An Integrated Framework for Measuring Product Development Performance in High Technology Industries.

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ABSTRACT

One of the major challenges in managing new product development is the difficulty in measuring product development performance. "Although new product development projects are inherently multidisciplinary, studies of development projects typically adopt a singular functional perspective of performance. Inherent functional differences contribute to a natural tendency toward myopic evaluation of development efforts. The result is a uni-dimensional and incomplete view of the innovation process and outcomes (Tatikonda and Montoya-Weiss 2001)." We present an integrated framework for measuring product development performance. The framework emphasizes the need for recognition of the relationships between metrics used by design, manufacturing, and marketing functions, and proposes a three-stage model for exploring the relationships among various performance metrics used by different functions involved in a product development project and their relationship to business success. Using a database of 38 product development projects in the high tech electronics manufacturing sector, we attempt to validate the proposed framework empirically and identify directions for further research.

KEYWORD: High Tech Manufacturing, New Product Development Performance, New Product Development, Technology Management.

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1. Introduction

New product development is a strategic business activity by intention or by default (Whitney 1988). It is not only the critical linkage between a business organization and its market, but it is also fundamental to business success. Business organizations need to manage their product development activities strategically to gain competitive advantage in the market place. Firms that fail to manage their product development activities strategically are not only running their business from a position of disadvantage but also risking their future (Fitsimmons, Kouvelis and Mallick 1991).

The critical role of product development in the survival and success of business organizations and the need for managing it strategically is being recognized increasingly in both the academic (Finger and Dixon 1989a, 1989b, Brown and Eisenhardt 1995, Griffin and Hauser 1996, Krishnan & Ulrich 2001) and practitioner (Gates 1999, Chesbrough and Teece 2002, Welch and Kerwin 2003) literature. However, management of new product development remains a major challenge. One of the challenges in managing new product development results from the difficulty in measuring product development performance (Foster, Linden, Whitley and Kantro 1985a & 1985b, Clark & Fujimoto 1991, Griffin & Page 1993 & 1996, Hultink & Robben 1995, Meyer, Tertzakian & Utterback 1997, Hauser 1996, 1998a, 1998b, Tatikonda and Montoya-Weiss 2001).

A major problem in measuring product development performance arises because of the multidimensionality of product development outcomes (Craig and Hart 1993). Often it is not very clear if a single metric is adequate for measuring product development performance or multiple metrics are necessary. Moreover, if a decision is made to use a single metric it is not clear which one of the several available metrics should be used. A meta-analysis of determinants of new product development (Montoya-Weiss and Calantone 1994) identified 47 published research works that have used a single measure of success or failure for product development performance. They found the way success and failure was defined varied widely across these studies.

The problem becomes significantly more complex if we decide to use multiple measures of performance. Now, instead of selecting a single measure from a set of available measures we are confronted with selecting a subset from a given set of available measures. A study of extant literature (Griffin and Page 1993) identified 75 distinct measures used by academics and the business community. However, the study failed to find any consensus on the usefulness of these measures. This not only raises questions of how we should be selecting an appropriate subset of metrics that is useful, but also how these various measures are related to each other. In a subsequent study the authors attempted to address these questions by identifying 16 metrics and categorized them into five categories (Griffin and Page 1996). However, the question remains as to how these various measures are related to each other and to the business success? Can success in any one of these dimensions only be achieved through sacrifice of success in other dimensions? Or, does success in any one of these dimensions lead to improvement in other dimensions?

The problem of measuring product development performance is exacerbated due to the fact that a product development project is often a part of a product development program and its performance can be measured at the individual project level as well as at the project portfolio level. Since projects within a portfolio may have different objectives the performance metrics used for measuring these projects are different and can be in conflict with each other. High performance at the project level may not always lead to high performance at the portfolio level. This is because all product development projects within a product development program may not have the same objectives. The objectives may be different and can be in conflict with each other. The typical product development pipeline of a firm consists of different projects at different stages of their life cycles. Some of these projects are intended for building market share, others for revenue generation and still others for market maintenance. This leads to difficulty in measuring disparate projects with common measures. It is proposed that product development projects should be measured based on the business strategy. However, such a prescription requires that a relationship be specified between the product development strategy and recommended measures. Griffin and Page (1996) used a simulation model to develop such a specification. However, it is not clear if such an approach will lead to business success and no empirical support was provided.

In addition we must also address the time frame of the measurement problems Zaheer, Albert, and Zaheer 1999). Metrics that are suitable for measuring short-term performance may not be suitable for measuring long-term performance. Thus, we need to delineate the metrics that are appropriate for short-term performance measure from those for long-term performance. Also it is necessary that the short-term metrics that we use are aligned with the long-term performance that we desire. Failure to recognize this relationship can lead to short-term gain at the expense of the long-term objectives of the firm (Hays & Abernathy 1980). A recent study of 197 large Dutch companies has confirmed that all measures are not equally suitable for measuring both long-term and short-term performance (Hultink and Robben 1995). The authors emphasized the importance of time perspective in the measurement problem. However, they failed to address how short-term measures are related to longer-term measures.

Any one or a combination of the above factors often leads to difficulty in measuring product development performance. However, the need for measuring new product development performance remains. Managers need to identify sources of their problems and to determine reasons for their success to focus their effort on activities that not only lead to product development success but also result in efficient and effective use of expensive product development resources. Similarly, the academic community has the need to produce research findings that can be generalized. "Although new product development projects are inherently multidisciplinary, studies of development projects typically adopt a singular functional perspective of performance. Inherent functional differences contribute to a natural tendency toward myopic evaluation of development efforts. The result is a uni-dimensional and incomplete view of the innovation process and outcomes. A more robust model of the innovation process would include a broader range of criteria that plays interrelated roles in determining product profitability, marketability, product quality, and timeliness. This suggests the need for an integrated, or cross-functional, perspective of the drivers of product development performance (Tatikonda and Montoya-Weiss 2001)." In an extensive review of the new product development literature Brown & Eisenhardt (1995) emphasized the need for understanding the relationship between various metrics used for measuring product development performance. The problem of measuring product development performance is also identified as an important area of research in a recent survey of the new product development literature (Krishnan and Ulrich 2001).

In this paper we attempt to address this void by developing an integrated framework for measuring product development performance. We identify a set of metrics widely used in the product development literature by the engineering (Finger and Dixon 1989a and 1989b), manufacturing (Krishnan and Ulrich 2001), and marketing (Griffin and Hauser 1996) functions and combine them into an integrated framework. We argue that these metrics should not be used independently and provide a three-stage model for exploring their relationships. Using a survey of 38 new product development projects in the high tech electronics manufacturing sector, we attempt to validate the proposed framework and demonstrate how the proposed framework can help us gain a better insight into the relationships between various performance metrics and business success, particularly for high tech electronics manufacturing.

This paper is organized into six sections. In section 2, we present the arguments for the proposed framework and develop the conceptual model. In section 3, we describe the data collection and sampling methodologies used for testing the framework. In section 4, we present our findings and an analysis of our findings. In section 5 we discuss our findings within the context of the high tech electronics sectors. In section 6, we summarize the contributions of this research, discuss the limitations of our study and identify directions for future research.

2. Theoretical Model & Propositions

Business organizations exist to create value for their stakeholders. Metrics used for measuring performance is a critical linkage between actions and outcomes (Hauser and Katz 1998). Since product development is one of the critical processes through which business organizations create value for their customers and capture value for their shareholders, we argue that any metric used for measuring product development performance must be in alignment with this objective of value creation. Further, we posit that product performance and unit cost are the two significant drivers of customer value. Thus, we propose to specify product development performance as a function of the performance and the unit cost of the product. We then evaluate the effect of research and development (R&D) expenditure and product development time on product performance and unit cost, which in turn affects the market share and profitability of a firm. Our arguments for the proposed conceptual model hypothesizing the relationships between

R&D expenditure, product development time, product performance, unit cost, market share and profitability of a firm will follow.

Competitive advantage is created through offering products that provide value to customers that is superior to their competitors. Firms compete with one another to capture market segments by offering attractive products and services that enhance customer value. According to Zeithaml (1988), the value of a product or service as perceived by the customer is closely related to customer purchase decisions and this perceived value is the customers' overall assessment of the utility of a product based on perceptions of what is received and what is given. Customer value for a product is the "customers' perception of what they want to have happen in a specific use situation, with the help of a product or service offering, in order to accomplish a desired purpose or goal." Customer's value depends on the product performance (how well the product meets the customers' expectations) and the product price (what the customer pays for the product offering). Thus for successful performance, the goal of the new product development function of a firm is to enhance customer value by increasing the product performance and decreasing the product price and its value can be assessed along these two dimensions. Zirger and Maidique (1990) examined 330 new products in the electronics industry and showed that product performance and its value to customers significantly affected product profitability. Thus in this research, we measure product development performance along these two dimensions -- product performance and product price.

Products are designed to help customers meet their needs. Product performance measures the effectiveness of a product's ability to perform its primary function. It tells us how well a specific product is able to deliver what it is supposed to do. Product development is a deliberate business process involving scores of generic decisions including – concept development, supply-chain design, product design and production ramp-up and launch (Krishnan and Ulrich 2001). These decisions are vital for successful product performance and require a thorough analysis and research of the pros and cons of the possible ramifications. A considerable amount of resources in the form of R&D expenditure are required in each of these decision categories to meticulously design and develop a product and to identify and eliminate potential technical problems that might arise in the future stages. Thus more R&D resource employed increases the possibility of solving a technical problem earlier. It also increases the possibility of arriving at a better design solution. But, increased R&D resource consumption also causes an increase in the overall costs, which causes the product cost to increase. Since the price that a firm charges in the market is bounded below by the cost, increased product cost often results in an increased product price.

Proposition 1a: Product performance is positively related to research and development expenditure.

Proposition 1b: Unit cost is positively related to research and development expenditure.

Time as a metric for measuring product development performance has gained significant popularity in the academic and practitioner literature (Clark and Fujimoto 1989, Adler, Vien Nguyen and Schwerer 1995, Eisenhardt and Tabrizi 1995, Reinertsen and Smith 1991, Hartley, Meredith, McCutcheon and Kamath 1997, Griffin 1997, Swink 1999). The use of time as a metric for measuring new product development has appeared as speed-to-market (Tatikonda and Rosenthal 2000), launched on time, and concept-to-market in the new product development literature (Griffin & Page 1993 and 1996). Importance of time as a source of competitive advantage is recognized in the business strategy literature as *time-based competition* (Stalk 1988). U.S. industry is increasingly looking at accelerated new product development (APD) as a new source of competitive advantage (Crawford 1992). In a survey of 120 R&D directors from technology-based companies, 79% indicated high importance to APD (Gupta and Wilmon 1996) and a study by the consulting firm McKinsy Inc. reports a loss of 33% of after-tax profit when products are six months late as against a loss of 3.5% from overspending up to 50% on product development is often cited as a supporting argument for shortening product development time (Reinertsen 1983, Dumaine 1989, Smith 1988).

However, time can also be viewed as a resource. It is a critical input to the new product development process. For a given level of product development resource, the longer the time available to study the user needs, develop and test alternative concepts for technical feasibility the greater is the likelihood that a better solution will be found. This will also lead to consumption of product development resources over a longer period of time leading to an increase in the cost allocated to the final product. However, any attempt to reduce product development cost through increased pressure on speed may have many costly side effects such as increased focus on incremental innovation and mistakes during the product development process all of which lead to products with poor technical performance (Crawford 1992). We therefore summarize our arguments in the following two propositions.

Proposition 2a: Product performance is positively related to product development time.

Proposition 2b: Unit cost is positively related to product development time.

New products are designed to solve a customer need. Thus success of new product development must be measured by how well the product is being accepted by the customers. There are several measures of customer acceptance in the new product development literature such as customer acceptance, customer satisfaction, attainment of revenue goals, revenue growth, attainment of market share goals and unit sales goals (Griffin and Page 1993). We use market share to measure the level of customer acceptance of a new product. This is because market share is one of the widely used measures of new product performance in the literature (Griffin and Page 1993 & 1996) and the search for new markets (Gupta and Wilmon 1996) along with strengthening existing markets is one of the primary motivations for new product development. The competitive position of a firm is determined by its market power as defined by the share of the market it commands. Higher market share enables firms to charge higher prices, achieve economies of scale, erect entry barriers through advertising, distribution and shelf space, and reduce competitive activity, resulting in higher profitability (Buzzell, Gale and Sultan 1975, Porter 1980, Kekre and Srinivasan 1990). Thus, market share is a measure of competitive strength and depends on how effectively the firm is able to transform a market opportunity into a saleable product. The success of a product or service in the market depends on the customer value for the product, which is contingent upon the extent to which it meets the customer expectations within their purchasing power.

Spreng et al.(1996) suggest that the customer evaluation of product performance contributes to their evaluations of satisfaction. Cooper and Kleinschmidt (1987) showed product superiority in terms of product performance, features and innovativeness to be key factors in differentiating new product winners from losers. However, high performance alone cannot guarantee that customers will purchase a product especially when it is priced high (Zeithaml 1988). Thus, it is our position that increased product performance and decreased price contributes to higher customer value and satisfaction. Since, the firm's ability to offer a lower price is limited by the unit cost, we summarize our arguments with the following two propositions.

Proposition 3a: Higher product performance is related to higher market share.

Proposition 3b: Unit cost is negatively related to market share.

New product development is the life-blood of a firm. The financial success of the new product development projects is critical for ensuring the viability of a firm. Several financial measures are used in the product development literature such as break-even time, attainment of margin goals, attainment of profitability goals, internal rate of return (IRR) and return on investment (ROI). We choose to use ROI as the metric for measuring financial success because of its widespread use in the new product development literature and furthermore a new product development project must be able to provide an adequate return on the investment to remain profitable. Return on investment, as the term is defined is a ratio of two components: return in the numerator and investment in the denominator. Increase in return on investment of a firm can be realized from either increased revenues or decreased costs or both. The return that is earned on a new product development project is a function of the price per unit and the market share. As we have argued before, we posit that the higher the performance of a product the higher the market share it will be able to capture leading to higher return for a given level of investment. Similarly, a reduction in investment in product development and manufacturing will be evidenced in lower unit cost and a higher level of return on investment. Thus, higher product performance and lower product cost contribute to higher return on investment.

Proposition 4a: Product performance is positively related to return on investment.

Proposition 4b: Unit cost is negatively related to return on investment.

Business organizations must not only create value for their customers through new product design but must also be able to capture a part of that value for their shareholders. As mentioned before, a higher market share enables firms to charge higher prices, achieve economies of scale, erect entry barriers through advertising, distribution and shelf space, and reduce competitive activity, resulting in higher profitability (Buzzell, Gale and Sultan 1975, Porter 1980, Kekre and Srinivasan 1990) and thus the market share is a measure of its competitive strength. However, the relationship between market share and profitability is often in question (Cook 1985, Acker and Dey 1986, Jacobson 1988, Jacobson and Acker 1985) and it is possible that a product that captures high market share could still be unprofitable. Thus, there is a need for a measure of commercial performance, which not only includes the market-based measure of performance but also the financial performance. A survey of the Product Development Management Association members found that "a vast majority (86%) of firms who already measure success and failure focus on obtaining a picture of the balanced end results of individual products. They measure whether the customer's needs have been met while simultaneously producing financial results for the firm (Gupta and Wilmon 1996)." We use market share to measure customer acceptance and return on investment (ROI) to measure profitability and combine these two measures into a measure of overall business or commercial performance (Montoya-Weiss and Calantone 1994). Here market share is a measure of effectiveness of a product development project in gaining customer acceptance and return on investment is a measure of the efficiency of a product development project in recovering its investment. Thus, they are both positively related to the overall business performance. We summarize our discussions in to the following two propositions.

Proposition 5a: Market share is positively related to the overall business success.

Proposition 5b: The return on investment is positively related to the overall business success.

We present a three-stage framework summarizing the proposed relationships in propositions (1) – (5) in Figure 1. In the first stage, the framework focuses on R&D expenditures and product development times. These two metrics are used to measure two important inputs to the product development process (e.g., money and time) and are linked to the budget and schedule of a product development project. The second stage of the framework focuses on the value created by the product development project. It uses product performance and unit cost objectives to define value from the customers' perspective and provides a linkage between the internal measures used in the first stage and the external measures used in the last stage. The last stage of the framework focuses on the business performance. Two metrics are used to measure the attainment of the market share objectives and return on investment objectives and are linked to the effectiveness and efficiency of a product development project. Thus, we have an integrated framework that not only captures the functional perspective of research and development (Finger and Dixon 1989a and 1989b), manufacturing (Krishnan and Ulrich 2001), marketing and finance (Griffin and Hauser 1996) but also shows how these various metrics used by different functions are related over time (Zaheer, Albert and Zaheer 1999) and functional space (Fitzsimmons, Kouvelis and Mallick 1991).

3. Methodology

We use a questionnaire based mailed survey methodology to validate the proposed framework (Patten 2001). The need for theory development and testing using empirical methodology in the operations management area is well recognized (Adam & Swamidass 1989) and the value of empirical research is being increasingly recognized in the operations management literature. Data for this analysis is obtained using a survey instrument developed for a larger study to explore the relationship of quality and product development speed. Through a series of case studies (Flynn, Flynn, Amundson, and Schroeder 1999) and an extensive review of the new product development literature, a list of questionnaire items related to product development quality and product development speed was compiled along with new product development success measures. In order to capture a multifunctional perspective, these questions were grouped into three questionnaires one targeted to the project sponsor, one targeted to the team leader, and one targeted to the members of the project team. The unit of analysis for this survey was a project. Thirty-eight new product development projects in five companies in the electronics industry were considered for this study. For each company, the research team solicited participation from the project managers. For each project, the project manager distributed the questionnaires to the multiple members of the project team. A total of 456 questionnaires were distributed to various members from each of the project teams, which included the project sponsor, the team leader, up to five team members, as well as various levels of management and product development support, quality managers and procurement managers who responded to this survey. The numbers of completed questionnaires collected and returned were 383 leading to a response rate of 84%.

For each project, the respondents were asked to answer a wide range of questions related to product development practice and performance. The part of the questionnaire and the items that we use for this study is presented in Appendix 1.

Each respondent was asked to evaluate the performance of the project under study along the seven dimensions: (1) Project R&D budget (OUTRAND), (2) Time-to-market (OUTTIME), (3) Technical performance to specifications (OUTPERF), (4) Unit cost of the product (OUTCOST), (5) Market share objective (OUTMARK), (6) Return on investment (OUTROI), and (7) Overall commercial success (OUTSUCC). Respondents indicated their response using a seven-point scale (1=Significantly worse than expected, 2= Worse than expected, 3=A little worse than expected, 4=On target, 5=A little better than expected, 6=Better than expected, 7=Significantly better than expected). "Similar subjective scales have been used extensively in both the management and marketing literature and have been shown to be highly correlated with objective measures of financial performance (Xi, Song and Stringfellow 1998)."

Perceptual measures were used in this study since a large number of different projects where surveyed. While the products were all developed in the High tech electronics industry, the products differed in their intended purpose, features, physical size, unit cost, and other characteristics. As a result, it was thought that the best common measure of performance across all projects was their achievement of success relative to the target or goals set for that project. This approach will permit us to combine data from 38 disparate projects. Measuring performance relative to target is a common approach used in past studies (Griffin and Page 1996).

For each project, the total number of individual respondents for each question in the survey ranged from two to seven. Individual responses were summed and divided by the number of responses to arrive at an average response for each project. The use of multiple respondents increases the reliability of the measures used thereby increasing confidence in these measures.

4. Results

The summary descriptive statistics from our findings are presented in Tables 1 and 2. Pearson Correlations indicating relationships between the variables are provided. While some correlations are not statistically significant, all correlations are in congruence with the proposed framework. Nevertheless, correlations are not adequate in testing our framework because we have proposed both direct and indirect paths in Figure 1. Therefore, we use path analysis to test the proposed framework.

** Insert Table 1 and 2 here**

Due to the small size of the sample, we use a set of linear regression equations to test the proposed paths in the framework instead of a comprehensive structural equation model. The following five linear equations are used to represent the relationships between the various performance metrics as hypothesized by the proposed framework.

$$OUTPERF = a_1 + b_1*OUTRAND + c_1*OUTTIME \quad (1)$$

$$OUTCOST = a_2 + b_2*OUTRAND + c_2*OUTTIME \quad (2)$$

$$OUTMARK = a_3 + b_3*OUTPERF + c_3*OUTCOST \quad (3)$$

$$OUTROI = a_4 + b_4*OUTPERF + c_4*OUTCOST \quad (4)$$

$$OUT\ SUCC = a_5 + b_5*OUTMARK + c_5*OUTROI \quad (5)$$

Each of the five relationships in the framework was tested independently using the linear regression model of the SAS (Statistical Analysis System, Version 8) package. The main results of the analysis are presented in Table 3. A visual representation of the results from the above path model is presented in Figure 2.

** Insert Table 3 here **

First, we examine the regression equation (1) to test proposition 1a and 2a. To support proposition 1a, we must find a positive relationship between R&D expenditure (OUTRANDD) and product performance (OUTPERF). However, because of the way we ask our questions in Table 1, a negative relationship is required to support proposition 1a. But we failed to find a statistically significant relationship ($p = 0.9182$) as proposed.

Thus, proposition 1a is not supported. Similarly, a negative relationship between the product development time (OUTTIME) and product performance (OUTPERF) is required to support proposition 2a. We also did not find the negative relationship to be statistically significant as proposed (p=0.3319). The lack of statistical support for propositions 1a and 2a is explained by the statistical insignificance (p=0.5650) of the regression model represented by equation (1).

Second, we examine the regression equation (2) to test propositions 1b and 2b. We find that the regression equation (2) is statistically significant (p=0.0073) and 24% of variation in the product cost (OUTCOST) is explained by the research and development expenditure (OUTRAND) and product development time (OUTTIME). The relationship between research and development expenditure (OUTRAND) and product cost (OUTCOST) is positive as hypothesized, but not statistically significant (p=0.2194). The relationship between product development time (OUTTIME) and product cost (OUTCOST) is positive as hypothesized and it is statistically significant (p=0.0426). Thus, proposition 1b is not supported but proposition 2b is supported by the results.

Third, we examine the regression equation (3) to test propositions 3a and 3b. We find that the regression equation (3) is statistically significant (p=0.0304) and 18% of variation in the market share performance (OUTMARK) is explained by product performance (OUTPERF) and product cost (OUTCOST). However, we failed to find a positive relationship between product performance (OUTPERF) and market share (OUTMARK) as hypothesized. Also the relationship is not statistically significant (p=0.2890). The relationship between product cost (OUTCOST) and market share (OUTMARK) is positive as hypothesized and is statistically significant (p=0.0087). Thus, proposition 3a is not supported but proposition 3b is supported.

Next, we examine the regression equation (4) to test propositions 4a and 4b. We find that the regression equation (4) is statistically significant (p=0.0019) and 28% of variation in the profitability performance (OUTROI) is explained by product performance (OUTPERF) and product cost (OUTCOST). We did not find a statistically significant relationship between product performance (OUTPERF) and profitability (OUTROI) as hypothesized (p=0.9630). The relationship between product cost (OUTCOST) and profitability (OUTROI) is positive as hypothesized and is statistically significant (p=0.0019). Thus, proposition 4a is not supported but proposition 4b is supported by the results.

Finally, we examine the regression equation (5) to test propositions 5a and 5b. We find that the regression equation (5) is statistically significant (p=0.0001) and 57% of variation in the overall success (OUTSUCC) is explained by market share performance (OUTMARK) and profitability (OUTROI). We find a statistically significant positive relationship (p=0.0080) between market share (OUTMARK) and overall success (OUTSUCC) as hypothesized. The relationship between profitability (OUTROI) and overall success (OUTSUCC) is positive as hypothesized, but not statistically significant. (p=0.1336). Thus, proposition 3a is supported but proposition 5b is not supported by the results.

In summary, we had statistical support for four of the five regression equations used to model the proposed framework. These are equations (2), (3), (4), (5). We also found statistical support for propositions 2b, 3b, 4b and 5a. But we failed to find any statistically significant support for the remaining propositions. We will discuss our findings in the next section.

5. Discussion

Since our data is from electronics product development in a high tech industry, we interpret the findings relative to that industry. The industry effect on business performance is well recognized in the literature (Porter 1980). The velocity of change, defined recently as industry "clockspeed" in the external business environment sets the pace of business operations within an industry and it can be used to classify and analyze an industry (Fine 1996). Firms operating in the electronics industry are faced with a high rate of change in technology and market conditions and accordingly can be classified as a "high-clockspeed" industry (Mendelson and Pillai 1999). It is well known that electronics are subject to short product life cycles and associated fast new product development (Eisenhardt and Tabrizi 1995, Fine 1998, Mendelson and Pillai 1999). We note that product development time is a significant variable in our analysis leading to low product development costs relative to target cost. Time compression is an industry specific effect for High tech electronics that might not apply to other more stable and less time sensitive industries.

We also found that product cost in the electronics industry was significantly related to high market share relative to its target. Low cost in the electronics industry is a attribute that can be used to "buy" market share, at least in the initial phase of new product introduction. As we see from our analysis, costs lower than target also serve to increase ROI above its target, more so than superior product performance.

We note there is a significant relationship between market share and business success. It has been shown that market share can lead to business success (Szymanski, Bharadwaj and Varadarajan 1993), especially, in the high-tech electronic sector where profit margins are always under pressure. Also, the significant relationship between cost and market share indicates the cost sensitive nature of this market. Thus, from our findings we can see that the speed of product development is very critical in this High-Tech sector because of its impact on unit cost and market share, which are in turn the primary determinants of market success and business success.

Our analysis has implications for managers for high tech companies in the electronics industry, in particular. To achieve business success and relatively high market share, they should stress low product cost and fast product development time. While we have been able to identify these variables as statistically significant drivers of market share and business success, we do not deny the importance of other variables that were not significant in our model. These non-significant variables could be significant in larger samples, with other measurement methods, or in other industries. The relevance of these variables to new product development remains to be determined in future studies.

Our findings have implications for academic research. We have shown that variables that were thought to be independent (Griffin and Page, 1996) are related in high tech electronics companies. This result probably differs from previous research because we gathered our data from only one industry and at the project level rather than the firm level. Future studies should address these cross-functional relationships in other situations to advance our theoretical understanding of the contingent relationships, such as industry, that might affect these relationships.

6. Conclusions

Product development is inherently a multifunctional endeavor. However, study of product development has evolved from different academic disciplines with different functional perspectives. One of the challenges in managing product design arises from this fragmented view of the product development process. The difference in functional perspectives leads to different emphases on different product development outcomes. An understanding of the relationships between various metrics used by different functional disciplines is essential for avoiding a dysfunctional approach to managing product design and ensuring commercial success of a product development project. In this paper we attempted to address this problem with an integrated framework for measuring product development performance. The framework consists of a three-stage model for product development performance. In the first stage, the model focuses on the research and development costs and development time. The second stage focuses on the product performance and unit cost. The third stage focuses on the market share and return on investments that is finally linked to the overall commercial success measure. The first stage of the model will help a manager focus on the budget and schedule of a new product development project. Thus, the focus of the first stage of the model is on the short term. As a new product approaches its market release, its value is determined by its performance and unit cost. The second stage of the model will force our attention to this direction. Finally, in the long run, a development project should be able to return value to the company through market and financial success. This is the focus of the third stage. Thus, the framework not only captures the multifunctional perspectives from research and development, manufacturing, marketing, and finance functions but also captures the difference in the time perspectives as we move from the first to the second and from the second to the third stage into an integrated model. This is the primary contribution of this paper.

We also attempted to validate the proposed framework empirically using data from 38 product development projects in the electronics industry. The findings provided evidence for the relationships proposed in the framework. Some of the relationships proposed were not statistically significant. Thus, we are able to present only partial empirical validation of the proposed framework. This does not invalidate the proposed model but may be due to the nature of the sample used from High tech electronics companies. A second limitation of this study arises due to its focus on a single industry. By focusing on a single industry, we were able to control for the industry effects, but this limits the extent to which the findings from this study can be generalized. A more extensive study covering a wider range of industries is necessary to develop this framework further.

References

Acker, David A. and George S Dey (1986). "The Perils of High-Growth Markets," Strategic Management Journal, 7 (September –October), 409-21.

Adler, P. S., A. M. Vien Nguyen and E. Schwerer (1995). "From Project to Process Management: An Empirically-based Framework for analyzing Product development time." Management Science 41(3): 458-484.

Buzzel, R. D., Bradley T. Gale and Ralph M. Sultan (1975). "Market Share - the key to Profitability," Harvard Business Review, Jan – Feb 1975.

Brown, Shona L. and Kathleen M. Eisenhardt (1995). "Product Development: Past Research, Present Findings and Future Directions," Academy of Management Review, 4, 2 April: 343-378.

Chesbrough, Henry W. and David J. Teece (2002). "Organizing for Innovation: When Is Virtual Virtuous?" Harvard Business Review, August 01, 2002:127-135

Cook, Victor J. Jr. (1985). "The Net Present Value of Market Share," Journal of Marketing, 49 (Summer) 49-63.

Cooper, R., E. Kleinschmidt (1987). "New Products: What separates winners from losers." Journal of Product Innovation Management, Vol. 4, No. 3: 169-184.

Clark, K. B., and T. Fujimoto (1991). Product Development Performance, Boston, MA: Harvard Business School Press.

Clark, K. B., and T. Fujimoto (1989). "Lead Time in Automobile Product Development: Explaining the Japanese Advantage," Journal of Engineering and Technology Management, No. 6: 25-58.

Craig, A. and S. Hart (1993), "Dimensions of success in new product development". In Perspectives on Marketing Management, Volume 3, Chapter 10, M. J. Baker (ed). London John M. Wiley & Sons. Ltd. :207-243.

Crawford, C. Merle (1992), "The Hidden Costs of Accelerated Product Development," Journal of Product Innovation Management," Vol. 9:188-199.

Dumaine, Brian (1989). "How Managers Succeed through speed," Fortune, February 13: 54-59 .

Eisenhardt, Kathleen M. and Benham N. Tabrizi (1995) "Acceletating Adaptive Process: Product Innovation in the Global Computer Industry," Administrative Science Quarterly, Vol. 40, Issue 1:84-110.

Fine, C. H. (1998). Clock Speed – Winning Industry Control in the Age of Temprorary Advantage, Perseus Books..

Finger, S. and J. R. Dixon (1989a). " A review of research in mechanical enginnering design, part I: Descriptive, prescriptive and computer–based models of design processes," Research Engineering Design, Vol 1, No. 1:51-68.

Finger, S. and J. R. Dixon (1989b). " A review of research in mechanical enginnering design, part II: Representations, Analysis, and Design for the life cycle," Research Engineering Design, Vol 1, No. 2:121-137.

Fitzsimmons, J. A., P. Kouvelis, and D. N. Mallick (1991), "Design Strategy and Its Interface with Manufacturing and Marketing Strategy: A Conceptual Framework," Journal of Operations Management, Vol. 10, No. 3:398-415.

Flynn, Barbara B., E. James Flynn, Susan D. Amundson and Roger G. Schroeder (1999). " Product Development Speed and Quality: A New Set of Synergies?" Stahl, M.J. (ed.), Perspectives in Total Quality, Oxford, U.K., Blackwell.

Foster, Richard N., Lawrence H. Linden, Roger L. Whiteley, and Alan M. Kantrow (1985a). "Improving the Return on R&D –I, Research Management, Volume XXVIII, No 1, January-February:12-17.

Foster, Richard N., Lawrence H. Linden, Roger L. Whiteley, and Alan M. Kantrow (1985b). "Improving the Return on R&D –II, Research Management, Volume XXVIII, No 1, March-April: 13-22.

Gates, William (1999). Business@the Speed of Sound, Warner Books 1999.

Griffin, A. (1993). "Metrics for Measuring Product Development Cycle Time." Journal of Product Innovation Management 10(Mar): 112-125.

Griffin, A. (1997). "The Effect of Project and Process Characteristics On Product Development Cycle Time." Journal of Marketing Research XXXIV (Feb 97): 24-35.

Griffin, A. and J. R. Hauser (1996). "Integrating R&D and Marketing: A review and analysis of the literature," Journal of Product Innovation Management, Vol. 13, No. 3:191-215.

Griffin, A. and A.L. Page (1996). "PDMA success measurement project: Recommended measures for product development success and failure." Journal of Product Innovation Management, Vol. 13: 478-496.

Griffin, A. and A. L. Page (1993). "An Interim Report on Measuring Product Development Success and Failure," Journal of Product Innovation Management, Vol. 10: 291-308.

Gupta, Aloke K., and David Wilemon (1996) "Changing Patterns in Industrial R&D Management," Journal of Product Innovation Management, Vol. 13:497-511.

Hart, S. (1993). Dimensions of Success in New Product Development: An exploratory investigation, Journal of marketing management 9:23 –41.

Hartley J. L., J. R. Meredith, D. McCutcheon and R. R. Kamath (1997). "Suppliers' Contributions to Product Development: An Exploratory Study," IEEE Transactions on Engineering Management, Vol. 44, No. 3, August: 258-267.

Hauser , John R. (1996), "Metrics to Value R&D: An Annotated Bibliography," Marketing Science Institute, Special Report No. 96-121.

Hauser, John R. and Gerald M. Katz (1998a). "Metrics: You Are What You Measure!" Working Paper #172-98, Sloan WP#4009, Sloan School of Management, MIT, Cambridge, MA.

Hauser, John R. (1998b) "Research, Development, and Engineering Metrics," Working Paper, Sloan School of Management , MIT, Cambridge, MA.

Hultink, E. J. and H. S. J. Robben (1995), "Measuring New Product Success: Differences that Time Perspective makes," Journal of Product Innovation Management, Vol. 12:392-405.

Hayes, R. H. and W. J. Abernathy (1980). "Managing our way to economic decline," Harvard Business Review, Vol. 58, No. 4:67-77.

Jacobson, Robert and David A. Acker (1985) “Is Market Share All That It’s Cracked Up To Be?” Journal of Marketing, 49 (Fall):11-22.

Jackobson, Robert (1988), “Distinguishing Among Competing Theories of the Market Sahare Effect,” Journal of Marketing, 52 (Ocotober):68-80.

Kekre, S. and K. Srinivasan (1990). "Broader Product Line: A Necessity to Achieve Success?" Management Science, Vol. 36, No. 10: 1216-1231.

Krishnan, V. and K. T. Ulrich (2001) “Product Development Decisions: A Review of the Literature,” Management Science, Vol. 47, No. 1, January:1-21.

Mahajan, V. and J. Wind (1992). "New product models- Practice, shortcomings and desired improvements." Journal of Product Innovation Management Vol. 9, June: 128-139.

Memdelson, Haim and Ravindran R. Pillai (1999). “Industry Clockspeed: Measurement and Operational Implications,” Manaufacturing & Service Operations Management, Vol. 1, No. 1:1-20.

Meyer, M. H., P. Tertzakian and J. M. Utterback (1997), “Metrics for Managing Research and Development in the Context of the Product Family,” Management Science, Vol. 43, No. 1, January: 88-111.

Montoya-Weiss, M. M. and R. Calantone (1994), “Determinants of New Product Performance: A Review and Meta-Analysis,” Journal of Product Innovation Management,” Vol. 11: 397-417.

Patten, Mildred L (2001). Questionnaire Research: A Practical Guide, Pyrczak Publishing, Los Angeles, CA, 2001.

Porter Michael E. (1980). Competitive Strategy, Free Press, New York.

Reinertsen, Donald G. (1983). "Whodunit? The search for new-product killers," Electronic Business, July 1983: 62-66.

Reinertsen, D. and P. Smith (1991). Developing Products in Half the Time. New York, Van Nostrand Reinhold Publishers.

Smith, Preston G. (1998). "Winning the new product rat race," Machine Design, May 12:95-98.

Song, X., Parry (1997). "The determinants of Japanese new product success." Journal of Marketing Research 34(Feb): 64-76.

Spreng, R. A., S.C. MacKenzie, R.W.Olshavsky (1996). "A reexamination of the determinants of consumer satisfaction." Journal of Marketing Vol. 60, No. 3:15-32.

Stalk, G. Jr. (1988). "Time-The Next Source of Competitive Advantage," Harvard Business Review, July-August :41-51.

Szymanski, David M., Sunder G. Bharadwaj and P. Rajan Varadarajan (1993), "An Analysis of the Market Sahare Profitability Relationship," Journal of Marketing, 52, July :1-18.

Swink, M. (1999). "Threats to new product manufacturability and the effects of development team integration processess," Journal of Operations Management, Vol. 17, No. 6.

Tatikonda, Mohan V. and Stephen R. Rosenthal (2000). "Successful Implementation of product development projects: Balancing firmness and flexibility in the innovation process." Journal of Operations Management, Vol. 18, No. 4: 401-425.

Tatikonda, M. V. and M. Montoya-Weiss (2001), "Integrating Operations and Marketing Perspectives of Product Innovation: The Influence of Organizational Process Factors and Capabilities on Development Performance," Management Science,Vol. 47, No. 1, January :151-172.

Uttal, B. (1987). "Speeding Ideas to Market," Fortune , 2, March :62-66.

Welch, David and Kathleen Kerwin (2003). "Rick Wagoner's Game Plan," Business Week, February 10, 2003:52-60.

Whitney, D. T. (1988). "Manufacturing by Design," Harvard Business Review," Vol. 66, No. 4, July-August :83-91.

Xie, Jinhong, X. Michael Song and Anne Stringfellow (1998). "Interfuntional Conflict, Conflict Resolution Styles and New Product Success: A Four-Culture Comparison," Management Science, Vol. 44, N0. 12, Part 2: S192-S206.

Zeithaml, V. A. (1988). "Consumer Perceptions Of Price, Quality, And Value: A Means-End Model and Synthesis of Evidence." Journal of Marketing, Vol. 52, July :2-22.

Zaheeer, Srilata, Stuart Albert and Akbar Zaheer (1999). "Time Scales and Organizational Theory," Academy of Management Review," Vol. 24, No. 4:725-741.

Zirger, B. J. and M. Maidique (1990). "A model of new product development: An empirical test," Management Science, Vol. 36: 867-883

Appendix 1: NPD Performance Outcomes

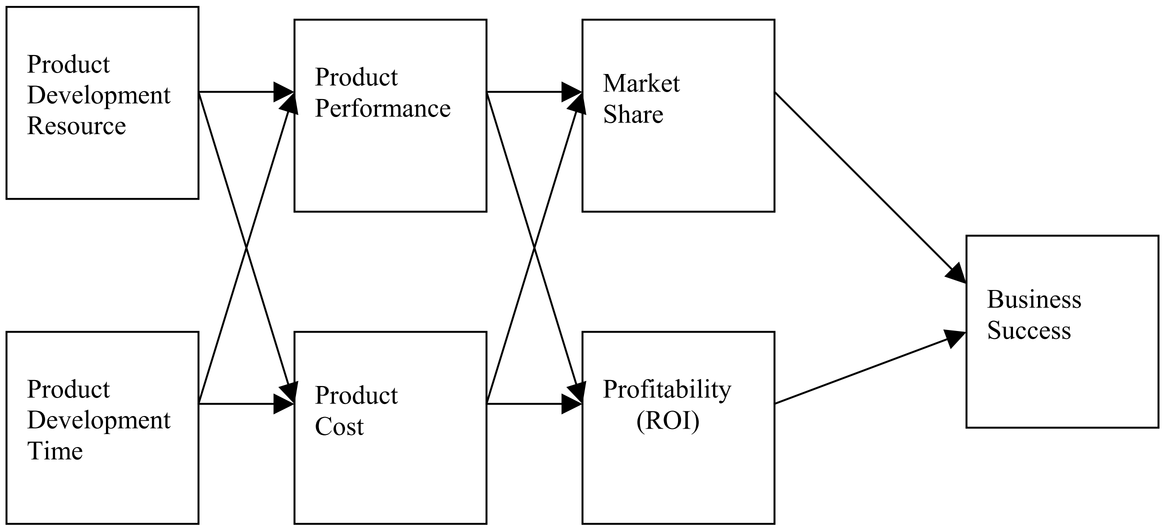
To what extent were the following objectives met, relative to your expectations? Please leave the item blank if you do not know how well an objective was met.

Please circle your response using the following seven-point scale:

1 = Significantly worse than expected
2 = Worse than expected
3 = A little worse than expected
4 = On target
5 = A little better than expected
6 = Better than expected
7 = Significantly better than expected

1	2	3	4	5	6	7	Product technical performance to specifications
1	2	3	4	5	6	7	Projected unit cost of the product
1	2	3	4	5	6	7	Projected R&D budget
1	2	3	4	5	6	7	Our time-to-market objective
1	2	3	4	5	6	7	Our market share objective
1	2	3	4	5	6	7	Our return-on-investment objective
1	2	3	4	5	6	7	The overall commercial success of the product

Figure 1: Proposed Framework for Measuring Product Development Performance



<u>Stage 1</u>
Product Development Performance

<u>Stage 2</u>
Value Created for the customer

<u>Stage 3</u>
Business Performance

Table 1: Summary Descriptive Statistics for NPD Performance Metrics

Metric	N	Mean	Standard
OUTRANDD	38	4.03860	0.71852
OUTTIME	38	3.96046	1.18224
OUTPERF	38	4.97525	0.74746
OUTCOST	38	4.53584	0.99994
OUTMARK	38	4.11021	1.26609
OUTROI	38	4.09204	0.92909
OUTSUCC	38	4.47719	1.22934

Table 2: Pearson Correlations among NPD Performance Metrics

	OUTSUCC	OUTMARK	OUTROI	OUTPERF	OUTCOST	OUTRANDD
OUTMARK	0.73729***					
OUTROI	0.68967***	0.79609***				
OUTPERF	0.09831	0.01582	0.23015			
OUTCOST	0.29865*	0.39223**	0.53202***	0.42119***		
OUTRANDD	0.07397	0.42804**	0.48545**	-0.07294	0.38631**	
OUTTIME	-0.01612	0.29380*	0.29298*	-0.17832	0.45941***	0.49299***

Statistically significant at *p<10%, **P<5%, ***P<1%

Table 3: Regression Analysis for the Path Model

Y	a_i	b_i	X_1	c_i	X_2	R^2	p>F
OUTPERF	5.36309***	0.02057	OUTRAND	-0.11890	OUTTIME	0.0321	0.5650
OUTCOST	2.15893**	0.29383	OUTRAND	0.30053**	OUTTIME	0.2448	0.0073
OUTMARK	2.94875**	-0.30761	OUTPERF	0.59347***	OUTCOST	0.1810	0.0304
OUTROI	1.81737*	0.00916	OUTPERF	0.49144***	OUTCOST	0.2831	0.0019
OUTSUCC	0.90722	0.49910***	OUTMARK	0.37110	OUTROI	0.5724	0.0001

Statistically significant at *p<10%, **P<5%, ***P<1%

Figure 2: Observed Relationships for Product Development Performance