Value Driven Product Planning and Systems Engineering

H.E. Cook and L.A. Wissmann

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To Valle and Juliana

Preface

Engineers and scientists often need to sell an innovative idea for a new product or a new product improvement to top management. Sometimes their tendency is to focus on the "WOW!" of the new technology at the expense of making a convincing business case. When the new technology represents a large cost reduction, there will be much less of a problem in convincing management to approve the project if the investment level is acceptable. The major rub comes when the new feature or technology is an improvement in customer value that also generates an increase in cost. This makes the sell difficult in spite of the fact that many of the inventive products available today are widely used because they provide very high value in relation to their added cost.

For example, the laptop computer is infinitely more versatile than the inexpensive slide rule or abacus. Disc brakes are far superior to less costly drum brakes and radial tires are superior to bias-belted. The modern automobile itself is far superior to the horse and buggy for general transportation. Commercial aircraft provide value well beyond that for ocean liners for people who have limited time for travel. The list, of course, is almost endless but unfortunately, that does not make selling improved value any easier when costs are also increased. Because any change involves risk, getting the approval to develop and implement a new technology is far from certain because decision makers may not have confidence in the analysis methodology supporting the proposal if it appears ad hoc

Nevertheless, engineers and scientists are expected by management to come up with innovative ideas that make it to the marketplace so they need to have a well-grounded, convincing methodology for selling the value improvement and profitability of their proposals. Many engineers and scientists also occupy product planning and systems engineering positions as decision makers who review and select ideas for improving value and profits that come from others inside and outside the company. Thus, as buyers, they also need a methodology for accurately evaluating the financial impact of new features and technologies while anticipating what their major competitors are likely to do to improve their next generation of product.

These problems are exacerbated in today's global economy because the number of competitors has increased markedly in many product segments and there are

many technological alternatives available for consideration. The problem of anticipating the moves of your major competitor is particularly challenging because most firms keep their plans very secure. As a result, the engineer or scientist as product planner must learn to think like its major competitor using customer value as a guide.

The objective of this book is to support engineers and scientists in assessing the likely business case for new, innovative product concepts and product improvements. We have tried to strike the right balance between rigor and simplicity. Rigor is compromised if product planning is based solely on the gut feel of a top executive. For example, when the Ford Taurus hit the marketplace in the mid 1980s, the CEO of a major competitor privately observed that the "potato shape" would never catch on; which means that it would not have seen the light of day in his company. Of course, the Taurus was the most successful car released by Ford in the last twenty years. However, a deep, protracted analysis that crosses all of the t's and dots all of the i's leads to products that are late to market.

The view here is that the use of simple but quantitative tools, which allow a wider range of options to be considered relatively quickly, can be catalytic in bringing fresh, exciting products to market. The tools do not have to be perfect. Only better than what is being used and capable of improvements based upon feedback and learning from prior applications. There is also an important role for intuition in the early stages of product planning and this book describes a methodology for quantifying it for initiating the planning process. Top executives are encouraged to use it to quantify their intuition or gut feel.

The book may also appeal to marketing research specialists as it includes methods and viewpoints, which may be unfamiliar to them. For example, in spite of its simplicity, the linear demand model is shown to provide both qualitative and quantitative insight into pricing and forecasting demand. Moreover, the connection between the linear and logit models is used to show that the price coefficient in the utility expression is different if demand floats as in a real market or is fixed as in certain surveys. The Direct Value survey method, which has been developed in the engineering literature, is covered here in some detail because its simplicity minimizes cognitive stress on respondents and provides a straightforward means for assessing customer value.

The book is divided into four descriptive chapters, twelve case studies, and six appendices. Chapter 1 focuses on understanding customer value and its influence on price, demand, and profit. Chapter 2 describes the methods used to assess value and to construct surveys for accurately measuring value. Chapter 3 shows how to compute value and its statistical properties from survey results using spreadsheet programs without the need for special software. The spreadsheet expressions used in the computations are included as part of most tables. This facilitates the use of the material as a textbook supporting a course on customer value, which could be offered to students who have had an introductory course in statistics. Chapter 4 is a simulated product planning exercise for the redesign of an automobile, which demonstrates the use of the tools and methods developed. The case studies analyze

and solve a variety of product planning problems using the methods developed and the spreadsheet templates downloaded from the publisher's webpage.[1]

The expressions that show how value influences demand and price are presented in Appendix A. The methods for developing and classifying value curves for continuous attributes are developed in Appendix B. Value curves are mirror images of Taguchi's curves for the cost of inferior quality and they have been incorporated into design of experiments at the system level.[2] A key outcome is that the concept of robustness can now be imbedded formally into system design and linked in a seamless manner to Taguchi's robust methods for component design. Product planners are encouraged to combine intuition and information from human factor studies to make rough, initial assessments of value curves. The results are then used to develop the formal survey needed to make a more accurate assessment of value.

Appendix C describes how to use the spreadsheet templates to analyze the value of individual product attributes from the responses to a survey and how to determine the total value of each of the products competing in a market segment from their demand and price trends. Templates are also provided for estimating the variable costs of competing products and for computing the change in value when automotive attributes are changed. Appendix D shows how to use the results from a classical conjoint analysis survey to arrive at a measure of customer value in a more accurate and meaningful manner than given by classical part worth analysis. Appendix E demonstrates the special considerations that need to be made when analyzing the results from a presence/absence survey because of the number of choices not being constant from one choice set to the next. This problem, to our knowledge, has not been addressed before. Appendix F describes the use of orthogonal arrays (OAs) in designing surveys

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[1] http://www.springer.com/978-1-84628-964-4

[2] Cook HE (2005) Design for six sigma as strategic experimentation. ASQ Quality Press, Milwaukee, WI

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1

Customer Value: A Key Financial Metric

Synopsis

Two types of financial metrics are examined, fundamental and bottom-line. The classic bottom-line metrics of demand, price, and profit are determined by the fundamental metrics of value to the customer, cost, and the pace of innovation. Special attention is given to value because in our experience it is the least understood fundamental metric. Although value is highly subjective, it can be assessed in dollars in a straightforward manner and used in setting price and forecasting demand. For example, the optimal price for a good sold by a monopoly is simply the sum of its value and cost, divided by two. If value or cost increases by $10, the monopolist should increase price by only $5. Pricing power is greatly reduced when competitors enter the market. Graphs based upon the classic Cournot model show that price falls dramatically as the number of competitors increase, this being painfully obvious to anyone who has experienced market dilution as a result of the addition of new, viable competitors. A new metric that measures the innovative power of an advanced technology is introduced to aid the setting of research and development priorities.

1.1 Financial Metrics: Bottom-line and Fundamental

The "bottom-line" metrics of cash flow, demand, price, and return on investment are driven by a second set of financial metrics represented by value to the customer, cost, and the pace of innovation. Get them right relative to competition and impressive bottom-line results should follow. Because of their importance, we call value to the customer, variable cost, and the pace of innovation the "fundamental metrics." Most of us have heard them expressed as "better, cheaper, and faster," today's mantra for surviving in the highly competitive global

marketplace. Customer value is the measure of better; variable cost is the measure of cheaper; and the pace of innovation is the measure of faster.[1]

Cost estimating is a well-developed skill in most firms. Relocating manufacturing operations to low wage locations is a major means of reducing costs today. The traditional ways of using existing components wherever possible, and reducing overall design complexity, of course, still apply.

The methods for improving the pace of innovation or speed are also well-known: increase the use of simulation software versus prototype hardware for developing new designs, reduce the layers of management to speed decision making, and increase the use of teams that cut across design, engineering, manufacturing, marketing, service, and finance. Finally, it is necessary to have strong-willed, knowledgeable, and persistent champions leading new product development teams within a disciplined innovation process (Carlson and Wilmot, 2006).

Our experience is that value is poorly understood relative to cost and speed. Some of the ignorance comes from the belief that the highly subjective nature of value prevents it from being quantified. But this is simply not correct and there are several excellent books on value that look at it from different perspectives thereby providing both quantitative and qualitative insight and understanding.

The classic book by Ben-Akiva and Lerman (1985) takes the reader through a rigorous development of the mathematical foundations for assessing value using discrete choice analysis. The more recent book by Louviere, Hensher, and Swait (2000) includes the major developments since 1985 and explores the elements of stated choice surveys in detail and depth. More descriptive books stress the strategic side of customer value while minimizing the mathematical development. These include the books by DeBonis, et. al. (2002), Gale (1994), Kordupleski and Simpson (2003), and Pardee (1996). The recent book by Carlson and Wilmot (2006) emphasizes the importance of customer value in driving the innovative process. The authors stress the need to generate a quantifiable "value proposition" as a key element in successfully selling a new product concept to a firm's management or to a venture capitalist. Kim and Mauborgne (2005) have emphasized the need for discovering value opportunities in new market spaces where competition is non-existent, at least initially.

This book strikes a balance between simplicity and rigor using a four step process:

Step one: Use of the simple but insightful linear demand model to introduce the concept of value and to show clearly how price is related to value, cost, and the number of competitors.

Step two: Use of surveys for assessing value that are easy for respondents to complete with minimal cognitive stress. Such surveys are also easy to design. The analysis of the outcomes for value is straightforward using the logit model in its simplest form.

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[1] For simplicity in what follows, we will use the word "value" to mean customer value and "cost" to mean variable cost.

Step three: Use of aggregate value assessments based upon all survey responses. But value, if necessary, can also be disaggregated along demographic lines such as gender, age, income, education, geographical location, ethnicity, and lifestyle to provide additional insight.

Step four: Use of analysis and statistical tools for assessing value that can be automated using a spreadsheet program without the need of special software.

1.2 Quantifying Value

So how do you go about quantifying something as subjective as value? Fortunately, for many product planning problems, you only need to discover how value changes when one or more attributes of the product are modified.[2] The process for measuring a value change starts by documenting how demand for an existing product changes with value and price. The relationships can be understood best by considering the demand D for a product sold by a monopoly:

$$D = K(V - P) \tag{1.1}$$

In this expression, K is an empirical constant, V is value, and P is the price of the product. It follows from Equation (1.1) that the change in demand is a function of the changes in value and price:

$$\delta D = K(\delta V - \delta P) \tag{1.2}$$

Thus, if price is changed by δP and value is not changed, then demand D changes by $\delta D' = -K\delta P$.

If the firm holds price fixed but changes a Critical-To-Value (CTV) product attribute g by δg,[3] this causes product demand to change by $\delta D''$. Since δP is zero, we see from Equation (1.2) that the value change δV due to the change in the attribute is exactly $\delta D''/K$ dollars.

Now assume that the CTV attribute is changed by an amount δg^* and that price is carefully tweaked by an amount δP^* such that demand does not change. It follows from Equation (1.2) that the value change, δV^*, is exactly equal to the price change, $\delta V^* = \delta P^*$, and independent of the empirical coefficient K. This property is very important because it shows that the value change for a product

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[2] Occasionally, however, we do want to know the total value of a product which can be estimated using linear demand theory from the prices and demands within a given market segment.

[3] For example, CTV attributes of a laptop computer include its weight, time to boot up, speed of computation, and keyboard feel. The CTV attributes of an automobile include its exterior and interior style, acceleration performance, interior noise level, fuel economy, and range.

improvement can be estimated by setting it equal to the price increment that leaves demand unchanged. This price increment can be determined using a survey designed specifically for this purpose (Donndelinger and Cook, 1997).

1.3 The Impact of Customer Value

1.3.1 Fly Me to the Moon

To explore the relationship of value to demand, price, and profits in more depth, let's consider a fictitious company that is planning to offer flights to the moon. The company, which will initially enjoy a monopoly for this route, has made many prove-out flights to the moon without incident so the trip is deemed safe. The company has invested $70,000,000 in the venture and is now wrestling with how to price the ticket, which will guarantee a buyer a seat on one of the flights within the next two years. After this period, the company's monopoly ends and several competitors are expected to enter the market.

If the ticket price was $100, you might jump at the opportunity but if priced at $10,000 you might not. Somewhere within this range there is a price, let's say $4,000, which you would grudgingly pay for the trip. Although the value of the ticket to you would be your limit price of $4,000, this will not necessarily be the asking price for the ticket. The reason is that the seller must set a single price for a group of buyers who value the trip differently. This is the classic pricing problem for a mass produced good sold by a monopoly.

The targeted demographic group for the trip consisted of 100,000 individuals having ages, incomes, education levels, and spirited lifestyles similar to yours. A sample of 2000 from this group were randomly selected and asked about their willingness to pay for a round trip moon flight over a range of prices. Their simulated responses are shown as the fractional demand function versus price in Figure 1.1. At a price of $0 all respondents said that they would purchase a ticket. However, no one in the sample said they would purchase a ticket if it was priced over $5000. Thus, the demand function is seen adequately described by Equation (1.1) with a single, aggregate value V equal to $5,000, which is also called the market reservation price or choke price.[4]

The company can use the demand information in Figure 1.1 to develop the optimal ticket price as follows. First, the company must determine if the total available flight capacity over the next two years is a limiting constraint. If capacity were only 20,000 passengers, which is 20% of the segment, the optimal price would be $4,000, which can be read directly from Figure 1.1 because it is the

[4] The question is begged as to how serious the survey results for value should be accepted. The empirical record according to Louviere, et. al. (2000, p. 21) is very supportive of the findings from stated choice surveys. As surveys reveal both the mean and standard deviation of value, the conservative approach is to take value as equal to the mean less two standard deviations.

largest price that will yield 20,000 customers. However, since the total flight capacity is actually 100,000 (100 flights can be made over two years with each flight having 1000 seats), the total flight capacity is not a limiting constraint.

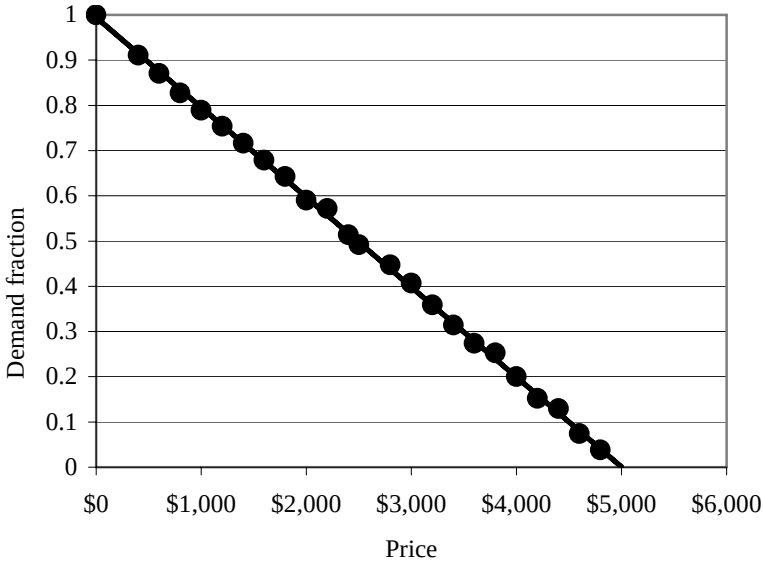

Figure 1.1. Simulated demand versus ticket price for a flight to the moon

Next, the company needs to consider how price affects gross revenue which is equal to the number of passengers times the price they are willing to pay resulting in the parabolic form shown in Figure 1.2. The optimal price for maximizing gross revenue is seen to be $2,500, which is equal to $(V + C)/2$. The variable cost C per passenger is zero here as the overall cost of a trip is fixed and independent of the number of passengers. Note that the price of $2,500 is well below the tickets' value of $5,000! At the optimal price, we see from Figure 1.1 that the company can expect to have 50,000 passengers (0.5 × 100,000) over the next two years. Thus, it will need to schedule only 50 flights and each should be full with 1000 passengers, thereby generating gross revenues of $2,500,000 per flight. This amount is twice the maximum shown in Figure 1.2 because if 100 flights were scheduled they would only be half-full at the optimal price. The company has estimated that the operational cost per trip is $500,000 and independent of the number of passengers. Thus, over the two year period, net revenue should be $100,000,000, which exceeds the amount invested by $30,000,000.

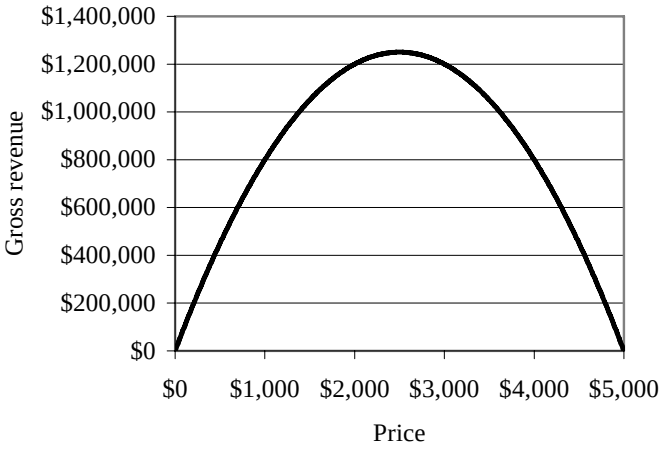

Figure 1.2. Gross revenue per flight as a function of ticket price

In this example, value was viewed in two different ways, one being the limiting price at the individual's level and the other being the limiting price at the aggregate level for a well-defined, demographic segment. Both viewpoints are useful. If a company could fully customize and price its product for any given customer, then the individual view is appropriate. Custom built homes are a good example. But most mass-produced products and services are aimed at a demographic segment and carry a single, base price and feature set. However, optional features are often available, which can be purchased to provide a degree of individual customization.

1.3.2 Shifting the Demand Curve by Improving Value

Two linear demand curves are shown in Figure 1.3 for a monopoly. The dashed line is the new demand function, which has been shifted because of an improvement in product value. The parameter K is equal to 2 units per year per $ for both and it can be assumed to be unchanged if the shift in value is not too large. Value is $10 for the solid line and $14 for the dashed line. The $4 in added value shifted the demand curve positively by $4. Demand goes to zero as price approaches value because buyers gain nothing in paying $10 or $14 to get $10 or $14, respectively, in value. The added variable cost is assumed to be $1.

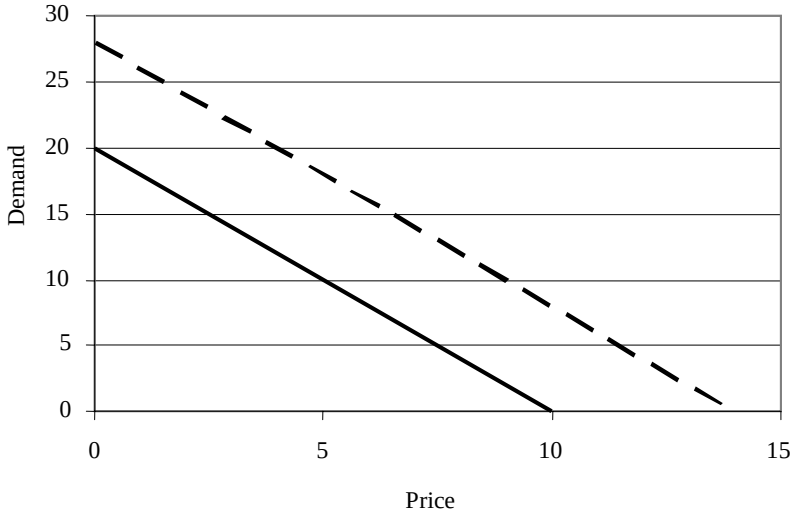

Figure 1.3. A change in value shifts the demand curve

The annual cash flow, A, shown in Figure 1.4 for each of the two demand curves in Figure 1.3 was computed using:

$$A = D[P - C] - F - M \tag{1.3}$$

In Equation (1.3), the terms F and M are the annual fixed costs and investment, respectively. The cash flows in Figure 1.4 are again parabolic having a maximum at a price half-way between cost and value. Fixed cost and investment were assumed zero for simplicity. A large cash flow increase occurs because the $4 in added value versus the $1 in added cost generated an increase in both price and demand.

1.3.3 Does Profit Maximization Gouge the Customer?

Profit maximization may suggest that the customer is being unfairly treated. To explore this point of view, consider the transaction in Figure 1.5. The largest price the buyer will pay is the value of the product, V, and the smallest price that a seller will likely consider is the variable cost, C. When a buyer and seller have equal bargaining power, they should receive the same net value for a transaction in that the net value to the seller given by $P - C$ should equal the net value to the buyer given by $V - P$. When the two net values are equated, the price they jointly arrive at is one-half value plus cost. This is the same expression for price that optimized revenue for the monopoly in Figure 1.2. If we extend this analogy to a monopoly selling products to a consumer group, the monopoly is simply sharing

equally with its customers the net value created much like the outcome in Figure 1.5. Thus, profit maximizing monopolists are not the devils sometimes depicted. The rest of society in Figure 1.5 is also a concerned participant in the transaction as a result of the cost of externalities, G, which is almost always negative due to the environmental impact of the manufacture, use, and disposal of the product.

Figure 1.4. Cash flows for the linear demand curves in Figure 1.1 are parabolic

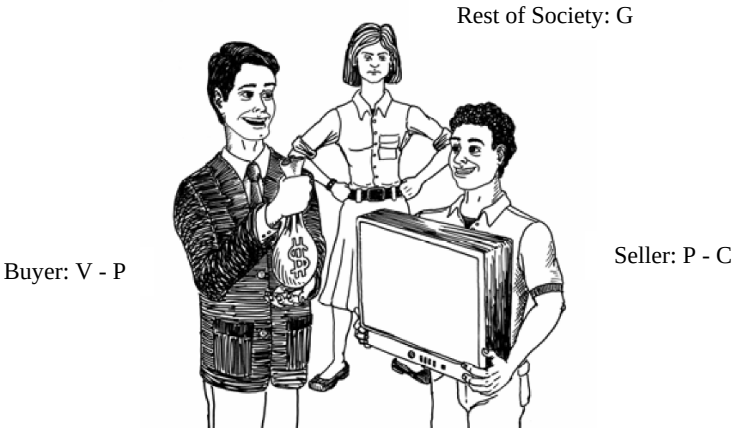

Figure 1.5. Schematic of net value changes for a simple transaction. (Redrawn from Source: Cook HE (1997) Product Management, Kluwer Academic, Figure 2.16, p. 44, © 1997, with kind permission Springer Science and Business Media.)

It has been suggested that a monopolist should price below the level that generates maximum revenue as this will limit competitors from entering the market. (See, for example, Kim and Mauborgne, 2005, p. 213). But this does not assure that competitors will not enter the market at a later time. Moreover, when the

monopolist lowers price, it reduces revenues available for new product development and encourages an increase in capacity to meet the added demand. Thus, when competitors do enter the market, the original monopolist is saddled with additional excess capacity for a product that has likely not grown much in value. An alternate strategy is for the monopolist to maintain the optimal price, plough substantial resources into innovative research and development, and incorporate the fruits of those activities in its product in a timely manner. This causes its product to grow continuously higher in value and lower in costs, making all would-be competitors think long and hard about entering its market.

1.3.4 The Innovative Power of a New Technology

The Innovative Power (IP) of a new technology measures the rate at which net value is being generated during development. It is equal to the added value δV less the added cost δC divided by the development time t_D needed to go from concept to production:

$$IP \equiv \frac{\delta V - \delta C}{t_D} \tag{1.4}$$

The pace of innovation is defined as $1/t_D$. If development time increases, the pace slows. Consider the addition of the second rear sliding door to the Dodge minivan in the 1997 model year, which added $1,250 in value based upon a national survey conducted jointly by Wu (1998) and Lee (1998). Assume that its added variable cost was $100 and its development time took 36 months. With these quantities, the innovative power per vehicle of this new feature was $32 per vehicle per month of development.[5] In isolation, the $32 per vehicle per month does not convey much information. However, it becomes very meaningful when ranked against other possible advanced research and development projects. A key competitive aspect of the second sliding door was that it represented a feature that a competitor could not duplicate without either making a costly tear-up of its current design or waiting until its next major redesign to make the change.

1.4 Market Dilution

1.4.1 Loss of Pricing Power

When competitors enter the market, the loss of pricing power of the original monopolist gives a solid edge in the net value for a transaction to the customer.

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[5] A full accounting of added value must include the impact of the technology on the environment, representing the externalities.