CHAPTER ONE

Introduction

Clockwise from top left: Photo by Stuart Cohen; Copyright 2002 Hewlett-Packard Company. Reproduced with permission; Courtesy of Boeing; Courtesy of Volkswagen of America; Courtesy of Rollerblade, Inc.

EXHIBIT 1-1
Examples of engineered, discrete, physical products (clockwise from top left): Stanley Tools Jobmaster Screwdriver, Hewlett-Packard DeskJet Printer, Boeing 777 Airplane, Volkswagen New Beetle, and Rollerblade In-Line Skate.

The economic success of most firms depends on their ability to identify the needs of customers and to quickly create products that meet these needs and can be produced at low cost. Achieving these goals is not solely a marketing problem, nor is it solely a design problem or a manufacturing problem; it is a product development problem involving all of these functions. This book provides a collection of methods intended to enhance the abilities of cross-functional teams to work together to develop products.

A *product* is something sold by an enterprise to its customers. *Product development* is the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product. Although much of the material in this book is useful in the development of any product, we explicitly focus on products that are engineered, discrete, and physical. Exhibit 1-1 displays several examples of products from this category. Because we focus on engineered products, the book applies better to the development of power tools and computer peripherals than to magazines or sweaters. Our focus on discrete goods makes the book less applicable to the development of products such as gasoline, nylon, and paper. Because of the focus on physical products, we do not emphasize the specific issues involved in developing services or software. Even with these restrictions, the methods presented apply well to a broad range of products, including, for example, consumer electronics, sports equipment, scientific instruments, machine tools, and medical devices.

The goal of this book is to present in a clear and detailed way a set of product development methods aimed at bringing together the marketing, design, and manufacturing functions of the enterprise. In this introductory chapter we describe some aspects of the industrial practice of product development and provide a roadmap of the book.

Characteristics of Successful Product Development

From the perspective of the investors in a for-profit enterprise, successful product development results in products that can be produced and sold profitably, yet profitability is often difficult to assess quickly and directly. Five more specific dimensions, all of which ultimately relate to profit, are commonly used to assess the performance of a product development effort:

- ***Product quality:*** How good is the product resulting from the development effort? Does it satisfy customer needs? Is it robust and reliable? Product quality is ultimately reflected in market share and the price that customers are willing to pay.
- ***Product cost:*** What is the manufacturing cost of the product? This cost includes spending on capital equipment and tooling as well as the incremental cost of producing each unit of the product. Product cost determines how much profit accrues to the firm for a particular sales volume and a particular sales price.
- ***Development time:*** How quickly did the team complete the product development effort? Development time determines how responsive the firm can be to competitive forces and to technological developments, as well as how quickly the firm receives the economic returns from the team's efforts.
- ***Development cost:*** How much did the firm have to spend to develop the product? Development cost is usually a significant fraction of the investment required to achieve the profits.

- ***Development capability:*** Are the team and the firm better able to develop future products as a result of their experience with a product development project? Development capability is an asset the firm can use to develop products more effectively and economically in the future.

High performance along these five dimensions should ultimately lead to economic success; however, other performance criteria are also important. These criteria arise from interests of other stakeholders in the enterprise, including the members of the development team, other employees, and the community in which the product is manufactured. Members of the development team may be interested in creating an inherently exciting product. Members of the community in which the product is manufactured may be concerned about the degree to which the product creates jobs. Both production workers and users of the product hold the development team accountable to high safety standards, whether or not these standards can be justified on the strict basis of profitability. Other individuals, who may have no direct connection to the firm or the product, may demand that the product make ecologically sound use of resources and create minimal dangerous waste products.

Who Designs and Develops Products?

Product development is an interdisciplinary activity requiring contributions from nearly all the functions of a firm; however, three functions are almost always central to a product development project:

- ***Marketing:*** The marketing function mediates the interactions between the firm and its customers. Marketing often facilitates the identification of product opportunities, the definition of market segments, and the identification of customer needs. Marketing also typically arranges for communication between the firm and its customers, sets target prices, and oversees the launch and promotion of the product.
- ***Design:*** The design function plays the lead role in defining the physical form of the product to best meet customer needs. In this context, the design function includes engineering design (mechanical, electrical, software, etc.) and industrial design (aesthetics, ergonomics, user interfaces).
- ***Manufacturing:*** The manufacturing function is primarily responsible for designing, operating, and/or coordinating the production system in order to produce the product. Broadly defined, the manufacturing function also often includes purchasing, distribution, and installation. This collection of activities is sometimes called the *supply chain.*

Different individuals within these functions often have specific disciplinary training in areas such as market research, mechanical engineering, electrical engineering, materials science, or manufacturing operations. Several other functions, including finance and sales, are frequently involved on a part-time basis in the development of a new product. Beyond these broad functional categories, the specific composition of a development team depends on the particular characteristics of the product.

Few products are developed by a single individual. The collection of individuals developing a product forms the *project team.* This team usually has a single team leader, who could be drawn from any of the functions of the firm. The team can be thought of as

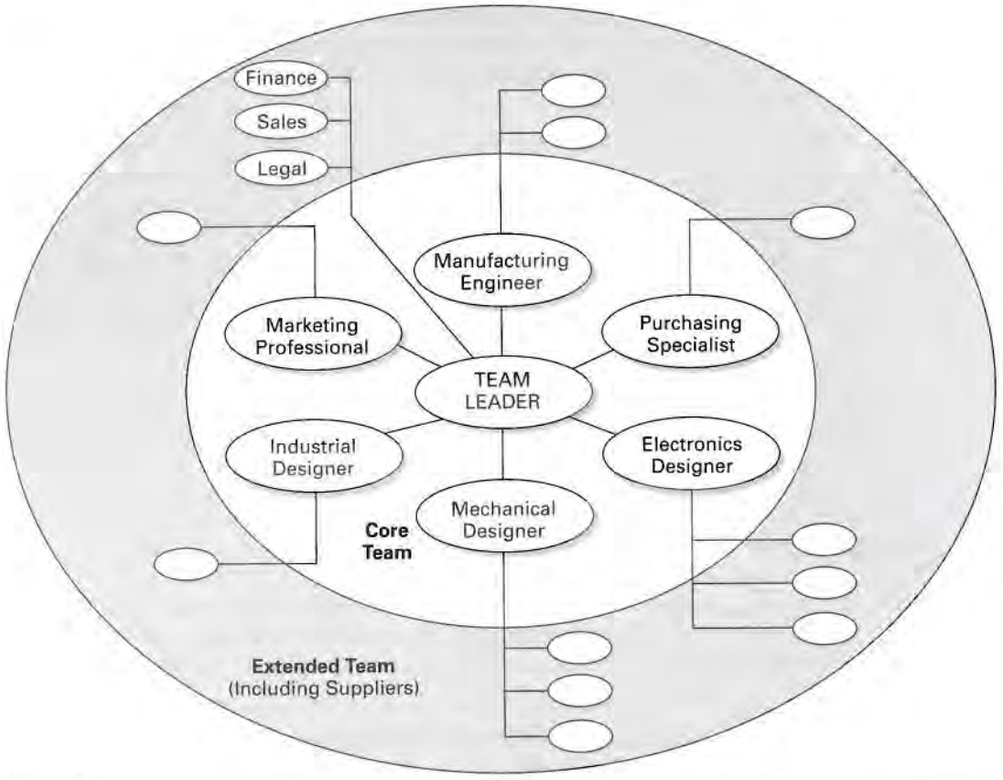

EXHIBIT 1-2 The composition of a product development team for an electromechanical product of modest complexity.

consisting of a *core team* and an *extended team.* In order to work together effectively, the core team usually remains small enough to meet in a conference room, while the extended team may consist of dozens, hundreds, or even thousands of other members. (Even though the term *team* is inappropriate for a group of thousands, the word is often used in this context to emphasize that the group must work toward a common goal.) In most cases, a team within the firm will be supported by individuals or teams at partner companies, suppliers, and consulting firms. Sometimes, as is the case for the development of a new airplane, the number of external team members may be even greater than that of the team within the company whose name will appear on the final product. The composition of a team for the development of an electromechanical product of modest complexity is shown in Exhibit 1-2.

Throughout this book we assume that the team is situated within a firm. In fact, a for-profit manufacturing company is the most common institutional setting for product development, but other settings are possible. Product development teams sometimes work within consulting firms, universities, government agencies, and nonprofit organizations.

	Stanley Tools Jobmaster Screwdriver	Rollerblade In-Line Skate	Hewlett-Packard DeskJet Printer	Volkswagen New Beetle Automobile	Boeing 777 Airplane
Annual production volume	100,000 units/year	100,000 units/year	4 million units/year	100,000 units/year	50 units/year
Sales lifetime	40 years	3 years	2 years	6 years	30 years
Sales price	$6	$200	$130	$20,000	$200 million
Number of unique parts (part numbers)	3 parts	35 parts	200 parts	10,000 parts	130,000 parts
Development time	1 year	2 years	1.5 years	3.5 years	4.5 years
Internal development team (peak size)	3 people	5 people	100 people	800 people	6,800 people
External development team (peak size)	3 people	10 people	75 people	800 people	10,000 people
Development cost	$150,000	$750,000	$50 million	$400 million	$3 billion
Production investment	$150,000	$1 million	$25 million	$500 million	$3 billion

EXHIBIT 1-3 Attributes of five products and their associated development efforts. All figures are approximate, based on publicly available information and company sources.

Duration and Cost of Product Development

Most people without experience in product development are astounded by how much time and money are required to develop a new product. The reality is that very few products can be developed in less than 1 year, many require 3 to 5 years, and some take as long as 10 years. Exhibit 1-1 shows five engineered, discrete products. Exhibit 1-3 is a table showing the approximate scale of the associated product development efforts along with some distinguishing characteristics of the products.

The cost of product development is roughly proportional to the number of people on the project team and to the duration of the project. In addition to expenses for development effort, a firm will almost always have to make some investment in the tooling and equipment required for production. This expense is often as large as the rest of the product development budget; however, it is sometimes useful to think of these expenditures as part of the *fixed costs* of production. For reference purposes, this production investment is listed in Exhibit 1-3 along with the development expenditures.

The Challenges of Product Development

Developing great products is hard. Few companies are highly successful more than half the time. These odds present a significant challenge for a product development team. Some of the characteristics that make product development challenging are:

- ***Trade-offs:*** An airplane can be made lighter, but this action will probably increase manufacturing cost. One of the most difficult aspects of product development is recognizing, understanding, and managing such trade-offs in a way that maximizes the success of the product.
- ***Dynamics:*** Technologies improve, customer preferences evolve, competitors introduce new products, and the macroeconomic environment shifts. Decision making in an environment of constant change is a formidable task.
- ***Details:*** The choice between using screws or snap-fits on the enclosure of a computer can have economic implications of millions of dollars. Developing a product of even modest complexity may require thousands of such decisions.
- ***Time pressure:*** Any one of these difficulties would be easily manageable by itself given plenty of time, but product development decisions must usually be made quickly and without complete information.
- ***Economics:*** Developing, producing, and marketing a new product requires a large investment. To earn a reasonable return on this investment, the resulting product must be both appealing to customers and relatively inexpensive to produce.

For many people, product development is interesting precisely because it is challenging. For others, several intrinsic attributes also contribute to its appeal:

- ***Creation:*** The product development process begins with an idea and ends with the production of a physical artifact. When viewed both in its entirety and at the level of individual activities, the product development process is intensely creative.
- ***Satisfaction of societal and individual needs:*** All products are aimed at satisfying needs of some kind. Individuals interested in developing new products can almost always find institutional settings in which they can develop products satisfying what they consider to be important needs.
- ***Team diversity:*** Successful development requires many different skills and talents. As a result, development teams involve people with a wide range of different training, experience, perspectives, and personalities.
- ***Team spirit:*** Product development teams are often highly motivated, cooperative groups. The team members may be colocated so they can focus their collective energy on creating the product. This situation can result in lasting camaraderie among team members.

Approach of This Book

We focus on product development activities that benefit from the participation of all the core functions of the firm. For our purposes, we define the core functions as marketing, design, and manufacturing. We expect that team members have competence in one or more specific disciplines such as mechanical engineering, electrical engineering, industrial design, market research, or manufacturing operations. For this reason, we do not discuss, for example, how to perform a stress analysis or to create a conjoint survey. These are disciplinary skills we expect someone on the development team to possess. The integrative methods in this book are intended to facilitate problem solving and decision making among people with different disciplinary perspectives.

Structured Methods

The book consists of methods for completing development activities. The methods are structured, which means we generally provide a step-by-step approach and often provide templates for the key information systems used by the team. We believe structured methods are valuable for three reasons: First, they make the decision process explicit, allowing everyone on the team to understand the decision rationale and reducing the possibility of moving forward with unsupported decisions. Second, by acting as "checklists" of the key steps in a development activity they ensure that important issues are not forgotten. Third, structured methods are largely self-documenting; in the process of executing the method, the team creates a record of the decision-making process for future reference and for educating newcomers.

Although the methods are structured, they are not intended to be applied blindly. The methods are a starting point for continuous improvement. Teams should adapt and modify the approaches to meet their own needs and to reflect the unique character of their institutional environment.

Industrial Examples

Each remaining chapter is built around an example drawn from industrial practice. The major examples include the following: a line of bowling equipment, a digital copier, a cordless screwdriver, a mountain bike suspension fork, a power nailer, a dose-metering syringe, an electric scooter, a computer printer, a mobile telephone, an automobile engine, a mobile robot, a seat belt system, a coffee-cup insulator, a digital photo printer, and a microfilm cartridge. In most cases we use as examples the simplest products we have access to that illustrate the important aspects of the methods. When a screwdriver illustrates an idea as well as a jet engine, we use the screwdriver. However, every method in this book has been used successfully in industrial practice by hundreds of people on both large and small projects.

Although built around examples, the chapters are not intended to be historically accurate case studies. We use the examples as a way to illustrate development methods, and in doing so we recast some historical details in a way that improves the presentation of the material. We also disguise much of the quantitative information in the examples, especially financial data.

Organizational Realities

We deliberately chose to present the methods with the assumption that the development team operates in an organizational environment conducive to success. In reality, some organizations exhibit characteristics that lead to dysfunctional product development teams. These characteristics include:

- ***Lack of empowerment of the team:*** General managers or functional managers may engage in continual intervention in the details of a development project without a full understanding of the basis for the team's decisions.

- ***Functional allegiances transcending project goals:*** Representatives of marketing, design, or manufacturing may influence decisions in order to increase the political standing of themselves or their functions without regard for the overall success of the product.
- ***Inadequate resources:*** A team may be unable to complete development tasks effectively because of a lack of staff, a mismatch of skills, or a lack of money, equipment, or tools.
- ***Lack of cross-functional representation on the project team:*** Key development decisions may be made without involvement of marketing, design, manufacturing, or other critical functions.

While most organizations exhibit one or more of these characteristics to some degree, the significant presence of these problems can be so stifling that sound development methods are rendered ineffective. While recognizing the importance of basic organizational issues, we assume, for clarity of explanation, that the development team operates in an environment in which the most restrictive organizational barriers have been removed.

Roadmap of the Book

We divide the product development process into six phases, as shown in Exhibit 1-4. (These phases are described in more detail in Chapter 2, Development Processes and Organizations.) This book describes the concept development phase in its entirety and the remaining phases less completely, because we do not provide methods for the more focused development activities that occur later in the process. Each of the remaining chapters in this book can be read, understood, and applied independently.

- Chapter 2, Development Processes and Organizations, presents a generic product development process and shows how variants of this process are used in different industrial situations. The chapter also discusses the way individuals are organized into groups in order to undertake product development projects.
- Chapter 3, Product Planning, presents a method for deciding which products to develop. The output of this method is a mission statement for a particular project.
- Chapters 4 through 8, Identifying Customer Needs, Product Specifications, Concept Generation, Concept Selection, and Concept Testing, present the key activities of the concept development phase. These methods guide a team from a mission statement through a selected product concept.
- Chapter 9, Product Architecture, discusses the implications of product architecture on product change, product variety, component standardization, product performance, manufacturing cost, and project management; it then presents a method for establishing the architecture of a product.
- Chapter 10, Industrial Design, discusses the role of the industrial designer and how human interaction issues, including aesthetics and ergonomics, are treated in product development.
- Chapter 11, Design for Manufacturing, discusses techniques used to reduce manufacturing cost. These techniques are primarily applied during the system-level and detail-design phases of the process.

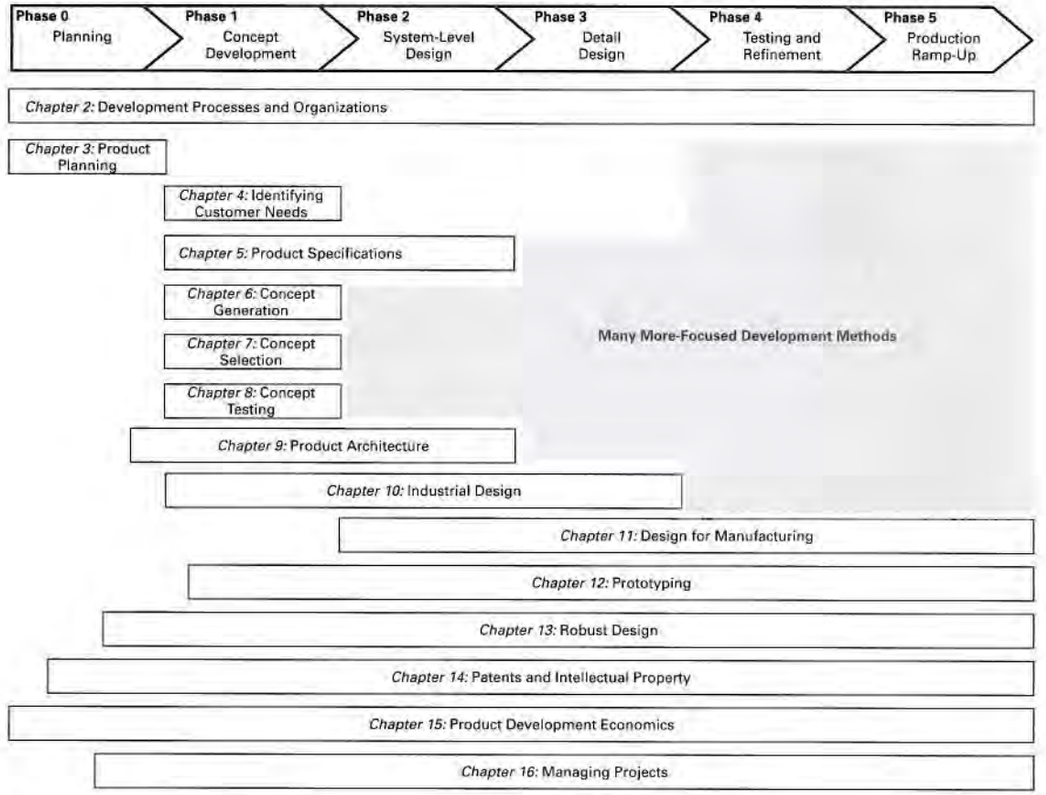

EXHIBIT 1-4 The product development process. The diagram shows where each of the integrative methods presented in the remaining chapters is most applicable.

- Chapter 12, Prototyping, presents a method to ensure that prototyping efforts, which occur throughout the process, are applied effectively.
- Chapter 13, Robust Design, explains methods for choosing values of design variables to ensure reliable and consistent performance.
- Chapter 14, Patents and Intellectual Property, presents an approach to creating a patent application and discusses the role of intellectual property in product development.
- Chapter 15, Product Development Economics, describes a method for understanding the influence of internal and external factors on the economic value of a project.
- Chapter 16, Managing Projects, presents some fundamental concepts for understanding and representing interacting project tasks, along with a method for planning and executing a development project.

References and Bibliography

A wide variety of resources for this chapter and for the rest of the book are available on the Internet. These resources include data, templates, links to suppliers, and lists of publications. Current resources may be accessed via
www.ulrich-eppinger.net

Wheelwright and Clark devote much of their book to the very early stages of product development, which we cover in less detail.

Wheelwright, Stephen C., and Kim B. Clark, *Revolutionizing Product Development: Quantum Leaps in Speed, Efficiency, and Quality,* The Free Press, New York, 1992.

Katzenbach and Smith write about teams in general, but most of their insights apply to product development teams as well.

Katzenbach, Jon R., and Douglas K. Smith, *The Wisdom of Teams: Creating the High-Performance Organization,* Harvard Business School Press, Boston, 1993.

These three books provide rich narratives of development projects, including fascinating descriptions of the intertwined social and technical processes.

Kidder, Tracy, *The Soul of a New Machine,* Avon Books, New York, 1981.

Sabbagh, Karl, *Twenty-First-Century Jet: The Making and Marketing of the Boeing 777,* Scribner, New York, 1996.

Walton, Mary, *Car: A Drama of the American Workplace,* Norton, New York, 1997.

Exercises

1. Estimate what fraction of the price of a pocket calculator is required to cover the cost of developing the product. To do this you might start by estimating the information needed to fill out Exhibit 1-3 for the pocket calculator.
2. Create a set of scatter charts by plotting each of the rows in Exhibit 1-3 against the development cost row. For each one, explain why there is or is not any correlation. (For example, you would first plot "annual production volume" versus "development cost" and explain why there seems to be no correlation. Then repeat for each of the remaining rows.)

Thought Question

1. Each of the chapters listed in Exhibit 1-4 presents a method for a portion of the product development process. For each one, consider what types of skills and expertise might be required. Can you make an argument for staffing the development team from start to finish with individuals possessing all of these skills and areas of expertise?

CHAPTER TWO

Development Processes and Organizations

Courtesy of AMF Bowling Worldwide

EXHIBIT 2-1
A ball return, one of AMF Bowling's products.