warranty costs were just over \$700 million in 1965 and this increased to \$5 billion by 1988 [13]; according to Thomas Roehm (SAS Automotive Practice Manager), this figure is currently 8.5 billion dollars. As a result of the substantial costs of administering and servicing claims, warranty has a significant impact on the total profits of a manufacturing business. Similarly, for businesses where new products purchased constitute a major component of the total operating budget, ineffective management of warranties can have a significant impact on total operating costs.

The cost of servicing a warranty depends on the reliability of the product as well as the product usage mode and the maintenance and care exercised by the buyer. Product reliability, in turn, depends on the decisions made during the design and manufacturing of the product. Warranty servicing costs can be reduced through better design and greater control during manufacturing. However, this results in higher unit manufacturing cost. Warranty and price play an important role in determining total sales and the implication of reliability on warranty cost is of great importance to manufacturers.

The normal (or base) warranty is integral to product sale and is factored into the sale price. In contrast, extended warranties are warranties that buyers can purchase by paying an additional amount, so that the item is covered for a period beyond that stated in the base warranty. Extended warranties are not only offered by manufacturers, but also by third parties such as dealers, many insurance companies and some credit card operators (such as American Express). It has been a source of additional revenue to businesses offering extended warranties. Ford recorded profits in excess of \$100 million from sales of extended warranties in 1988 despite fierce competition from independent insurers. Sears alone is reputed to have sold over \$1 billion worth of extended warranties in 1991 [14]. In the case of home electronics, at least half of the profits at some major appliance stores are due to sales of extended warranties [15].

### 1.4.2 Warranty Decisions

As mentioned earlier, warranty serves as a promotional tool that allows a manufacturer to differentiate its product from those of its competitors. Offering better warranty terms signals better product quality and greater assurance and this in turn leads to greater sales.

This implies that warranty decisions need to be made in a framework that takes into account the strong link between technical aspects (such as design and manufacturing) and commercial aspects (revenue generated by sales and the manufacturing and warranty servicing costs) from an overall business perspective.

The following is an illustrative sample of some of the decision problems that a manufacturer needs to address:

1. How does product reliability affect claims over the warranty period?
2. What is the impact of poor quality control during production on the expected warranty servicing cost?
3. What is the expected warranty servicing cost as a function of the terms of the warranty policy?
4. What should be the optimal investment in reliability improvement, given the warranty terms?
5. What testing effort should be undertaken to reduce the risk that the warranty cost will not exceed some specified value?
6. What warranty strategy should be used to promote the product?
7. What is the expected number of spares needed to service failures of a non-repairable component over the warranty period?

8. How should one deal with the logistic issues for effective warranty servicing?
9. How should service agents for servicing claims under warranty be selected?
10. How should the contract with the service agent be drafted to provide incentives for honesty and for provision of the best possible service?
11. What kind of data should be collected for effective warranty management?
12. How does one develop an effective warranty management system?
13. How should a manufacturer administer warranties for consumer durables?
14. How should a manufacturer administer warranties that include reliability performance measures?
15. How should a manufacturer respond to changes in warranty legislation?
16. How can a warranty dispute be resolved?

Manufacturing is a complex system involving the following four stages:

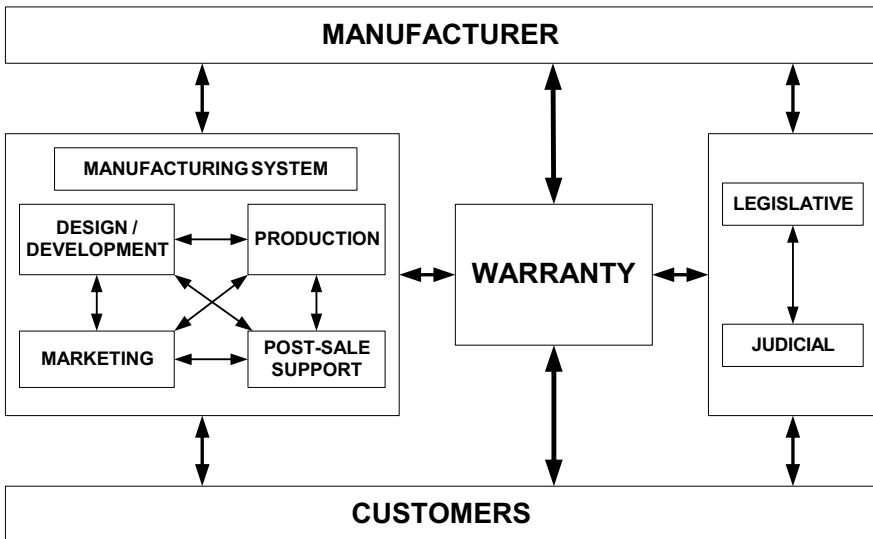
- Design and Development
- Production
- Marketing
- Post-sale Support

Warranty decisions must be made taking into account the link between warranty and other decisions at each of these stages. In addition, legal aspects, including the legislative and judicial processes relating to production and sale of products, must be taken into account. Figure 1.1 shows the different key elements that are relevant for solving a variety of warranty decision problems, some of which were discussed earlier. Each of the elements involves several variables and these interact with each other. These interactions need to be taken into account in effective warranty decision-making and will be discussed in more detail in later chapters of the book.

### **1.4.3 Warranty Management**

Management needs to be done at two different levels – strategic and operational. Strategic Management deals with decision-making with regard to all aspects of the product from an overall business viewpoint and over the product life cycle, which encompasses the period from initial conception to manufacture and marketing to product obsolescence. As such, the time frame is long and the decision-making needs to take into account the uncertain nature of the impact of external factors (for example, the economy, competitors actions, etc.) and some internal factors (for example, outcome of research and development). A strategy is a managerial outline for the future. Within a business, there are both long-term strategic objectives and shorter-term operational goals that affect the structure and functionality of business dynamics. Strategic management aims to integrate these into a consistent overall “business strategy” outlining the future direction of the company within a specified planning period (medium to long term). Operational management is responsible for achieving the day-to-day intermediate steps needed to reach the strategic objectives.





**Figure 1.1.** Warranty and manufacturing

Organization's strategies are set by top management and influence strategies at lower levels. These include technical/operational strategies such as the following:

- *Technical strategies* – outline goals, expectations and measures by which product performance can be ascertained and improved.
- *Design and development strategy* – concerned with product design, development and testing; developed in response to new product strategy objectives for design and reliability.
- *Manufacturing strategy* – covers the quality and cost aspects of production.
- *Material purchasing strategy* – oversees the selection and quality of materials, parts and components from suppliers, and associated contractual issues.
- *Process control strategy* – concerned with the size of production lots, monitoring methods, the design of the product and process, and the manufacturing cost; outlines procedures for sampling and testing and standards for acceptance, and helps to monitor process quality.
- *Process maintenance strategy* – describes the procedures for maintenance scheduling and aims to minimize unplanned down time and associated costs.

Commercial strategies that are developed in response to corporate strategies to control cost and promotional aspects include the following:

- *Marketing strategy* – involves assessing the potential market to ascertain what product features, price, and warranty terms are in demand, and developing strategies for pricing and for advertising in response to these.

- *Post-sale servicing strategy* – outlines procedures and objectives for warranty terms, extended warranty issues, and repair strategies.
- *Service strategies* – developed to provide benefits to customers and deal with customer dissatisfaction.

## 1.5 Objectives of the Book

The main objective of the book is to present an approach to strategic warranty management from an overall business point of view. This implies addressing a variety of warranty-related decision problems, taking into account the link between warranty and the different elements of manufacturing. Strategic warranty management requires that the warranty strategy must be formulated in conjunction with other functional (technical and commercial) strategies. Operational strategies then need to be developed to address various issues, taking into account the link between warranty and activities at the different elements of manufacturing.

The book is designed to help managers manage the internal warranty process. Critical to the success of this is the systems approach, involving the use of analysts to execute some of the essential steps. Managers need to understand what analysts need in order to carry out their tasks. One of these is a data collection system. Proper data collection is critical. The different kinds of data generated at each of the four elements of a manufacturing system (shown in Figure 1.1) will be discussed in later chapters and the relevance of these for warranty decision-making will be highlighted throughout the remainder of the book.

In addition, the analyst needs several different tools and techniques for model building, analysis and optimization. We do not discuss this in detail, but do cite appropriate references. As such, the book is a good starting point for analysts who will assist managers responsible for product warranty in a business.

The book deals with a variety of issues relating product warranty and manufacturing. Many of these are illustrated using one or more of the following products.

Product 1: Photocopier

Product 2: Automobile

## 1.6 Outline of the Book

The book is comprised of 15 chapters. In this section we give a brief outline of each chapter.

### *Chapter 1. Introduction and Overview*

Chapter 1 begins with a brief discussion on the scope and focus of the book. Effective warranty management requires a framework that can integrate the different technical and commercial aspects of manufacturing. These are discussed briefly and the chapter concludes with an outline of the book.

*Chapter 2. Products and Product Quality*

Chapter 2 begins with a discussion of products and alternate ways of classifying products. It then looks at various measures of product performance.

*Chapter 3. Product Warranty*

The concept, role and different perspectives on warranty are discussed in Chapter 3. A taxonomy for warranty is presented along with a range of warranty policies.

*Chapter 4. Warranty Management*

Chapter 4 deals with warranty management at both strategic and operational levels. At the strategic level, warranty strategy must be decided in conjunction with other technical (design, production) and commercial strategies (marketing, servicing). This is done using the concept of a product life cycle consisting of five stages: (i) Front-end, (ii) Design and Development, (iii) Production, (iv) Marketing, and (v) Post-sale Support. At the operational level, decisions regarding several technical issues (such as testing for reliability) and commercial issues (such as inventory levels for effective servicing of claims) are addressed in a manner that ensures that they are compatible with the strategic decisions.

*Chapter 5. Systems Approach to Warranty Management*

The systems approach is a very general approach for solving many different kinds of problems. It is an important tool for evaluation of alternate options and decision-making with regard to optimal strategies. The key element of the approach is the use of mathematical models. In Chapter 6 we discuss the systems approach and discuss some issues relating to model building.

*Chapter 6. The Role and Use of Data in Warranty Management*

There are many types of data that are of importance in the context of warranty management. These include test data, economic data, claims data and numerous others. In Chapter 6, we discuss the collection, analysis, interpretation and uses of data for modeling, prediction, and other aspects of warranty management.

*Chapter 7. Warranty Cost Analysis*

Chapter 7 deals with warranty cost analysis from both manufacturer and buyer perspectives. This involves the use of models to predict warranty claims, taking into account important variables such as product reliability, warranty-servicing actions, customer usage patterns, and so forth.

*Chapter 8. Warranty Considerations in Product Design and Development*

The reliability of a product depends on the engineering of the product based on decisions made during the design and development stages. The reliability of a product can be improved through better design and development and such an improvement leads to lower warranty costs. Reliability improvement, however, involves additional costs and is worthwhile only if the reduction in warranty costs exceeds these costs. Chapter 8 deals with the interaction between warranty and design and development.

*Chapter 9. Implications of Warranty on Production Decisions*

Because of variability in production, the quality of items produced varies. In the simplest characterization of this variability, an item is classified as either conforming to design specifications or not. The reliability of nonconforming items is low and results in high warranty costs. Chapter 9 looks at the link between product quality and warranty. There are several strategies for improving product quality. All involve additional costs. Optimal decisions with regard to quality control and improvement take into account the trade-off between the cost of quality and warranty costs.

*Chapter 10. The Role of Warranty in Marketing*

Warranty in the marketing context serves a dual role. It provides (i) information regarding product reliability and (ii) assurance against product failures over the warranty period. Better warranty terms (such as a longer warranty period) improve sales. This results in higher revenue, but also results in greater warranty costs. This, in turn, impinges on the sale price. Thus the choice of warranty terms, as a marketing strategy, must take into account the interaction between price, warranty terms, and sales. Chapter 10 looks at this issue and at decision-making with regard to marketing strategies, taking into account the interaction between warranty and marketing variables.

*Chapter 11. Warranty Logistics*

Warranty logistics deals with all of the operations necessary for servicing warranty in the most cost-effective manner. Here we deal with issues such as location of warehouses for spare parts and repair facilities, inventory levels for spares, and warranty servicing strategies. In many cases, a third party carries out the servicing of warranty. This raises several new issues (such as adverse selection, moral hazard, contracts, etc.) that the manufacturer must address. Chapter 11 deals with these issues and with strategies for cost-effective warranty servicing.

*Chapter 12. Reliability Improvement Warranties*

Reliability Improvement Warranty (RIW) policies are different from standard warranties in that the RIW requires that the manufacturer carry out reliability improvement if the reliability performance falls short of the levels stated in the warranty contract. The management of such warranties poses new challenges and these are discussed in Chapter 12.

*Chapter 13. Financial, Societal and Legal Aspects of Warranty*

The accounting of warranty for taxation purposes is important because of the dual (promotional and protectional) roles of warranty. In addition, any warranty decision must take into account relevant warranty legislation, much of which has arisen in response to issues pursued by the consumerism movement. Finally, warranty disputes occasionally arise for a variety of reasons. These factors must be taken into account in the overall management of warranty and are briefly discussed in Chapter 13.

### *Chapter 14. Warranty Management System*

Warranty management requires linking warranty decisions with decision-making at the different stages of the product life cycle. This must be done in an integrated manner. The warranty management system needed for accomplishing this is addressed in Chapter 14. The key elements of a warranty management system are (i) a data collection system, (ii) a package of tools and techniques for data analysis and for model building, analysis and optimization, and (iii) a user interface to assist the manufacturer in making proper decisions for effective warranty management.

### *Chapter 15. Conclusion*

Chapter 15 summarizes the salient points of the book in the form of guidelines to assist manufacturers in the strategic management of warranty from an overall business viewpoint.

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