2007-03-07

Evaluating the Application of Modularity to Reduce Market Risk in Technology Push Products

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EVALUATING THE APPLICATION OF MODULARITY TO REDUCE MARKET RISK IN TECHNOLOGY PUSH PRODUCTS

by

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A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

Department of Mechanical Engineering

Brigham Young University

April 2007

BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

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ABSTRACT

EVALUATING THE APPLICATION OF MODULARITY
TO REDUCE MARKET RISK IN TECHNOLOGY
PUSH PRODUCTS

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Technology push product development presents a number of challenges over the more typical market pull product development. Despite these challenges, enough advantages exist to motivate firms to develop technology push products at greater risk. Modularity is a tool that can address some of these challenges. Currently most research and application of modularity have focused on market pull product development efforts. The research in this thesis explores the value of modularity in technology push product development through the development of methods and the analysis of 68 example products including 35 technology push products.

A method has been developed for quantifying the degree to which a product is market pull and technology push by applying scores derived from customer feedback. In the development of the scoring method, the meaning of the terms market pull and technology push have been explored and clarified allowing for beneficial application. The scoring

method was applied to 68 example products and then statistically evaluated to determine the effect that the market pull and technology push scores have on the probability of product success. With the market pull and technology push scores as a basis for the probability of success, the effect of modularity in technology push products can be determined. The concept of technology modularity was introduced in comparison to product modularity. Each of the 35 technology push products was evaluated to determine the level of both product and technology modularity present. These levels are used to statistically evaluate the affect of modularity on the probability of product success. This research presents methods for determining if technology modularity can significantly improve the probability of product success with examples indicating its value and application. Technology modularity, and its application, is validated as an important concept for technology push product developers. Three example products are provided to illustrate the application of this research to improve product development decisions. The methods, results, and conclusions of this research provide product developers with a powerful tool to aid them in the successful development and commercialization of technology push products.

ACKNOWLEDGMENTS

I would like to thank Dr. Spencer Magleby for his continued guidance during the course of this research and his immeasurable impact on my graduate school experience. His insights and contributions to this work were invaluable along with those of Dr. Jordan Cox and Dr. Alan Parkinson. I would also like to recognize the Ira A. Fulton College of Engineering and Technology and the Marriott School of Management at Brigham Young University for a broadened perspective of both engineering and business through the Product Development Program. Last, but not least, I would like to thank my wife, Tiffany, for her ongoing patience, and my two daughters who have endured with her.

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Chapter 1 INTRODUCTION

Products are a fundamental part of the world's economy. The goods sector represents one-fifth of the GDP in the United States and additionally provides a foundation for much of the service sector[1]. For firms that develop products, their growth depends on the introduction of new products that can provide additional revenue and hopes of increased margins. Many risks are involved in the development of new products. These risks are escalated when the product to be developed involves new technologies and/or pursues new markets. A firm's ability to understand these risks and implement appropriate product development methods can be a critical step to successfully commercializing a new product.

1.1. Background

This research aims to bring together two independent areas of product development research and to provide a method for evaluating the benefit of their coexistence to product developers. The two research areas are modularity and technology push product development.

1.1.1. Modularity

The process of designing and engineering products that accomplish the goal of cheaper quicker adaptability as market needs change has been the focus of many researchers. Pine[2] introduced the concept of "mass customization" which describes the strategy of offering customized products at mass produced prices. Pine states "Customers can no longer me lumped together in a huge homogenous market, but are individuals whose individual wants and needs can be ascertained and fulfilled." Mass customization suggests that an approach must be employed that allows customization to be offered at a cost near that of mass production manufacturing. The most prevalent approach in industry to accomplish the feat of mass customization is to base the design on common modules with common interfaces. This approach is referred to as modularity. Often modules are connected in a way that results in common structure or architecture. This form of modularity is most often referred to as a product platform. In their book, The Power of Product Platforms. Meyer and Lehnerd[3] define product platforms as "a set of subsystems and interfaces that form a common structure from which a stream of derivative products can be efficiently developed and produced." Product developers are able to employ product platforms to create a multiple related products, commonly referred to as a product family. Numerous consumer products exist today that make use of modularity and product platforms resulting in a product family. Examples include cars, tools, computers, bicycles and even airplanes.

The competitive environment among product companies usually requires products to be developed and manufactured at the lowest cost possible. As a result many products are designed to reside within a family of products that share common components and features. The product family approach based on modularity or product platforms has allowed companies to achieve some significant advantages.

The auto industry provides a clear example of the advantages hinted at in Meyer and Lehnerd's definition of product platforms. The basic car design is composed of subsystems, such as the engine, drive train, and body that interface with one another to form the common structure of a car. First, product families are able to offer more product variety to their customers without incurring the cost of an entirely new product. Nearly every model of car manufactured today has dozens of configurations available to customers. Whether it is 2 or 4 doors, automatic or manual transmission, the auto makers can appeal to a larger group of customers with a single car design. These configuration changes are usually achieved at a fraction of the cost of designing an entirely new vehicle.

A second advantage of product families is the ability to adapt to changing customer needs. Again the auto makers are able to create derivative cars each year that meet new customer needs. The majority of the underlying components remain the same from year to year along with the overall design while small changes are made that follow market trends. Again these changes are done at a fraction of the cost of designing an entirely new vehicle while being able to meet many of the new customer needs. By reducing development times and cost, derivative products with the same platform can be created rapidly. Manufacturing equipment can remain largely the same between product variants, so much so in the car industry that variants can often be manufactured on the same line. Economies of scale can also be achieved in manufacturing and purchasing through common components in product families.

Having recognized these advantages, many of the car makers have expanded the product family concept to include several different car models and can even extend across brands. Through the use of common components such as the chassis, engine, and others, what appear to be entirely different cars are being developed at a fraction of the cost. The product platform or modularity strategy has contributed to the auto industry's ability to offer a highly complex product at a price that is unrivaled by other products of comparable mechanical complexity.

1.1.2. Technology Push

In product development, two common classifications for new products are market-pull and technology-push. These two classifications describe the key driver for why the product development effort was undertaken. Market-pull product development usually takes place when some kind of need is discovered in the marketplace that currently is either being ignored, not well served, or just not recognized. In this case, developers are able to approach concept generation through developing concepts that fulfill this identified market need. Technology-push products, on the other hand, do not begin with a market need but instead with a technology. The company who owns such a technology approaches product development in a fundamentally different way. Instead of the market needs driving the concept generation in the design, the firm's technology takes on that driving role. First and foremost, the product must incorporate the firm's technology and then meet a market need. If the company discovers an unmet market need but is unable to incorporate their technology, the opportunity is usually foregone.

A classic example pointed out by Ulrich and Eppinger[4] is that of Gore-Tex®. Over the years, W.L. Gore & Associates have created dozens of products in several industries that incorporate their expanded Teflon sheet technology. Many of these products, such as their dental floss, medical products, and waterproof-breathable outerwear, were developed based on the idea that once potential customers witnessed the benefits of these products they would then recognize their need for it. For W.L. Gore and other firms developing technology-push products, this means that they often must develop new products without having the security of consumers expressing a need for their product, or at least a product containing their technology, and thus running the risk that the consumer may never recognize the need the product or technology promises to fulfill.

An excellent example of the risk of developing technology push products is the personal digital assistant (PDA). Apple developed the concept years before the first PalmPilot with the Newton. The Newton contained technology that would rival future PDAs for years to come. With virtually no market information to justify their technology, Apple pushed the Newton onto shelves. As the market became aware of this new product and their own needs, the Newton became the brunt of many jokes due to its overcomplexity. Despite a myriad of features and technology, the few features the average consumer was interested in were cumbersome to use in the Newton. Learning from the mistakes of Apple's design, US Robotics launched the PalmPilot three years later. After 3 more years, Palm had developed 8 new models as the needs of customers were discovered and changed resulting in their outstanding success which led to a 73% share of a rapidly growing U.S. market.[5] Since the failure of the Newton, Apple has stayed out of this market entirely.

Stories like that of the Newton have made many companies reluctant to plunge their funds into technology-push products. Despite the obvious risk, these products are the ones that create entirely new markets and have the potential to offer margins rarely seen by their market-pull counterparts.

1.1.3. Combining Modularity and Technology Push Product Development

Design for modularity methods and techniques have mainly targeted existing products or well-understood markets in both industry and academic research. The availability of market information eases the task of developing systematic methods to design for modularity. A common trend involves reviewing a company's product offerings then grouping them into product families to be redesigned in order to save cost through the advantages discussed previously. Unfortunately, at this point much time and money has already been wasted. Efforts in industry or academic research have been limited in designing for modularity in technology-push products.

The unavailability of market and customer data for technology-push products increases the need for adaptability to changing customer needs. Considering the risk of most technology-push products, the ability to adapt the product quickly and cost-effectively once available to customers could be the difference between success and failure of a new product launch. Modularity is a strategy that can make this adaptability possible. Modularity could allow companies to design products that can be adapted quickly at a lower cost as the customer and market needs emerge over time. The value of modularity in technology-push products is further supported by the widely read and accepted theories of Geoffrey Moore among high-tech business circles in Crossing the Chasm[6] and Inside the Tornado[7], which are discussed in detail in Chapter 2.

Why the literature and industry has focused on more mature market pull products for modularity may be due to the abundance of market and manufacturing information available for mature market pull products that most technology push products lack. The intense focus that firms of technology push products have on their technology versus the actual product and its manufacturing lead these firms to overlook modularity during product development. Possibly the tendency for higher margins in technology push products reduces the necessity for manufacturing efficiencies and therefore the consideration of designing for modularity. Whatever the reason, designing for modularity in technology push products is uncommon in both the literature and in industry. However, the research presented in this thesis clearly supports that the limitations of designing for modularity in technology push products does not outweigh the benefits.

1.2. Thesis Objective

Understanding the value of modularity in technology-push products could significantly reduce the market risk involved in their development. The objective of this thesis is to develop a method for evaluating the impact modularity can have on technology-push products and present preliminary results of applying this method. To develop such a method this research follows these steps:

1. Develop a market-perception based scoring system for market-pull/ technology-push products and apply this system to a set of example products.
2. Develop an evaluation method for determining the effect of these scores on success and apply this method to the example set of products.
3. Build on the previous method to develop an evaluation method for determining the impact modularity has on the success rates of technology-push products and apply this method to set of example products.
4. Illustrate how the knowledge gained through the evaluation methods can be applied to new products through the results of the set of example products.

Overall, the information and conclusions obtained through this thesis are aimed to help firms better understand and hopefully improve their chance for success in launching a technology-push product.

1.3. Thesis Outline

This outline provides an overview of the research presented in this thesis. Following this section, Chapter 2 presents the review of the current published literature on the both technology-push products and modularity. This chapter will provide a glimpse of the current boundary of knowledge in these fields while revealing the void that this research intends to fill. Chapter 3 describes the research approach including the four steps followed to achieve the goal described in the thesis objective above. The scope and delimitations of this thesis research are presented along with a description of how the results of this research will be evaluated.

Chapter 4 presents the concepts of market pull and technology push in depth and provides explanation and justification of how this classification is used throughout this research. A method for determining a market pull score and technology push score is developed forming a foundation for this research then applied to 68 example products. Chapter 5 then presents a method for evaluating how the market pull and technology push scores effect product success. This method is applied to the 68 example products. Chapter 6 builds on the methods in the previous chapters to evaluate the impact of modularity in technology push products. Again the method developed in this chapter is applied to the example products presented in chapters 4 and 5. Chapter 7 illustrates how the knowledge obtained through applying the proposed methods can benefit product developers through 3 case study products. Chapter 8 then summarizes the conclusions and contributions of the research and how the thesis objective was met. Additionally, areas of potential future research are discussed.

Chapter 2 LITERATURE REVIEW

Considerable research has been done on both technology push product development and design for modularity. This chapter looks at the research and publications most pertinent to the thesis objective. The start of this chapter will cover the current state of technology-push product development. The research in this field will establish knowledge of the processes utilized along with revealing some of the unique constraints of technology-push product development. The current state of design for modularity and related research will then be reviewed. Various aspects of this research will be considered including the product development processes employed to design for modularity, classification and evaluation schemes, the management of variety within a product line, and finally techniques and methods to design for modularity in market-pull products. The review of these topics will help provide a foundation of knowledge that will be used throughout this research.

2.1. Technology-Push Product Development

2.1.1. Classification of Product Development Types

The terms "technology push" and "market pull" are widely used throughout the literature, but the oversimplification into two types has caused extensive clarification and additional classification methods. Some of these classifications stay close to the technology push/market pull terminology and others have abandoned or ignored it completely.

Greg Bishop's[8] offers a review of some of the classification types in his thesis including the example in Figure 2-1 by Hartmann and Meyer.

QUADRANT	DESCRIPTION
Evolutionary	Lowest risk, but possibly limited economic potential.
Leverage Base	Somewhat higher risk. For a global company, opportunities of this type tend to be geographical.
Discontinuities	Somewhat higher risks. This case refers to technology substitution, a familiar situation.
Radical	Highest risk. If the market is large, this may offer the greatest opportunity.

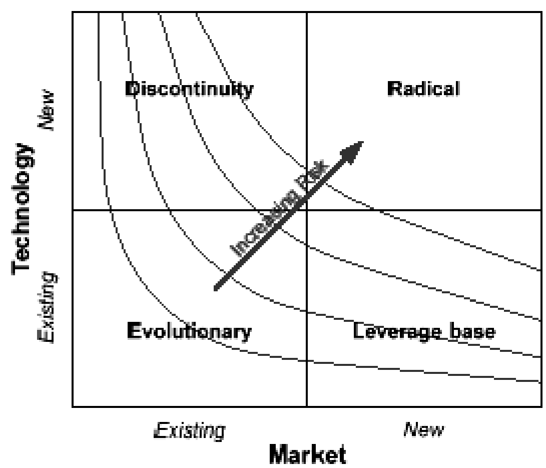

Figure 2-1: Product Development Classification Example

In addition to the classification types discussed by Bishop, Wheelwright and Clark[9] suggest types based on the degree of change represented by the product. They offer five types:

1. R&D/Advanced Development Projects
2. Alliance or Partnered Projects
3. Incremental or Derivative Projects
4. Breakthrough or Radical Projects

5. Platform or Next-Generation Projects

Although each of the classification types in the literature offer benefits that the market pull technology push classification does not, none have been as widely used. For this reason, this thesis will focus on the market pull technology push classification system, although chapter 4 presents clarifications and enhancements to it.

2.1.2. Technology-Push Development Processes

Because of the unique challenges of technology-push products both industry and academics have recognized the need to deviate from traditional product development processes to effectively develop technology-push products. Of the literature reviewed, three techniques were employed in the creation of development processes for technology-push products. The first technique is to start with a traditional development process and then make minor adjustments for technology-push products. The advantage of this method is that it builds off an often proven effective development process. The second method is to create a more drastically different process by essentially starting from scratch and building the entire process around the technology-push constraints. This technique still results in many of the same steps involved in a traditional process but overall is more unique. The advantage of this technique is a process that is more truly tailored to technology-push products although without the more proven track record. The last technique is to develop a process that applies to both market pull and technology push product development. The advantage is obvious, only one process is needed; however, the disadvantage is the tendency to be over-generalized. This review provides a prominent example of each of these techniques found in the current literature.

2.1.2.1. Adapting Traditional Development Processes

Ulrich and Eppinger present a generic product development process in their book *Product Design and Development*. The process involves the six phases shown in Figure 2-2:

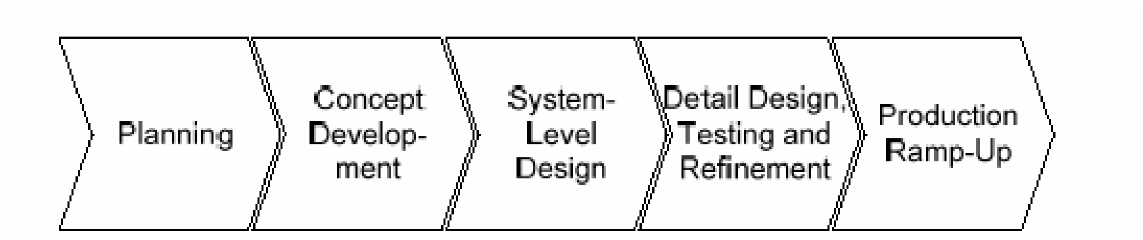

Figure 2-2: Generic Product Development Process (Ulrich and Eppinger)

Ulrich and Eppinger[4] explain how this generic product development process can be followed with a technology-push product with only minor modifications. Modifications need to be made in the planning phase shown in Figure 2-3 to incorporate the technology into market opportunities. They mention two important requirements for technology-push success: the technology must offer a clear competitive advantage and alternative technologies need to be unavailable or impractical.

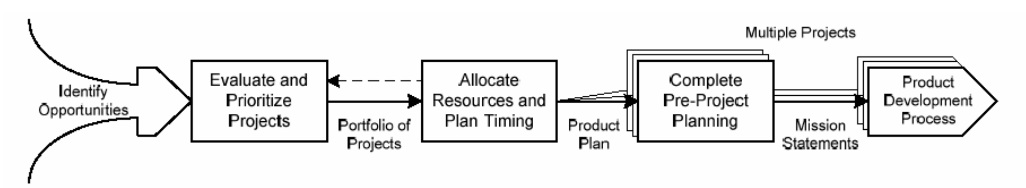

Figure 2-3: Product Planning Steps (Ulrich and Eppinger)

Despite the proven value of this process, some weaknesses exist in its use with technology-push products. One weakness becomes evident in the step after planning where the modifications are suggested. The concept development stage is further broken down into steps as shown in Figure 2-4.

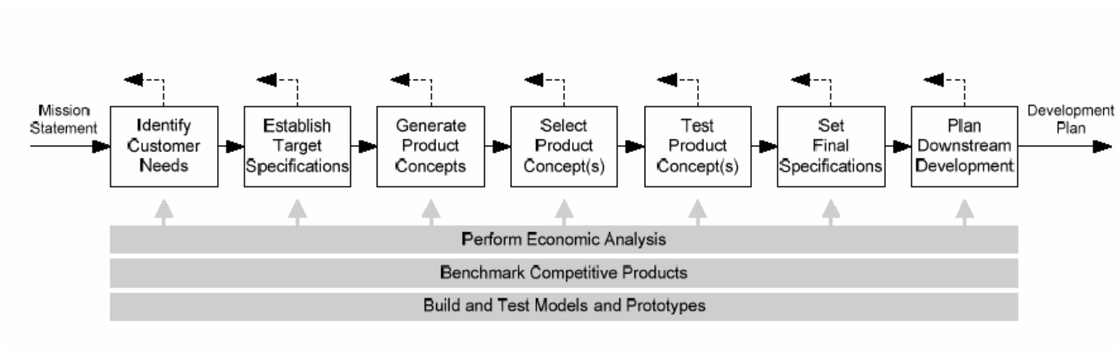

Figure 2-4: Concept Development Steps (Ulrich and Eppinger)

The entire concept development process is strongly based on the information discovered in the first step of the process: Identifying customer needs. The modification previously suggested by Ulrich and Eppinger to adapt the planning phase of the generic product development process implies that despite a technology being pushed into a product, the product itself is more less market-pull. This is implied because the concept development phase depends on the identification of customer needs. Although customer needs can be identified for any potential product, for many technology-push products the customer needs are so misunderstood by both the customer and company that attempts to obtain information can end up being costly and deceiving. These unspoken and misunderstood needs are often referred to as latent needs in marketing literature. This doesn't suggest that attempts to gather information on latent customer needs in technology-push products is a waste of time but does suggest that the information should be used with skepticism. Many successful technology products wouldn't exist today if decisions were based off of initial customer need information. The PDA market mentioned earlier provides a simple example. Initial needs for a digital information storage system would have suggested that the general public was unwilling to accept the inefficiency of entering information electronically along with the inherent risk of losing information because of the electronic storage. Based on this customer feedback companies like Apple and US Robotics may have searched for other products to push their new technology into.

2.1.2.2. Technology-Push Specific Design Processes

Greg Bishop[8] offers some of the challenges of technology-push (TP) products in his thesis work. First is the inherent difficulty with certain objectives in the TP product development. These include factors such as the previously mentioned lack of customer needs information and the difficulty of selecting both a product and market for the technology with a myriad of options. The second challenge is that established TP models are unclear and not comprehensive. Bishop's work attempts to overcome this through evaluation, consolidation, and expansion of the current TP models. Also, little validation exists for continued refinement of these models. The third challenge is the lack of support from management and company culture. Clayton Christensen offers valuable insight into this problem in his book *The Innovator's Dilemma*[10]. Christensen provides evidence for the tendency of companies to provide funding to development projects that provide incremental improvements that can demand a higher price through improvement of meeting the market's needs. Technology-push products, like the disruptive technologies presented in *The*

Innovator's Dilemma, usually get second priority to the more predictable returns of their market-pulling incremental improvement counterparts.

Bishop proposes a new TP model shown in Figure 2-5 that involves more comprehensive steps prior to the concept development steps outlined by Ulrich and Eppinger. The process does provide many early opportunities to establish a modular product architecture such as the 'Planning Previous to Product Development' step but no implicit effort is made to integrate design for modularity into the TP model.

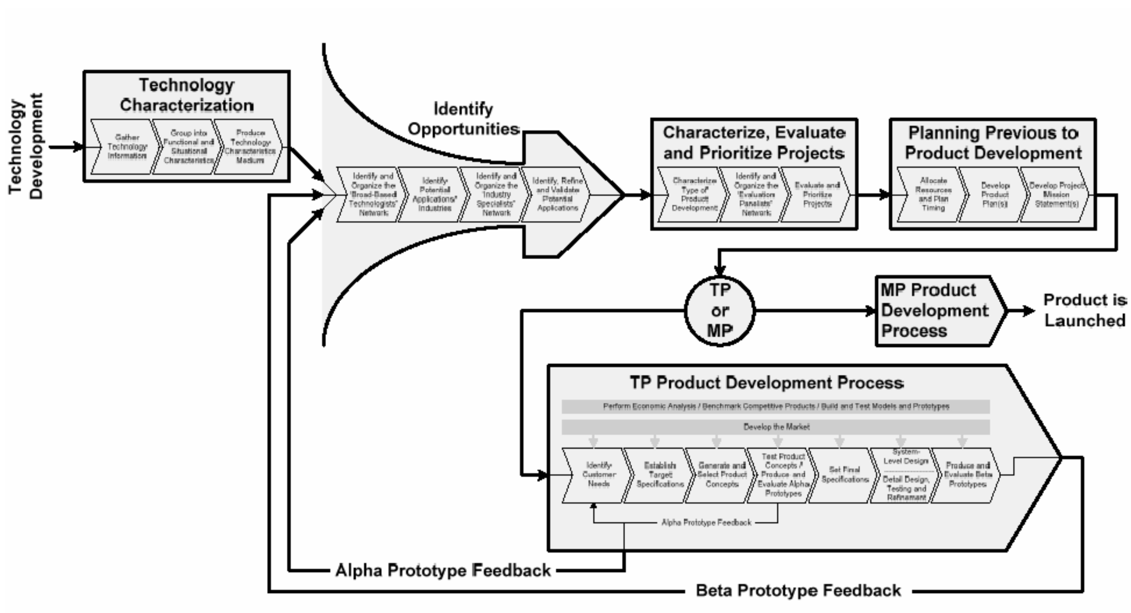

Figure 2-5: The New Comprehensive TP Model (Bishop)

2.1.2.3. Combined Market Pull and Technology Push Processes

Some product development models have been promoted that combine the unique development needs of market pull and technology push products into a single process. The model developed by Rothwell[11] and Trott[12] shown in Figure 2-6 addresses both market pull and technology push product development, but the overgeneralization makes its useful application to nearly any product impractical.

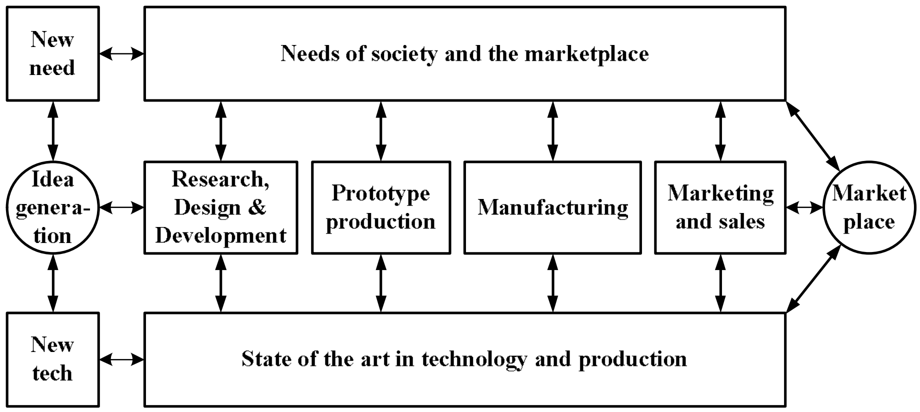

Figure 2-6 - Combination MP/TP Model

2.1.3. Technology Push Success Factors

Several researchers and practitioners have worked to identify factors of success that reduce the risk of new product development. Bishop[13] reviewed the success factors cited in the literature for technology push product development. In his review of 10 literary sources, the most often cited success factor for technology-push product development was a focus on the customers/end users. In other words, the most common factor of success was "the customer or end user needs were considered during the development of the product." The results of Bishop's work are shown in Table 2-1. The darkened squares show the number of success factors cited by a specific author that can be grouped into the success factors category created by Bishop.

Table 2-1: Categories of Success Factors, their Relative Ranking and Literary Sources

SUCCESS FACTORS CATEGORIES	Souder	Isaacs & Tang	Branscomb & Auerswald	Himmelfarb	Lynn & Reilly	Samli & Weber	Spivey et al.	Paul	Ulrich & Eppinger	Lynn et al.	Number of Factors	Number of Sources
There is a Focus on Customers/End Users	4		1	3	1	1	3	2		1	16	8
Internal/External Networks Were Used	2	4	2	2	2		2				14	6
There is Management Support	2	4	1	1	2	2	1				13	7
The Development Team is Dynamic, Motivated and/or Talented		3	4		4						11	3
A Combination of MP and TP is Used	2			3	1	2					8	4
The Market is Developed During or Directly After Product Development	3			1			1	1			6	4
The Technology Offers a Clear Advantage		2				1			2		5	3
Alternatives Were Carefully Examined	2			1					1		4	3

2.2. Design for Modularity

Design for modularity techniques and research have targeted a wide variety of goals. These include the creation of development processes, evaluation and classification methods, variety management techniques, and methods that provide decision-making tools to improve the design of modular or family products. The development of processes to design for modularity has followed a similar path to that of technology-push products. Evaluation and classification methods have been developed to aid product developers in better understanding a modular design and what the specific types of modularity will tend to accomplish. To improve the management of variety with a product line the current research has applied quantitative marketing techniques to better understand the value of variety. In addition research has provided several methods to improve the design decisions that affect a company's ability to provide variety through derivative products. These areas of research are discussed in the following sections.

2.2.1. Development Processes

As with technology-push products, the adaptation approach can be taken with the generic product development process provided by Ulrich and Eppinger. The suggested adaptation is recommended when a product platform already exists within a company. In the same way that the design of a technology-push product is based around the technology, a product design can be based around an existing product platform. Essentially the platform can be considered the technology, the difference being that the platform usually has already demonstrated its value in the marketplace.

Small adaptations to the generic process may provide a sufficient process for the development of a product based on a product platform, but the generic design doesn't provide sufficient steps for the development of a platform itself. In describing product architecture, Ulrich and Eppinger point out that architecture begins to emerge in concept development. They state that "the maturity of the basic product technology dictates whether the product architecture is fully defined during concept development or during system-level design." They continue to explain that "Product architecture is one of the development decisions that most impacts a firm's ability to efficiently deliver high product variety. Architecture therefore becomes a central element of the product concept." This emphasizes the importance of deliberately designing the product architecture so that derivative products can be developed more efficiently. They then describe a tendency that may be the cause for so much failure in technology-push products –

> However, when the new product is the first of its kind, concept development is generally concerned with the basic working principles and technology on which the product will be based. In this case, the product architecture is often the initial focus of the system-level design phase of development.

The tendency to neglect the product architecture or the design of the product platform in technology-push products inhibits a company's ability to efficiently provide variety through derivative products. As previously mentioned, the risk of technology-push products only increases the need to design product platforms that result in the efficient development of derivative products as unknown customer needs emerge after the initial product launch.

Kamrani and Salhieh[14] propose a more thorough development process for modular products in their book *Product Design for Modularity*. This process is shown in Figure 2-7. Similar to the concept development process shown in Figure 2-4, the first step in the process deals with identifying customer needs referred to as a *Needs Analysis* in this process. The objective of the needs analysis is basically identical to that proposed by Ulrich and Eppinger in the first step of the concept development phase. Tactics such as surveying and interviewing prospective purchasers or customers are suggested. Kamrani and Salhieh distinguish various needs based on different types of product and customer requirements. Quality Function Deployment (QFD) is suggested as an effective method of identifying customer requirements and then translating them into technical specifications. The House of Quality (HOQ) is the main method used within the QFD process which allows cross-functional common sense to be applied in a systematic way.

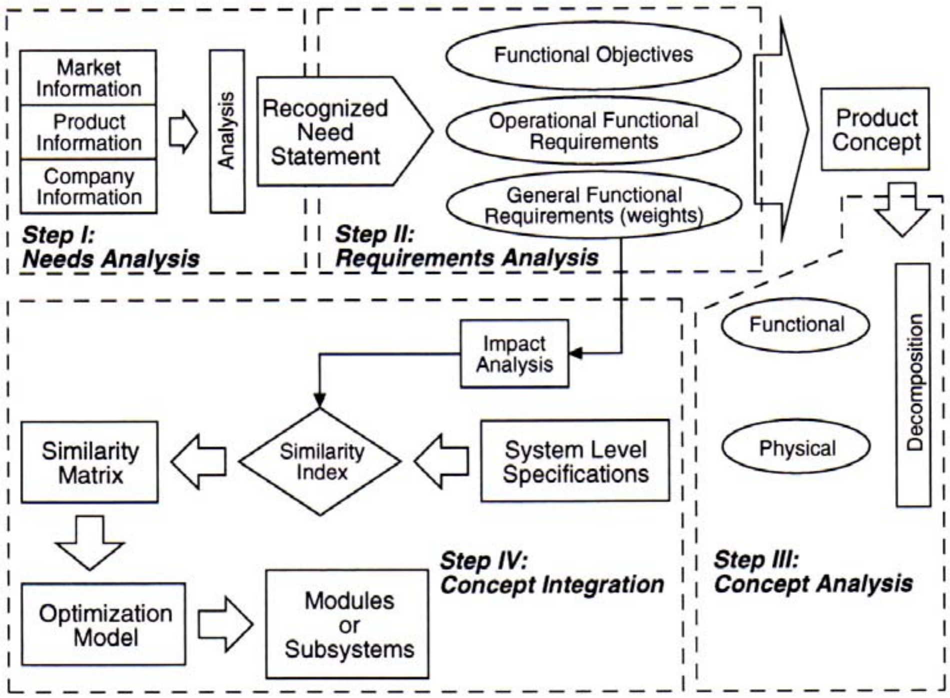

Figure 2-7: Design for Modularity Process (Kamrani and Salhieh)

The next step in the design for modularity process is the *Product Requirementz Analysis*. Again this step is similar to the second step of the concept development process outlined by Ulrich and Eppinger. The objective of this step is to translate the needs analysis information into functional and physical constraints on the design. Once the product requirements are defined the third step is the *Product/Concept Analysis*. At this point the design for modularity process starts to deviate more drastically from the generic approach. Functional and physical decomposition is performed to provide a better understanding of the entire product. Physical decomposition decomposes the product based on actual parts or components while functional decomposition is aimed at representing the behavior of the product and its parts.

Once decomposition is complete the final step can occur: *Product/Concept Integration*. At this stage several considerations are taken into account during this step. These include identifying the impact of system-level specifications on the general functional requirements. The degree of association between components is considered through the use of a similarity index. The final part of this step is actually grouping the components into modules. Components with high association are grouped together.

Simpson, et al[15] presents the Product Platform Concept Exploration Method (PPCEM). This method is to assist product developers in the design of a product family through the step-by-step method shown in Figure 2-8.

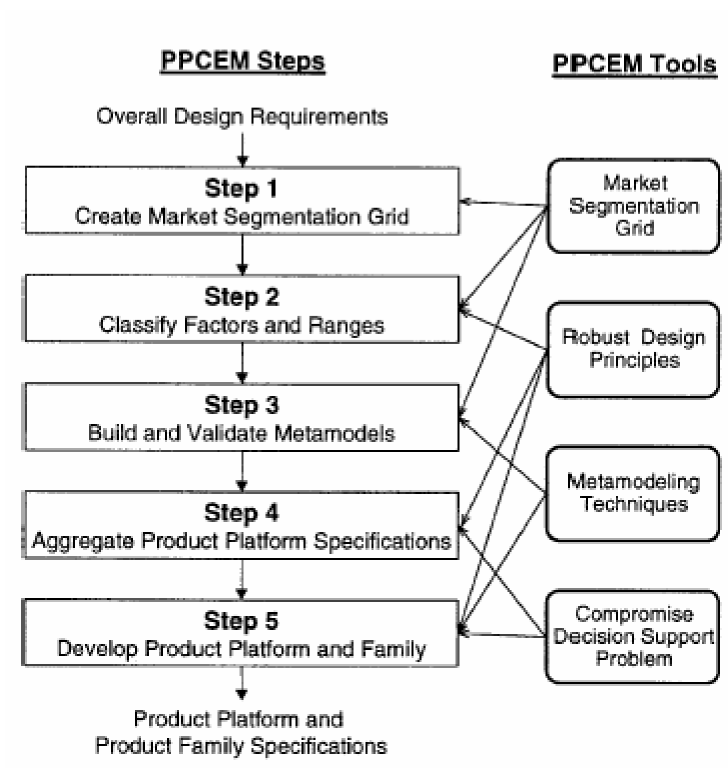

Figure 2-8: PPCEM Steps and Tools (Simpson)

The steps of the PPCEM assist the designer in formulating the problem and how to solve it, although the implementation of these steps has the potential to vary greatly from one product family design to the next. One of the key benefits of the PPCEM is "scalability", which the authors define as the capability of a product platform to be "scaled" or "stretched" by varying one or more of its design parameters to satisfy different customer or market requirements.

2.2.2. Evaluation and Classification of Modularity

Mattson describes three general levels of modularity are discussed in the literature – design, manufacturing and consumer phase modularity[16]. These levels are defined as follows:

> *Design Phase Modularity*: A product is modular at the design phase if the product function is defined through the combination of various modules, and at least one module has been previously designed.
>
> *Manufacturing Phase Modularity*: A product is modular at the manufacturing phase if the product function is determined, by a manufacturing process or assembly step, through the addition, subtraction or substitution of previously designed modules.
>
> *Consumer Phase Modularity:* A product is modular at the consumer phase if a consumer, through the addition, subtraction or substitution of previously designed modules, can modify the product function.

Matt Strong[17] presents some valuable ideas for classifying and evaluating modular product concepts in his thesis. The Modular Type Space (MTS) shown in

Figure 2-9 is presented as a means to compare competing modular product design concepts. One of the valuable metrics developed for the MTS is the degree of modularity. The degree of modularity provides a quantitative score based on a comparison of the number of modules to the number of product functions. The functions are best determined through functional decomposition of the product concept. The degree of modularity score can provide insight into the amount of variety a given product design is capable of. Strong uses the product classification obtained through the MTS to achieve strategic objectives.

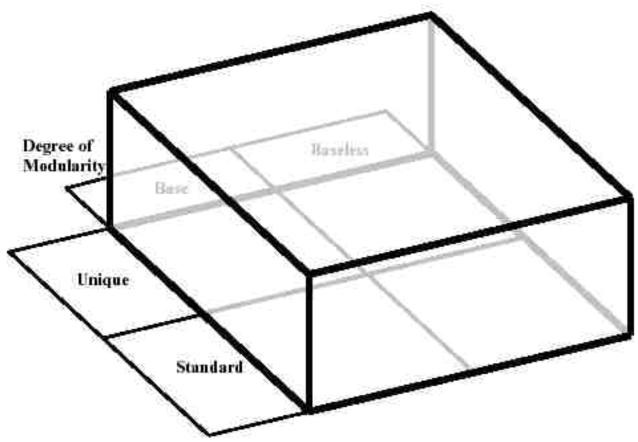

Figure 2-9: Modular Type Space (MTS)

2.2.3. Managing Variety

Martin and Ishii[18] provide three indices to help managers and designers better manage the variety within a product line. The first is the commonality index (CI). This index measures the relative number of common parts in a product family. An increase in the CI indicates more variety with fewer unique parts. A CI score between 0 and 1 is determined with equation (2.1).

$$CI = 1 - \frac{u - \max p_j}{\sum_{j=1}^{v_n} p_j - \max p_j} \tag{2.1}$$

u = # unique part numbers
p_j = # parts in model j
v_n = final # of varieties offered

The Differentiation Index (DI) essentially measures how much additional work in process (WIP) inventory is created by adding variety along with the value added to the process. A decrease in the DI indicates that value is added later in the process which reduces complexity and therefore cost. A DI score between 0 and 1 is determined with equation (2.2).

$$DI = \frac{\sum_{i=1}^{n} d_i v_i a_i}{n d_1 v_n \sum_{i=1}^{n} a_i} \tag{2.2}$$

v_i = # of different products exiting process i
n = # of processes
v_n = final # of varieties offered
d_i = average throughput time from process i to sale
d_1 = average throughput time from beginning of production to sale
a_i = value added at process i

The final index is the setup index (SI) which measures the relative cost involved in additional setups required for added variety. This measure is intended to provide a general indicator of the effect variety has on setups not an actual cost. A SI score between 0 and 1 is determined with equation (2.3).

$$SI = \frac{\sum_{i=1}^{n} v_i c_i}{\sum_{j=1}^{v_n} C_j}$$

v_i = # of different products exiting process i
c_i = cost of set - up at process i
C_j = total cost (material, labor, and overhead) of jth product

(2.3)

These indices are then used to improve decisions concerning product variety. The authors use commonality graphs to aid in the decision making process. These graphs visually document commonality of components with respect to process sequence, lead-time of components, and amount of variety desired by the customer.

Otto[19] presents a method to determine the number of performance levels to be offered within a product family on the basis of additional revenue and costs. This method leans heavily on the data from a thorough conjoint analysis. Using conjoint data, Otto is able to derive a revenue model which takes into account both customer and market considerations. The cost is estimated based on the fixed cost and the additional cost of each additional level with the additional cost of increased performance taken into account. Although this method provides a quantitative approach to a problem that has generally been handled qualitatively, Otto recognizes that the conjoint data must be comprehensive and representative in order for the approach to yield valuable results. For the conjoint data to be comprehensive it must represent all products in the entire market including competitors' products and still competitor's future product offerings are ignored. Comprehensive and representative conjoint data of an entire market in most cases is difficult to obtain.

2.2.4. Design for Modularity Methods in Market-Pull Products

Yu, et al.[20] proposes to determine the portfolio architecture based on customer needs which lends itself to more mature products. No attempt has been made to integrate development and manufacturing cost. The following process is proposed.

1. Identify customer needs through interviews, focus groups, questionnaires, conjoint analysis, etc.
2. Survey customers for the relative importance of each need and determine mean
3. Survey customers for target values of needs and determine the mean and standard deviation
4. Construct a usage distribution by following the use of a single product in different usage situations and collect the target values for each need for the different usage.
5. Means and standard deviations are determined for target values within a usage situation

In Yu's research three types of portfolio architecture are used: fixed, platform, and adjustable. Based on the results from the customer data, designers are able to make knowledgeable decisions about the components within a design. When need variation is small, a fixed portfolio architecture is implied. When needs cannot be met with a single need value, platform families and adjustability should be considered. When the need distribution demonstrates ergodicity, adjustable architectures should be considered. If deviation within the time distribution is sufficiently small then platform architecture should be considered.

In a more recent work, Martin and Ishii[21] present tools for making design decisions concerning platform variety. Their research proposes the use of two indices to make design decisions concerning product platform architectures. The first index is the generational variety index (GVI) which considers the redesign effort of the anticipated future generations of the product. The inputs to the index are determined for a given product through the use of some quality function deployment (QFD)[22] tools and through engineering expertise and intuition. Martin an Ishii use QFD in two phases. Phase I establishes the link from customer needs to engineering metrics. Phase II establishes the link from engineering metrics to the specific components. An example of the two phases of QFD applied to the design of a water cooler is shown in Table 2-2 and Table 2-3.

Table 2-2: QFD Phase I (Martin and Ishii)

Customer Requirements \ Engineering Metrics	Cool Down Time (min)	Water temperature (C)	Cold Water Volume (gal)	Power consumption (W)	Width (in)	Height (in)	Depth (in)	Volume flow rate (gal/min)	MTBF (hrs)	Cost ($)
Fast cool down	X									
Cold water		X								
High capacity			X							
Low energy usage				X						
Compact					X	X	X			
Fill cup quickly								X		
Reliable									X	
Low cost										X

Table 2-3: QFD Phase II (Martin and Ishii)

Engineering Metrics \ Components	Fan	Heat Sink	TEC	Power Supply	Chassis	Plumbing	Reservoir	Insulation	Fascia
Cool Down Time (min)	X	X	X	X			X	X	X
Water temperature (C)									
Cold Water Volume (gal)							X		
Power consumption (W)	X		X	X					
Width (in)					X				X
Height (in)									
Depth (in)					X				X
Volume flow rate (gal/min)						X	X		
MTBF (hrs)									
Cost ($)		X		X	X		X		X

The GVI score is obtained through the seven step process outlined below:

GVI Step 1: Determine market and desired life of product platform

GVI Step 2: Create QFD matrix

GVI Step 3: List expected changes in customer requirements

GVI Step 4: Estimate engineering metric target values

GVI Step 5: Calculate normalized target value matrix

GVI Step 6: Create GVI matrix

GVI Step 7: Calculate GVI

Direct input from the team members was determined to be the best process for determining GVI. The GVI matrix and the calculated GVI for the water cooler example is shown in Table 2-4.

Table 2-4: GVI Matrix (Martin and Ishii)

	Components								
Engineering Metrics	Fan	Heat Sink	TEC	Power Supply	Chassis	Plumbing	Reservoir	Insulation	Fascia
Cool Down Time (min)	3	6	3	1			6	1	6
Water temperature (C)									
Cold Water Volume (gal)							9		
Power consumption (W)	1		3	3					
Width (in)					6				6
Height (in)									
Depth (in)					6				6
Volume flow rate (gal/min)						9	1		
MTBF (hrs)									
Cost ($)		1		1	3		3		6
GVI	4	7	6	5	15	9	19	1	24

The other index is the coupling index (CI) which measures the degree of coupling among the product components. The CI score for a product obtained through the following six step process:

CI Step 1: Develop basic physical layout for the product
CI Step 2: Draw control volume around components
CI Step 3: List specification flows required between components
CI Step 4: Build a graphical representation of the specification flows
CI Step 5: Estimate sensitivity of components to changes
CI Step 6: Calculate coupling index (CI)

Coupling is broken down into both receiving and supplying to estimate how much design changes to a specific component affect other components and how much changes in other components affect the component under consideration. A partial CI matrix for the water cooler example is shown in Table 2-5 with the coupling index-receiving (CI-R) in the right column and the coupling index-supplying (CI-S) in the bottom row.

The individual component sensitivities seen in the matrix in Table 2-5 come from a qualitative estimate where a sensitivity of 0 suggests that no specifications will affect the receiving component and a sensitivity of 9 suggests that even a small specification change will affect the receiving component.

With these to indices complete for a given product designing for variety may take place. Martin and Ishii suggest different approaches to reducing the GVI and CI scores for the product along with using the indices to make decisions about standardization and modularization. The steps for design for variety are as follows:

DFV Step 1: Generate GVI and CI for the design
DFV Step 2: Order the components
DFV Step 3: Determine where to focus efforts
DFV Step 4: Develop product platform architecture

Table 2-5: Coupling Index Matrix (Martin and Ishii)

Components REQUIRING Information \ Components SUPPLYING Information	Fan	Heat Sink	TEC	CI-R
Fan		Press resist 9 x dim 3 z dim 3	Heat output 3 x dim 1 z dim 1	20
Heat Sink	Pressure curve 3 x dim 3 z dim 3		Heat output 3 x dim 3 z dim 3	18
TEC		Heat sink cond 3 Effective HS area 3		6
CI-S	9	21	14	44

Through the information obtained through the design for variety steps, a designer is able to design the product platform architecture to standardize as many parts as possible across generations and attempt to modularize the rest.

Siddique and Rosen[23] identify two approaches to product family development: aggregation and differentiation or diversification. The aggregation approach involves determining a common platform for a company's existing products. The diversification approach is a more proactive path which involves determining a common platform for a set of products that have yet to be developed. Siddique and Rosen's work focuses on the aggregation approach like many others in the literature. The diversification approach is more relevant to the focus of this thesis.

Du, et al.[24] does an excellent job reviewing the current literature on *Variety Design and Variety Fulfillment*. They also offer a valuable comparison of modularity and commonality shown in Table 2-6.

Table 2-6: A Comparison of Modularity and Commonality (Du, Tseng, Jiao)

	Modularity	*Commonality*
Focused Objects	Type (Class)	Instances (Members)
Characteristic of Measure	Interaction	Similarity
Analysis Method	Decomposition	Clustering
Product Differentiation	Product Structure	Product Variants
Integration/Relation	Class-Member Relationship	

They mention three types of modularity in product realization: functional, technical, and physical. Since modularity attempts to separate a product into independent parts, decomposition is a main method of analysis. Three types of commonality also exists according to Du, et al. functional, design and process views. Commonality and modularity relate in that "a product family, is described by modularity and product variants differentiate according to the commonality among module instances." Two types of variety can be observed, namely functional variety and technical variety. Functional variety is used broadly to mean any differentiation in the attributes related to a product's functionality, from which the customer could derive certain benefits. On the other hand, technical variety refers to diverse technologies, design methods, manufacturing processes, components and/or assemblies, etc., which are necessary to achieve specific functionality of a product required by the customer. In other words, technical variety can be further categorized into product variety and process variety. They also provide three basic methods for variety generation: attaching/removing, swapping, and scaling.

In order to generate variants four elements are proposed: selection constraints, parameter propagation, include conditions, and variety generation. The variant derivation process is shown in Figure 2-10.

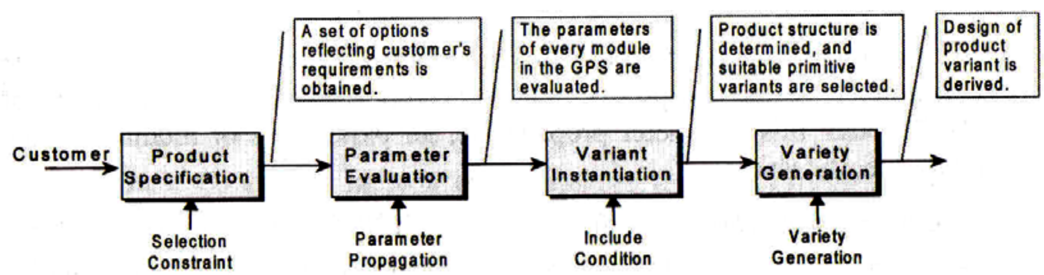

Figure 2-10: Variant Derivation Process (Du, Tseng, Jiao)

2.3. Modularity in Technology Push Products

Of the literature reviewed, one indirect link was found between modularity and technology push products. In Crossing the Chasm[6] and Inside the Tornado[7], Moore describes the difficulties faced by high-tech firms to penetrate the market with their new product. In Crossing the Chasm, Moore vividly describes a *chasm* that occurs in the market for high-tech or technology push products. This chasm, which occurs between the adoption of a firm's product by *visionaries* and the *mainstream market*, has claimed the failure of an unprecedented number of high-tech firms. This is the chasm that the Apple Newton fell victim to. This chasm is created by the dramatically different needs of the early market *visionaries* and the mainstream market *pragmatists*. This change in needs of the marketplace occurs at a time that most firms are unstably low on cash. The vast majority of the money needed for complete development has been spent but only a fraction of the market has been penetrated keeping revenues small and profits negative. The money and time required to adapt to the needs of the mainstream market is often more than a fledgling startup or a scrutinized division of a corporation can bear. Moore offers a strategy for navigating through the chasm and into mainstream market success in Inside the Tornado. Moore presents the bowling alley theory, a strategy which involves focusing sequentially on a series of specific and related segments and applications within the market. These segments and applications also require the product to be adapted to specific needs although they require much less time and money than meeting the needs of the mainstream market. Essentially this strategy involves taking on the risk of entering the mainstream market one segment and application at a time instead of all at once. To successfully implement this strategy, a firm is still required to adapt their product even if it is only small portions of the whole product. If adaptation is critical to this widely accepted strategy for the high-tech industry, then cost and time effective methods for adapting the high-tech or technology-push product should also be critical. Furthermore, Moore specifically mentions the need to adopt a mass customization strategy once the mainstream market growth begins to taper off while suggesting that further development costs be kept to a minimum. Accomplishing this simultaneously can be difficult if the initial design engineers made no effort to allow for customization or modularity in the initial product.

2.4. Summary and Conclusions

The current literature offers many insights into both technology-push product development and design for modularity. Many methods, processes, and techniques along with other valuable information has been presented on these topics. Currently no research has been found in the literature that directly addresses the topic of designing for modularity in technology-push products. Although many of the techniques, methods, etc. covered in the literature reviewed could be adapted to address this issue, including the process and steps developed by Ulrich and Eppinger, Kamrani and Salhieh, and Bishop along with the various indices developed by Martin and Ishii, such adaptations have yet to be presented in the literature. The literature has been clear to present the benefits that can be gained through designing for modularity and the challenges of technology-push products. As a result the need for the work presented in this thesis is supported by the review of the current literature.

Chapter 3 RESEARCH APPROACH

The purpose of this chapter is to describe the research approach taken in this thesis. This includes (1) the process followed to create a positive contribution to the boundary of existing knowledge (2) the assumptions, scope and delimitations of this thesis and (3) the means of evaluating the results of this thesis for their validity. The results of this research will be compared to the items presented in this chapter to establish valid conclusions concerning the contribution of this research.

3.1. The Process

The process followed in this research is shown in the following steps.

1. Develop a clear and effective method for quantifying market pull and technology push characteristics in products.
2. Apply this classification method to a set of products to be evaluated throughout this research.
3. Develop a method for evaluating the influence of the market pull and technology push characteristics on the probability of a product being successful and apply this method to the set of products.
4. Develop a method for evaluating the effect that modularity has on technology push products' probability of success and apply this method to the set of products.

5. Demonstrate how to apply the knowledge gained from the set of products studied to improve product development decisions in 3 case study products.

The methods developed are intended to provide a quantitative evaluation of risk including the benefits of modularity in technology-push products. The results are expected to influence product developers to apply these methods to evaluate risk in the development of technology push products and give more consideration to the incorporation of modularity in the development of technology-push products. This research will provide methods for acquiring quantitative evidence of the effect of modularity on the probability of success for technology push product and provide preliminary results of applying these methods.

3.2. Assumptions and Delimitations

This process and research makes the following assumptions. First, that the set of products evaluated represent a greater population of products. Limitations are set forth in chapter 4 that narrow the population in which this research infers conclusions. Additionally, the set of products is taken from an independent source to reduce any chance of bias introduced by the author. Numerous classification methods are developed and applied throughout the research, which in and of themselves have underlying assumptions. However, this research attempts to explain the classification methods in hopes to disclose these underlying assumptions.

A few assumptions and limitations have been made in execution of the developed method on the set of products evaluated throughout this research that classify the results as preliminary and not conclusive. First, the results obtained from the set of products chosen may not be representative of all products. Second, the consumer data gathered is not comprehensive due to a small number of total respondents for each product. Additionally, some respondents for some of the products may not have considered themselves part of the target market. As a result the scores determined for any individual product may not be accurate; however, the assumption is made that these inaccuracies are random and normally distributed. The data is considered sufficient to first, provide an illustration of how the data is used in the execution of the described method, and second to provide initial evidence of the impact of the results on the product population the analyzed set of products represents.

This research provides general guidelines. It is the responsibility of product developers to identify unique circumstances that may cause a specific product to deviate dramatically from the example results or results obtained through execution of the presented method.

This research will only provide a quantitative evaluation of the effect of modularity on the success of technology-push products. It does not provide methods for successfully applying modularity to technology push products. This will be left to product developers and represents an opportunity for future researchers.

3.3. Evaluating Thesis Results

As previously discussed, this research develops a method for quantitatively evaluating product success. The criteria outlined below will be used to evaluate the success of the research in achieving the thesis objective.

- Follows the four steps outlined in the thesis objective and further described above in Section 3.1
- Statistical results demonstrate a confidence of 90% or greater with a corresponding p-value < 0.10.

- Method can be applied to a set of products that demonstrate the contribution of the research
- Results provide convincing evidence for change in current technology-push product development practices

The success of meeting these criteria will be discussed in the conclusions of this research in Chapter 8.

3.4. Summary

This chapter describes the details of the research approach that will assist in achieving the thesis objective. This includes explanation of the process followed, the assumptions and delimitations, and the method of evaluation of the thesis objectives.

Chapter 4 UNDERSTANDING TECHNOLOGY PUSH V. MARKET PULL PRODUCTS

Because the development of a new product nearly always involves unique characteristics and considerations, numerous classifications, methods, and processes have been developed in the literature and in industry[8,9,10,25,26]. One of the most common product development classifications includes only two categories, market pull and technology push. In general, technology push products are considered to be higher risk with a lower success rate[13], but no empirical studies have been found to quantify this claim or provide further insights.

This chapter examines the market pull and technology push definitions and classification and explores the relationship between market pull and technology push. The literature study[13] performed by Bishop provides ample support for the need to remain customer-focused in the development of new products, particularly technology push products. The lack of a clear customer-focus in the current market pull or technology push classification hinders product developers in accurately identifying methods that can reduce the risk of developing a new product. Since the market is nearly always the final say in the success of a product, this research refines the current definitions and classification through a market-perception based approach. These refined definitions are then used throughout this research to classify the example products so each can be appropriately analyzed.

4.1. Observations of Market Pull and Technology Push Products

The simple classification of market pull and technology push leads to confusion as many products don't seem to naturally fit in either category or, on the contrary, seem to fit in both. The literature implies that the classification of a product as market pull or technology push is mutually exclusive. This appears to be the result of the classification initially being created to describe products that clearly demonstrated characteristics of one or other. However, when the classification is applied to all products, the deficiencies become evident. Despite the literature implying a mutually exclusive relationship, many examples of products can be cited that contest the existence of such a relationship, yet the current research has neither defended this mutually exclusive relationship nor challenged it.

4.1.1. Market Pull

The generally accepted definition of market-pull product development is when some kind of need or opportunity is discovered in the marketplace that currently is either being ignored, not well served, or just not recognized. In this case, firms are able to approach product development through developing product concepts that fulfill this identified market need. Numerous models, tools, and processes have been developed to increase the odds of success in market-pull products[4,27,28]and many have been successfully implemented.

Most new cars provide an excellent example of market-pull products. Car manufactures are able to identify a segment of the automotive market that is not being well-served. Studies are done on the segment of the market to determine their specific needs. Rarely does the newly developed car incorporate any significantly new technologies. Instead the product development efforts are aimed at incorporating the features the identified segment of the market values at a price-point they are willing to pay.

4.1.2. Technology Push

As described in Chapter 1, the generally accepted definition of technology push product development is to begin not with a market need but instead with a new technology, which in many cases is proprietary. The firm who owns such a technology approaches product development in a fundamentally different way. Instead of the market needs playing number one in the design, the firm's technology takes on that honored role. First and foremost, the product must incorporate the firm's technology and then meet a market need. If the company discovers an unmet market need but is unable to incorporate their technology, the opportunity is usually foregone. The example of Glide dental floss by W.L. Gore & Associates provides a clear example of a technology push product through the incorporation of their ePTFE technology.

4.1.3. Classification Confusion

For examples such as Gore products, the simple market pull or technology push classification seems sufficient. Unfortunately many products aren't that simple to classify. Hybrid-powered vehicles provide a clear example of this problem. Gas-electric hybrid engines are one of the most significant technological advances in the automotive industry over the past decade. So, are hybrid vehicles a market pull or technology push product? The automotive industry identified a segment of the market wanting more fuel-efficient environmentally-friendly vehicles but they also chose to meet this need through pushing a new technology onto the market. Hybrid vehicles have been on the mass market in the United States since 1999 and have yet to receive universal acceptance even within the targeted segment. This indicates that this new technology was pushed onto the market, but at the same time the market's need for fuel-efficient environmentally-friendly vehicles indicates a market pull. For a hybrid vehicle, such as the Toyota Prius, and many other products the market pull or technology push classification is inadequate. In general terms, the current market pull or technology push classification is unable to provide sufficient insight in a situation where the market is expressing a need and a technology firm finds they can meet that need through the creation of a product based on their technology. Additionally, the current classification provides little insight if a new product does not meet a need the market is asking for and also does not incorporate any new technologies.

4.1.4. A Complete Classification Matrix

These observations lend themselves to considering both market pull and technology push in the classification of products. This type of classification is shown in Figure 4-1 along with examples of products that fit the characteristics of each quadrant. Products that fall into quadrant II are what would traditionally have been considered market pull products. The example shown in Figure 4-1 is the Casio Exilim digital camera. This camera aims straight at the market need for smaller higher resolution digital cameras. This particular camera measures up as one of the smallest on the market of digital cameras with comparable performance and features. On the technology side, this camera has managed to pack common digitital camera technology into a smaller box through some gradual improvements.

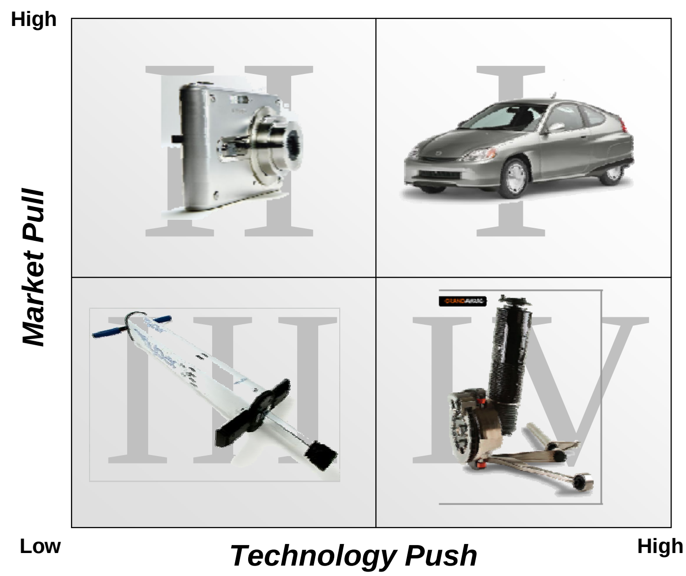

Figure 4-1: Comprehensive Market Pull/Technology Push Classification Matrix

Products in quadrant IV are what would traditionally have been considered technology push products. The example shown is a new vehicle suspension system developed by Bose. Unlike traditional suspension, this system incorporates a revolutionary electro-mechanical damping technology. This technology is likely to take the automotive market some time to become comfortable with. Additionally the average automotive consumer isn't aware of their need for an entirely new suspension technology in their car.

The confusion of the traditional terminology is resolved in both quadrants I and III. Quadrant I products are both market pull and technology push and quadrant III products are neither market pull or technology push. The example in quadrant I is the Honda Insight, the first commercially available gas-electric hybrid vehicle in the United States. As previously explained, this product is high in both market pull and technology push classification. The example in quadrant III is the Flybar 1200. This product is the latest and greatest pogo-stick. The Flybar uses better materials than a traditional pogo-stick and replaces the spring with a bunch of large rubber bands. Technologically, the product contains nothing that would create uncertainty among the market, but when was the last time you heard someone say "I wish someone made a better performing pogo-stick."

The quadrants shown in Figure 4-1 indicate that a product falls into one of four categories. Although this is convenient for discussion purposes, a scoring system will be introduced later that treats both market pull and technology push as continuous factors. The scoring system provides additional power to understanding a product's behavior and success in the marketplace, which will be discussed throughout the remainder of this research.

4.2. The Customer's Perception

A clear and valuable method for evaluating a product as market pull or technology push is required. To understand the association between market pull and technology push in a way that impacts the product's future success, we must explore the customer's perception of the terminology.

4.2.1. Technology Push

Some important issues must be addressed to adequately establish a clear and customer focused definition of technology push products. The current definitions state that product development 'starts' with the technology. Is 'starts' a necessary word in the definition of technology-push products? Drawing on the hybrid vehicle example, car manufacturers recognized the need for more fuel efficient vehicles due to increasing gas prices and environmental constraints. In working to meet this need, they discovered gas-electric hybrid engine technology as a possible solution. Since the technology was not first, the current definition would support the assertion that hybrid vehicles are not technology-push. Again the customer's perception is the important factor. Since the details of when the technology entered the product development process is not always available or obvious to the product's intended customer nor do they generally care, the timing of the technology should be excluded from the definition because it has little to do with the customer's perception. Essentially the important question here is - was the market specifically asking for the technology or were they asking for a benefit that the technology could potentially deliver?

Similar to the issue of the word "starts" in the common definition of technology push are the words "new" or "proprietary". When the customer's perception is considered, the value of these words in the definition fades. What effect does the newness of the technology have on the customer? From the customer's perspective, the newness of the technology may have little influence on his purchase decision, but again her trust in the technology will. A customer may have less time to develop trust in a new technology, but just because a technology has been around for a long time doesn't mean a customer will trust it. An example of this is the diesel engine in the United States car market. The diesel engine has been around almost as long as the spark-ignited engine - both over a century. But the average American car buyer is still skeptical of diesel engine technology which continues to capture only a small segment of the overall U.S. car market. So although the newness of a technology may have an effect on the customer's perception, it should not directly affect the classification of a product as technology push or not.

The same reasoning applies to the use of the word "proprietary". Although a high correlation exists between proprietary products and technology push products, the average consumer has little awareness or concern of the proprietary nature of the products they purchase. Although a product containing proprietary technology may have certain implications, the proprietary status, like newness, generally has no direct impact on the consumer's buying decision and therefore should not determine the classification of a product as technology push or not.

Another question that is not directly stated in the typical technology-push definition, but eventually becomes an issue in classification, is the relationship between the technology and the product. In Inside the Tornado, Moore[7] describes how the most technology-adverse consumers have no hesitance adopting technologies that are deeply imbedded within a product. He provides the example of a high-end car with numerous microprocessor-controlled functions. A consumer of this car may detest computers but have no problem with this car because he or she will never interact directly with the technology. Visibility is the key principle here. Since customer perception is the focus, then visibility to the market determines if the technology will have an effect on consumer's behavior. If the technology is exposed in the marketing and selling activities, then market visibility will be high. If any of the product features, functions, specifications that the market values are significantly changed by the technology, then the visibility will likely be high.

In the case of hybrid vehicles, since it is safe to assume that no consumer today would purchase a hybrid vehicle without being aware of the gas-electric hybrid engine technology, the visibility of this technology in this product is high. A good rule-of-thumb for gauging visibility is if a brief sales-pitch description of the product mentions the technology then the visibility tends to be high and the customer's perception of the given technology should be accounted for.

4.2.2. Market Pull

The definition of market-pull always includes the term "opportunity" or "need". Since the word "need" tends to be more from the customer side and opportunity from the business side, sticking with need maintains the focus on the customer. Much like the discussion of technology above, awareness becomes an important factor. If the customer is not aware of a need they may have, commonly referred to as a latent need, then significantly more market risk is assumed. If the customer has shown awareness of the need a firm's product intends to meet, then the market risk is significantly lower. Again since the objective is to focus on the customer to reduce market risk, the customer's awareness of the need to be met is a critical factor. Since identification of the customer need as the first step in the development of the product has little to no visibility to the customer, it has no obvious effect on the customer perception. Therefore, the best evaluation of the development of a new product as market pull or not is to find out if potential customers are aware of the need, or better yet, are customers asking for the need to be fulfilled.

4.3. The Market Pull and Technology Push Scoring System

Eliminating the aspects of the definitions of market pull and technology push that do not maintain a customer focus is only the first step. The next step is to develop questions directed to customers to determine how they would classify a product as market pull and technology push. Based on the discussion above, the questions in Table 4-1 were generated to elicit an understanding of the customer's viewpoint of market pull or technology push. These questions are to be asked in a survey or interview form. The first question, called the "Thought Prompt", orients the customer for answering the remaining questions. For the next two questions, the potential customer should consider a "yes" answer and respond by stating the degree to which they agree or disagree as shown in Table 4-2. The first statement evaluates the customer's viewpoint on the pull of the market for the development of a new product. The second statement evaluates the customer's viewpoint on the push of a technology onto the market for the development of a new product. These responses determine a products Market Pull Score and Technology Push Score. The market pull score is simply the number next to the response shown in **Table 4-2**. The technology push score is calculated by subtracting the response from 7 to invert the response. This transforms the data so that a high technology push score correlates to a high degree of technology push characteristics in a product instead of vice-versa. These scores allow product developers to better understand the degree to which their customers consider their product market pull and technology push.

Table 4-1: Product Survey

Thought Prompt:	**What benefit does this product offer?**
Question 1:	**Are you asking for this benefit?**
Question 2:	**Do you trust the technologies used to deliver this benefit?**

Table 4-2: Customer Product Statement Responses

Product Statement Responses		
1	**-**	**Strongly Disagree**
2	**-**	**Disagree**
3	**-**	**Somewhat Disagree**
4	**-**	**Somewhat Agree**
5	**-**	**Agree**
6	**-**	**Strongly Agree**

4.4. Population

When discussing the population of this research, two populations must be considered – the consumer and the product. For firms employing the evaluation above, the consumer population should be from of the product's target market. For example, if the product is a new tennis racket, then the population would likely be tennis players. This can be further broken down based on the specific market the firm intends to capture market share in. The second population, the product population, is the type of products studied that this research may be applied to. The population is limited to products that are commercially available to consumers. Products that don't involve any traditional mechanical manufacturing have also been excluded to narrow the scope of this research. This exclusion includes such products as software and pharmaceuticals. To fit this description, for a product to be included in the population of interest the following characteristics must be demonstrated -

- The product must have a tangible, manufacturable, and mechanical element – no software, pharmaceuticals, etc.
- The product must be able to be purchased by a typical consumer involving mass or near-mass production – no industrial, military, government or similar products.

4.5. Sample Population

The primary focus of this research is on the product population, so a sufficient sample population of products was needed to apply the scoring system to. The products studied were taken from the annual "The Best of What's New" articles published in Popular Science each December[29]. By choosing a third-party product list, bias was removed that may have been created by the author choosing the products to be studied. First, the article from December 1998 was chosen as the base pool which included 100 products. The 1998 product list was chosen in order to provide a five plus year lag in order to evaluate the success of the products, discussed in Chapter 5. Five years was chosen because it represents a standard duration in the business world for evaluating return on investment. In addition, the criteria described above in the Population section was used to screen the 100 products.

Any product that did not fit the previously described criterion was removed from the sample of products. Additionally, the product needed to be an actual product ready for commercialization – not just an idea, invention, achievement, technology, or hoped for future product.to ensure that the success of the product could be adequately evaluated later in this research. After these criterion were applied, the 100 products were reduced to 68. A list of the 68 products is provided in Table 4-3.

Table 4-3: Product List

***Popular Science* Product List**			
1	Liquidmetal Golf Clubs	***35***	1999 Cadillac DeVille Massage Seat
2	Panasonic KX-TGM240 GigaRange	***36***	1999 Mercury Cougar
3	Kodak DC260	***37***	Nikon Pronea S
4	Sony Vaio 505F	***38***	Panasonic DVD-L10 Palm Theater
5	Copperhead ACX	***39***	Thomson's 55-inch P5500
6	1999 Oldsmobile Alero	***40***	1999 Porsche 911
7	Replay TV	***41***	Nikon Coolpix 900
8	Apple iMac	***42***	Philips IS-2630
9	Olympus D-400	***43***	Compaq Presario 5600 Series
10	Iridium	***44***	Volvo S80
11	Air Hog	***45***	Iomega Clik disk
12	1999 Honda Odyssey	***46***	Diamond Multimedia Rio PMP300
13	Hobie Mirage	***47***	Makita 14.4 volt Cordless Drill
14	NuvoMedia Rocket ebook	***48***	A.T. Cross Co. Crosspad
15	Craftsmen Redi Drill	***49***	1999 Chevrolet Silverado
16	Canon EOS-3	***50***	Ryobi Landscaper Series
17	Lego Mindstorms Robotic Invention Kit	***51***	Sony DCR-PC1
18	1999 Lexus RX300	***52***	Clarion AutoPC
19	Canon ZR	***53***	3Com Palm III
20	PFG Industries EasyFloor	***54***	Adv. Energy Sys. PV Panels
21	Yamaha's Silent Electric Violin	***55***	Globewave Com.plete PC Card
22	K2 ACX Smart Shocks	***56***	Kidde Safety Nighthawk
23	1998 Volkswagon New Beetle	***57***	Fujichrome MS 100/1000
24	Motorola V Series	***58***	1999 Jeep Grand Cherokee
25	Fuji Endeavor 3500ix Zoom MRC	***59***	Pentax IQ Zoom 200
26	Philips Audio CD-Recorder CDR765	***60***	Rollerblade Coyote
27	IBM Aptiva SE7	***61***	Toshiba Portege 7000 Series
28	Sony Mavica MVC-FD91	***62***	Canon EOS D2000
29	1999 BMW 3 Series	***63***	Daewoo Miracle Phone
30	1999 Land Rover Discovery	***64***	1999 Saturn Coupe
31	Viking Clap Skate	***65***	Raytheon Premier I
32	Minolta Vectis Weathermatic Zoom APS	***66***	Moen PureTouch
33	Garmin NavTalk	***67***	Sony Ruvi Camcorder
34	Minolta Vivid 700	***68***	Pioneer HTV

For each of the 68 products, potential customers were surveyed. The statements in Table 4-1 were modified slightly to account for the fact that these products were introduced over 5 years ago. The modified statements are shown in Table 4-4. As stated previously, the focus for this research was the product population and not the consumer population. The goal was not to do a thorough marketing study on each of the 68 products, but to acquire enough consumer data to provide sufficiently accurate mean market pull and technology push scores. The mean scores were obtained by surveying four potential consumers for each product. The consumers had varying degrees of market familiarity with the different products. Two steps were taken to mitigate any inaccuracies this may have introduced to the analysis. First, care was taken to make sure that the individual responses were random and independent from the other consumers' responses. As a result, inaccuracy associated with the mean response for a given product would be normally distributed and not bias the analysis of the overall data set. Second, respondents were asked to respond to a statement concerning how familiar they are with the market for each given product. This was asked in order to weight the responses according to how familiar the respondent was with the given product's market.

During the survey, each potential customer was asked to respond to the two statements after mentally answering question 1 given their knowledge in the year 1998 for the given product. The intended meaning of the words "market" and "technologies" used in the statements were explained to respondents to avoid any confusion. Market was defined as "the group within the general population that would have interest in purchasing the given product or any comparable product." Technologies were defined as "any part or aspect of the product that helps the product achieve the desired function or results." As part of the instructions, a product was provided with responses and annotations as an example to provide a thorough explanation (See Appendix A). The respondents were then given the short description of the product provided in the Popular Science article (See Appendix B). These descriptions are a paragraph in length and provide an accurate equivalent to the sales pitch a customer would be likely to receive. Their brevity also acted to eliminate details that would have little impact on the average customer's purchase decision.

Table 4-4: Modified Product Survey Questions

Question 1:	**What benefit does this product offer?**
Statement 1:	**The market was asking for this benefit.**
Statement 2:	**The market trusted the technologies used to deliver this benefit.**
Statement 3:	**I am familiar with this market.**

4.6. Analysis & Results

For each of the 68 products, 12 responses were gathered for a total 816 responses. The numerical values shown in Table 4-2 were assigned to each response. The response to Statement 3 concerning market familiarity was used to weight the responses to Statements 1 and 2. Obviously, the responses to Statement 1 provide an estimate of how market pull a product should be considered, and the responses to Statement 2 provide and estimate of how technology push a product should be considered. The market pull score and technology push scores were calculated as previously discussed then weighted to obtain a mean for both scores. The weighted mean scores and the respondents data for each product is included in Appendix C.

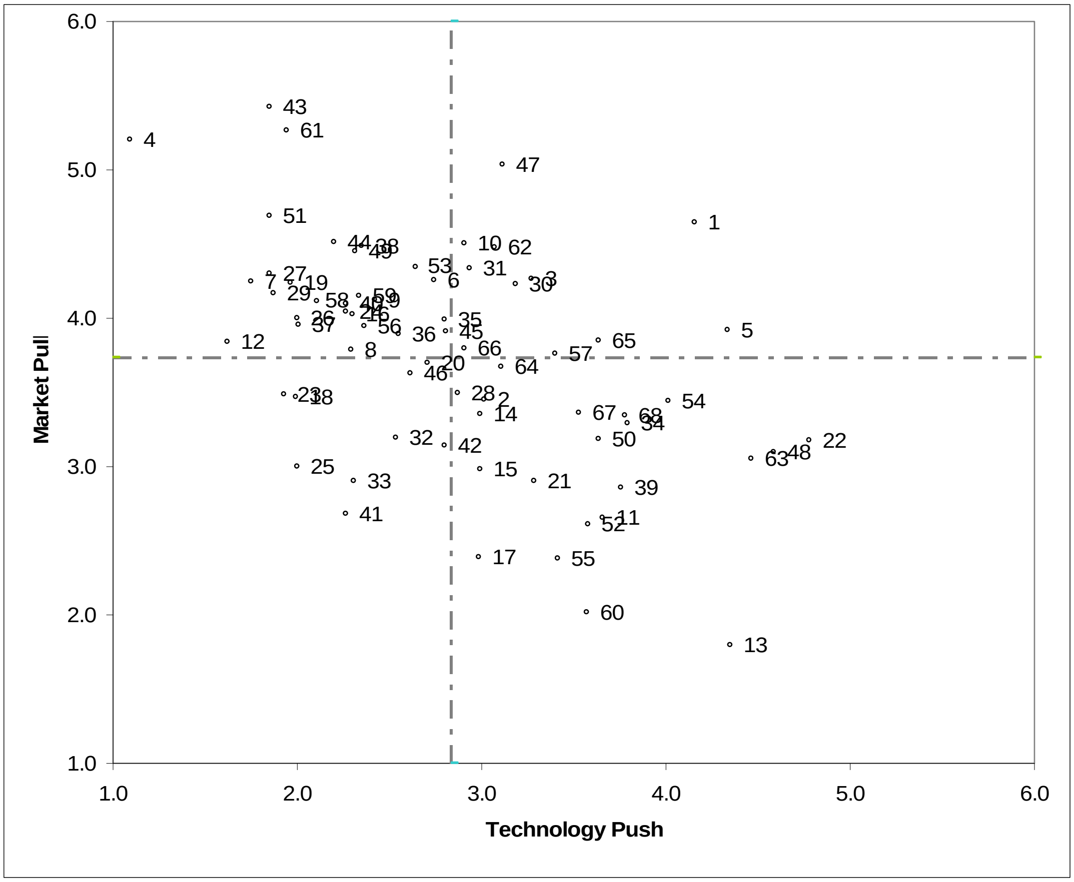

Figure 4-2: Plotted Market Pull and Technology Push Mean Scores

Based on the mean weighted response, each product could be plotted according to the degree of market pull and technology push. This is shown in Figure 4-2 above. The dashed lines represent the overall mean market pull (horizontal) and technology push (vertical) scores for all products. **Figure 4-2** illustrates the continuous nature of both the market pull and technology push scores.

4.7. Inference

There is no distinct lines between a product being technology push or not. The quadrants introduced by Figure 4-1 can be applied to Figure 4-2 for discussion purposes, but the boundary can't realistically be strictly defined. As products get closer to a given corner of the plot, they will tend to fit the description of that quadrant more closely. The distribution of the data supports the premise the traditional classification of market pull and technology push is not comprehensive since no two groups are clearly apparent. Additionally, the data provides evidence that separating market pull and technology push into two factors have independent value. A calculated correlation coefficient of 51% results between the market pull and technology push scores. This means that only 26% of the variation in the market pull score is explained by the technology push score, or vice-versa. Enough unexplained variation exists to warrant the use of market pull and technology push as independent and continuous descriptors. The next chapter explores the value of treating the classifications independently when determining the probability of product success.

Chapter 5 SUCCESS IMPLICATIONS OF TECHNOLOGY PUSH AND MARKET PULL PRODUCTS

The literature supports the assertion that market pull products are generally lower risk than technology push products. To further understand the value of the market pull and technology push classification matrix discussed in chapter 4, the success of the 68 products was considered. Success can be interpreted in many different ways and can be determined by innumerable factors, however, the goal of this research is to determine the effect that the market pull and technology push characteristics of a product has on its success.

5.1. Research Question

1. Is a product's market pull score associated with the product's future success?
2. Is a product's technology push score associated with the product's future success?
3. Is a product's market pull and technology push score associated with the product's future success when considered simultaneously?
4. Does the effect of the market pull and technology push scores change with different expectations of success?

5.2. Hypotheses

1. As a product's market pull score increases the probability of product success increases.
2. As a product's technology push score increases the probability of product success decreases.
3. The market pull score and the technology push score both significantly contribute to a product's probability of success.
4. As a firm's expectations of success increase, the effect of the market pull score increases and the effect of the technology push score decreases.

5.3. Evaluation of Product Success

In addition to the market information gathered on each product, the success of each product needed to be determined. When the list was developed, the products had either just been commercialized or were yet to be commercialized, there was little evidence of success in compiling the list just the anticipation of success; therefore, the products chosen provided an unbiased sample concerning actual product success. Since success is ultimately dependent on a firm's objectives, the success of the product was considered in multiple ways based on the following assumptions. Success and failure for each product was considered for 3 different categories.

Category 1 – "Niche" Market Success

> If the product or a derivative of the product was still on the market with acceptance in small niche groups in the market after 5 years it was considered a success in the *Niche* category.

Category 2 – "*Common*" Market Success

If the product or a derivative of the product became common after 5 years and was considered a significant player but not one of the top market leaders, it was considered a success in the *Common* category.

Category 3 – Market "*Leader*" Success

If the product or a derivative of the product received widespread acceptance after 5 years and was considered one of the few market leaders it was considered a success in the *Leader* category.

These categories are an attempt to capture the different expectations of a firm in commercializing a new product. Obviously a product that was successful in Category 3 was automatically considered successful in Categories 1 and 2, and so forth. Each product was researched to determine at what category level it would still be considered successful if any. The success category of for each product is shown in Appendix D.

A note should be made about the anticipated results of this research based on the chosen sample. One bias does exist in the data in representing all new consumer products in general. The sample studied was considered to be the 68 best new products of the year. Therefore the inferences made based on this research would only apply to products of a similar caliber. Since thousands of new products are developed every year which weren't considered the "best" this research is likely to be biased towards only the highest potential products. However, the trends identified by this sample of products are believed to provide insight into all new consumer products in general. This will be discussed further in the inferences section, but should be noted now when discussing the results.

5.4. Testing the Hypotheses

For testing the association of the probability of success with the market pull and technology push scores, a logistic regression was performed on each of the 3 success categories. The drop-in-deviance was calculated for both the market pull score and the technology push score and the combined model for each of the 3 success categories and then a p-value was calculated for each drop-in-deviance based on a chi-squared distribution.

5.5. Results

The results of hypotheses 1 – 3 stated in Section 5.2 are presented below for each success category followed by the results of hypothesis 4.

5.5.1. The Niche Success Category

The results of hypotheses 1, 2 and 3 are shown in Table 5-1. For the niche success category, the null hypothesis can be rejected for each of the 3 hypotheses in Section 5.2 at a 90% confidence level. It is interesting to note that the significance and the magnitude of the coefficient of the market pull score is much less than that of the technology push score. The market pull score clears the 90% confidence range while the technology push and combined score both exceed a 99% confidence. As hypothesized, an increasing market pull score and a decreasing technology push score are associated with an increasing probability of product success. Additionally, the use of both scores significantly reduces the model deviance, and therefore there is sufficient evidence to support the value of both scores in determining the probability of success in products that are attempting to succeed in niche markets. The equation for calculating the probability of success given a product's market pull and technology push scores is shown in equation (5.1).

Table 5-1: Analysis Results for Niche Success Category

		Coefficient	Deviance	Drop-in-Deviance	p-value
	Intercept	3.66	78.60		
Hypothesis 1 -	Market Pull Score (MP)	0.22	74.75	3.85	0.0498
Hypothesis 2 -	Technology Push Score (TP)	-1.25	66.38	12.22	0.0005
Hypothesis 3 -	MP + TP		66.08	12.51	0.0019

$$\%Success = \frac{e^{(3.66+0.22*MP-1.25*TP)}}{1+e^{(3.66+0.22*MP-1.25*TP)}} \qquad (5.1)$$

Probability of Niche Success Prediction Model

5.5.2. The Common Success Category

The results of hypotheses 1, 2 and 3 are shown in Table 5-2. For the common success category, the null hypothesis can be rejected for each of the 3 hypotheses at a 90% confidence level. In fact, the null hypothesis could be rejected at the 99.9% confidence level for each of the three hypotheses. In this category, it is interesting to note that the magnitude of the coefficient of the market pull score is smaller than the technology push score but they are much closer than in the niche category. The coefficients suggest the scores have a more equal influence on the probability of success in this category. Again, as hypothesized an increasing market pull score and a decreasing technology push score are associated with an increasing probability of product success. Additionally, the use of both scores significantly reduces the model deviance, and therefore there is evidence to support the value of both scores in determining the probability of success in products that are attempting to become common within their markets. The probability of a product becoming common in the market is expressed by equation (5.2).

Table 5-2: Drop-in-Deviance Results for Common Success Category

		Coefficient	Deviance	Drop-in-Deviance	p-value
	Intercept	-0.36	94.21		
Hypothesis 1 -	Market Pull Score (MP)	0.88	82.00	12.21	0.00047
Hypothesis 2 -	Technology Push Score (TP)	-1.20	78.47	15.74	0.00007
Hypothesis 3 -	MP + TP		74.04	20.17	0.00004

$$\%Success = \frac{e^{(-0.36+0.88*MP-1.20*TP)}}{1+e^{(-0.36+0.88*MP-1.20*TP)}} \qquad (5.2)$$

Probability of Common Success Prediction Model

5.5.3. The Leader Success Category

The results of hypotheses 1, 2 and 3 are shown in Table 5-3. For the leader success category, the null hypothesis can be rejected for each of the 3 hypotheses at a 90% confidence level and like the common success category could be rejected at a 99.9% confidence level for all three hypotheses. In this category, it is interesting to note that the magnitude of the coefficient of the market pull score is significantly higher than the technology push score suggesting that the market pull score has a stronger influence on the probability of success in this category. Again, as hypothesized an increasing market pull score and a decreasing technology push score are associated with an increasing probability of product success. Additionally, the use of both scores significantly reduces the model deviance, and therefore there is sufficient evidence to support the value of both scores in determining the probability of success in products that are attempting to become market leaders within their markets.

Table 5-3: Drop-in-Deviance Results for Leader Success Category

		Coefficient	Deviance	Drop-in-Deviance	p-value
	Intercept	-5.63	76.48		
Hypothesis 1 -	Market Pull Score (MP)	1.82	58.21	18.27	0.00002
Hypothesis 2 -	Technology Push Score (TP)	-1.23	63.72	12.76	0.00035
Hypothesis 3 -	MP + TP		53.20	23.28	0.00001

$$\%Success = \frac{e^{(-5.63+1.82*MP-1.23*TP)}}{1+e^{(-5.63+1.82*MP-1.23*TP)}} \qquad (5.3)$$

Probability of Leader Success Prediction Model

5.5.4. Analysis of Hypothesis 4

Each of the sections above describing the three success categories described a different relationship between the influences of the market pull score in comparison to the technology push score. This can be further explained by Figure 5-1 which shows the 50% probability line for each of the three success categories. So for a given success category, a product falling on the left side of the line would be more likely to succeed than fail, while products on the right side would be more likely to fail than succeed.

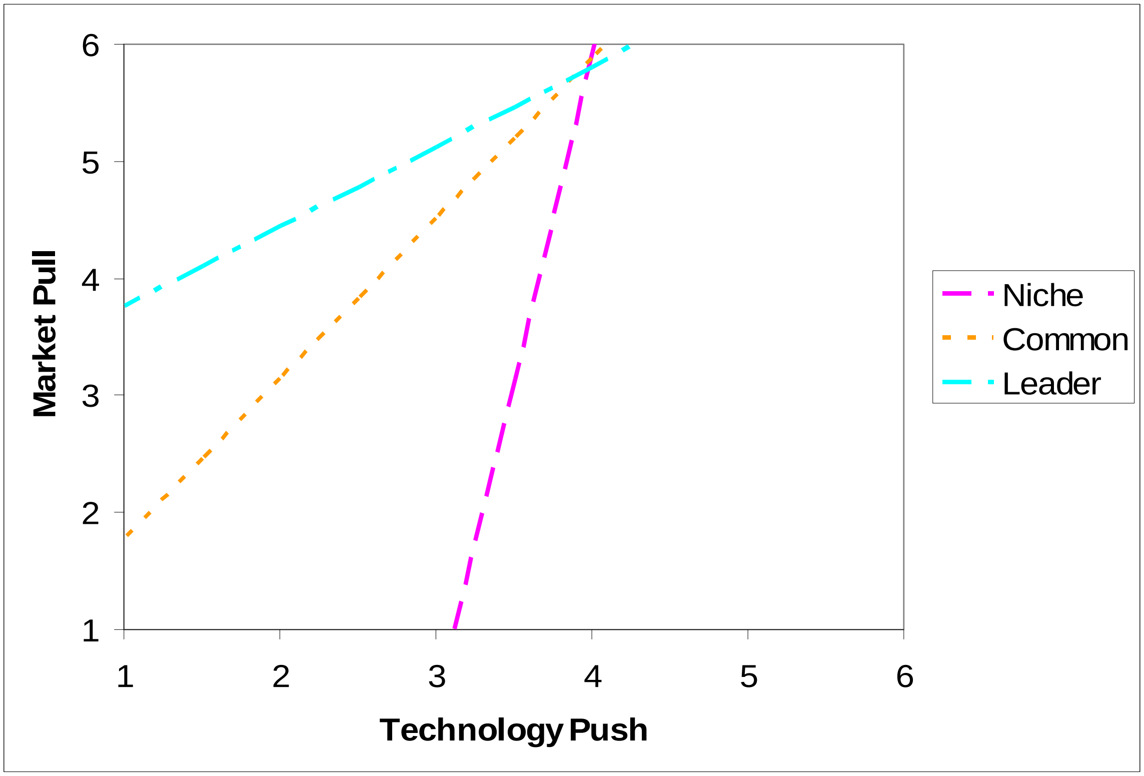

Figure 5-1: Probability of Product Success

For the niche category, the steep slope indicates a dominant influence of the technology push score on product success. For the common category, the slope of the line is close to 1 indicating equal influence of the market pull score and the technology push score. For the leader category, the shallow line indicates a dominant influence of the market pull score on product success. These results support hypothesis 4 which states that as a firm's expectations of success increase, the importance of the market pull score increases and the importance of the technology push score decreases.

The crossing of the three lines was unexpected and definitely deserves some discussion. With further investigation and consideration, two reasons seem to provide an explanation for this unexplained phenomenon. First, a lack of products in that area reduces the accuracy of the model for that particular region. However, the changing slopes of the three lines still indicate a convergence of the success categories probabilities in that region. The crossing occurs at a market pull score approaches 6 and a technology push score of near 4. In general, products that score near a 6 in market pull tend to be in highly competitive markets. For example, product number 43 shown in Figure 5-2 is a desktop computer.

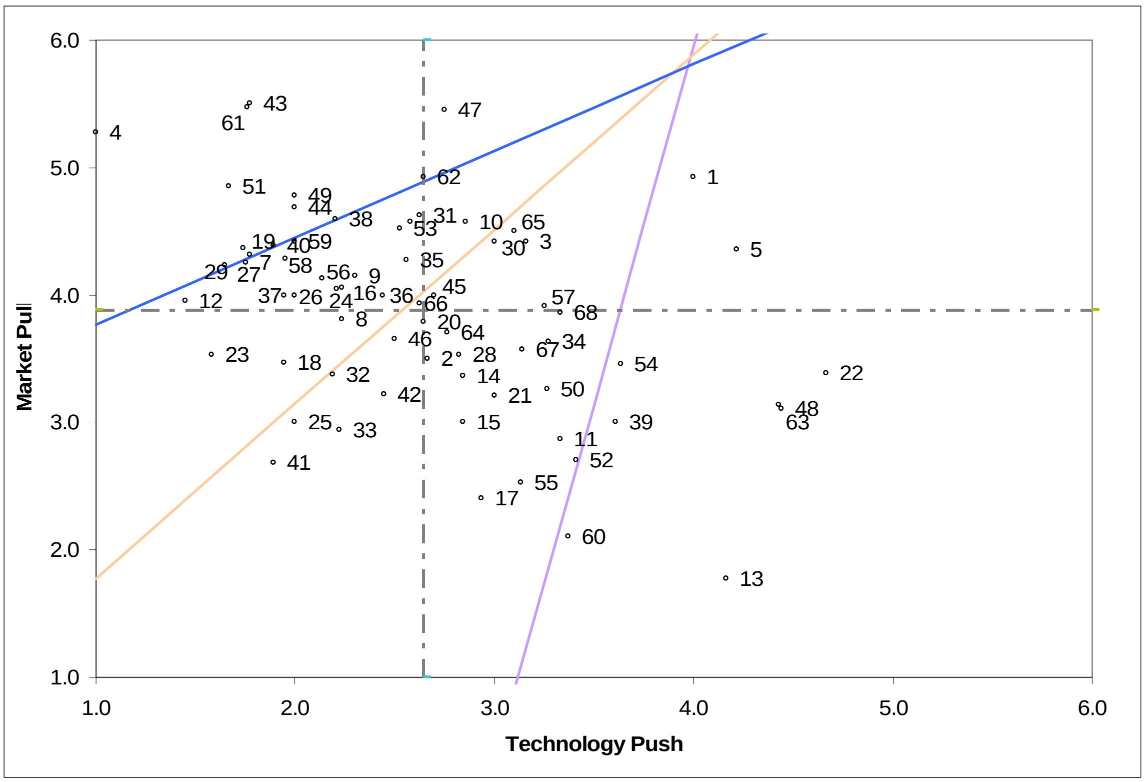

Figure 5-2: Products & Probability of Success

This is an important insight because it suggests that when a high market pull score is present which can indicate high competition having a technology to differentiate the product from competitors may become beneficial as a firm's expectations of success increase. For instance, the desktop computer shown as product 43 is a Compaq Presario. The expectations of success for this product would definitely fall in the leader category as Compaq was definitely shooting for market leadership with their Presario line. This desktop offers a flat-screen monitor, a fairly new technology for the desktop market at the time. Traditionally, one might assume that this new technology might reduce the probability of success for this product. However, with a high expectation for market success, a flat-screen monitor provides product differentiation setting them apart from most other desktops on the market at the time and thereby increasing their probability of success. So under further consideration, it is not totally surprising that an increasing technology score may provide some benefit when the goal is market leadership with a product with a high market pull score in a competitive market.

5.6. Inference on Product Success

The results shown in the figures above may provide insight into where a firm should spend money to increase the likelihood of success for a product they are developing. By taking the normal to the line that best describes their success objective with the product, they gain an understanding of the most efficient way to increase the probability of success. This might determine the allocation of marketing dollars, where more or less could be spent educating the market about the technology or more or less educating the market about their need for what the product offers in order to maximize the probability of success given a set amount of funding. This same information may be useful to product developers in making design decisions and also has significant value in considering a products lifecycle and how to best approach derivative products.

Essentially, these results suggest the following for the three success categories --

Niche Success Category - Firm's developing products aiming to be successful in niche segments should focus on improving the image and trust in the marketplace of the technologies within the product to increase the probability of success.

Common Success Category - Firm's developing products aiming to be common in the marketplace should focus on both establishing the need for the benefits their product offers and improving the trust of the technologies within the product to increase the probability of success.

Leader Success Category - Firm's developing products aiming to be market leaders should focus on firmly establishing the need for the benefits their product offers to increase the probability of success.

The logistic regression analysis performed allows a product developer to better understand the probability of success of a new product based on the firm's market objectives. It should be noted that the probabilities are only reliable for the best of product ideas since this is what the sample is most representative of. However, it might be assumed that all products will follow a similar pattern and even slopes but with the overall success rates skewed to a lower value.

Chapter 6 EVALUATING MODULARITY IN TECHNOLOGY PUSH PRODUCTS

Having empirically established the effect that a product's market pull and technology push characteristics have on the probability of success, we can now look deeper at the role modularity plays in the success of technology push products. Modularity can influence the probability prediction presented in Chapter 5 in two ways. First it can act independently from the market pull and technology push scores to change the probability of success either positively or negatively. Second, it can affect the market pull and/or technology push scores directly which then impact the probability of success. Since this second influence is part of the perception of the customer, it has already been accounted for in the approach presented in Chapter 5. This chapter will focus on the how modularity independently affects the probability of success in technology push products using the market pull and technology push scores as the starting point. In order to do this, we first must discuss a simplified method for identifying the level of modularity within technology push products. Then using this method, we can evaluate the influence the level of modularity has on the probability of success.

6.1. Levels of Modularity

To better understand the value of modularity in the development of technology push products, different levels of modularity must to be identified. The three general levels of modularity defined in the literature review – design, manufacturing and consumer phase modularity will be applied in this chapter. Not only do these levels provide information about which point in the product development process modularity is involved, but they also gives an indication of the degree of modularity. In most cases, manufacturing-phase modularity builds upon design-phase modularity, and likewise, consumer-phase modularity builds upon manufacturing-phase modularity. This relationship is illustrated in Figure 6-1.

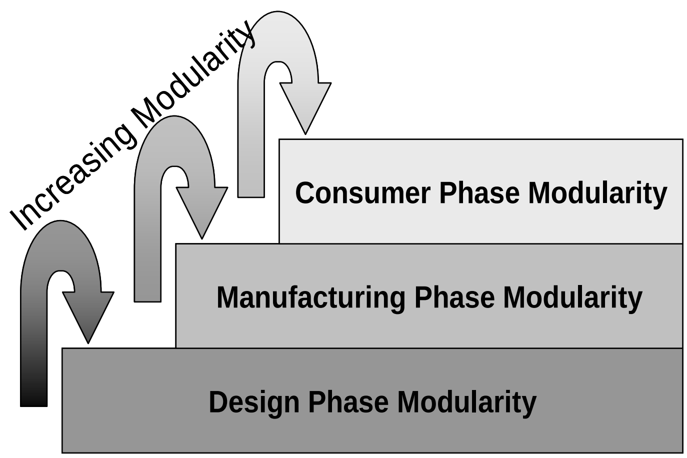

Figure 6-1: Levels of Modularity

To gain a better understanding of how modularity has affected the performance of technology push products, identification of the level of modularity can provide valuable insights. When considering technology push products, the level of modularity can be considered from two perspectives. The first perspective is to consider the product as a whole, or what will be referred to as product modularity, and the second is to look specifically at how the technology interfaces with the rest of the product, which will be referred to as technology modularity.

An example would be a bicycle. One could consider the introduction of hydraulic-disc brakes on bicycles as technology push when first introduced. The product modularity of a bike with hydraulic-disc brakes would fall into the manufacturing or consumer level. Nearly all bikes today share identical components with other bikes even outside of the product family and brand achieving manufacturing-level modularity. Higher-end bikes achieve some consumer-level modularity by allowing consumers to choose or interchange certain components such as wheels, pedals, and seats.

Similarly, the technology modularity would achieve at least manufacturing-level modularity since the same hydraulic-disc brake assembly is generally used on multiple bike models. Also the same bike can be offered with or without the technology. In other words, hydraulic-disc brakes (the technology) can be treated as an option for a given bicycle. The bicycle with hydraulic-disc brakes may be able to provide consumer-level technology modularity; however, most do not. The consumer is not able to simply switch between using the said technology and using say traditional v-brakes. To do so would require more than just switching out the technology component, but may require an entirely new wheel assembly among other parts. For pure consumer-level technology modularity, the consumer would be able to switch to or away from the technology without affecting the rest of the bicycle and hopefully with a fair deal of ease. However, the example isn't completely void of consumer-phase technology modularity since a consumer owning a high-end bicycle is able to switch between using the hydraulic-disc brake technology and not using it without requiring an entirely new bicycle. The levels of modularity, as described by this example, are not discreet levels but more continuous and overlapping. This research treats these levels as discreet for simplicity while still allowing for the continuous nature to be accounted for.

Identification of product modularity and technology modularity will be explained further throughout this chapter.

6.1.1. Identification of Product Modularity

This section describes the method of identifying the level of product modularity in a given product. For each level, a brief identification description is provided and an example product that fits the description.

6.1.1.1. Design Phase Identification

> *Design-phase Product Modularity* – clear and significant design similarities to previous or future products developed by the firm (generational changes).

An example of a new technology push product that exhibits design-level product modularity is the Adidas 1 – a new running shoe that uses a microprocessor to modify the soles firmness between every step.

Clearly Adidas has used their extensive knowledge of running shoe design in the development of this shoe. In fact the majority of the shoe hosts strong similarities to other running shoes made by Adidas. However, with the exception of maybe the shoelaces, despite these design similarities all the components of this Adidas 1 are unique to this shoe and are not used in other shoe models. Therefore, no manufacturing-level modularity is present in this product.

Figure 6-2: Adidas 1

6.1.1.2. Manufacturing Phase Identification

> *Manufacturing-phase Product Modularity* - The existence of common components which is typically found in product families.

An example of a new technology push product that presents manufacturing level product modularity is the Sony DCR-DVD7 DVD Handycam® Camcorder. Straying from the current MiniDV standard in digital camcorders, this camcorder employs DVD recording technology eliminating the tape. Sony leverages their vast experience in camcorders in this product having clearly used modularity at the design level. Additionally, Sony has gleaned some of the components, such as the lens, from their other DVD recording camcorders and also from their miniDV models. This sharing of components qualifies this product for manufacturing-level modularity. Only a small degree of consumer-level modularity is demonstrated in this product through the ability to use several different types of DVD media, which additionally can be used in other products such as DVD players and computers. This is a step closer to consumer-level modularity than miniDV camcorders, but still doesn't provide a thorough example of a technology push product that achieves consumer-level product modularity because the consumer has almost no effect on the product function.

Figure 6-3: Sony DCR-DVD7 DVD Handycam® Camcorder

6.1.1.3. Consumer Phase Identification

> *Consumer-phase Product Modularity* – The presence of components or features that can be changed by the consumer to modify the product function.

An example of a technology push product that exhibits consumer-phase modularity is the Petzl Duo Headlamp. In the past few years, LED technology has improved allowing for significantly brighter economical LEDs. As a result this technology was applied to a number of new applications including headlamps and flashlights. Acceptance in the headlamp market has been very rapid, but a few products have allowed consumers to hang on to the old incandescent or halogen technologies while still enjoying the advantages of the new LED technology. The Petzl Duo allows the consumer to choose between using the LED bulbs or a halogen bulb by simply flipping the switch.

Figure 6-4: Petzl Duo

It is important to note that consumer-phase product modularity can be achieved in several different ways. The example of the Petzl Duo provides the consumer the ability to change a function of the product by integrating multiple modules into a single product and allowing the consumer to activate the module of their choice. Another approach is to provide a common interface that multiple modules can be interchanged by the consumer. These modules can either be included with the initial product purchase or sold in addition to the product as accessories. For the Petzl Duo, this could have resulted in a design that allowed the consumer to, for instance, screw in either the LED unit or the halogen bulb unit in the same manner as household light bulbs that allow the consumer to change the lighting function by choosing different lighting technologies as shown in Figure 6-5.

Figure 6-5: Light Technology

6.1.2. Identification of Technology Modularity

Technology modularity represents a subset of product modularity. One of the core concepts of modularity is the use of common interfaces. Such common interfaces allow for new parts to be added or exchanged to a product without changes to the remainder of the product. This allows a firm to offer multiple products or a single product with multiple functions while reducing costs through overlapping design, manufacturing, and distribution. In the case of technology modularity, modularity is used to separate a given technology within a product into a module with some form of common interface. Like product modularity, technology modularity can exist at the same three levels – design, manufacturing, and consumer. As a subset of product modularity, a level of technology modularity will not always exist when that product modularity level is present. However, the same level of product modularity will exist whenever that level of technology modularity is present. This is best understood through the following examples.

6.1.2.1. Design Phase Identification

> *Design-phase Technology Modularity* – Strong design similarities to products within the firm not involving the same technology.

The Maytag Neptune is a new line of clothing washers that use a new technology for agitating the clothing. The technology claims to offer the advantages of both top-load and front-load washers, while avoiding the disadvantages of both. At first, the Neptune appears similar in appearance to many of the other top-load washers Maytag offers. The exterior body and the wash cycle controls all bear resemblance to the other top-load washers, although they share no common parts. However, once the lid is opened the differences become evident as the new agitator technology deviates significantly from the traditional top-load agitator. Although Maytag gives no indication of taking advantage of common parts from their traditional washers, they've clearly leveraged their extensive design knowledge in the design of the new Neptune washer.

Figure 6-6: Maytag Neptune Topload Washer. Inside view (right) of new drum technology.

6.1.2.2. Manufacturing-Phase Identification

> *Manufacturing-phase Technology Modularity* – The sharing of components/parts between products within the firm with and without the technology of interest.

A great example of a product that achieves manufacturing-phase technology modularity is the 2005 Honda Civic. In 2005 Honda began offering the Civic with a new gas-electric hybrid engine. The new hybrid Civic was offered side-by-side with traditional Civics allowing the hybrid engine to be treated as an option. Outside of the drive-train, nearly all the parts are shared in common between the hybrid Civic and the traditional Civic.

Figure 6-7: Honda Civic Hybrid Sedan (left) and Honda Civic Sedan (right)

6.1.2.3. Design Phase Identification

> *Consumer-phase Technology Modularity* – The ability by the consumer to change the product to utilize or incorporate the technology or not.

An example that fits into this category is best described by first explaining a failed product that did not utilize consumer-phase technology modularity. One of the products studied in this research was the NuvoMedia Rocket ebook. This product was an early attempt at replacing traditional paper books with a single electronic book that can download book content from the Internet. This product failed across all categories of this research. However, electronic book content, especially reference type books have become common place among PDA users today. One key difference is the use of consumer-phase technology modularity. The owner of a PDA has the choice to embrace the technology of electronic books by loading the needed software and book content or they can stick to the traditional functions of their PDA and continue to read books on paper. By providing content to PDA's, the providers of this electronic book content have given the consumer the choice to embrace this new technology at significantly lower risk. If the consumer of the Rocket ebook decided that books were meant to be read on paper after experiencing this technology, he would be left with another useless yet expensive piece of electronics.

Figure 6-8: PDA

6.1.3. Observations of Product and Technology Modularity

The presence of product modularity and also technology modularity appear to offer some reduction of risk in technology-push products. Modularity, especially technology modularity, can offer the consumer an opportunity to try a new technology with a smaller leap away from existing technologies and in some consumer-phase cases a smaller degree of commitment. Benefits such as these seem to suggest that product and technology modularity have value in technology push products. The next chapter empirically explores if product and technology modularity actually offer product developers a tool to reduce the risk associated with technology push product development.

6.2. Success Implications of Modularity in Technology Push Products

Some of the examples given in the previous section suggest that product and technology modularity can reduce the risk of technology push product development. From these observations the following research question and hypotheses were formed to evaluate how the level of modularity influences the probability of success.

6.2.1. Research Question and Hypotheses

Research Question: Is increasing levels of product and technology modularity associated with a product's future success?

To answer this research question, the following two hypotheses were formed:

Hypothesis 1: A technology push product's probability of success increases as the level of *product modularity* increases.

Hypothesis 2: A technology push product's probability of success increases as the level of *technology modularity* increases.

6.3. Method of Testing Hypothesis

To test the two hypotheses all the products from Chapter 4 whose scores indicated technology push characteristics were considered. This was determined by including all products whose technology push score was at least one standard deviation below a mean score of 3.5. A mean score of 3.5 represents the neutral territory between 'somewhat agree' and 'somewhat disagree' indicating that respondents were split with some responding positively and others negatively. Making the dividing line a standard deviation below neutral includes products that would typically receive a significant number of responses from individuals that indicated the product had technology push characteristics. For the products studied, this was 36 of the 68 products. For each of the 36 products the level of both product and technology modularity was determined through researching each individual product. Design and manufacturing-phase modularity could be identified by looking at the other products the company offered both presently and in the past in addition to other information published by the company and the industry.

Because of the difficulty of determining a legitimate classification for the Lego Mindstorms product, due to the inherit modular nature of Lego products, the author chose to remove this product from the dataset prior to performing the analyses. With the level of product and technology modularity determined in each of the 35 products, analysis was performed to determine the association with the probability of success.

Table 6-1: Numeric Modularity Scores

Level of Modularity	Numerical Score
Design-Phase	1
Manufacturing-Phase	2
Consumer-Phase	3

Logistic regression was again chosen as the best tool to evaluate the dataset. The goal of this analysis was to determine if the level of modularity provided additional predictive value in determining the probability of success when combined with the model derived in Chapter 5. For this reason, the market pull and technology push coefficients and scores were included in the analysis. The level of modularity for both product and technology were given a discreet numerical score as shown in Table 6-1 above. The modularity scores for the 35 products are shown in Table 6-2. The same methodology and success categorization was followed in this analysis.

Table 6-2: Product & Technology Modularity Scores

	Modularity	
Technology Push Product	**Product**	**Technology**
Liquidmetal Golf Clubs	0	0
Panasonic KX-TGM240 GigaRange	2	2
Kodak DC260	2	1
Copperhead ACX	2	1
1999 Oldsmobile Alero	2	2
Iridium	0	0
Air Hog	2	0
Hobie Mirage	2	2
NuvoMedia Rocket ebook	0	0
Craftsmen Redi Drill	2	0
PFG Industries EasyFloor	2	0
Yamaha's Silent Electric Violin	2	1
K2 ACX Smart Shocks	0	0
Sony Mavica MVC-FD91	2	0
1999 Land Rover Discovery	2	2
Viking Clap Skate	3	3
Minolta Vivid 700	0	0
1999 Cadillac DeVille Massage Seat	3	3
Thomson's 55-inch P5500	1	0
Iomega Clik disk	1	0
Makita 14.4 volt Cordless Drill	2	2
A.T. Cross Co. Crosspad	0	0
Ryobi Landscaper Series	2	2
Clarion AutoPC	1	0
Advanced Energy Systems PV Panels	0	0
Globewave Com.plete PC Card	0	0
Fujichrome MS 100/1000	1	0
Rollerblade Coyote	1	1
Canon EOS D2000	3	3
Daewoo Miracle Phone	0	0
1999 Saturn Coupe	2	1
Raytheon Premier I	1	0
Moen PureTouch	2	1
Sony Ruvi Camcorder	1	0
Pioneer HTV	2	2

6.4. Analysis and Results

Both hypotheses were tested for each success category as done in chapter 5. The drop-in-deviance from the logistic regression is calculated by determining the deviance from some intercept. That deviance is then subtracted from the model's deviance when some predictive factor is included to get the drop-in-deviance which can be evaluated for statistical significance. In this analysis the intercept is the market pull/technology push (MP:TP) model provided by Chapter 5. The level of product modularity and the level of technology modularity are the predictive factors of which a drop-in-deviance was determined. The drop-in-deviance for the two factors was first calculated individually. The value of combining the factors in the model was evaluated by determining the additional drop-in-deviance of adding the factor with less significance to the model of the factor with more significance. This method would ensure that only factors that add statistically significant predictive value to the model would be included. These calculations are presented in the following sections.

6.4.1. Niche Success Category Results

Both product modularity and technology modularity, as shown in Table 6-3, provide a significant increase in the probability of success for the niche success category individually. However,, adding the product modularity factor to a model with technology modularity does not add significant value as the drop-in-deviance is only 0.31, which corresponds to a p-value of 0.58. Although the p-value of adding product modularity provides a failure to reject the null hypothesis, if product modularity alone was present in a product the coefficient of 0.44 indicates that product modularity increases a product's probability of success. For the niche category, two predictive models have been included. Equation 6.1 should be used when only product modularity is present. Equation 6.2 should be used when technology modularity is present.

Table 6-3: Niche Success Drop-in-Deviance

		Coefficient	Deviance	Drop-in-Deviance	p-value
	Base Model (Intercept)		42.86		
Hypothesis 1 -	**Product Modularity (PM)**	0.44	40.09	2.77	0.096
Hypothesis 2 -	**Technology Modularity (TM)**	1.20	36.40	6.46	0.011

The following predictive equation occurred for the niche success category:

$$\%Success = \frac{e^{(3.66+0.22\times MP-1.25\times TP+0.44\times PM)}}{1+e^{(3.66+0.22\times MP-1.25\times TP+0.44\times PM)}} \qquad (6.1)$$

Niche Success Model for Product Modularity

$$\%Success = \frac{e^{(3.66+0.22\times MP-1.25\times TP+1.20\times TM)}}{1+e^{(3.66+0.22\times MP-1.25\times TP+1.20\times TM)}} \qquad (6.2)$$

Niche Success Model for Technology Modularity

6.4.2. Common Success Category Results

Only technology modularity provides a significant increase in the probability of success for the common success category as shown in Table 6-4. The coefficient implies that product modularity has a positive effect; however, we cannot state this with 90% confidence so it cannot be included in the model.

Table 6-4: Common Success Drop-in-Deviance

		Coefficient	Deviance	Drop-in-Deviance	p-value
	Intercept (Base Model)		40.84		
Hypothesis 1 -	**Product Modularity (PM)**	0.27	39.45	1.38	0.240
Hypothesis 2 -	**Technology Modularity (TM)**	0.57	37.64	3.20	0.074

The following predictive equation occurred for the common success category:

$$\%Success = \frac{e^{(-.36+0.88\times MP-1.20\times TP+0.57\times TM)}}{1+e^{(-.36+0.88\times MP-1.20\times TP+0.57\times TM)}} \qquad (6.3)$$

Common Success Model for Technology Modularity

6.4.3. Leader Success Category Results

Although, both coefficients are positive no significance could be established in the Leader category as shown in Table 6-5. Only 5 products of the 35 analyzed achieved market leader success of which all 5 products had either manufacturing-level or consumer-level technology modularity. The best explanation for why technology modularity did not show significance despite all 5 *Leader* products contained technology modularity is sample size. Small sample sizes are an inherent weakness of logistical regression. To determine if a statistical claim can be made about modularity in the market leader success category, more products would need to be analyzed that exhibit technology push attributes while achieving market leader success.

Table 6-5: Leader Success Drop-in-Deviance

		Coefficient	Deviance	Drop-in-Deviance	p-value
	Intercept (Base Model)		18.41		
Hypothesis 1 -	**Product Modularity (PM)**	0.27	17.42	0.99	0.321
Hypothesis 2 -	**Technology Modularity (TM)**	0.40	16.80	1.62	0.204

6.5. Conclusion

As stated in the previous sections, both product modularity and technology modularity significantly increase the probability of success of product's attempting to achieve niche market success. Additionally, technology modularity significantly increases the probability of success of product's attempting to achieve common market success. Another important observation can be made from studying the results. The coefficient, or in other words the effect, of both product and technology modularity on success is positive for all success categories, but the magnitude of that effect decreases as the product's expectation of success increases. This observation suggests that modularity plays a decreasing role as other factors, outside of the scope of this research, must combine for a product to have the high probability of achieving considerable market penetration. The results even suggest that the role of modularity may even be insignificant when market leadership is desired.

The next chapter will explore a number of examples that will provide context to the significance of this conclusion and also the application of the methods developed in this research.

Chapter 7 EXAMPLES

The results of the research presented in Chapter 6 provide product developers with a tool to assist them in quantifying the value of technology modularity in technology push products. The application of the methods presented in this research merely suggests that technology modularity can increase the probability of success for some products. Examining a few examples will show how the results obtained from these methods can be beneficial to product developers. The first and last examples will be taken from the dataset used throughout this research, while the second example comes from a product development effort at Brigham Young University.

7.1. Hobie Mirage

The Hobie Mirage product provides an excellent example of a technology push product that could benefit from this research. The Hobie Mirage is a sea/lake kayak that uses a new technology, called the Mirage Drive, to propel the vessel forward instead of the traditional handheld paddle. The technology involves oscillating dorsal fins that are powered by the kayaker pedaling with his legs.

Figure 7-1: Hobie Mirage Drive Dorsal Fins

The research from chapter 5 showed that this product received a market pull score of 1.8 and a technology push score of 4.2 landing it as one of the highest risk products of those surveyed. Assuming that Hobie's expectations for this product and future derivative products is that it will become common in the sea/lake kayak market, these scores correspond to a probability of success of 2.2%. Without considering modularity, the product developers would need to decide if they are willing to take a 45:1 risk of failing or if they are willing to adopt a different expectation of success. By aiming for a niche level of success, Hobie could increase their probability to nearly 25% changing their odds to 3:1. Still this offers little comfort to a firm that may be risking it all on the success or failure of their next product launch.

Technology modularity, for some technology push products, can offer firms a solution that can provide some comfort for high risk technology push products. The Hobie Mirage closely resembles the traditional paddled kayak. For the general kayak design, a high degree of design-phase product and technology modularity was used. Some manufacturing-phase modularity was achieved with some universal parts between the traditional kayak and the Mirage, but only to a small degree. No consumer-phase modularity was achieved for either the product or the technology however.

When Hobie factors into the model that they will use manufacturing-phase technology modularity, the probability of success for this product to become commonplace in the sea/lake kayak market jumps to 6.5%. This jump of 4.3% seems more significant when you consider the odds of failure have dropped from 45:1 to less than 15:1. For the niche market, the probability of success makes an astounding jump from less than 25% to almost 78%. For this estimate to be more on the conservative side, Hobie should consider adding additional manufacturing-phase technology modularity. This could be done by designing the Mirage to share the same body with the traditional kayaks with only some minor changes to the manufacturing process to allow for the new drive train to be mounted to the body. As can be seen in Figure 7-2, the kayak on the left with the Mirage Drive technology is already very similar to the kayak on the right without the technology; however, upon close examination one can see the main bodies are still different.

Figure 7-2: Hobie Kayaks

For Hobie, the next question that should be asked is "Can consumer-phase modularity be practically achieved on this product, and if so, how much will it improve the probability of success?" Consumer-phase technology modularity would be fairly easy to achieve on this product. The Mirage Drive technology can already be removed from the product. Hobie could manufacture a kayak that would allow the consumer to choose to use the technology or not. This could be as simple as a twist in plug that fills the hole that is used for mounting the Mirage Drive. The consumer would purchase the kayak and be offered the choice of purchasing the Mirage Drive or a paddle. If they change their mind later, the kayak would already be designed to work with either technology. The consumer could also have both a paddle and the Mirage Drive and choose to take the paddle and remove the Mirage drive or vice-versa for any given occasion. This would significantly reduce the risk for the consumer that may be skeptical of the new Mirage Drive technology. If they chose to purchase the Mirage Drive with their kayak and didn't like it, they would still have a traditional kayak, whereas with the current design the kayak is only intended to be used with the Mirage Drive installed. If Hobie could establish this consumer-phase technology modularity design as feasible and practical, the probability of success for this product to become commonplace in the market increases to 11%, another significant jump representing odds of 8:1. For niche market success, the probability increases to over 92%.

7.2. The Y-Flex

A recently developed product concept from Brigham Young University's Compliant Mechanisms Research provides an excellent example of the application of this research. The Y-Flex is a home fitness machine that simulates the feel of free weights through implanting compliant mechanism technology. The concept offers the potential of cheaper manufacturing and distribution costs which ultimately provides the consumer with a more economical fitness machine without sacrificing performance. This product demonstrates similar attributes as the Hobie Mirage. Despite the advantages the technology provides, the deviation from traditional weights tends to create some skepticism and reluctance in the mind of the consumer, a standard characteristic of technology push products. Additionally, many consumers may struggle to connect the benefit this product offers with the needs they have in a home fitness machine.

Figure 7-3: Y-Flex Prototype Machine

To increase the probability of success for a firm that chooses to license this technology and commercialize this product, technology modularity should be considered. Assuming the Y-flex has market pull and technology push scores similar to the Copperhead ACX baseball bat previously studied and that the firm has the goal to become common in the market, the probability of success without any modularity is only 17%. Through applying design-phase technology modularity, which is almost a given if the firm has any background developing home fitness machines, the probability of success increases to almost 27%. If the firm explores the possibility of implementing manufacturing-phase technology modularity, the probability of success increases to almost 39%. This could be accomplished by using the same basic frame and bench for both the Y-flex machine and a traditional stacked weight machine.

Finally the firm could consider the practicality of applying consumer-phase technology modularity. If this can be practically achieved, the probability of success would jump to 53%, which means the firm would be more likely to succeed than fail. From a design standpoint, achieving consumer-phase technology modularity for this product would be relatively simple. A common interface could be designed that would allow the consumer to choose at the time of purchase which technology they would like to purchase with their standardized frame and bench. If traditional stack weights are chosen, a cartridge for the weights would be purchased that can simply interface with the standardized frame. However, if the consumer chooses the Y-flex technology then, instead of the stacking weights and cartridge, the Y-flex cartridge would be purchased, which would interface with the frame and bench in the same way as the stack weights. The consumer could also purchase both giving them the option to switch between the traditional weights and the Y-flex technology. For the Y-flex concept, a design that accomplishes consumer-phase technology modularity is even easier to visualize when one realizes that the frame and bench for the Y-flex prototype was taken from a traditional stack weight machine. With a potential increase in the probability of success for this product of 36%, technology modularity is a design strategy a firm can't afford not to seriously consider.

7.3. LiquidMetal Technologies

Like the first example, the last example provided in this research comes from the set of products analyzed – Liquidmetal® golf clubs. This example has been chosen because it provides an opportunity to apply this research to a less obvious situation than the previous two examples, yet to a company that truly defines technology push product development.

Before application of this research, some background needs to be provided to this product[30]. The developer of Liquidmetal® golf clubs is Liquidmetal Technologies, a company formed in 1987 to commercialize the use of amorphous alloy, which at the time could only be processed into thin coatings and films. However, in 1993 researchers at Caltech developed the first commercially viable amorphous alloy in a bulk form.

Liquidmetal Technologies gained exclusive rights to this technology from Caltech. Amorphous alloys or Liquidmetal® has very promising properties for a number of applications and now that the company had a way to process it in bulk form, they began exploring these applications. On segment of promise was sporting goods products. In 1997, Liquidmetal Technologies entered the golf industry with Liquidmetal golf clubs.

Today Liquidmetal golf clubs are no longer on the market. Even worse the company lost $44.5 million attempting to penetrate the golf industry, only to abandon it in 2001. So how could this story have been different? How could Liquidmetal Technologies have used this research to make better decisions?

First, they could have evaluated the golf market to discover where they fall in the Comprehensive Market Pull/Technology Push Classification Matrix by asking potential customers the following questions after providing them with a brief sales pitch of the product.

- What benefit does Liquidmetal Golf Clubs offer?
- Is this a benefit you've been asking for in golf clubs?
- Do you think the technology in Liquidmetal Golf Clubs can deliver this benefit?

Based on the research done, they would have discovered, as this research did, that they fell approximately in the 90^{th} percentile for their market pull score and approximately the 95^{th} percentile for their technology push score. Although the high percentile of the market pull score speaks well to the products probability of success, the even higher percentile for the technology push score does not. To sum it up, LiquidMetal Technologies would have discovered that golfers don't believe these clubs can do the job they claim to. Based on the amount of money spent in pursuing this product, it is safe to assume that

LiquidMetal Technologies wanted to achieve at least common place in the golf market with their new clubs. These scores correlate to a probability of success of about 30% to become common in the market.

LiquidMetal may have been fine with these odds especially if nothing could be done to change them. However, this research shows that these odds are changeable. From a technology modularity standpoint, LiquidMetal technologies had a major disadvantage - they had no experience in developing golf clubs. This makes applying modularity difficult. With no previous design experience, even achieving the simplest level of modularity, design-phase, may be unfeasible. Before determining that modularity can't realistically be applied, the effect on the probability of success if they were to use it should be evaluated. By merely applying design-phase technology modularity, Liquidmetal golf club's probability of success increases to 43%. Applying manufacturing-phase modularity would cross the 50% line and gain them access to a 57% probability of success, almost doubling their current probability.

The evaluation of Liquidmetal golf clubs in the context of this research would have hopefully caused Liquidmetal Technologies to consider technology modularity, even if it meant reevaluating the venture strategically. Knowing their own inability to apply technology modularity to this product, Liquidmetal Technologies may have more deeply considered gaining access to modularity through a strategic partnership with a firm already competent in the design and manufacture of golf clubs. This research provides them with some indication of the value of such a partnership.

Is there any evidence that such a strategy would have increased their probability of success? Yes. Since discontinuing their costly efforts in the golf industry in 2001, Liquidmetal Technologies has entered the tennis and the baseball industry. However, this time they are doing exactly what this research may have convinced them to do in 1997 -

partner. They've partnered with Head for the tennis racquets and Rawlings for the baseball bats shown in Figure 7-4.

Figure 7-4: Head LiquidMetal Tennis Racquet & Rawlings LiquidMetal Baseball Bat

These products have gained a lot of publicity and have already become common in the market. In the case of one of the Head LiquidMetal tennis racquets, Tennis Warehouese performed racquet reviews with 6 play testers. Their overall summary of this racquet is included below and provides a glimpse of the product's success.

> Our team noticed a heftier feel to the Liquidmetal Radical MP compared to the two previous Radicals. In most instances the extra heft was welcomed by our playtesters, with the exception of Chad on the volley and Mark on the serve. The most noticeable features our team found were the comfort and solid feel of the racquet. Two of our team members have decided to switch to the Liquidmetal Radical MP since participating in the playtest which says a lot for a racquet introducing a brand new technology.[31]

7.4. Conclusions

The products explained in this chapter provide examples of how this research can be applied to product development decisions. In the examples, the value of technology modularity in technology push product development is illustrated. Discussion is provided with each example to show how the firm might actually apply technology modularity to their product and the impact this would have on the product's probability of success. Each example provides an increase in the probability of success when the firm incorporates technology modularity and models how the application of the methods in this research might influence critical product development decisions. Realistic technology modularity solutions are presented for each example and in the case of LiquidMetal golf clubs, evidence is presented that the solution suggested would have likely had positive results.

Chapter 8 CONCLUSIONS

A number of conclusions for product development can be made as a result of this research. The sections below discuss the conclusions by first addressing the achievements of the research, then describing how the thesis objective was met, and last the impact of the research on product development and opportunities for further research in this area.

8.1. Research Achievements

The achievements of this research fall under three areas. The first is the contribution to the use and knowledge of the market pull and technology push classifications. The second is the methods developed for evaluating product success based on a market pull and technology push score and the level of product and technology modularity for technology push products. The third is the preliminary results of applying the developed methods that indicates a positive impact of modularity, especially technology modularity, on the successful development of technology push products. The conclusions in each of these areas is discussed below.

8.1.1. Market Pull v. Technology Push

The classifications of market pull and technology push were previously confusing and the benefit they offered to product developers was unclear despite their widespread use. This research provides a customer perception approach to classifying a product as market pull and technology push. This approach helps product developers stay tuned in to their customers and additionally offers qualitative scores. These qualitative scores provide a means of comparison between products and allows for the calculation of a probability of success based on the work done in this research.

8.1.2. Methods for Evaluating Product Success

The main contribution of all this research is the development of methods to quantitatively evaluate a product's probability of success including the impact of modularity on technology push product development. These methods were successfully applied to a set of sample products and results obtained. The results obtained from applying the methods were then demonstrated on three example products. Additionally the term, *technology modularity* was developed in the process of this research.

8.1.3. Preliminary Results of Applying Methods

The results obtained from the application of the developed methods provide the following conclusions:

1. Product success increases with an increasing *Market Pull Score* and decreases with an increasing *Technology Push Score.*
2. Modularity, and to a greater degree *technology modularity,* increases success of technology push products. However, the magnitude of the impact of modularity on success decreases as the product's expectations of market dominance increases.

These results, although preliminary, provide a starting point for both future researchers and product developers in quantitatively understanding product success in terms of market pull and technology push along with modularity for technology push products.

8.2. Achieving the Thesis Objective

Methods for determining the impact of modularity, especially technology modularity in technology push products have been successfully developed and preliminary results obtained. These methods include a market-perception based scoring system for market-pull/ technology-push products, a method for determining the effect of these scores on product success, and a method for determining the impact modularity has on the success rates of technology-push products. Each of these methods was applied to a set of examples products and preliminary results obtained and discussed. The results of these methods on the example products were then applied to 3 case study products to illustrate how the knowledge gained can benefit product development efforts.

8.2.1. Evaluation of Thesis Results

The criteria established in Chapter 3 for evaluating the thesis results have been met and are individually addressed below:

- The four steps outlined in the thesis objective in Section 3.1 and also described above were followed.
- All statistical conclusion made had a confidence of 90% or greater with a corresponding p-value < 0.10.
- Results were applied to example products that demonstrate the contribution of the research
- The results provide convincing evidence for change in current technology push product development practices

8.3. Research Impact and Future Opportunities

In addition to impacts previously discussed, this research provides product developers a tool for evaluating the risk of new product development efforts. The ability to evaluate the risk of technology push product development and implement solutions to mitigate this risk will hopefully motivate firms to more frequently attempt the development of products incorporating new technologies. Additionally, this research hopes to be a motivation for firms and researchers to improve the development of technology push products.

The initial evidence provided by this research supports the use of technology modularity in technology push product development. To solidy this premise, the method to determine market pull and technology push scores should be applied to a large set of representative products that are brand new to the market. After 5 years, the methods for determining probability of success could be applied and final conclusions about modularity in technology push product development could be made.

The results of this research and the future work suggested will hopefully spur the development of better methods and processes for modularity and technology push product development. In turn, technology push product development might become more predictable and less risky, and as a result, more worthy technologies will reach the hands of consumers.

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APPENDIX

APPENDIX A – CUSTOMER SURVEY INSTRUCTIONS

The following is a questionnaire about a number of products that were first introduced to the market in 1998. For each product, you will need to ask yourself what benefits the product provides and then you will be asked to respond to 3 statements for each product. Respond to the questions according to your knowledge and recollection as if you were in the year 1998. It will help if you take a second to remind yourself where you were in 1998 and what you may have been doing to jog your memory of the year you will be answering questions about. Please answer every question as best as you can.

The following is an example of the questions for the following products. Some explanation is provided for your benefit in the example, but you are only required to circle a response throughout the survey.

Flybar 1200

The company that brought us the original pogo stick in 1918, SBI Enterprises, has scrapped the steel coil spring in favor of 12 huge rubber bands. Each "thruster" can store 100 pounds of energy when stretched by 300 percent—creating a trampoline-like power system that can send an adult pogoist more than five feet high (the record so far is nearly eight feet). You can customize the 20-pound, aircraft-grade aluminum Flybar for your weight. "Depending on how high you want to bounce and how much you weigh, you can get it to produce 1,200 pounds of thrust if you're so inclined," says co-designer and pro skateboarder Andy Macdonald. Oh, we're inclined ... to wear a helmet.

Mental Question – What benefits does this product offer?

-A higher bouncing pogo stick.

Respond to the statements as if you were in 1998 (Underline your response)-

The market* was asking for this benefit.

Strongly Disagree | <u>Disagree</u> | Somewhat Disagree | Somewhat Agree | Agree | Strongly Agree

-I'm not aware of anyone that needs a better pogo stick

The market trusted the technologies** used to deliver this benefit.

Strongly Disagree | Disagree | Somewhat Disagree | Somewhat Agree | Agree | <u>Strongly Agree</u>

-I trust that rubber bands and aluminum will work fine for this product.

I am familiar with this market*.

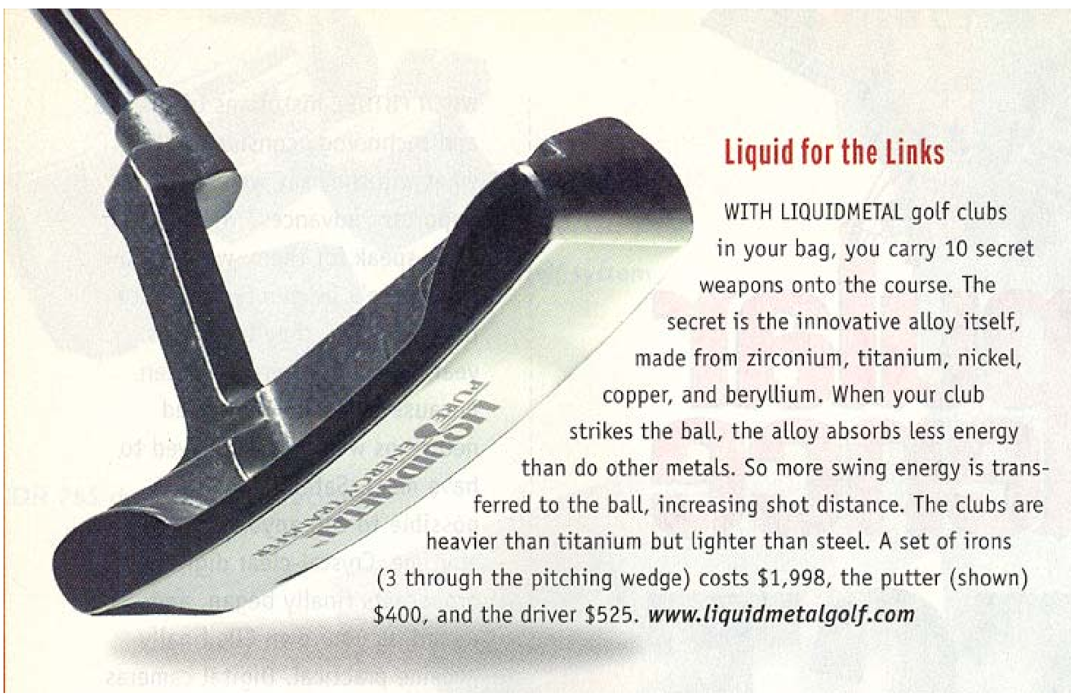
Totally Unfamiliar | Unfamiliar | Somewhat Unfamiliar | Somewhat Familiar | <u>Familiar</u> | Totally Familiar

-I'm familiar with the type of people that may purchase this product and other products that I would consider to fit into this market.

* Market is defined as the group within the general population that would have interest in purchasing the given product or any comparable product.

** Technologies are defined as any part or aspect of the product that helps the product achieve the desired function or results.

APPENDIX B – POPULAR SCIENCE "BEST OF WHAT'S NEW" PRODUCT DESCRIPTIONS



Liquid for the Links

WITH LIQUIDMETAL golf clubs in your bag, you carry 10 secret weapons onto the course. The secret is the innovative alloy itself, made from zirconium, titanium, nickel, copper, and beryllium. When your club strikes the ball, the alloy absorbs less energy than do other metals. So more swing energy is transferred to the ball, increasing shot distance. The clubs are heavier than titanium but lighter than steel. A set of irons (3 through the pitching wedge) costs $1,998, the putter (shown) $400, and the driver $525. ***www.liquidmetalgolf.com***

Walk and Talk for a Mile

PANASONIC'S KX-TGM240 GigaRange has the longest range of any cordless phone yet—an impressive 7,700 feet, or more than a mile. That's 20 times the range of regular cordless phones and eight times that of 900MHz phones. The GigaRange accomplishes its distance record by transmitting calls from the base station to the handset on the 2.4GHz band of frequencies, instead of the smaller 900MHz band. Price: $300. ***www.panasonic.com***

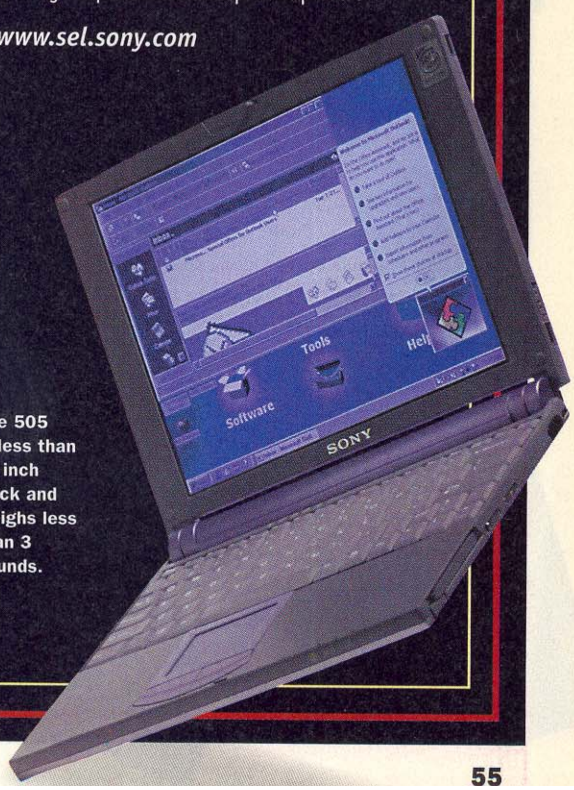
Film-Like Digital

CAN A CONSUMER digital camera match the quality of a film camera? Kodak's DC260 Zoom camera ($999) makes a strong case that it can. Its 1.6 million CCD sensor and 3X optical zoom lens yield sharp digital pictures comprised of 1,536 by 1,024 pixels—enough data for photorealistic printouts in 8 by 10 format. The DC260 also has a burst mode for taking up to eight pictures in rapid-fire fashion, and it records and plays voice notes as well. ***www.kodak.com***

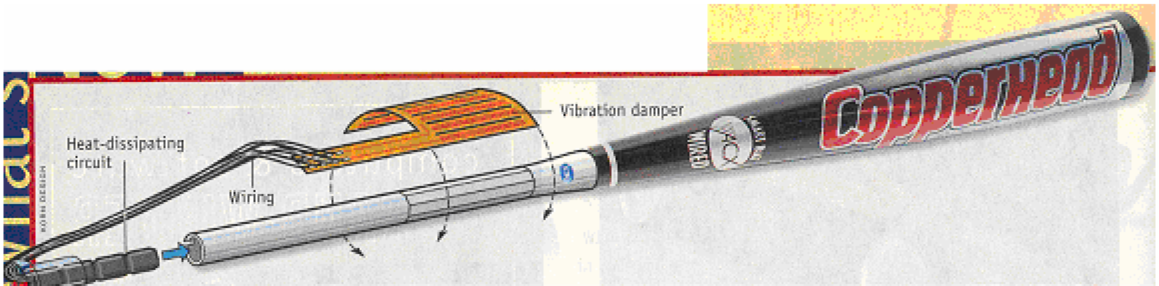
THE ULTIMATE IN PORTABILITY

SONY'S DAZZLINGLY downsized Vaio 505G and its successor, the 505F, changed the rules for mobile computing in 1998. The 505 fits in almost any briefcase without straining your shoulders. Yet it handles real work, thanks to its 233MHz Pentium processor, 32MB of memory, 4-gigabyte hard drive, 56Kbps modem, and 10.4-inch color screen. And by connecting external floppy and CD-ROM drives, the $1,999 505F converts into a very capable desktop computer.

www.sel.sony.com



The 505 is less than an inch thick and weighs less than 3 pounds.

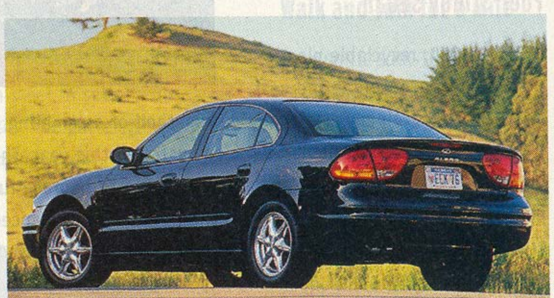


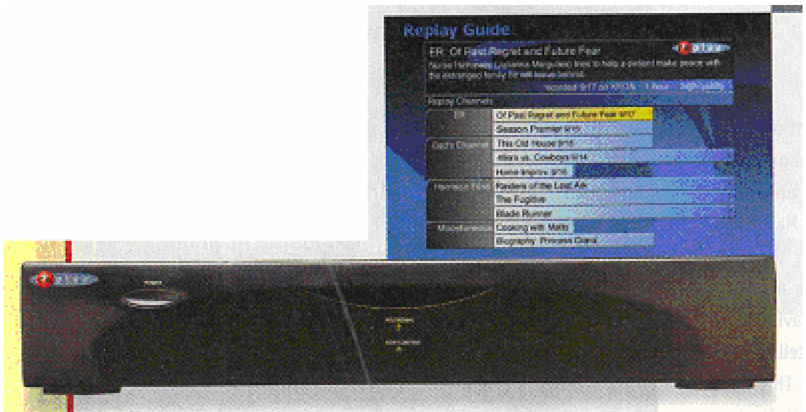
King of Swing

THE COPPERHEAD ACX baseball bat by Worth is the first to use damping technology to take the sting out of your swing—and increase the sweet spot for truer hits. A layer of piezoelectric material around the base—about 6 inches from the bottom—is the key. The material converts the mechanical vibrations of the bat into an electric current. A red light at the knob of the bat tells you that the damping material is working. Price: about $300. ***www.worthsports.com***

Pleasure Without the Price

THE 1999 OLDSMOBILE ALERO IS A HIGHLY affordable car that proves that driving need never be dull. A new suspension and chassis utilize the latest technology, the body structure is greatly enhanced, and the V6 engine gets a power boost. The result is a lively and responsive sedan that reacts precisely to the driver's inputs—providing driving pleasure that defies the price tag. If the Alero hasn't leapfrogged the Japanese competition, it hops directly into the center of it. Base price: $16,325. ***www.oldsmobile.com***



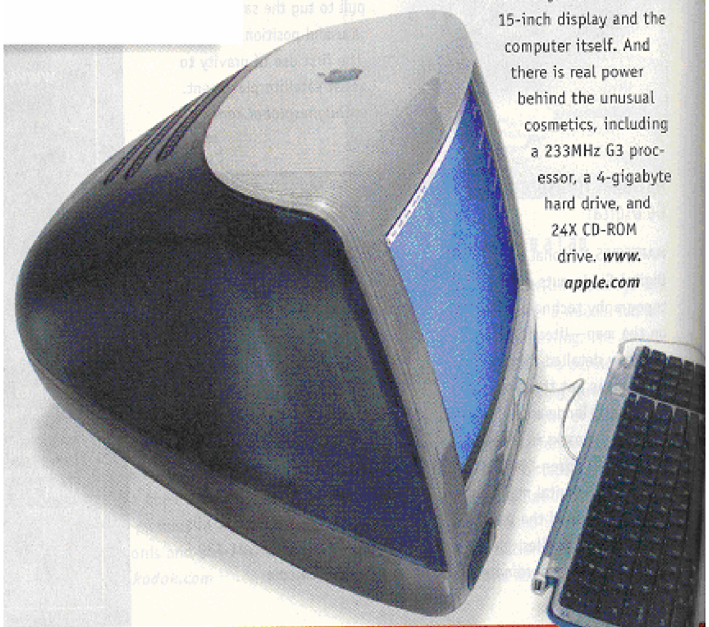


Play It Again, Sam

AT THE TOUCH of a button, you can pause a live broadcast of *Casablanca* —or 15 minutes into the film, you can decide to go back and record it from the start. These two never-before-available options come courtesy of Replay TV, a VCR-like device that continually records the incoming TV signal on an internal hard drive like those used by computers. The basic $995 box comes with seven hours of storage capacity, which can be upgraded to 40 hours. Other features include the ability to create customized channels based on favorite shows or stars. Sports fans will like the ability to do their own instant replays. ***www.replaytv.com***

Translucent Comeback

IF YOU'RE A MACINTOSH FAN, Apple's much publicized exit from the home computer scene was distressing. But the wildly stylized iMac ($1,299) offers plenty of reasons for celebrating the return of the home Mac. Easily the most striking home computer of the year—maybe ever—the iMac sports a translucent aqua and white body that houses the 15-inch display and the computer itself. And there is real power behind the unusual cosmetics, including a 233MHz G3 processor, a 4-gigabyte hard drive, and 24X CD-ROM drive. ***www.apple.com***



:ion, see RESOURCES or visit WWW.POPSCI.COM

A Digital Camera for Film Buffs

THE OLYMPUS D-400 is the best execution yet of a digital camera that looks and feels like a film camera. That film-like feeling comes from the 3X optical zoom and a through-the-lens autofocus system. The D-400's ($799) digital heritage, though, is evident in its 1.3-million-pixel resolution, LCD display, and a burst mode that lets you takes 10 pictures in ½-second increments. Store pictures on an 8-megabyte flash memory card, which fits into a floppy-disk adapter for computer use. ***www.olympusamerica.com/camera/camera.html#digital***

HELLO, SATELLITE, GET ME CENTRAL

THE FIRST OF its kind, a new satellite phone system called Iridium enables mobile users to make calls to and from anywhere on the planet—without worrying about local incompatible cell-phone systems. The $5 billion Iridium system is comprised of 66 satellites in low Earth orbit, 421 miles above the ground. Each phone costs about $3,000, and service averages about $1.70 per minute plus long-distance charges. Pagers, costing about $500, are available as well.

www.iridium.com

Iridium's antenna picks up satellite signals.

BEST of What's New

Hoggin' the Air

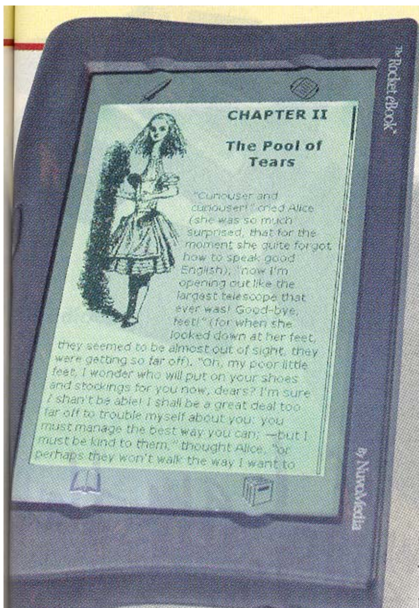
THE AIR HOG IS THE FIRST MODEL airplane to use air pressure in conjunction with a piston to power its propeller. The see-through engine purrs like that of a conventional gas-powered model airplane—but there's no messy refilling with gas or replacing spark plugs. "Refueling" the plane with air is as easy as attaching a docking station—analogous to a bike pump (left)—and pumping away. Then, simply flick the propeller, throw the plane—it's that easy—and watch it loop and bank delightfully at distances of more than 100 yards. Just be careful of trees. Price: about $40. ***www.spinmaster.com***

Innovative People Mover

A COMBINATION PEOPLE MOVER and rec room, the 1999 Honda Odyssey offers a slew of innovations that add convenience and practicality to a roomy minivan. The rear seat row is expansive and does a disappearing act when not needed; the handling equals that of many passenger cars; and the fuel economy ranks with the best in its class. Honda's first truck sets new standards for moving a group in comfort and style. Base price: $23,000. ***www.honda.com***

Kayak with Flippers

A CROSS BETWEEN a seal's flipper and an underwater sail powers the Hobie Mirage, a kayak that lets you exercise your legs as well as your arms. The total body workout is accompanied by a good turn of speed, made possible by the innovative Hydro-Sail Drive "flippers" that drive the boat forward, propelled by the operator's legs. For maximum speed, a paddle adds to the package. Price: $495. ***www.hobiecat.com***



Rewritable Book

AS THE FIRST electronic book, one 20-ounce Rocket ebook from NuvoMedia can replace dozens of dust-gathering tomes on your shelves. Rocket ebook stores up to 4,000 pages of material purchased and downloaded via the Internet. Then you simply transfer the documents to Rocket ebook for easy reading anywhere. When you're done, delete the material or transfer it back to your computer's hard drive for storage. ***www.rocketbook.com***

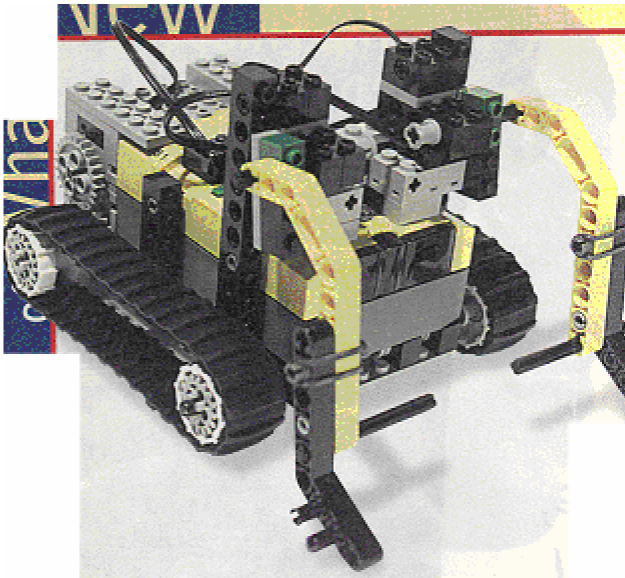
Five Bits in One

THE INGENIOUS 12-volt cordless Craftsman Redi Drill lets you load five drill or screwdriving bits in its housing. Slide a switch to move each bit before a tiny window for selection. Then push a lever forward to ease the selected bit out, twist the chuck to tighten, and you're ready to go. The price is about $160. ***www.sears.com***

AN EYE FOR AUTOFOCUS

CANON'S EOS-3 35mm SLR camera doesn't just make one leap forward: It makes several at once, and on several fronts. First, its faster eye-control system now works in conjunction with a new autofocus—built around a new CMOS sensor chip—that uses 45 points of focusing, rather than the usual five. Next, an innovative flash system lets you control multiple flash units wirelessly from the $1,900 camera body. And an optional motor drive boosts continuous shooting from five frames per second to seven. ***www.usa.canon.com***

A new CMOS chip provides 45 points of focus.



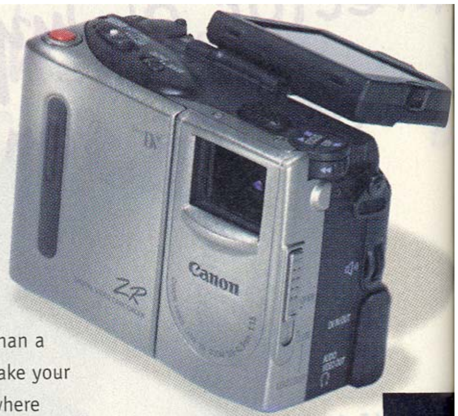
Make-Your-Own Robot

WE'RE ACCUSTOMED TO FASHIONING fantastic creations with pieces of Legos, but here, perhaps, is the ultimate: The Lego Mindstorms Robotic Invention Program, which lets you build your own operational robots. In addition to those familiar-looking fit-together pieces, special PC software lets you program how you want parts of the robot to move in response to light or touch. You can design them to accomplish tasks—a "bulldozer" can pile sticks, for instance. Each kit retails for $200. ***www.legomindstorms.com***

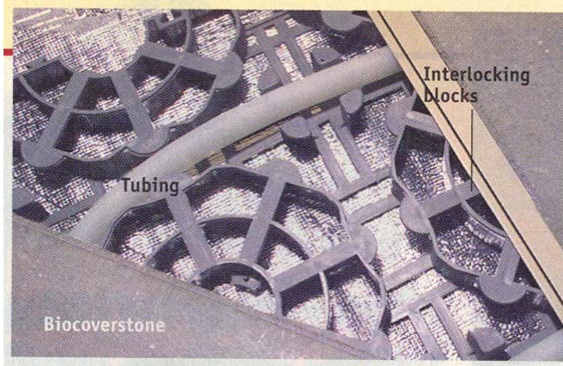
Comfy Off-Roader

A COMPROMISE FOR THOSE who want the looks and some of the abilities of a sport-utility vehicle but don't want to sacrifice highway ride and handling, the 1999 Lexus RX300 carves new ground. Still up to the occasional backcountry foray, this hybrid offers good fuel economy, visibility, and highway manners that recognize the primary role of an all-around people mover that still likes to play on weekends. Base price: $33,205. ***www.lexususa.com***

Digital Video to Go



THE SMALLEST digital video camcorder to date, Canon's ZR ($1,199) packs the latest in DV technology into a clever device that looks and feels more like a point-and-shoot film camera than a camcorder, letting you take your movie-making gear anywhere you go. With both a movie mode and a photo mode, it can serve as a still camera too. You can get close up with an 11X optical zoom lens, and its movable 2.5-inch color LCD enables you to see what you are shooting from any angle. ***www.canondv.com***



Easy Radiant Heating

TRADITIONAL RADIANT heat systems—which run warm water through tubing embedded in a concrete subfloor—are costly to repair if a leak develops. Now EasyFloor from PFG Industries uses plastic interlocking blocks instead of concrete. A thin "biocoverstone" made of sand, clay, and stone, which distributes the heat, covers the blocks. The removable coverstone allows access to the tubing below. Price: $4 per square foot, not including installation. ***www.pfgindustries.com***

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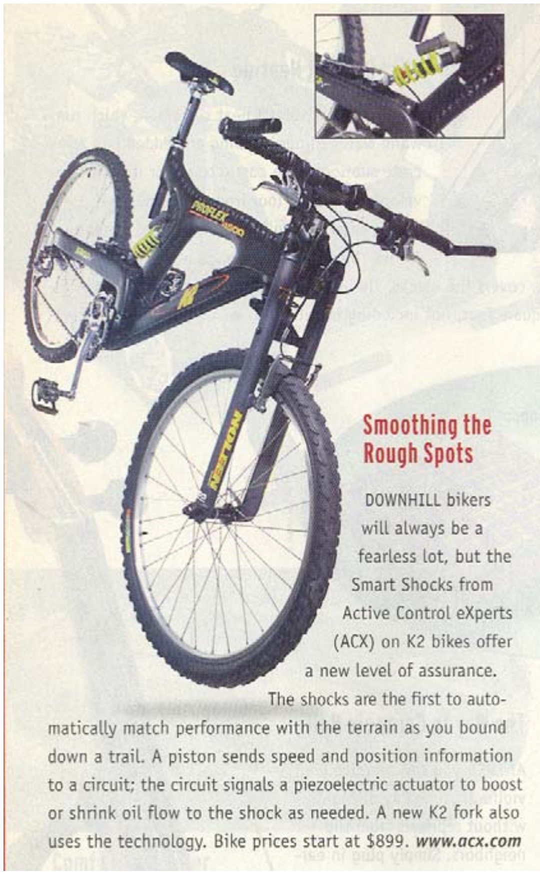
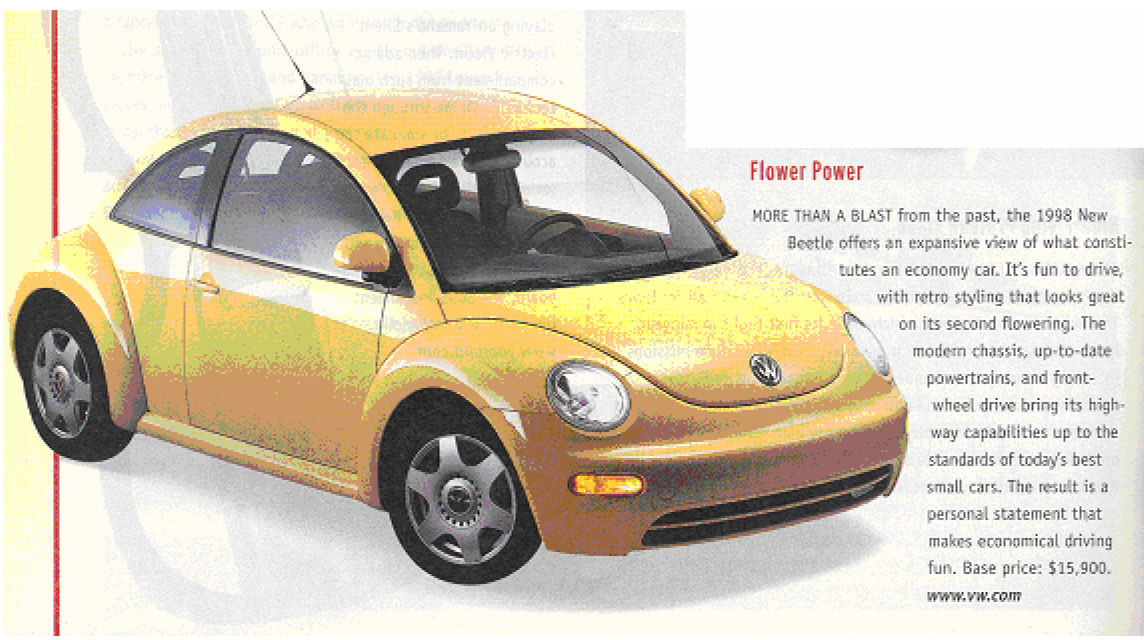
The Way to Carnegie Hall

AT LAST, you can practice your violin anytime day or night—without reprisals from the neighbors. Simply plug in earphones to hear what you're playing on Yamaha's Silent Electric Violin. Then add accompaniment from such masters as Yo-Yo Ma through the auxiliary jack, or simulate the acoustics of Carnegie Hall with reverb. When you've perfected your skills, use the line-out jack to share your music with the world. Without the soundboard, the $695 instrument functions as a real violin.
www.yamaha.com



Smoothing the Rough Spots

DOWNHILL bikers will always be a fearless lot, but the Smart Shocks from Active Control eXperts (ACX) on K2 bikes offer a new level of assurance. The shocks are the first to automatically match performance with the terrain as you bound down a trail. A piston sends speed and position information to a circuit; the circuit signals a piezoelectric actuator to boost or shrink oil flow to the shock as needed. A new K2 fork also uses the technology. Bike prices start at $899. ***www.acx.com***



Flower Power

MORE THAN A BLAST from the past, the 1998 New Beetle offers an expansive view of what constitutes an economy car. It's fun to drive, with retro styling that looks great on its second flowering. The modern chassis, up-to-date powertrains, and front-wheel drive bring its highway capabilities up to the standards of today's best small cars. The result is a personal statement that makes economical driving fun. Base price: $15,900. ***www.vw.com***

Tiniest Cellphone Ever

SHOWN ACTUAL size, the Motorola V Series cellphone is so diminutive you may at first mistake it for a toy. But it's all business: The phone has a 160-minute talk time and 160-hour standby lithium-ion battery. An optional extended-life battery provides 660 minutes talk time and 660 hours standby. Currently available in analog, the V Series will be available for GSM, TDMA, and CDMA networks early next year. Price: approximately $600, depending on service provider. ***www.motorola.com***

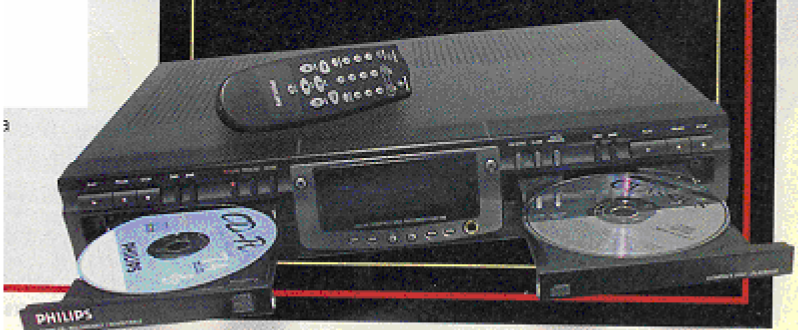
Clever Zoomer

SURE, TINY APS zoom cameras let you shoot just about anywhere. But how many can put you in the picture? Fuji's Endeavor 3500ix Zoom MRC ($479) comes with an integrated remote control, enabling you to leisurely position yourself in the frame without worrying about a ticking timer. The remote card easily snaps on and off the camera, serving as a lens cover when attached to the front, and a control panel when on the back. Even so, the 3500ix is barely bigger than a deck of cards and has a 2.8X zoom lens. ***www.fujifilm.com***

SPINNING YOUR OWN

ALWAYS WANTED to record your own compact discs? For the first time, Philips makes that capability both affordable *and* simple with its Audio CD-Recorder CDR765. The 765 is the first CD recorder with two CD drive mechanisms, which makes recording your own CDs as easy as placing a pre-recorded disc on one tray and a blank disc in the other. You can make copies of your music CDs or compile your own "greatest hits" collections from several CDs. The Philips unit records at twice the normal playback speed, and you can also play two CDs simultaneously—a nice perk if you have speakers in different rooms. Price: $599.

www.philips.com

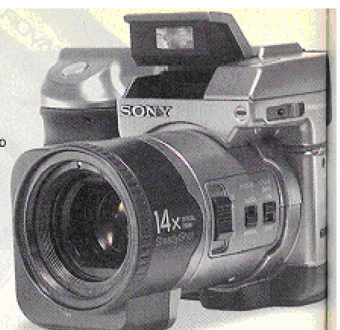


Dual decks let you record your own CDs.

Style With Substance

WANT IT ALL? IBM's sleek black Aptiva SE7 ($2,399) is arguably the most powerful home PC to date. Its 450MHz Pentium II processor, 128MB of memory, 16.8-gigabyte hard drive, DVD-ROM drive, and 56Kbps modem make it this year's best, no-compromises home PC. Add its optional flat-panel display, and you've got a stylish and speedy package that's prepared to run the most demanding 3-D games or handle the most complex home publishing projects—while still looking great in the living room. ***www.ibm.com/aptiva***

More Versatile Maverick

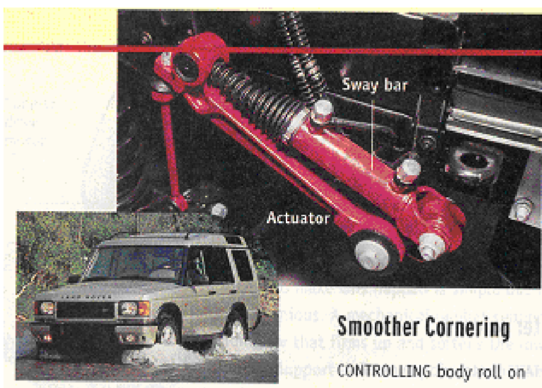


SONY'S LATEST Mavica models make cramped floppy disks go a long way. The Mavica MVC-FD91 ($1,099) uses new compression technology to bump up picture quality from so-so VGA (640 by 480) to XGA (1,024 by 768), which is far better for prints. But there's lots more: The FD91 has a 14X optical zoom lens—longest of any digital camera—and a unique movie mode that captures up to 60 seconds of MPEG digital video and audio on a floppy. A version with a 3X optical zoom, the MVC-FD81, sells for $899. ***www.sony.com***

Sporty Sedan

ENGINEERING A COMPACT sedan to perform as well as a flat-out sports car has been BMW's goal for its 3 Series sedans. The latest generation, for 1999, is better in all respects—roomier and more powerful, with a superior ride and sense of precision that are landmarks in a competitive field. The outstanding performance of this sedan is the result of careful design and engineering that minimize weight and maximize responsiveness. The car is well worth the price, which starts at $26,400.

www.bmwusa.com



Smoother Cornering

CONTROLLING body roll on sport-utility vehicles is problematic, since long spring travel and its associated tendency to cause excessive body sway are essential to successful scrambling over rough terrain. Now the 1999 Land Rover Discovery uses an active sway bar that automatically stiffens to reduce the rolling action. It's an important enhancement to the safety and convenience of sport-utilities. A package including the option should cost about $2,000 to $3,000.

www.landrover.com

A RECORD-BREAKER FOR SPEEDSKATERS

THIS YEAR, THE CLAP SKATE from Viking took the Olympics by storm, shattering speed-skating records. In clap skates, the blade assembly is hinged at the front of the skate. This construction provides skaters with a longer, more powerful stride—and forced a world-wide change in skating technique for the first time in the 500-year-old history of the sport. Ironically, the patent for clap skates dates from the end of the last century but new materials, along with extensive testing by Dutch junior speed-skating team members, made the skate viable only now. Price range: $400 to $500.

The distinctive sound of toppling records: the clap skate.

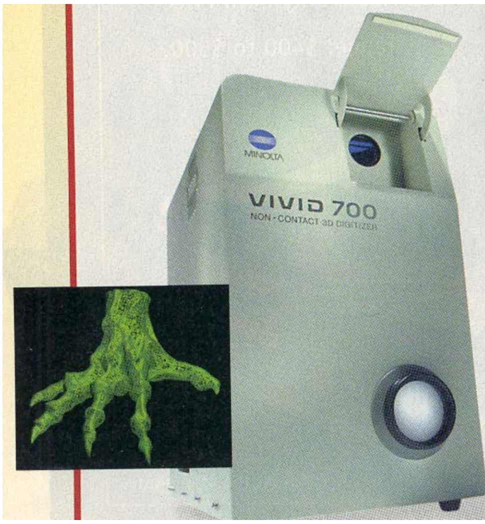
New

Underwater Zoomer

NOW YOU CAN TAKE better close-ups of coral reefs and tropical fish with the world's first underwater zoom camera, the Minolta Vectis Weathermatic Zoom Advanced Photo System (APS) camera. Its 1.7X zoom lens ranges from 30mm to 50mm within a housing that's water-resistant down to 33 feet. The rugged camera is also the first to feature underwater autofocus. Price: $350. ***www.minoltausa.com***

Call of the Wild

GARMIN'S NAVTALK is the ultimate in outdoor survival gear: a combination analog cellphone and GPS receiver. Need help but aren't sure of your location? No problem. Simply use the cellphone to call for help, and the GPS unit to explain where you are. Or merely call another NavTalk unit and transmit your location with the touch of the button. The GPS receiver includes mapping software for the United States, Canada, and South America. Price: $500. ***www.garmin.com***

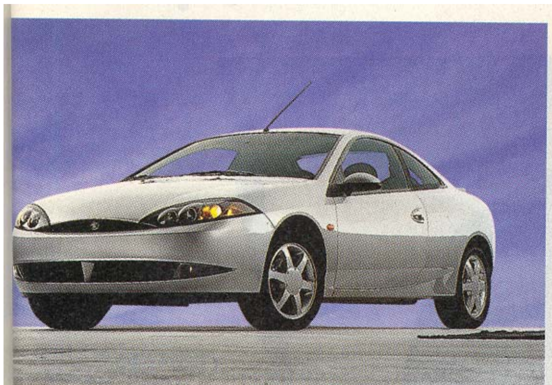


Taking in the Real World

TODAY'S FLATBED SCANNERS digitize photos and other flat objects. But tomorrow's scanners will digitize 3-D objects. Minolta's Vivid 700 3-D scanner offers a glimpse of that future today. Designed for imaging professionals, the Vivid 700 is the size of a small suitcase, making it the first truly mobile 3-D scanner. Vivid 700 employs an autofocus zoom lens to capture a 400- by 400-point color image in less than 1 second, and 360-degree images can be stitched together from multiple scans. Price: $37,000. ***www.minolta3d.com***

Massages While-U-Drive

WITH A TOUCH OF a button, the massaging seat feature on the 1999 Cadillac DeVille goes to work on your aching back. The technology to make this happen is simple but ingenious. A mechanical lumbar support—a bar that firms up and softens the lower back support—rotates up and down. The effect is like a soothing hand along your spine. In a world of features that stretch the limits of high tech, this one just makes you feel good. Price for option: $200. ***www.cadillac.com***

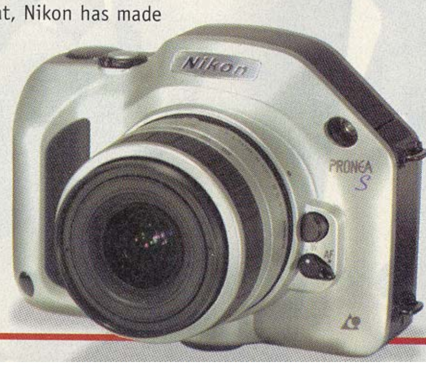


Smart and Stylish

THE 1999 Mercury Cougar represents a breath of fresh air for sport coupes. The stylish exterior design indicates fresh thinking, as does the interior. Despite a rakish profile, the vehicle maintains roominess and comfort, both front and rear. Crisp handling and a smooth powerplant cap off the package, which emerges as an affordable touring coupe. Prices start at $16,595. ***www.mercuryvehicles.com***

Smallest SLR Camera

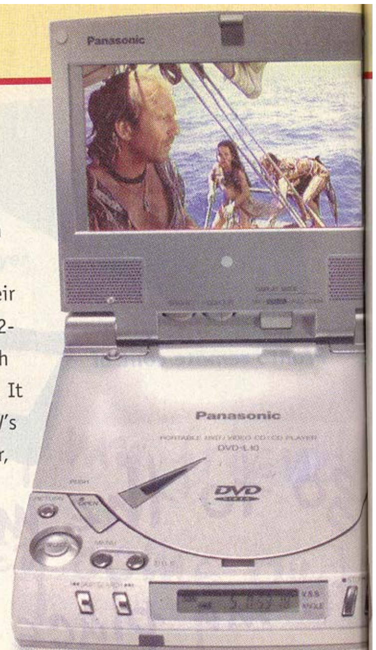
THE WORLD'S SMALLEST SLR CAMERA, Nikon's Pronea S camera adapts the small size configuration inherent to Advanced Photo System (APS), with its small film cartridges, to work with a smartly designed SLR camera that appeals to the serious hobbyist. The Pronea S can be used with existing Nikkor 35mm lenses. And by using the APS format, Nikon has made the Pronea S very lightweight at 1 pound. The $520 Pronea S can be used in both automatic and manual focus modes. ***www.nikonusa.com***



DVD Movies to Go

WITH PANASONIC'S DVD-L10 Palm Theater, the first portable DVD player, movie buffs can take their favorite discs on the road. The 2-pound player features a 5.8-inch LCD screen and stereo speakers. It can also be plugged into any TV's RCA jacks for a larger screen. Or, plug in headphones for listening to audio CDs. The nickel-metal-hydride battery lasts 2 hours with the display on. The player costs about $1,400.

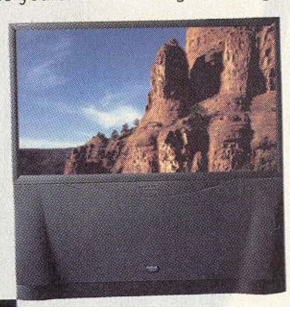
www.panasonic.com



All Set for Digital TV

THE DIGITAL TELEVISION revolution begins with broadcasts starting this year, and the best TV to watch them on is Thomson's 55-inch P55000 projection model. It displays a digital TV picture in a 16:9 wide-screen aspect ratio. And unlike other models, the $6,999 set contains a satellite TV tuner so you can receive digital TV signals from space. No need to wait until digital signals come to your area either: The P55000 receives existing analog TV channels as well.

www.rca.com



The Beat Goes On

STILL MARCHING TO A different drummer—who happens to have great rhythm—Porsche remakes the 911 for 1999 with modern refinements including a water-cooled engine, a new suspension that is nearly civilized, and a new shape that enhances the car's distinctive lines. The quintessential sports car, the 911 has earned a place among the classics of sports car design as an uncompromised expression of the most precise way to travel. Base price: $65,030.

www.porsche-usa.com

Twist and Shoot

NIKON'S CLEVER Coolpix 900 ($899) literally offers a new angle on digital photography. You pivot the camera's 3X zoom lens and its accompanying flash to get just the angle you want while still viewing the 2-inch color LCD. The Nikkor lens' incredibly refined 945-step autofocus system captures precisely focused images and records them as highly detailed 1,280-by 960-pixel digital images. And unlike many digital cameras on the market, the Coolpix 900 has manual controls for key picture elements, such as exposure and white balance, just as the better film cameras do.

www.nikonusa.com

Calling the Internet

THE ULTIMATE message and information center, the Philips IS-2630 screen phone lets you send and receive e-mail, browse the Web, and, of course, make phone calls. The phone displays basic Web pages on its color VGA touchscreen panel. Also included are calendar and address book programs, plus a wireless keyboard for typing messages. Price: $650. ***www.philipsconsumer.com***

A Most Modern Desktop

COMPAQ'S super-sleek, super-fast Presario 5600 Series has many of tomorrow's PC features today. Available with Pentium II processors as fast as 450MHz and hard drives as big as 12 gigabytes, the Presario 5600 is one of the fastest home PC models to date, and its optional flat-screen color LCD arguably makes it the most futuristic. With both USB and 1394 (Firewire) ports located up front, the Presario 5600 makes it easier than with other PCs to plug in digital cameras and camcorders as well. Prices range from $1,899 to $2,499. ***www.compaq.com***

TECHNO TOUR DE FORCE

VOLVO LEAPS into the luxury car field with a sedan that encompasses new technologies in an efficient and handsome package. The first transverse-mounted inline six-cylinder in a front-wheel-drive, the car sets new standards for smoothness, while the turbo option offers outstanding acceleration as well. A sophisticated multiplex wiring system maximizes the efficiency of onboard computers. The side-curtain airbags and anti-whiplash seating are part of an unsurpassed safety package. The S80 is a technological tour de force that is a pleasure to drive. Price: $35,820.

www.volvocars.com

Five can repose in comfort in the roomy Volvo S80.

Smile for the Disk

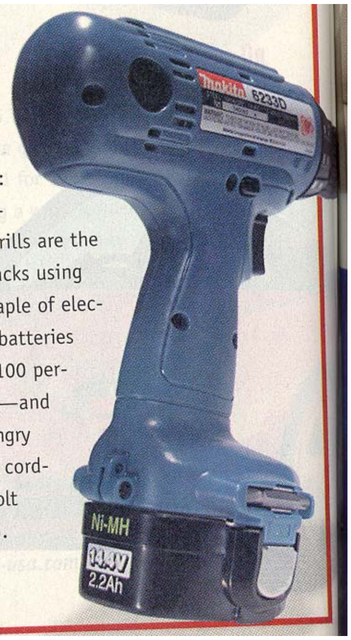
IF YOU LIKE your electronics small and cheap (and who doesn't?), you'll love Iomega's Clik disk. Barely 2 inches square (shown actual size), the Clik disk holds 40MB of data and costs about $10. That makes it the smallest and most affordable portable disk to date. In digital cameras, Clik will let you take more pictures before transferring them to your PC. And Clik might also be used in mobile computers, cellular phones, and other portable electronics. ***www.iomega.com***

Make and Take Digital Music

LIKELY TO BE a welcome forerunner of things to come, Diamond Multimedia's Rio PMP300 digital audio player is the first that lets you download near-CD-quality MPEG 3-format audio files from the Internet—and then take them on the road. You can also encode songs from your CD collection on your PC with included software. Then transfer as much as 60 minutes of music to the $200 player at a time. ***www.diamondmm.com***

More Juice for Tools

THIS YEAR, Makita introduced two cordless drills—a 12- and a 14.4-volt—with an important difference: Instead of heavy nickel-cadmium batteries, the new drills are the first with lighter power packs using nickel-metal hydride, a staple of electronics products. The new batteries improve run time by 55 to 100 percent over previous batteries—and will allow full-size power-hungry tools like circular saws to go cordless too. Prices: $440 (12-volt kit) and $480 (14.4-volt kit). ***www.makita.com***



Write 'n' Store

DEVELOPED using technology created by IBM, the Crosspad from A.T. Cross Co. lets you transfer handwritten notes made on a standard paper pad to a computer. A pad underneath the paper and a special pen together recognize the characters you've written, and store them in memory—as much as 50 pages' worth. These notes can be transferred to a computer as individual text files for later editing and searched using keywords. The $399 Crosspad comes in two sizes: 8½ by 11 inches and 6 by 9 inches. ***www.cross.com*** and ***www.ibm.com***

Improved Icon

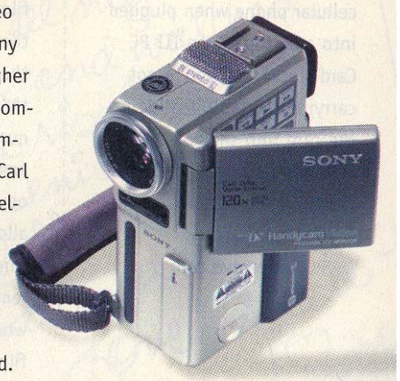
REENGINEERING AN AMERICAN automotive icon is no small feat. General Motors' 1999 full-size pickups, the Chevrolet Silverado and GMC Sierra, offer increased horsepower and fuel economy; a roomy cab, combined with a stronger chassis; and brakes and steering that set new standards for an easy-to-drive load hauler. The result is a modern update of a classic workhorse. Base price: $15,955. ***www.chevrolet.com*** and ***www.gmc.com***

Engineering Success

RYOBI North America has solved the age-old problem of four-strokes: You couldn't turn them upside down, or the oil would drain out of the top vent hole and the engine would seize. The CleanAir 4-Stroke 26cc engine has a vent hole in its crankshaft and is designed so that the oil level never blocks the hole. The engine can be used in virtually all outdoor power tools, including the Landscaper Series string trimmer (shown). The price is around $229. ***www.ryobi.com***

Mini Movie Maker

SONY'S DCR-PC1 DIGITAL video camera/camcorder is one tiny powerhouse. It packs in higher quality and more powerful components than any other palm-size camcorder. It features Carl Zeiss lenses, a 2.5-inch swiveling color LCD viewfinder, and image stabilization technology. All of these are packed into a trim body weighing just under a pound. Price: $1,899. ***www.sony.com***



Car Commander

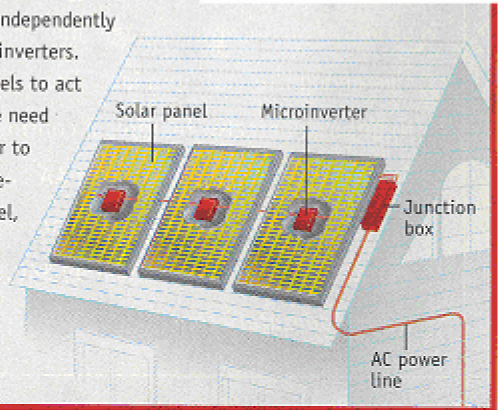
WITH CLARION'S AUTOPC, you can tell your car what to do—and it actually listens. The first car computer that recognizes verbal commands, AutoPC has a more than 1,200-word vocabulary. It understands commands to change radio stations, provide turn-by-turn directions based on its Global Positioning System (GPS) navigation unit, or even read e-mail subject lines. Running on Microsoft's Windows CE operating system, the $1,299 AutoPC's control module fits in a single dashboard slot, with the computer and six-disc CD changer stored in the trunk. ***www.autopc.com***

Still the Handiest

WITH SLEEK NEW STYLING, more memory, and a feature that lets you beam your business card to another Palm III user, this year's model remains the gold standard for personal digital assistants. Palm III, from 3Com, delivers exactly what you need in a pocket-size device—a calendar, address book, notepad, expense tracker, and calculator—and nothing extraneous. But power users can install a host of applications, including a scorecard for golf games, scientific calculator, and e-mail. Price: $400. ***www.palmpilot.com***

Solar Power Made Easy

IN A SIGNIFICANT STEP forward for photovoltaic technology, Advanced Energy Systems and Ascension Technology have independently introduced PV panels that feature built-in microinverters. The small 250-watt microinverters allow the panels to act as their own AC generators, thus eliminating the need for direct-current wiring and an in-home inverter to convert DC current to AC current. In addition, because the microinverters are built into each panel, homeowners can start with a small system and add on. Cost: about $10 per watt, but prices are expected to fall quickly. ***www.advancedenergy.com*** and ***www.ascensiontech.com***



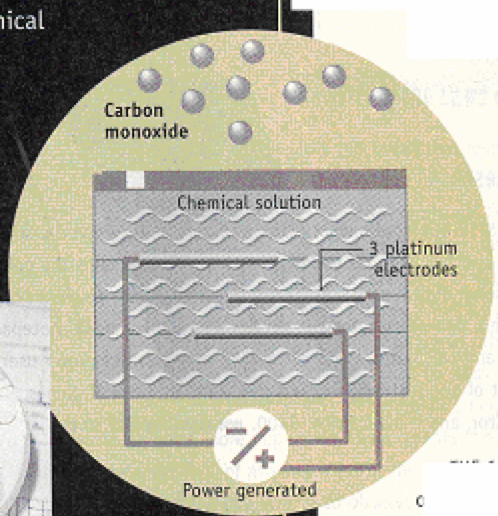
Calling Card

FOR THE FIRST TIME, one device takes care of all your communications needs. Globewave's $499 Com.plete PC Card is a cellular modem, a landline modem, and a cellular phone when plugged into a laptop's Type III PC Card slot. When you're not carrying the laptop, slide the card into the Com.plete Cellphone adapter handset ($40), which features a keypad and battery. ***www.globewave.com***

LIFE SAVERS

KIDDE SAFETY'S new Nighthawk carbon-monoxide detectors will ease the minds of homeowners: They feature an electrochemical sensor—the most accurate type of sensor to hit the home market. Long used in expensive industrial units, electrochemical technology—in which CO reacts with platinum electrodes in a chemical solution—only recently became inexpensive enough to mass-produce. The Nighthawk detector features a continuous readout, operates on three AA batteries, and comes with a five-year warranty. It costs approximately $40.

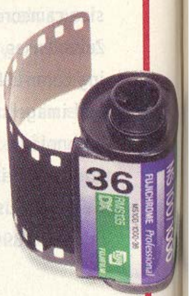
www.kiddesafety.com



Platinum detects carbon monoxide.

Do-It-All Film

WITH THE Fujichrome MS 100/1000 Professional slide film, photographers can lower the number of film types that they need to carry—while at the same time increasing the quality of the final work. New emulsion technology is the key: It allows the picture quality to remain high even when the 35mm film is pushed five stops. Price for a 36-exposure roll: about $14. ***www.fujifilm.com/home/press/pr_ms100fil.htm***

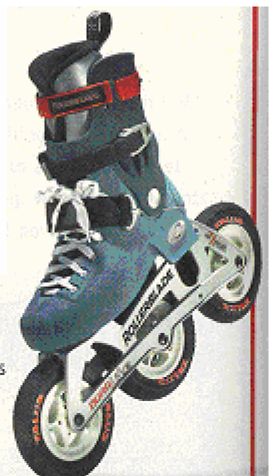


Grander Than Ever

THE 1999 JEEP GRAND CHEROKEE is a sport-utility with full off-road capability and handling approaching that of a car. A new four-wheel-drive system supplies power to any single wheel with the most traction, enhancing off-roading, while improvements in the suspension and steering and a new V8 powerplant add up to more confidence on the highway. The result is a new-generation sport-utility that still ranks with the best both on-road and off. Base price: $26,220. ***www.jeep.com***

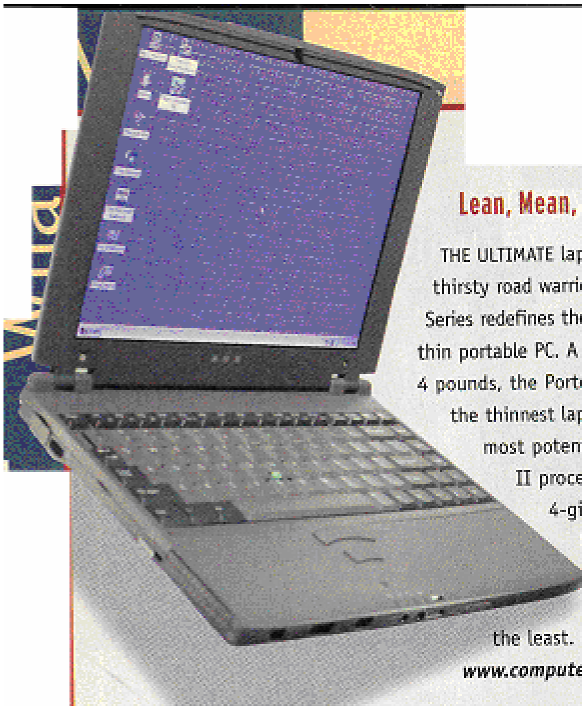
Zoom in Even Closer

PENTAX takes zoom lenses in point and shoot cameras to new lengths with its IQ Zoom 200. Despite the length of its 48-200mm lens, the $647 camera is only slightly larger than the IQ Zoom 160, the previous zoom record holder, at 160mm. An easy-to-use dial, which is reminiscent of SLR camera controls, atop the 12.2-ounce camera makes it easy to adjust the zoom to any desired length. ***www.pentax.com/Frames/iqz200/200.html***



Blades for Bike Paths

THE FIRST all-terrain inline skate, Rollerblade's Coyote lets you take that bumpy road or mountain trail with greater assurance of getting through in one piece. Equipped with three 6-inch pneumatic tires, the skates feature a unique drum brake for easy stopping on sand, gravel, and other loose surfaces. Price: $500. ***www.rollerblade.com***



Lean, Mean, and Mobile

THE ULTIMATE laptop for the power-thirsty road warrior, Toshiba's Portégé 7000 Series redefines the expectation of an ultra-thin portable PC. A mere 1 inch thick and only 4 pounds, the Portégé 7000 is both one of the thinnest laptops so far and one of the most potent, with a 300MHz Pentium II processor, 32MB of memory, a 4-gigabyte hard drive, and a luxurious 12-inch color LCD screen. Pound for pound, it's the most for the least. Prices start at $2,999. ***www.computers.toshiba.com***

The Pro's Digital Snapper

OUR EXPECTATIONS of professional digital cameras have been raised with the jointly developed Canon EOS D2000 and Kodak DCS 520 ($14,995). The CCD sensor in this camera not only produces incredibly detailed 2-megapixel (1,736 by 1,160 pixels) images, it uses new digital filtering technology to improve color trueness. ***www.canon.com*** or ***www.kodak.com***

The Bone Phone

DAEWOO'S Opentech designers were using their heads—literally—when they came up with the Miracle Phone, for the hearing impaired or those who work in noisy places. Placed against a bony area, such as behind the ear, a knob in the phone's handset transmits vibrations that recreate the sound of the caller through the bones of the skull. The phone also works in the conventional manner. Price: $200.

www.daewoo.com

Third One's the Charm

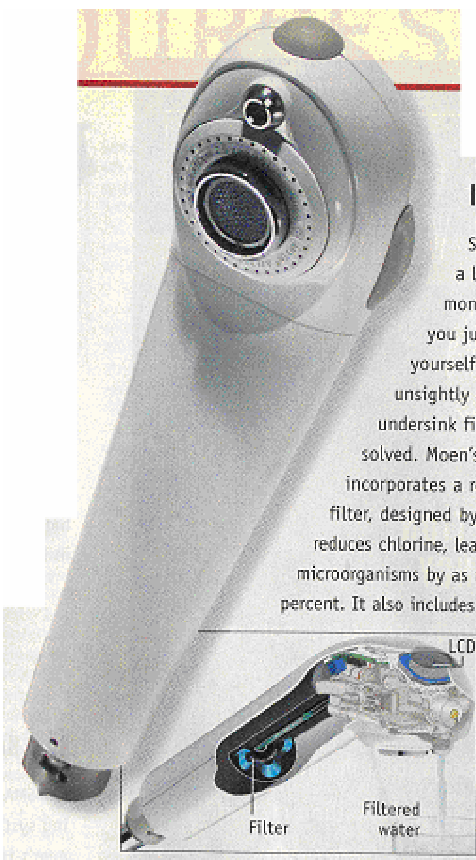
THE SCRAMBLE TO FIT IN THE BACK seat of a two-door coupe has ended with the introduction of a third door in the 1999 Saturn Coupe. A feature that eliminates the inconvenience of the two-door coupe, the rear-opening door is an ingenious solution that allows a passenger to enter while the front seats are full, or makes it easy to put packages in the rear. Price not yet set.

www.saturn.com

Greater Than the Sum of Its Parts

THE FIRST BUSINESS JET from a major manufacturer to boast an all-composite fuselage shell, the Premier I uses only half the parts needed for conventional aircraft. Fewer parts make the plane easier to assemble and maintain, lowering operating costs. Made by Raytheon Aircraft of Wichita, Kansas, the Premier I, which costs some $4 million apiece, began flight tests this fall.

www.raytheon.com/rac/premier1



In-Faucet Filter

SO BOTTLED water is a line item on your monthly budget, but you just can't bring yourself to install an unsightly counter or bulky undersink filter unit? Problem solved. Moen's PureTouch faucet incorporates a replaceable water filter, designed by Culligan, which reduces chlorine, lead, and harmful microorganisms by as much as 99.98 percent. It also includes an LCD that tells you the remaining life of the filter, which is designed to last for three months. Price: $399.

www.moen.com

Video Notebook

THE CAMERA-SIZED Ruvi camcorder from Sony is the first that lets you shoot 30 minutes of Hi8XR video as well as up to 350 still images that can be accompanied by 5 seconds of audio each. Weighing about 1 pound, the $799 camcorder works like a video notebook for capturing images quickly. A 3X optical zoom lets

you take close-ups and a 2.5-inch LCD display lets you see the results immediately. ***www.sony.com***

Cozy Home Theater

THE SMALLEST and best-sounding system we've seen, Pioneer's HTV virtual surround sound system proves that a tiny living room is no obstacle to home theater. The box fits nicely on top of your TV with its subwoofer stashed to the side. The speaker bar houses two speakers that reproduce all five surround sound channels virtually by adjusting the timing and frequency response differences of the sounds according to their location. Price: $499. ***www.pioneerelectronics.com***

APPENDIX C – COMPILED CUSTOMER SURVEY DATA

Weighted Mean Scores			
		Market Pull Score	Technology Push Score
1	Liquidmetal Golf Clubs	4.9	4.0
2	Panasonic KX-TGM240 GigaRange	3.5	2.7
3	Kodak DC260	4.4	3.2
4	Sony Vaio 505F	5.3	1.0
5	Copperhead ACX	4.4	4.2
6	1999 Oldsmobile Alero	4.6	2.6
7	Replay TV	4.3	1.8
8	Apple iMac	3.8	2.2
9	Olympus D-400	4.2	2.3
10	Iridium	4.6	2.9
11	Air Hog	2.9	3.3
12	1999 Honda Odyssey	4.0	1.5
13	Hobie Mirage	1.8	4.2
14	NuvoMedia Rocket ebook	3.4	2.8
15	Craftsmen Redi Drill	3.0	2.8
16	Canon EOS-3	4.1	2.2
17	Lego Mindstorms Robotic Invention Kit	2.4	2.9
18	1999 Lexus RX300	3.5	1.9
19	Canon ZR	4.4	1.7
20	PFG Industries EasyFloor	3.8	2.6
21	Yamaha's Silent Electric Violin	3.2	3.0
22	K2 ACX Smart Shocks	3.4	4.7
23	1998 Volkswagon New Beetle	3.5	1.6
24	Motorola V Series	4.1	2.2
25	Fuji Endeavor 3500ix Zoom MRC	3.0	2.0
26	Philips Audio CD-Recorder CDR765	4.0	2.0

27	IBM Aptiva SE7	4.3	1.8
28	Sony Mavica MVC-FD91	3.5	2.8
29	1999 BMW 3 Series	4.2	1.6
30	1999 Land Rover Discovery	4.4	3.0
31	Viking Clap Skate	4.6	2.6
32	Minolta Vectis Weathermatic Zoom APS	3.4	2.2
33	Garmin NavTalk	2.9	2.2
34	Minolta Vivid 700	3.6	3.3
35	1999 Cadillac DeVille Massage Seat	4.3	2.6
36	1999 Mercury Cougar	4.0	2.4
37	Nikon Pronea S	4.0	1.9
38	Panasonic DVD-L10 Palm Theater	4.6	2.2
39	Thomson's 55-inch P5500	3.0	3.6
40	1999 Porsche 911	4.4	1.9
41	Nikon Coolpix 900	2.7	2.5
42	Philips IS-2630	3.2	2.4
43	Compaq Presario 5600 Series	5.5	1.8
44	Volvo S80	4.7	2.0
45	Iomega Clik disk	4.0	2.7
46	Diamond Multimedia Rio PMP300	3.7	2.5
47	Makita 14.4 volt Cordless Drill	5.5	2.8
48	A.T. Cross Co. Crosspad	3.1	4.4
49	1999 Chevrolet Silverado	4.8	2.0
50	Ryobi Landscaper Series	3.3	3.3
51	Sony DCR-PC1	4.9	1.7
52	Clarion AutoPC	2.7	3.4
53	3Com Palm III	4.5	2.5
54	Advanced Energy Systems PV Panels	3.5	3.6
55	Globewave Com.plete PC Card	2.5	3.1
56	Kidde Safety Nighthawk	4.1	2.1
57	Fujichrome MS 100/1000	3.9	3.3
58	1999 Jeep Grand Cherokee	4.3	2.0
59	Pentax IQ Zoom 200	4.4	2.0
60	Rollerblade Coyote	2.1	3.4
61	Toshiba Portege 7000 Series	5.5	1.8
62	Canon EOS D2000	4.9	2.6
63	Daewoo Miracle Phone	3.1	4.4
64	1999 Saturn Coupe	3.7	2.8
65	Raytheon Premier I	4.5	3.1
66	Moen PureTouch	3.9	2.6
67	Sony Ruvi Camcorder	3.6	3.1
68	Pioneer HTV	3.9	3.3

		Respondent 1			
		Market Pull Response	Technology Push Response	<--(Inverted) Technology Push Response	Familiarity
1	Liquidmetal Golf Clubs	5	2	5	4
2	Panasonic KX-TGM240 GigaRange	4	4	3	5
3	Kodak DC260	4	3	4	6
4	Sony Vaio 505F	6	6	1	6
5	Copperhead ACX	4	2	5	3
6	1999 Oldsmobile Alero	5	5	2	6
7	Replay TV	3	4	3	5
8	Apple iMac	3	5	2	5
9	Olympus D-400	5	4	3	6
10	Iridium	5	2	5	3
11	Air Hog	3	3	4	5
12	1999 Honda Odyssey	5	6	1	5
13	Hobie Mirage	2	3	4	5
14	NuvoMedia Rocket ebook	3	4	3	6
15	Craftsmen Redi Drill	3	3	4	6
16	Canon EOS-3	5	5	2	5
17	Lego Mindstorms Robotic Invention Kit	2	4	3	4
18	1999 Lexus RX300	5	6	1	5
19	Canon ZR	6	5	2	6
20	PFG Industries EasyFloor	3	3	4	3
21	Yamaha's Silent Electric Violin	3	3	4	4
22	K2 ACX Smart Shocks	4	1	6	6
23	1998 Volkswagon New Beetle	5	6	1	6
24	Motorola V Series	6	5	2	5
25	Fuji Endeavor 3500ix Zoom MRC	3	5	2	5
26	Philips Audio CD-Recorder CDR765	4	4	3	5
27	IBM Aptiva SE7	6	5	2	6
28	Sony Mavica MVC-FD91	4	3	4	5
29	1999 BMW 3 Series	6	6	1	5
30	1999 Land Rover Discovery	4	4	3	6
31	Viking Clap Skate	6	5	2	2
32	Minolta Vectis Weathermatic Zoom APS	4	5	2	5
33	Garmin NavTalk	2	5	2	5
34	Minolta Vivid 700	3	4	3	2
35	1999 Cadillac DeVille Massage Seat	5	3	4	4
36	1999 Mercury Cougar	5	5	2	4
37	Nikon Pronea S	3	5	2	5
38	Panasonic DVD-L10 Palm Theater	3	4	3	4

39	Thomson's 55-inch P5500	2	3	4	4
40	1999 Porsche 911	5	5	2	4
41	Nikon Coolpix 900	2	3	4	5
42	Philips IS-2630	2	4	3	3
43	Compaq Presario 5600 Series	6	5	2	6
44	Volvo S80	5	5	2	5
45	Iomega Clik disk	5	3	4	5
46	Diamond Multimedia Rio PMP300	2	3	4	5
47	Makita 14.4 volt Cordless Drill	6	4	3	6
48	A.T. Cross Co. Crosspad	1	2	5	5
49	1999 Chevrolet Silverado	6	6	1	5
50	Ryobi Landscaper Series	3	3	4	5
51	Sony DCR-PC1	6	6	1	6
52	Clarion AutoPC	1	2	5	4
53	3Com Palm III	4	3	4	6
54	Advanced Energy Systems PV Panels	2	3	4	3
55	Globewave Com.plete PC Card	3	3	4	4
56	Kidde Safety Nighthawk	4	5	2	3
57	Fujichrome MS 100/1000	3	3	4	2
58	1999 Jeep Grand Cherokee	5	6	1	6
59	Pentax IQ Zoom 200	5	5	2	6
60	Rollerblade Coyote	1	5	2	6
61	Toshiba Portege 7000 Series	6	6	1	6
62	Canon EOS D2000	6	5	2	3
63	Daewoo Miracle Phone	3	1	6	2
64	1999 Saturn Coupe	3	5	2	4
65	Raytheon Premier I	4	4	3	4
66	Moen PureTouch	3	4	3	5
67	Sony Ruvi Camcorder	2	4	3	4
68	Pioneer HTV	3	3	4	4

		Respondent 2			
		Market Pull Score	Technology Push Response	<--(Inverted) Technology Push Score	Familiarity
1	Liquidmetal Golf Clubs	6	3	4	2
2	Panasonic KX-TGM240 GigaRange	5	5	2	6
3	Kodak DC260	4	3	4	5
4	Sony Vaio 505F	6	6	1	5
5	Copperhead ACX	5	3	4	5
6	1999 Oldsmobile Alero	5	6	1	5
7	Replay TV	3	5	2	5
8	Apple iMac	2	5	2	5
9	Olympus D-400	3	4	3	5
10	Iridium	4	5	2	4
11	Air Hog	2	4	3	4
12	1999 Honda Odyssey	3	6	1	6
13	Hobie Mirage	1	2	5	6
14	NuvoMedia Rocket ebook	2	3	4	5
15	Craftsmen Redi Drill	1	5	2	4
16	Canon EOS-3	2	5	2	4
17	Lego Mindstorms Robotic Invention Kit	1	4	3	4
18	1999 Lexus RX300	1	6	1	5
19	Canon ZR	3	6	1	5
20	PFG Industries EasyFloor	4	6	1	4
21	Yamaha's Silent Electric Violin	3	5	2	2
22	K2 ACX Smart Shocks	2	3	4	4
23	1998 Volkswagon New Beetle	1	6	1	5
24	Motorola V Series	5	6	1	5
25	Fuji Endeavor 3500ix Zoom MRC	2	6	1	5
26	Philips Audio CD-Recorder CDR765	5	6	1	5
27	IBM Aptiva SE7	2	6	1	5
28	Sony Mavica MVC-FD91	2	5	2	4
29	1999 BMW 3 Series	5	6	1	4
30	1999 Land Rover Discovery	5	4	3	4
31	Viking Clap Skate	5	5	2	1
32	Minolta Vectis Weathermatic Zoom APS	4	5	2	3
33	Garmin NavTalk	3	5	2	4
34	Minolta Vivid 700	2	5	2	1
35	1999 Cadillac DeVille Massage Seat	5	6	1	6
36	1999 Mercury Cougar	5	6	1	4
37	Nikon Pronea S	5	6	1	5
38	Panasonic DVD-L10 Palm Theater	5	5	2	5
39	Thomson's 55-inch P5500	2	5	2	5
40	1999 Porsche 911	4	6	1	5

41	Nikon Coolpix 900	1	6	1	5
42	Philips IS-2630	4	4	3	5
43	Compaq Presario 5600 Series	6	6	1	5
44	Volvo S80	6	6	1	4
45	Iomega Clik disk	3	4	3	4
46	Diamond Multimedia Rio PMP300	2	5	2	4
47	Makita 14.4 volt Cordless Drill	5	5	2	5
48	A.T. Cross Co. Crosspad	3	3	4	4
49	1999 Chevrolet Silverado	5	6	1	4
50	Ryobi Landscaper Series	1	5	2	3
51	Sony DCR-PC1	4	6	1	5
52	Clarion AutoPC	3	5	2	4
53	3Com Palm III	5	6	1	5
54	Advanced Energy Systems PV Panels	1	4	3	1
55	Globewave Com.plete PC Card	2	5	2	4
56	Kidde Safety Nighthawk	3	6	1	5
57	Fujichrome MS 100/1000	3	5	2	3
58	1999 Jeep Grand Cherokee	4	6	1	5
59	Pentax IQ Zoom 200	4	6	1	5
60	Rollerblade Coyote	2	3	4	5
61	Toshiba Portege 7000 Series	6	6	1	4
62	Canon EOS D2000	5	5	2	2
63	Daewoo Miracle Phone	2	4	3	1
64	1999 Saturn Coupe	6	4	3	4
65	Raytheon Premier I	6	5	2	1
66	Moen PureTouch	6	6	1	3
67	Sony Ruvi Camcorder	5	3	4	2
68	Pioneer HTV	5	5	2	2

		Respondent 3			
		Market Pull Score	Technology Push Response	<--(Inverted) Technology Push Score	Familiarity
1	Liquidmetal Golf Clubs	4	3	4	3
2	Panasonic KX-TGM240 GigaRange	3	4	3	3
3	Kodak DC260	4	5	2	4
4	Sony Vaio 505F	5	6	1	6
5	Copperhead ACX	4	4	3	4
6	1999 Oldsmobile Alero	4	3	4	3
7	Replay TV	6	6	1	5
8	Apple iMac	5	4	3	5
9	Olympus D-400	6	6	1	5
10	Iridium	6	5	2	4
11	Air Hog	4	4	3	2
12	1999 Honda Odyssey	4	5	2	4
13	Hobie Mirage	4	4	3	3
14	NuvoMedia Rocket ebook	6	5	2	4
15	Craftsmen Redi Drill	5	4	3	4
16	Canon EOS-3	5	5	2	4
17	Lego Mindstorms Robotic Invention Kit	4	3	4	3
18	1999 Lexus RX300	4	4	3	4
19	Canon ZR	4	5	2	4
20	PFG Industries EasyFloor	4	4	3	4
21	Yamaha's Silent Electric Violin	4	3	4	3
22	K2 ACX Smart Shocks	3	3	4	3
23	1998 Volkswagon New Beetle	4	4	3	3
24	Motorola V Series	3	4	3	4
25	Fuji Endeavor 3500ix Zoom MRC	4	4	3	5
26	Philips Audio CD-Recorder CDR765	5	5	2	5
27	IBM Aptiva SE7	5	5	2	5
28	Sony Mavica MVC-FD91	4	5	2	4
29	1999 BMW 3 Series	4	4	3	3
30	1999 Land Rover Discovery	5	4	3	4
31	Viking Clap Skate	4	4	3	3
32	Minolta Vectis Weathermatic Zoom APS	4	4	3	3
33	Garmin NavTalk	4	4	3	4
34	Minolta Vivid 700	5	4	3	4
35	1999 Cadillac DeVille Massage Seat	4	4	3	3
36	1999 Mercury Cougar	3	3	4	3
37	Nikon Pronea S	4	4	3	4
38	Panasonic DVD-L10 Palm Theater	5	5	2	5
39	Thomson's 55-inch P5500	4	4	3	3
40	1999 Porsche 911	3	4	3	3

41	Nikon Coolpix 900	4	4	3	4
42	Philips IS-2630	5	5	2	4
43	Compaq Presario 5600 Series	5	5	2	5
44	Volvo S80	4	4	3	4
45	Iomega Clik disk	5	5	2	5
46	Diamond Multimedia Rio PMP300	5	5	2	5
47	Makita 14.4 volt Cordless Drill	4	4	3	3
48	A.T. Cross Co. Crosspad	5	4	3	3
49	1999 Chevrolet Silverado	4	4	3	3
50	Ryobi Landscaper Series	3	3	4	2
51	Sony DCR-PC1	4	4	3	4
52	Clarion AutoPC	4	3	4	3
53	3Com Palm III	4	4	3	4
54	Advanced Energy Systems PV Panels	5	4	3	3
55	Globewave Com.plete PC Card	4	3	4	2
56	Kidde Safety Nighthawk	5	4	3	3
57	Fujichrome MS 100/1000	5	3	4	4
58	1999 Jeep Grand Cherokee	4	4	3	4
59	Pentax IQ Zoom 200	3	5	2	3
60	Rollerblade Coyote	3	3	4	3
61	Toshiba Portege 7000 Series	5	4	3	5
62	Canon EOS D2000	4	4	3	4
63	Daewoo Miracle Phone	4	3	4	2
64	1999 Saturn Coupe	5	4	3	3
65	Raytheon Premier I	3	2	5	1
66	Moen PureTouch	5	4	3	3
67	Sony Ruvi Camcorder	4	4	3	3
68	Pioneer HTV	4	3	4	3

		Respondent 4			
		Market Pull Score	Technology Push Response	<--(Inverted) Technology Push Score	Familiarity
1	Liquidmetal Golf Clubs	5	4	3	4
2	Panasonic KX-TGM240 GigaRange	1	4	3	4
3	Kodak DC260	6	5	2	4
4	Sony Vaio 505F	4	6	1	5
5	Copperhead ACX	4	1	6	2
6	1999 Oldsmobile Alero	4	3	4	5
7	Replay TV	5	6	1	5
8	Apple iMac	5	5	2	6
9	Olympus D-400	2	5	2	4
10	Iridium	3	4	3	3
11	Air Hog	3	4	3	4
12	1999 Honda Odyssey	4	5	2	5
13	Hobie Mirage	1	3	4	4
14	NuvoMedia Rocket ebook	3	5	2	4
15	Craftsmen Redi Drill	3	5	2	5
16	Canon EOS-3	4	4	3	4
17	Lego Mindstorms Robotic Invention Kit	3	5	2	4
18	1999 Lexus RX300	4	4	3	5
19	Canon ZR	4	5	2	4
20	PFG Industries EasyFloor	4	4	3	3
21	Yamaha's Silent Electric Violin	3	5	2	5
22	K2 ACX Smart Shocks	4	3	4	5
23	1998 Volkswagon New Beetle	4	5	2	5
24	Motorola V Series	2	4	3	5
25	Fuji Endeavor 3500ix Zoom MRC	3	5	2	5
26	Philips Audio CD-Recorder CDR765	2	5	2	5
27	IBM Aptiva SE7	4	5	2	6
28	Sony Mavica MVC-FD91	4	4	3	4
29	1999 BMW 3 Series	2	5	2	5
30	1999 Land Rover Discovery	4	4	3	5
31	Viking Clap Skate	4	4	3	2
32	Minolta Vectis Weathermatic Zoom APS	2	5	2	5
33	Garmin NavTalk	3	5	2	5
34	Minolta Vivid 700	3	3	4	4
35	1999 Cadillac DeVille Massage Seat	3	4	3	5
36	1999 Mercury Cougar	3	4	3	5
37	Nikon Pronea S	4	5	2	5
38	Panasonic DVD-L10 Palm Theater	5	5	2	6
39	Thomson's 55-inch P5500	4	2	5	6
40	1999 Porsche 911	5	5	2	6

41	Nikon Coolpix 900	4	5	2	5
42	Philips IS-2630	2	5	2	6
43	Compaq Presario 5600 Series	5	5	2	6
44	Volvo S80	4	5	2	6
45	Iomega Clik disk	3	5	2	6
46	Diamond Multimedia Rio PMP300	5	5	2	6
47	Makita 14.4 volt Cordless Drill	6	4	3	6
48	A.T. Cross Co. Crosspad	4	2	5	6
49	1999 Chevrolet Silverado	4	4	3	6
50	Ryobi Landscaper Series	5	4	3	5
51	Sony DCR-PC1	5	5	2	6
52	Clarion AutoPC	3	4	3	6
53	3Com Palm III	5	5	2	6
54	Advanced Energy Systems PV Panels	4	3	4	4
55	Globewave Com.plete PC Card	2	4	3	5
56	Kidde Safety Nighthawk	5	4	3	4
57	Fujichrome MS 100/1000	4	4	3	3
58	1999 Jeep Grand Cherokee	4	4	3	6
59	Pentax IQ Zoom 200	5	4	3	5
60	Rollerblade Coyote	3	3	4	5
61	Toshiba Portege 7000 Series	5	5	2	6
62	Canon EOS D2000	5	4	3	5
63	Daewoo Miracle Phone	3	3	4	2
64	1999 Saturn Coupe	2	4	3	6
65	Raytheon Premier I	5	4	3	4
66	Moen PureTouch	3	4	3	5
67	Sony Ruvi Camcorder	4	4	3	5
68	Pioneer HTV	4	4	3	6

APPENDIX D – PRODUCT SUCCESS CATEGORY

	Product	Success Category
1	Liquidmetal Golf Clubs	Failed
2	Panasonic KX-TGM240 GigaRange	Leader
3	Kodak DC260	Leader
4	Sony Vaio 505F	Leader
5	Copperhead ACX	Failed
6	1999 Oldsmobile Alero	Common
7	Replay TV	Niche
8	Apple iMac	Common
9	Olympus D-400	Leader
10	Iridium	Failed
11	Air Hog	Common
12	1999 Honda Odyssey	Leader
13	Hobie Mirage	Common
14	NuvoMedia Rocket ebook	Failed
15	Craftsmen Redi Drill	Failed
16	Canon EOS-3	Leader
17	Lego Mindstorms Robotic Invention Kit	Niche
18	1999 Lexus RX300	Common
19	Canon ZR	Leader
20	PFG Industries EasyFloor	Niche
21	Yamaha's Silent Electric Violin	Niche
22	K2 ACX Smart Shocks	Failed
23	1998 Volkswagon New Beetle	Leader
24	Motorola V Series	Leader
25	Fuji Endeavor 3500ix Zoom MRC	Niche
26	Philips Audio CD-Recorder CDR765	Failed
27	IBM Aptiva SE7	Common
28	Sony Mavica MVC-FD91	Common
29	1999 BMW 3 Series	Common

30	1999 Land Rover Discovery	Common
31	Viking Clap Skate	Leader
32	Minolta Vectis Weathermatic Zoom APS	Niche
33	Garmin NavTalk	Niche
34	Minolta Vivid 700	Niche
35	1999 Cadillac DeVille Massage Seat	Niche
36	1999 Mercury Cougar	Failed
37	Nikon Pronea S	Failed
38	Panasonic DVD-L10 Palm Theater	Niche
39	Thomson's 55-inch P5500	Niche
40	1999 Porsche 911	Common
41	Nikon Coolpix 900	Common
42	Philips IS-2630	Failed
43	Compaq Presario 5600 Series	Leader
44	Volvo S80	Common
45	Iomega Clik disk	Failed
46	Diamond Multimedia Rio PMP300	Niche
47	Makita 14.4 volt Cordless Drill	Leader
48	A.T. Cross Co. Crosspad	Failed
49	1999 Chevrolet Silverado	Common
50	Ryobi Landscaper Series	Niche
51	Sony DCR-PC1	Leader
52	Clarion AutoPC	Failed
53	3Com Palm III	Leader
54	Advanced Energy Systems PV Panels	Failed
55	Globewave Com.plete PC Card	Failed
56	Kidde Safety Nighthawk	Common
57	Fujichrome MS 100/1000	Failed
58	1999 Jeep Grand Cherokee	Leader
59	Pentax IQ Zoom 200	Common
60	Rollerblade Coyote	Failed
61	Toshiba Portege 7000 Series	Leader
62	Canon EOS D2000	Leader
63	Daewoo Miracle Phone	Niche
64	1999 Saturn Coupe	Niche
65	Raytheon Premier I	Niche
66	Moen PureTouch	Niche
67	Sony Ruvi Camcorder	Failed
68	Pioneer HTV	Common