AN INTEGRATED NEW PRODUCT DEVELOPMENT MODEL FOR THE TURKISH ELECTRONICS INDUSTRY

Birol Akova[a], Gündüz Ulusoy[b], Erbil Payzın[c], Ali Rıza Kaylan[a]

[a]Department of Industrial Engineering, Boğaziçi University, Istanbul, Turkey
[b]Manufacturing Systems Engineering, Sabanci University, Istanbul, Turkey
[c]Payzın Information Technologies Inc., Göztepe Istanbul, Turkey

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ABSTRACT

The aim of this study is to report on an integrated model of new product development (NPD) and the analysis of factors, which have a significant effect on new product development success. First, an integrated NPD model based on past research findings and suggestions of several researchers is built. A three-step model is constructed and is tested through a series of statistical tests and analysis. The data for the testing of the model is provided by an empirical study conducted in the Turkish electronics industry. Some practices for successful NPD are suggested.

1. INTRODUCTION

New product development (NPD) is a potential source of competitive advantage for many firms. NPD is one of the riskiest, yet most important endeavors of the modern corporation. New products are the lifeblood of organizations because rapidly changing technologies and fierce global competition quickly erode sales of existing products. The greater risk is not in developing new products, but in failing to innovate at a pace that matches changing customer needs. NPD is also important since it is a critical means by which members of organizations diversify, adapt, and even reinvent their firms to match evolving market and technical conditions. Effective NPD is virtually synonymous with success in high-technology industries such as electronics, aerospace, biotechnology, chemicals, and pharmaceuticals. Especially in the electronics industry, product generations are obsolete almost as soon as they hit the market.

Product innovation is a complex process driven by technology advances, changing customer needs, shortening product life cycles, and increased world competition. For success, it requires robust relationships within the firm and further between the firm and its customers and suppliers.

When we look at some statistics, it is seen that new products launched into the market within the last five years accounted for 33 percent of company sales in the years between 1976 and 1981; 40 percent from 1981 to 1986; and 42 percent between 1985 and 1990 (Cooper, 1993). It is also seen that on the average 55.9 percent of new products launched met the organization’s definition of success and 51.7 percent of new products launched were successful in terms of their profitability to the organization in the Product Development and Management Association member firms (Rosenau, 1996). This means approximately half of the new products failed. According to an empirical study conducted in the U.S., Europe, and Asia (Kluge et al., 1996), share of sales from new products introduced within the last 12 months (in 1991) was 45 percent for successful companies in the consumer/small products sub-industry and 49 percent for successful companies in the computers/communications sub-industry of the electronics sector. Best practices for these two sub-industries were respectively 80 percent and 82 percent.

In the following section of the study, a review of the new product development literature is introduced. The third section consists of definition of the problem, models and hypotheses of the study. The fourth section is about research methodology and results. Finally, a summary of the findings in the study is given at the last section.

2. A REVIEW OF THE NEW PRODUCT DEVELOPMENT LITERATURE

Some of the earliest studies on new product development emphasized the importance of market issues over purely technical ones for successful product development. For example, Myers and Marquies (1969) studied the development of 567 successful products and processes in over 100 firms and 5 industries. Their principal result was that market pull (i.e., identifying and understanding users' needs) was substantially more important to the success of the new products than technology push, and thus a cross-functional view was a key component of new product success.

Later studies added new product failures to the mix. The SAPPHO studies (e.g., Rothwell, 1972; Rothwell, 1974) were conducted using 43 success and failure pairs among chemical and instruments firms within the United Kingdom. The authors found that 41 factors, including understanding users' needs, attention to the market, efficient development, and senior leadership, were significantly related to successful product development. The SAPPHO studies were then followed by similar studies in other countries such as Finland (Kulvik, 1977), Hungary (Szakasits, 1974), and West Germany (Gerstenfeld, 1976).

Subsequent research sharpened the emergent emphasis on product advantages, market attractiveness, and internal organization. Particularly important two studies were by Cooper (1979) and Cooper and Kleinschmidt (1987). The first, the NewProd study

(Cooper, 1979), examined 102 successful and 93 failed products within 103 industrial firms in Canada. The subsequent study by Cooper and Kleinschmidt (1987) examined hypotheses from the NewProd and other studies using 203 products in 125 manufacturing firms, including 123 successes and 80 failures. Data were gathered from either the most knowledgeable manager or managers using a structured interview questionnaire. The authors observed that the most important determinant of product success was product advantage. The intrinsic value of the product, including unique benefits to customers, high quality, attractive cost, and innovative features, were the critical success factors. Such products were seen as superior to competing products in solving problems faced by the customers. Internal organization was also found to be critical to product success. Predevelopment planning was particularly important. This included developing a well-defined target market, product specifications, clear product concept, and extensive preliminary market and technical assessment. Other internal organization factors were also important, including cross-functional skills and their synergy with existing firm competencies. Top management support was also important, but less than other factors. Finally, Cooper and Kleinschmidt (1987) found that products that entered large and growing markets were more likely to be successful. In addition, products introduced into markets with low overall intensity of competition were more successful.

Cooper and Kleinschmidt (1993) conducted another NewProd study of product development in the North American and European chemical industries. The authors replicated some of their earlier findings. Most notably, they once again found that product advantage was most strongly associated with financially successful products. Contrary to their earlier study, the authors found in this case that market competitiveness had no relationship with product success.

Cooper (1999) brought together the critical success factors for successful product development: The importance of up-front work, voice of customer, differentiated products with unique customer benefits and superior value for the user, early and stable product definition, a strong market launch, having tough go/kill decision points or gates, organization as a cross-functional team led by a strong project leader, and international orientation. Here, international orientation implies the definition of the market as a global market and the utilization of team members from different countries.

The Stanford Innovation Project reported by Maidique and Zirger (1984, 1985) also emphasized product advantages and internal organization. Seventy product success/failure pairs initially were surveyed and from these, 21 case studies were subsequently conducted. A third study expanded the first two by examining 86 success/failure product pairs (Zirger and Maidique, 1990). According to conclusions drawn from that study, first, excellent internal organization was important, i.e., smooth execution of all phases of the development process by well-coordinated functional groups. Products that had top management commitment and were built on existing corporate strengths were also likely to be successful. In addition, product factors were critical. Successful products provided superior customer value through enhanced technical performance, low cost, reliability, quality, or uniqueness. Finally, market factors also affected product success. Early entry into large, growing markets was more likely to lead to success.

Parry and Song (1994) investigated NPD managers at 129 state-owned enterprises in the People's Republic of China to examine the generalizability of Cooper's work in Canada. They found that relative product advantage and the acquisition of marketing information were highly correlated with new product success, just as in Canada. Song and Parry (1996) also investigated the links between new product success and 10 factors in 404 Japanese firms and 788 new product introductions. They found that the most important success factor was product advantage. Other important success factors include predevelopment proficiency and marketing and technological synergy. Consistent with the past research on North American firms, market competitiveness was found to be the least important success factor.

The study reported by Kluge et al. (1996) surveyed the electronics industry worldwide and aimed to establish the success profiles and reasons for performance differences between companies, segments and regions. The survey polled a total of 102 companies consisting of 45 firms in Europe, 34 firms in the U.S., and 23 firms in Asia. The sectors investigated were consumer electronics/small products, computers/communication, large systems, and industrial electronics/measurement systems. Information on the success patterns of the leading companies and the behavior patterns of less-successful companies was derived from the evaluation of a detailed questionnaire, detailed on-site interviews, and a wide-ranging discussion in participant conferences, plus the experience gained from McKinsey consultancy projects. In the study, it was found that the successful firms concentrated on a small number of high-potential projects and they set ambitious cost or value goals for each project. Successful companies' particular strength lay in achieving maximum integration and flexibility. Finally, they provided their development engineers with maximum stimulation density by creating a particularly innovation-friendly environment. Their project organization consisted of independently responsible development teams containing top personnel and led by a managerially responsible project manager.

Loch et al. (1996) developed a two-step model for measuring the performance of the new product development function. They used data from the study reported above (Kluge et al., 1996) and they applied their model to a sample of 95 business units operating in three international electronics industries; consumer/small products, computers/communications, and industrial measurement/large systems. The authors found development productivity as a very important driver of business success. In addition, the computer industry rewards also design to cost and design quality. In contrast, the measurement and large systems cluster seems to mainly emphasize technical product performance.

Using the data from the study reported above (Kluge et al., 1996), Terwiesch et al. (1996) investigated the influence of market environment on business success and how market characteristics influence the importance of established new product development performance measures. The authors tested statistically the framework on data from 86 companies in 12 electronics industries worldwide. The authors found that product development performance was more important in technologically stable and mature industries. In addition, large companies could significantly impact their financial performance through product development, whereas the profitability of small firms was driven mainly by the industry environment. In a sequel to the above study, Terwiesch et al. (1998) presented a contingency model of NPD performance that explicitly accounts for the impact of differing market environments. The authors showed that NPD performance is important in slowly growing industries and/ or industries with long product life cycles but explains no profitability variance in fast changing industries.

Another research trend is to focus not on financial success but rather specifically on the speed of product development. For example, Gupta and Wilemon (1990) focused on accelerating product development pace. These authors polled 80 executives concerning factors that slowed or accelerated the development process. Their suggestions for fast product development emphasized internal organization, including the importance of early cross-functional, customer, and supplier involvement in the process and visible top management support, more resources, and better teamwork.

Tabrizi and Eisenhardt (1994) surveyed the effect of two theoretical models of fast processes on the speed of product development: compression and experiential. They used data from 72 product development projects in the fast-paced and fiercely competitive global computer industry. First, they found that a multifunctional team and experiential strategy of multiple iterations, extensive testing, frequent milestones, and a powerful project leader accelerated product development. Second, the authors found that the efficacy of strategies for fast product development was contingent upon the complexity and innovativeness of the product. The compression strategy worked best for complex products while the experiential worked best for innovative ones. Finally, they observed that planning and rewarding for schedule attainment were ineffective ways of accelerating pace.

A different type of product development research centers on communication. Moenaert et al. (1994) investigated 40 technologically innovative Belgian companies to examine the effects of project formalization, centralization, role flexibility, and interfunctional climate on cross-functional communication and innovation success. The authors found that communication flows between R&D and marketing increase under conditions involving formalization of projects, decentralization, positive interfunctional climate, and role flexibility. However, only project formalization and the quality of the interfunctional climate were found to have significant effect on project success.

McDonough et al. (1999) investigated the management of communication in global new product development teams (GNPDT's), which are becoming more and more prevalent due to the growing need for companies to compete in a global economy. The study discussed in the paper explored the communication challenges and the impact of various communication mechanisms on GNPDT performance. According to data gathered from phone and face-to-face interviews, they found that cultural business (problem-solving approach, the manner in which team members communicated with their leaders, the way in which decisions were made) and geographic dispersion (the different languages spoken by team members, the technological capability of a member's country of origin, the physical distance between team members) had a significant effect on communication.

McDonough et al. (2001) also investigated the use of global, virtual and colocated NPD teams. They found that the use of global teams is rapidly increasing. The global teams generally face greater behavioral and project management challenges. They have usually a lower performance, and firms face different problems associated with managing each type of NPD teams. These results support the importance of using computer based collaborative work environment and global NPD teams for meeting the challenge of global competition.

Griffin and Page (1993) tried to identify all product development success and failure measures used, organize them into categories of similar measures that perform roughly the same function, and contrast the measures used by academicians and companies to evaluate NPD performance. The authors compared the measures used in 77 published studies of NPD to those employed by the surveyed companies. They determined 75 measures of product development success and failure and only 16 of these measures were common across all three sources (measures used by practitioners, measures used by academicians, and desired measures). These 16 core success and failure measures were; customer acceptance, customer satisfaction, meeting revenue goals, revenue growth, meeting market share goals, meeting unit sales goals, break-even time, attaining margin goals, internal rate of return/return on investment, development cost, being launched on time, product performance level, meeting quality guidelines, speed to market, percentage of sales of new products in total sales. The authors also found that academicians tended to investigate product development performance at the firm level, whereas managers measured individual product success in the market, and indicated that they wanted to understand it more completely.

Brown and Eisenhardt (1995) organized NPD literature into three streams of research: (i) product development as a rational plan, (ii) communication web, and (iii) disciplined problem solving. The rational plan perspective emphasized that successful product development was the result of careful planning of a superior product for an attractive market and the execution of that plan by a competent and well-coordinated cross-functional team that operated with the support of senior management. The second stream focused on the communication among project team members and with outsiders. In the disciplined problem solving perspective, successful product development was seen as a balancing act between relatively autonomous problem solving by the project team and the discipline of a heavyweight leader, strong top management, and an overarching product vision. Then the authors synthesized the research findings into a model of factors affecting the success of product development. Figure (2.1) shows this synthesized model of Brown and Eisenhardt.

Ozer (1999) mentioned the importance of portfolio approach in product types (e.g. consumer electronics) that can be manufactured by the same technology, in a survey of new product evaluation models. He suggested the benefits of advanced neural network algorithms and supercomputers processing the massive consumer data effectively and identifying common consumer/consumption patterns in the market while this information can be quite valuable in an unstable environment to reduce new product risks and to develop long-term strategies. New pattern recognition techniques such as data mining can be used with every new product throughout its life cycle. Kappel et al. (1999) also suggested the importance and impact of information technology on the side of creative work design. In order to gain access to the complementary resources required for developing and marketing new products, alliances are stated to be very helpful in unstable environments to reduce new product risks and establish long-term market positions. Fruin (1998) pointed out the benefits of alliances in the electronics industry in Japan through the use of a case study.

Specifically for electronics industry, Jochen (2000) stated that highly dynamic markets require a careful management of concurrent engineering and prototyping, including the boot-strapping of consecutive generations of technologies by highly efficient emulation devices. These type of markets also require more open and flexible vendor-supplied design environments.

3. A MODEL OF NEW PRODUCT DEVELOPMENT

The main aim of corporations is to survive in the market place. Thus, they have to make profit in order to reach this goal. The principal means of profit is provided by the set of products of the company.

So far, the researchers have rarely tested a complete model of NPD and those who tested could find very few significant results. This may be because of the difficulty of finding detailed information about NPD in the industrial base or use of an inadequate model.

In this paper, NPD activities and performance of the electronics companies have been investigated. Using the findings from earlier studies and suggestions of the authors, firstly, an integrated model of NPD is constructed. Mainly, Brown and Eisenhardt's synthesised model (1995) mentioned in the literature review (Figure 2.1) inspired this study in the construction of an integrated model displayed in Figure 3.1. Then, this integrated model is tested with real data from the Turkish electronics industry. The test of the integrated model is performed in three phases. At the first phase, the *financial performance* sub-model of the integrated model is tested. And then, the *project performance* sub-model is tested. At the last phase, the design proficiency sub-model is tested. The *product design* proficiency sub-model is not seen in the integrated model in figure (3.1) since that model is investigated after finding design proficiency as a significant driver of project performance. The factors which have a significant effect on the financial success of new products in the first sub-model, on the performance of NPD projects in the second sub-model, and on the design proficiency of new products in the third sub-model have been investigated. Then suggestions have been developed for successful innovation. These three sub-models are explained in the following sections.

3.1. Financial Performance Model of New Product Development

The financial performance model of NPD is presented in Figure (3.1.1). According to this model;

- market conditions,
- product characteristics,
- fitness of new product with firm competencies,
- proficiency of NPD activities,
- market entry and new product marketing strategy,
- NPD project performance, and
- customer involvement in NPD projects

directly affect the financial performance of the new products in the market.

3.1.1. Hypotheses of the Financial Performance Model

In the light of this financial performance model, the following hypotheses have been put forward, where the dependent variable is taken as financial success of new products:

	Hypothesis	Sign of Relationship
1	Market size	+
2	Market growth	+
3	Frequency of new product introductions	-
4	Degree of competition	-
5	Superior products in terms of meeting customer needs	+
6	High quality products	+
7	Product complexity	-
8	Sufficiency of financial resources	+
9	Sufficiency of R&D/engineering skills	+
10	Proficiency of initial screening	+
11	Proficiency of user needs and wants study (detailed market study)	+
12	Proficiency of competitive analysis	+
13	Proficiency of market analysis	+
14	Proficiency of detailed financial analysis	+
15	Proficiency of advertising and promotion planning	+
16	Proficiency of lab tests	+
17	Proficiency of customer tests	+
18a	The use of follower strategy	+
18b	The use of first to market strategy	-
19a	The use of launching major innovations into new market strategy	+
19b	The use of launching major innovations into present market strategy	-
20	Using customer as a new product idea source	+
21	The number of NPD activities in which customers are involved	+
22	New product development time	-
23	Exceeding planned project duration	-
24	Exceeding planned project budget	-

3.2. Project Performance Model of New Product Development

The project performance model of NPD is seen in figure (3.2.1). In this model;

- new product technology strategy,
- fitness of new product with firm competencies,
- development personnel,
- proficiency of NPD activities,
- technical skills and capabilities,
- organization and team formation, and
- communication

are the direct drivers of NPD project performance.

3.2.1. Hypotheses of the Project Performance Model

The following hypotheses have been developed for the project performance model. Exceeding planned project duration has been taken as the dependent variable.

	Hypothesis	**Sign of Relationship**
1	Development of new technology as the new product's technology strategy	+
2	Improving own existing technology as the new product' s technology strategy	-
3	Sufficiency of financial resources	-
4	Sufficiency of research and development/engineering skills	-
5	Sufficiency of production skills	-
6	Sufficiency of research and development infrastructure	-
7	Sufficiency of production infrastructure	-
8	Average number of years of experience of the development personnel	-
9	Average number of training hours per development employee per year	-
10	Rewards for development project personnel	-
11	Training in project management skills	-
12	Training of teamwork	-
13	Use of matrix or project type of organization	-
14	Existence of a core project team	_
15	The number of simultaneous projects	+
16	Application of a project planning technique	_
17	Monitoring the physical progress of NPD projects	_
18	Proficiency of product definition	_
19	Proficiency of detailed technical assessment	-
20	Proficiency of product design	-
21	A clear statement of the objectives of the NPD projects by the management	-
22	The response time to the requests for information from other departments	+
23	Use of a computer based collaborative work environment	-

3.3. Design Proficiency Model of New Product Development

The design proficiency model of NPD is seen in Figure (3.3.1). According to this model;

- fitness of new product with firm competencies,
- proficiency of product definition,
- development personnel,

- technical skills and capabilities,
- organization and team formation, and
- communication

directly affect the design proficiency.

3.3.1. Hypotheses of the Design Proficiency Model

The design proficiency model includes the following hypotheses. Design proficiency has been taken as the dependent variable

	Hypothesis	**Sign of Relationship**
1	Sufficiency of financial resources	+
2	Sufficiency of research and development/engineering skills	+
3	Sufficiency of research and development infrastructure	+
4	Proficiency of product definition	+
5	Average number of years of experience of the development personnel	+
6	Average number of training hours per development employee per year	+
7	Rewards for development project personnel	+
8	Training of teamwork	+
9	Use of a computer based collaborative work environment	+
10	Competence of computer aided electronics or mechanical design (CAD)	+
11	Use of a formal NPD process	+
12	Existence of a core project team	+
13	The number of simultaneous projects	-
14	Existence of an identifiable and accountable project manager	+
15	The response time to the requests for information from other departments	+

4. RESEARCH METHODOLOGY

4.1. The Data

The data used in this study were provided from an ongoing project (TTGV-001/DS) named "New Product Development Capabilities of the Turkish Electronics Industry," funded by the Technology Development Foundation of Turkey (TTGV) and dealing with the comparison of NPD capabilities of the electronics companies among themselves as well as with the best practices in the world. In this project, detailed information has been collected through a questionnaire and an interview. The data used in this thesis study were obtained from the information collected through the questionnaire in the project.

The questionnaire was sent to 91 electronics companies, which are expected to develop new products, and the number of responding companies was 31. Three questionnaires were excluded since a large proportion of those was empty. Therefore, the number of useable questionnaires is 28. Total sales of these 28 companies constitute approximately 74 percent of total sales of the electronics industry. Distribution of the companies with respect to sub-industries is seen in table (4.1.1).

TABLE 4.1.1. Responding companies with respect to sub-industries

Sub-industry	**The Number of Firms**	**Example Products**
Consumer electronics	5	TV, audio, video
Telecommunications equipment	8	Phone, PABX
Professional and industrial electronics equipment	11	Control, medical
Military electronics	4	War systems

4.2. Measures of the Financial Performance Model

In the foregoing project, new products are described as the products developed by the firm since 1.1.1993 and they are separated into two types. The first one is the major innovations and the second one is the minor improvements. The major innovations are described as newly marketed products whose intended use, performance, characteristics, technical construction, design or use materials and components is new or substantially changed. Such innovations can involve radically new technologies or can be based on combining existing technologies in new uses. The minor improvements are described as existing products whose technical characteristics have slightly been enhanced or upgraded. Information in the questionnaire is requested for both types when necessary.

Besides, the new product development process is considered to consist of three phases, pre-development, development, testing and validation and include 28 activities. These activities are given in the Appendix.

The following measures have been used in the financial performance model.

4.2.1. Measures of the Independent Variables

	Likert Scale	
Measures	**1**	**5**
Market size	One or a few customers	Many customers
Market growth	No growth	Very quick growth
Frequency of new product introductions	Rare	Very frequent
Degree of competition	No competition	High competition
Superiority to competing products	Never superior	Always superior
Quality of new product	Never higher quality	Always higher quality
Product complexity comp. To competing products	Never complex	Always complex
Sufficiency of financial resources	Always insufficient	Always sufficient
Sufficiency of R&D/engineering skills	Always insufficient	Always sufficient
Use of the customer as new product idea source	Ineffective use	Very effective use

Measures	**0**	**1**	**5**
Proficiency of initial screening	Not performed	Very poor	Excellent
Proficiency of user needs and wants study (detailed market study)	Not performed	Very poor	Excellent
Proficiency of competitive analysis	Not performed	Very poor	Excellent
Proficiency of market analysis	Not performed	Very poor	Excellent
Proficiency of detailed financial analysis	Not performed	Very poor	Excellent
Proficiency of advertising and promotion planning	Not performed	Very poor	Excellent
Proficiency of lab tests	Not performed	Very poor	Excellent
Proficiency of customer tests	Not performed	Very poor	Excellent

Measures	**Measured by**
Use of follower strategy	The percentage of using this strategy as an entry strategy into the market for the major innovations of the firm since 1.1.1993
Use of first to market strategy	The percentage of using this strategy as an entry strategy into the market for the major innovations of the firm since 1.1.1993
Use of major innovations in new market strategy	The percentage of using this strategy as new product marketing strategy within major innovations by the firm since 1.1.1993
Use of major innovations in present market strategy	The percentage of using this strategy as new product marketing strategy within major innovations by the firm since 1.1.1993
Customer involvement	The percentage of activities, in which customers take part
New product development time	The time between the beginning of the initial screening of new product ideas and the end of full production and market launch
Exceeding planned project duration	The realised project duration after taking planned project duration as 100 units
Exceeding planned project budget	The realised project budget after taking planned project budget as 100 units

4.2.2. Measure of the Dependent Variable

Profitability of new products: Profitability of new products is measured by the percentage of the new products with major innovations developed and introduced by the firm since 1.1.1993 which have reached or exceeded their profit goals.

There are two reasons for using profitability of new products as financial performance indicator. The first one is that profitability is among 16 core new product success and failure measures used by practitioners and academicians according to Griffin and Page's study (1993). The other one is that profitability is essential to the survival of companies in the market.

In the next part, analysis and results of the financial performance model are reported.

4.3. Analysis and Results of the Financial Performance Model

The data of this study are based on the last four years' NPD activities and performance, that is, since 1.1.1993 until early 1997, of the companies. As mentioned before, the number of useable questionnaires was 28, however, since one company stated that it had recently started developing new products, it was excluded from the data set. Analysis of the financial performance model began with calculation of Pearson correlation coefficients between 26 independent variables and the dependent variable, reaching or exceeding profit goals, of the model.

Secondly, the variables that are correlated with the dependent variable by $p=0.25$ significance level were selected for further analysis. The selected variables and their correlation coefficients are seen in Table (4.3.1). Then, a principal component factor analysis was conducted with the selected variables for subsequent regression analysis. Because interpretation of the factor matrix is difficult, varimax rotation was performed. Varimax rotated factor matrix is seen in Table (4.3.2). The factor analysis resulted in a four-factor solution. While determining the number of factors to be extracted, latent root criterion, percentage of variance criterion, and scree test criteria were considered together (Hair et al., 1987).

As it is seen from Table (4.3.2), cumulative percentage of variance is 81.1, the minimum communality is 0.625, and the minimum absolute factor loading is about 0.53. These are acceptable values for a factor solution.

TABLE 4.3.1. Selected variables in the financial performance model

Independent Variables	Dependent Variable	
	Correlation Coefficient	**Significance Level**
1. *Market growth*	0.3906	P= 0.072
2. *Sufficiency of financial resources*	0.5911	P= 0.004
3. *Proficiency of competitive analysis*	0.3107	P= 0.159
Market Entry and NP Marketing Strategies		
4. Use of the follower strategy	0.3248	P= 0.140
5. Major innovations-new market strategy	0.4494	P= 0.036
6.Major innovations-present market strategy	-0.3203	P= 0.146
NPD Project Performance		
7. Development time	-0.4391	P= 0.041
8. Deviation from planned project duration	-0.2577	P= 0.247
9. Deviation from planned project budget	-0.4222	P= 0.050

TABLE 4.3.2. Varimax rotated principal component factor analysis matrix

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Major innov.-present market strategy	-0.860	-0.400	0.112	0.228	0.965
Major innovations-new market strategy	0.849	-0.083	-0.159	-0.284	0.834
Market growth	0.834	-0.031	0.202	0.061	0.741
Deviation from planned project duration	0.090	0.942	-0.029	-0.005	0.896
Deviation from planned project budget	0.088	0.915	-0.113	0.152	0.881
Sufficiency of financial resources	0.347	-0.530	0.472	-0.029	0.625
Proficiency of competitive analysis	0.097	-0.006	0.824	0.068	0.693
Use of the follower strategy	-0.169	-0.153	0.803	-0.013	0.697
Development time	-0.211	0.112	0.035	0.953	0.966
Eigenvalue	2.715	2.433	1.414	0.736	
Variance explained	30.2 %	27 %	15.7 %	8.2 %	
Cumulative variance	30.2 %	57.2 %	72.9 %	81.1 %	

Finally, multiple regression analysis was performed with the factors and statistically significant results were obtained. A summary of regression results is seen in Table (4.3.3).

According to regression results, all of the factors are significant and the regression model is appropriate: Significance of F=0.001, R^2=0.645, and adjusted R^2=0.562.

At the end of the statistical analysis, it was seen that nine of the individual hypotheses of the financial performance model were supported.

TABLE 4.3.3. A summary of financial performance model regression results

Factor	Dependent Variable	
	Sign of Relationship	**Significance Level**
Factor-1	(+)	0.0068
Factor-2	(-)	0.0352
Factor-3	(+)	0.0063
Factor-4	(-)	0.0194

Figure (4.3.1) shows the financial performance model of NPD with significant findings.

4.4. Measures of the Project Performance Model

As in the financial performance model, here the projects are the ones in which new products with major innovations are developed and introduced into the market.

The following measures have been used in the project performance model.

4.4.1. Measures of the Independent Variables

	Likert Scale	
Measures	**1**	**5**
Sufficiency of financial resources	Always insufficient	Always sufficient
Sufficiency of R&D/engineering skills	Always insufficient	Always sufficient
Sufficiency of production skills	Always insufficient	Always sufficient
Sufficiency of R&D infrastructure	Always insufficient	Always sufficient
Sufficiency of production infrastructure	Always insufficient	Always sufficient
Rewards for development project personnel	Never rewarded	Always rewarded
Training of project management	Never provided	Always provided
Training of teamwork	Never provided	Always provided
Existence of a core project team	Never existed	Always existed
Application of a project planning technique	Never applied	Always applied
Monitoring the physical progress of the projects	Never monitored	Always monitored
A clear statement of the objectives of the NPD projects by the management	Never clearly stated	Always clearly stated
The response time to the requests for information from other departments	Too late	Immediately

	Six-point Scale		
Measures	**0**	**1**	**5**
Proficiency of product definition	Not performed	Very poor	Excellent
Proficiency of detailed technical assessment	Not performed	Very poor	Excellent
Proficiency of product design	Not performed	Very poor	Excellent
Use of a computer based collaborative work environment	Not available	Not used	Extensively used

Measures	**Measured By**
Developing new technology	The percentage of using this strategy as the new product's technology strategy
Improving own existing technology	The percentage of using this strategy as the new product's technology strategy
Average years of experience of the development personnel	Directly asking the firms the average years of experience of the development personnel since graduation.
Average number of training hours per development employee per year	Directly asking the respondents the average number of training hours per development employee per year in the firm
Use of matrix type of organization	The percentage of matrix organization applied in the new product development projects
Use of project type of organization	The percentage of project organization applied in the new product development projects
The number of simultaneous projects	Directly asking respondents the number of new product development projects in which a core project team member generally work simultaneously

4.4.2. Measure of the Dependent Variable

Exceeding planned project duration: In the project performance model, exceeding planned project duration is used as the dependent variable. This item is measured by the realised project duration after taking planned project duration as 100 units. This can be seen as percentage of deviation from planned project duration.

The main reason for taking the exceeding planned project duration as the dependent variable in the project performance model is that launching new products into market on time is among 16 core new product success and failure measures used by practitioners and academicians according to Griffin and Page's study (1993). And also, time deviation causes budget deviation. The Pearson correlation coefficient between time and budget deviation is 0.8107 in $p=0.000$ significance level. Therefore, it can be said that time deviation is one of the important performance indicators of NPD projects.

In the next part, analysis and results of the project performance model are given.

4.5. Analysis and Results of the Project Performance Model

As in the financial performance model, firstly, Pearson correlation coefficients between 24 independent variables and the dependent variable, time deviation from planned project duration, were calculated during analysis of the financial performance model. Secondly, the variables that are correlated with the dependent variable by p=0.25 significance level were selected. The selected variables and their correlation coefficients are seen in Table (4.5.1).

TABLE 4.5.1. Selected variables in the project performance model

Independent Variables	**Dependent Variable**	
	Correlation Coefficient	**Significance Level**
New Product Technology Strategy 1. Developing new technology	0.5829	P= 0.002
2. *Sufficiency of financial resources*	-0.4093	P= 0.042
Training of Development Personnel 3. Average number of training hours 4. Training of project management	-0.2854 -0.3528	P= 0.167 P= 0.084
5. *Proficiency of product design*	-0.4951	P= 0.012
6. *Computer based collaborative work*	-0.3407	P= 0.096

Then, a principal components factor analysis was conducted with the selected variables for subsequent regression analysis. Since interpretation of the factor matrix is difficult, varimax rotation was performed. Varimax rotated factor matrix is seen in Table (4.5.2).

TABLE 4.5.2. Varimax rotated principal component factor analysis matrix

Variable	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Communality**
Computer based collaborative work	0.867	0.261	0.183	0.057	0.856
Proficiency of product design	0.863	-0.083	-0.174	0.262	0.850
Average number of training hours	-0.070	0.850	0.052	0.218	0.777
Training of project management	0.291	0.722	-0.254	-0.078	0.677
Developing new technology	0.015	-0.102	0.969	0.027	0.950
Sufficiency of financial resources	0.218	0.126	0.034	0.942	0.951
Eigenvalue	2.095	1.238	0.986	0.743	
Variance explained	34.9 %	20.6 %	16.4 %	12.4 %	
Cumulative variance	34.9 %	55.5 %	72 %	84.4 %	

The factor analysis resulted in a four-factor solution. Latent root criterion, percentage of variance criterion, and scree test criterion were considered together in determination of the number of factors to be extracted. As it is seen from Table (4.5.2), cumulative percentage of variance is 84.4, the minimum communality is 0.677, and the minimum factor loading is about 0.72. Thus, a four-factor solution provided a good structure with acceptable factor matrix values.

Finally, multiple regression analysis was performed with the factors and statistically significant results were obtained. Table (4.5.3) shows a summary of regression results.

TABLE 4.5.3. A summary of project performance model regression results

Factor	Dependent Variable	
	Sign of Relationship	**Significance Level**
Factor-1	(-)	0.0076
Factor-2	(-)	0.0642
Factor-3	(+)	0.0003
Factor-4	(-)	0.0287

According to regression results, all of the factors are significant and the regression model is appropriate: Significance of F=0.0002, R^2=0.637, and adjusted R^2=0.567.

As a result, it can be said that six of the individual hypotheses of the project performance model were supported. Figure (4.5.1) shows the project performance model of new product development with significant findings.

4.6. Measures of the Design Proficiency Model

The new products with major innovations are considered in the design proficiency model as in the financial performance and project performance models.

4.6.1. Measures of the Independent Variables

The following measures have been used in the design proficiency model.

	Likert Scale	
Measures	**1**	**5**
Sufficiency of financial resources	Always insufficient	Always sufficient
Sufficiency of R&D/engineering skills	Always insufficient	Always sufficient
Sufficiency of R&D infrastructure	Always insufficient	Always sufficient
Rewards for development project personnel	Never rewarded	Always rewarded
Training of teamwork	Never provided	Always provided
Existence of a core project team	Never existed	Always existed
Existence of an identifiable and accountable project manager	Never	Always
The response time to the requests for information from other departments	Too late	Immediately

	Six-point Scale		
Measures	**0**	**1**	**5**
Proficiency of product definition	Not performed	Very poor	Excellent
Use of a computer based collaborative work environment	Not available	Not used	Extensively used
Competence of computer aided electronics design	Not available	Very poor	Excellent
Competence of computer aided mechanical design	Not available	Very poor	Excellent

Measures	Measured By
Average years of experience of the development personnel	Directly asking the firms the average years of experience of the development personnel since graduation
Average number of training hours per development employee per year	Directly asking the respondents the average number of training hours per development employee per year in the firm
Use of a formal NPD process	The percentage of new products developed with a formal NPD process in the firm
The number of simultaneous projects	Directly asking respondents the number of NPD projects in which a core project team member generally work simultaneously

4.6.2. Measure of the Independent Variable

Proficiency of product design: Proficiency of product design is measured by a five-point scale (“1” is very poor and “5” is excellent) representing the proficiency level of this activity for the projects with major innovations.

Analysis and results of the design proficiency model are given in the next part.

4.7. Analysis and Results of the Design Proficiency Model

Once the analysis of the project performance model was completed, the design proficiency model started to be analyzed. As in the previous model analyses, firstly, Pearson correlation coefficients between 16 independent variables and the dependent variable, design proficiency, were calculated. Secondly, the variables, which are correlated with the dependent variable by p=0.25 significance level, were selected. The selected variables and their correlation coefficients are seen in Table (4.7.1).

TABLE 4.7.1. Selected variables in the design proficiency model

Independent Variables	Dependent Variable	
	Correlation Coefficient	**Significance Level**
1. *Sufficiency of financial resources*	0.3564	P= 0.087
Fit with Firm's R&D Competencies		
2. Sufficiency of R&D/engineering skills	0.378	P= 0.069
3. Sufficiency of R&D infrastructure	0.4893	P= 0.015
4. *Proficiency of product definition*	0.2585	P= 0.223
5. *Computer based collaborative work*	0.5942	P= 0.002
Project Leader and Core Team		
6. Existence of a core project team	0.3166	P= 0.132
7. Existence of a project manager	0.451	P= 0.027

Then, a principal component factor analysis was conducted with the selected variables for subsequent regression analysis. Because interpretation of the factor matrix is difficult, varimax rotation was performed. Varimax rotated factor matrix is seen in Table (4.7.2).

TABLE 4.7.2. Varimax rotated principal component factor analysis matrix

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Existence of a project manager	0.876	0.125	0.097	0.026	0.793
Computer based collaborative work	0.714	0.402	0.329	0.101	0.790
Sufficiency of financial resources	0.031	0.912	0.018	0.051	0.836
Sufficiency of R&D infrastructure	0.078	0.663	0.613	0.178	0.854
Sufficiency of R&D/engineering skills	0.004	0.009	0.942	0.067	0.891
Proficiency of product definition	0.208	0.092	0.038	0.885	0.837
Existence of a core project team	0.487	0.192	0.042	0.727	0.805
Eigenvalue	2.09	1.61	1.24	0.87	
Variance explained	29.9 %	22.9 %	17.7 %	12.4 %	
Cumulative variance	29.9 %	52.8 %	70.5 %	82.9 %	

The factor analysis resulted in a four-factor solution. Latent root criterion, percentage of variance criterion, and scree test criterion were considered together in determination of the number of factors to be extracted. As it is seen from Table (4.7.2), cumulative percentage of variance is 82.9, the minimum communality is 0.79, and the minimum factor loading is 0.663. Therefore, a four-factor solution provided a good structure with acceptable factor matrix values.

Finally, multiple regression analysis was performed with these four factors and statistically significant results were obtained. Table (4.7.3) shows a summary of regression results.

According to multiple regression results, all of the factors are significant and the regression model is appropriate: Significance of F=0.0003, R^2=0.604, and adjusted R^2=0.532.

TABLE 4.7.3. A summary of design proficiency model regression results

Factor	Dependent Variable	
	Sign of Relationship	**Significance Level**
Factor-1	(+)	0.0009
Factor-2	(+)	0.0079
Factor-3	(+)	0.018
Factor-4	(+)	0.0632

In conclusion, it is seen that seven of the individual hypotheses of the design proficiency model were supported. Figure (4.7.1) shows the design proficiency model of NPD with significant findings.

5. CONCLUSION

New product development is one of the riskiest, but most important activities of corporations. Especially, in high-technology industries, product innovation is crucial in order for the firms to survive in the market.

In this study, an integrated new product development model deriving from the findings of earlier studies and suggestions of the authors was constructed. Brown and Eisenhardt's synthesized model (1995) based on past research findings helped the study in construction of this integrated new product development model. Our aim was to test this model and develop suggestions for successful product innovation in the Turkish electronics industry. Analysis of the model was performed in three phases. Firstly, financial performance sub-model of the integrated model was analyzed. Secondly, project performance sub-model was analyzed. Finally, design proficiency sub-model was analyzed. At the end of the three-phased analysis, we reached an integrated new product development model with significant findings. Figure (5.1) shows this ultimate model.

Analysis of the financial performance model showed that growing markets, sufficient financial resources, proficient competitive analysis, using follower strategy, and launching new products with major innovations into new market positively and development time, deviation from planned project duration, deviation from planned project budget and launching new products with major innovations into present market negatively affected profitability of new products in the market.

Market growth was also found as significant factor in the studies of Cooper and Kleinschmidt (1993), Zirger and Maidique (1990), Pary and Song (1994). Growing markets are very attractive to companies. But, there is nothing about market growth which companies can do other than using it within the evaluation criteria of new product ideas and searching for such markets. Market uncertainty is also an important factor to build strategies on, as discussed in the work of Souder and Song (1997).

Financial resources enable the firm to perform some activities such as laboratory tests, customer tests, trial sales etc., so failure risk in the market can be reduced. Therefore, top management should allocate sufficient budget to NPD projects.

Song (1997) examined the interplay between a product's innovativeness, the NPD process and the product's performance in the marketplace and suggested that business and market opportunity analysis is an important determinant of profitability for incremental products because it provides the necessary product definition and positioning. Competitive analysis is a pre-development activity determining who the competitors are, strong points and deficiencies of the new product, strengths, weaknesses, strategies, and performance of the competitors. In fast changing electronics industry, these analyses shouldn't be omitted. Even the companies, which have high quality products, ought to perform competitive analysis.

Follower strategy as an entry strategy into market is to wait for the first in the market and after observing the rival new product's performance, to launch its own new product. For the Turkish electronics industry, follower strategy was found as important. It can be said that this result is expected when the technology level and changing macroenvironmental conditions are considered. But it is important for a firm to have innovation capability. As Chiesa et al. (1996) suggested, the main activities for technology acquisition include formulating the company's technology strategy, setting technological goals and plans; R&D management and organization -including the processes for R&D project management, the use of customer sources and relationships for technology acquisition, licensing and building technology alliances; management of intellectual property –the policies for protecting and exploiting the property rights. Such a technological scope should be established in a firm to become competitive in global markets.

New product marketing strategy was found as significant in the Turkish electronics industry. As it is seen from rotated factor matrix of the financial performance model, new product marketing strategies and market growth are placed under the same factor. New markets bring about some difficulties, but it means new customers; that is, a larger market. Therefore, companies should search for new markets and they shouldn't consistently work in the same market. But in today's global world, an increasing number of companies compete in international markets with different customer profiles. Employing global R&D teams is a new trend to overcome the difficulty of understanding internationally distributed different customer types.

Deviation from planned project duration and budget represents performance of new product development projects. Project performance was found as significant factor in many new product development surveys. Reducing development time has been also the subject of many articles and researches. Development time is an indicator of project performance as well as time to market. Shorter development duration than competitors enables the firms to control the entry time to the market, provides lower development cost, gives a chance to the firms to catch opportunities in the market. Therefore, companies should give importance to the development productivity and try to reduce new product development time.

Analysis of the project performance model indicated that using computer based collaborative work environment, proficient product design, training hours per development employee per year, project management training, and sufficient financial resources are positively and development of new technology as the new product's technology strategy is negatively related to performance of NPD projects.

Computer based collaborative work environment enables the development personnel to work quickly. It can be seen as a means of technical communication. Thus, the companies ought to have a computer based collaborative work environment as they grow and development personnel extensively use it. Past research suggests several potential barriers to cross-functional cooperation in NPD, like personality differences between functions, cultural differences or thought-worlds, language or jargon unique to each area, organizational responsibilities and reward systems, physical barriers etc. (Song et al. 1997), of course global teams face a greater degree of such barriers and needs careful management to achieve better performance. (McDonough III et al. 2001) The importance of the issue has leaded researchers to the management and communication problems in global teams of R&D. Nobel and Birkinshaw (1998) suggested that the management of international R&D can be facilitated by the definition of an appropriate 'structural context' to guide the activities of R&D unit managers.

Product design is the activity of NPD projects in which highest effort is spent. In this present study, it was observed that on the average 45 percent of total effort of NPD projects was spent for product design within the 28 development activities seen in the Appendix. Percentage of the second highest effort was about 7.5. This clearly indicates the importance of product design in the projects. Therefore, the firms should try to be proficient in the product design.

Training is an investment on human resources of a company. From the data of the study, it was seen that the average number of training hours was about 43.5 and the maximum number of training hours was 130 per development employee per year. Project management training provides development personnel efficient project management skills, especially, on time and resource management. Therefore, it can be said that the firms should give importance to training in general and to training on project management in particular.

As in the financial performance model, sufficiency of financial resources was found significant in the project performance model. Sufficient financial resources enable the companies to provide some resources such as development personnel, materials, equipment, and external services easily and quickly if needed. Thus, top management should assure sufficient financial resource for development projects.

New technology development for the new product's technology causes the firm to confront many uncertainties and problems. Solution of these problems takes time and project performance decreases. Therefore, the firms should carefully decide about the technology of new products and they shouldn't prefer new technology development for their new products' technology, if it is not necessary.

Analysis of the design proficiency model showed that existence of an identifiable and accountable project manager, using computer based collaborative work environment, sufficient financial resources, sufficient research and development skills and infrastructure of the company, existence of a core project team, and proficient product definition positively affect design proficiency.

An identifiable and accountable project manager assures coordination of separate design tasks and development personnel. Actually, while a project manager is selected for new product development projects, his/her communication skills and acceptance of his/her technical competence by project personnel are considered. In some companies, it was observed that project personnel select new product development project managers. A project manager also assures the communication between project personnel and top management. Therefore, new product development projects should have an identifiable and accountable project manager and the firms should look for leadership characteristics during recruitment of development personnel.

Using computer based collaborative work environment enables the development personnel to see each other's works and this provides an accord between separate design tasks. As it is stated before, the firms should have a computer based collaborative work environment and development personnel should extensively use it.

Sufficiency of financial resources was also found significant in the design proficiency model. This item is seen as a significant factor in all of the models. In fact, research and development/engineering function managers of the Turkish electronics companies evaluated the financing problems and lack of financial incentives related to venture capital, loans, taxation, and subsidies as the third important external obstructing factors for new product development. And general managers evaluated them as the second important external obstructing factors. As a result, it can be said that top management should allocate adequate budget to NPD projects, but at the same time, the state should financially support new product development projects and minimize bureaucracy.

Sufficient research and development skills and infrastructure enable the design personnel to develop new products successfully and easily. Thus, the firms, which aim to compete and survive in the market by developing new products, should have adequate research and development skills and infrastructure.

A core project team is a subset of project personnel who take part in the project from idea generation to launch, who continuously interact with each other and who have information about the whole project. In the study, it was seen that a core project team generally included members from marketing, research and development/engineering, and production functions. In addition to them, in some companies, personnel from finance, quality assurance functions involved in the core project team. Such a team provides information flow and easy communication between different functions throughout the project. Therefore, core project teams should be used in the NPD projects.

Product definition is a pre-development activity, in which customer needs, expectations, and other market inputs are converted into a product concept (Specific product functions, features, specifications, requirements, etc.). A clear and right product definition makes the development of new products easy. Quality function deployment (QFD) method can be used during product definition. However, it was observed that the majority of the Turkish electronics companies are not familiar with this technique. Training and application of the quality function deployment method may be beneficial for the proficient product definition. QFD is also useful in global issues. Griffin and Hauser (1996) pointed that QFD reduces the marketing/R&D barriers of different thought-worlds, languages and organizational responsibilities and provides mechanisms to increase information utilization across the functions as well as resolving conflict between them.

5.1. Future Research

This study investigates an integrated NPD model with the data of the Turkish electronics companies.

One research opportunity is to test the significance of some variables, which are found insignificant in the financial performance model, such as proficiency of initial screening, proficiency of user needs and wants study, and proficiency of lab tests on the project performance and design proficiency since may be indirectly related to financial performance.

Another research opportunity is to include the size of the company in the investigation in case it might have an effect on performance variables.

Early Supplier Involvement (ESI) is another issue that can be included to product design proficiency model. DFM, which will be very beneficial for the companies in many directions, would be easier by this way. Some researches upon ESI are as follows:

Dowlatshahi (2000) focused on facilitating an interface and collaboration among designer, buyer and suplier at three palanning horizons with respect to supplier relations. The main issues concerned in this relationship are, long-term strategic alliances; supplier R&D investment and financial strength; confidental relationship; reduction in the number of suppliers; information sharing; supplier plant visitation; supplier selection, evaluation and certification; supplier training/meetings and the inspection and receiving policy.

Wasti and Liker(1997) suggested that the level of supplier involvement in design work is positively associated with the customization and technological uncertainty of the design on hand; strategic importance of the design of the component to the customer; business dependence of supplier on the customer; number of years the supplier has supplied the customer; inhouse capabilities of the supplier; product development personnel resources of the supplier, competitiveness of the supplier's designs, success in the performance history of the supplier. And it is negatively associated with the availability of alternate suppliers for the design of the component on hand and level of performance monitoring activities undertaken by the customer.

Bidault et al.(1998) found that the office equipment sector displayed a much higher level of ESI adoption than did electrical appliances and consumer electronics. The analysis included that organizational choice seems to play a more important role in ESI adoption than do external factors. The industry segment also played a role, and surprisingly the level of ESI adoption was higher in American projects than in these studied in Japan and Europe. And they suggest that the notion of a growing technology mix continues to be important but requires an empirical approach different from the one employed to clarify its impact on ESI adoption.

Liker et al. (1996) pointed the benefits of gathering information at the earlier stages of the design process from the suppliers, instead of forcing them to produce the finished design. With set-based concurrent engineering, designers gradually reduce the set of possibilities rather than choosing an early winner. They reasoned that set-based techniques require experience and a strong working relationship between customer and supplier. And again, QFD plays an important role in set-based design practices.

Maffin and Braiden (2001) showed that the appropriate organizational process and other mechanisms relating to the roles and interfaces of manufacturing and suppliers are determined by a range of contextual factors, not least of which are the characteristics of individual projects in their research. Therefore, rather than adopt a model of best-practice, companies need to develop procedures which more adequately reflect their inherent needs and the types of project they undertake.

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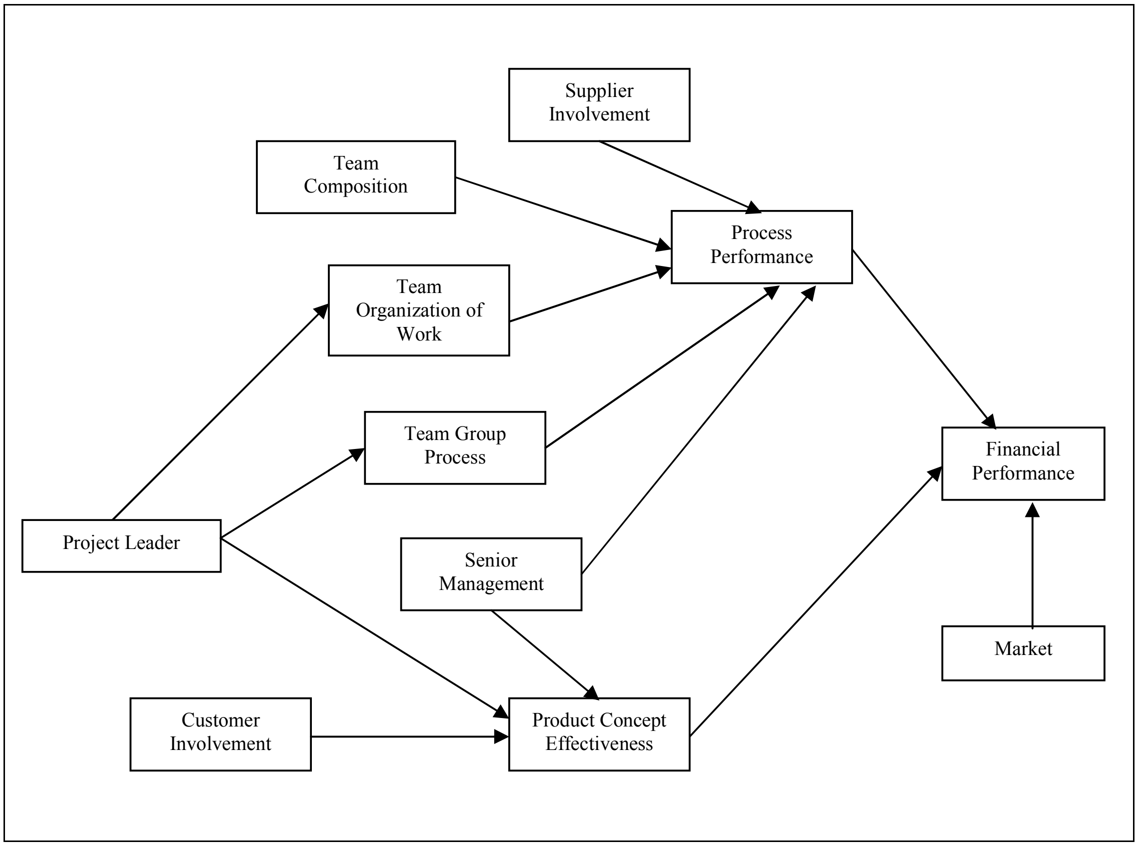


FIGURE 2.1. The synthesized model of S.L. Brown and K.M. Eisenhardt (Brown, 1995)

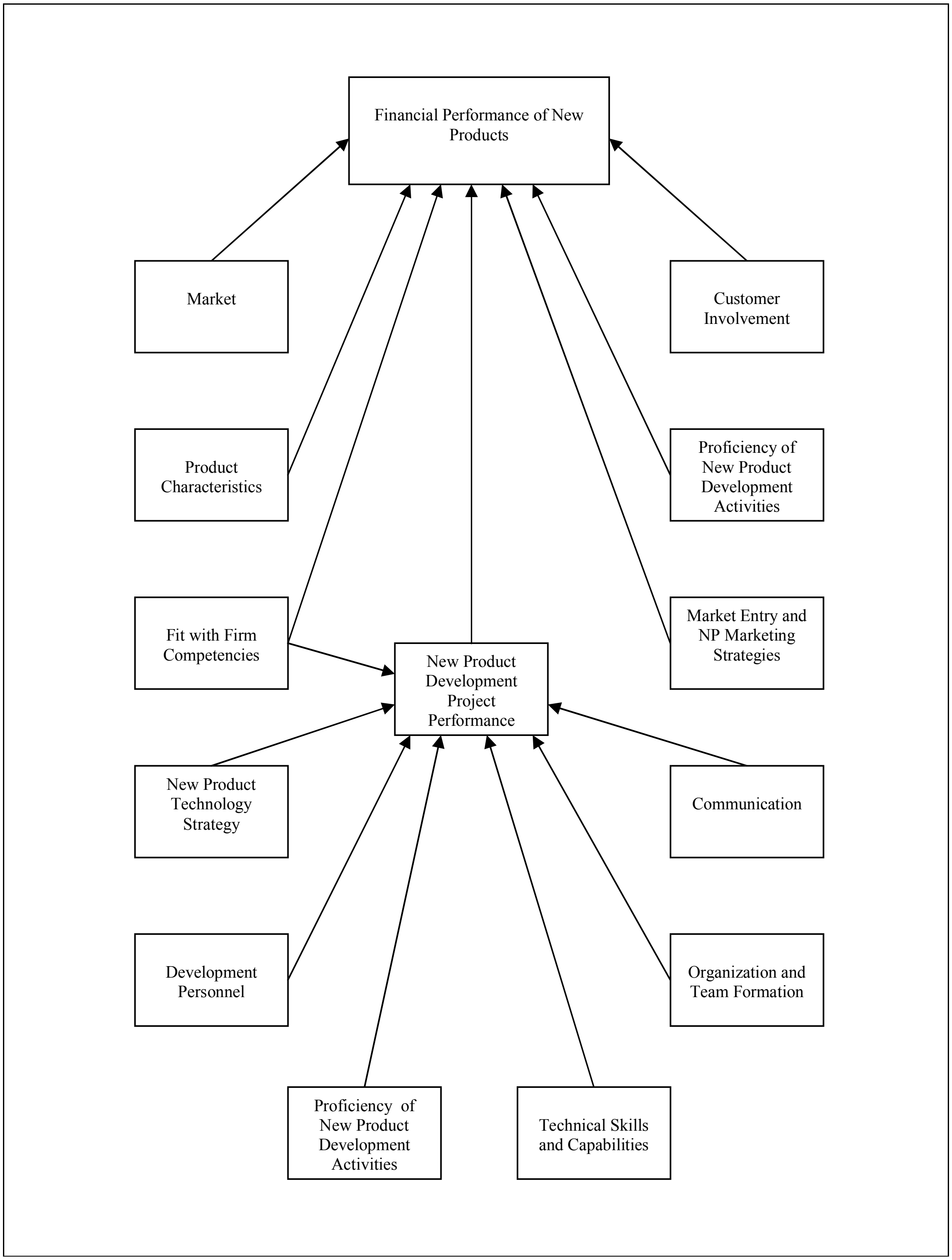


FIGURE 3.1. The integrated new product development model

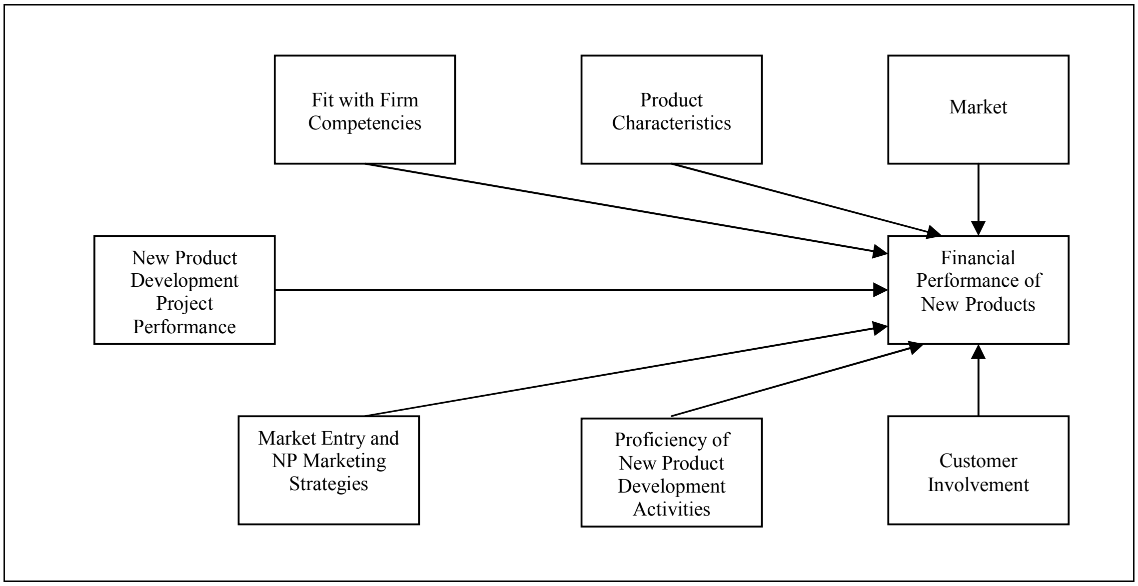


FIGURE 3.1.1. The financial performance model

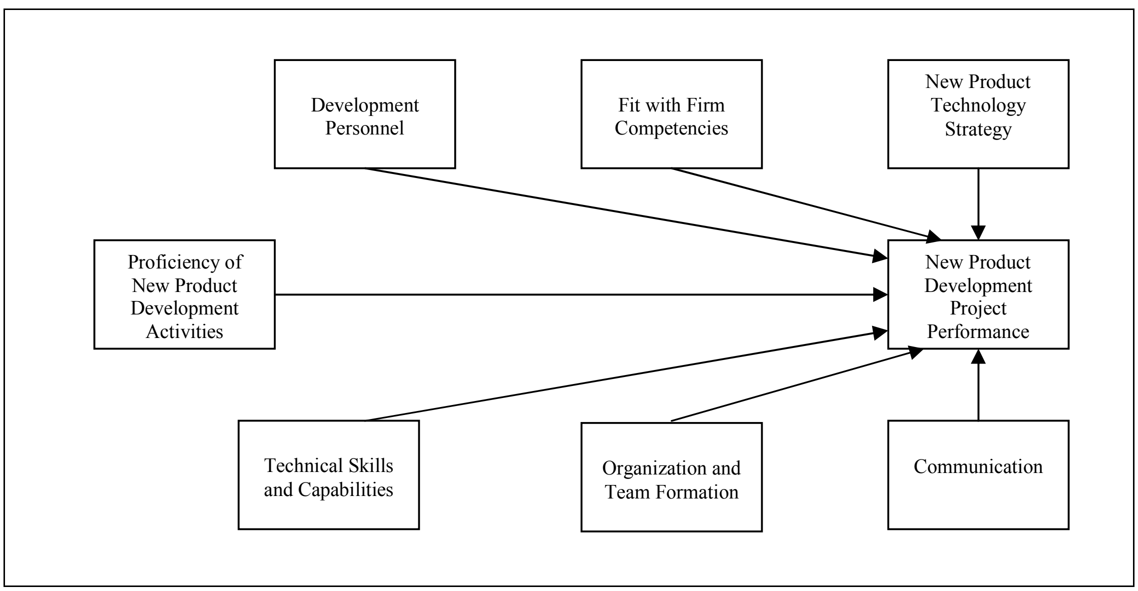


FIGURE 3.2.1. The project performance model

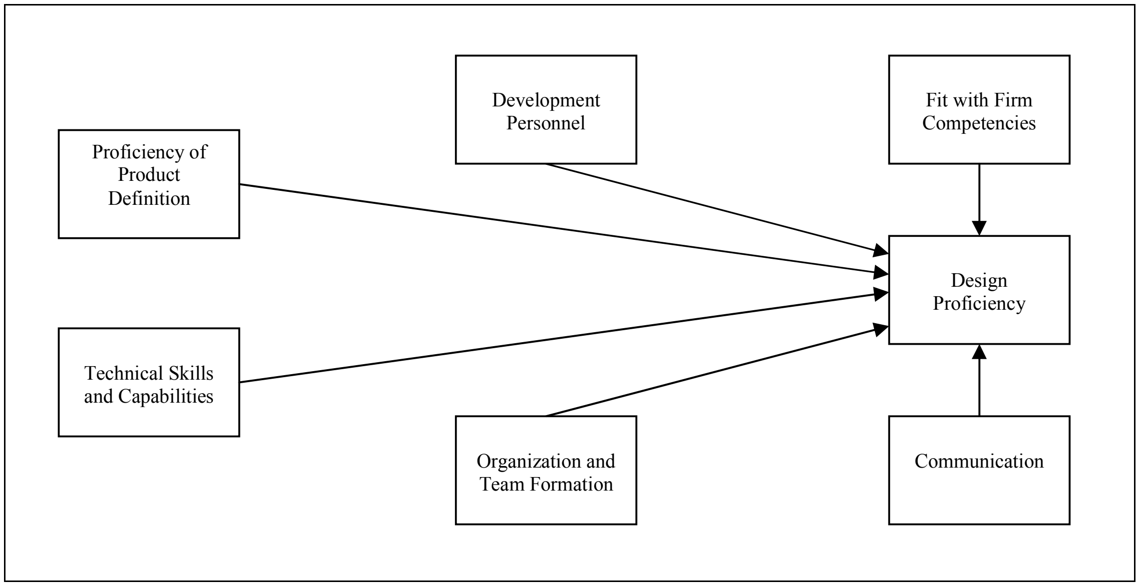


FIGURE 3.3.1. The design proficiency model

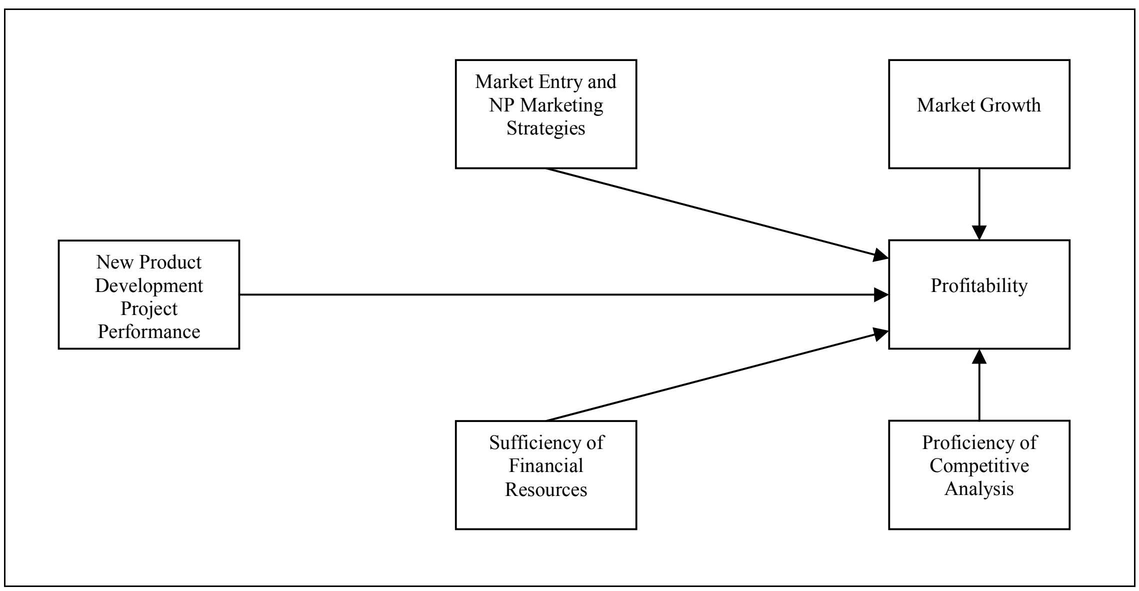


FIGURE 4.3.1. The financial performance model with significant findings

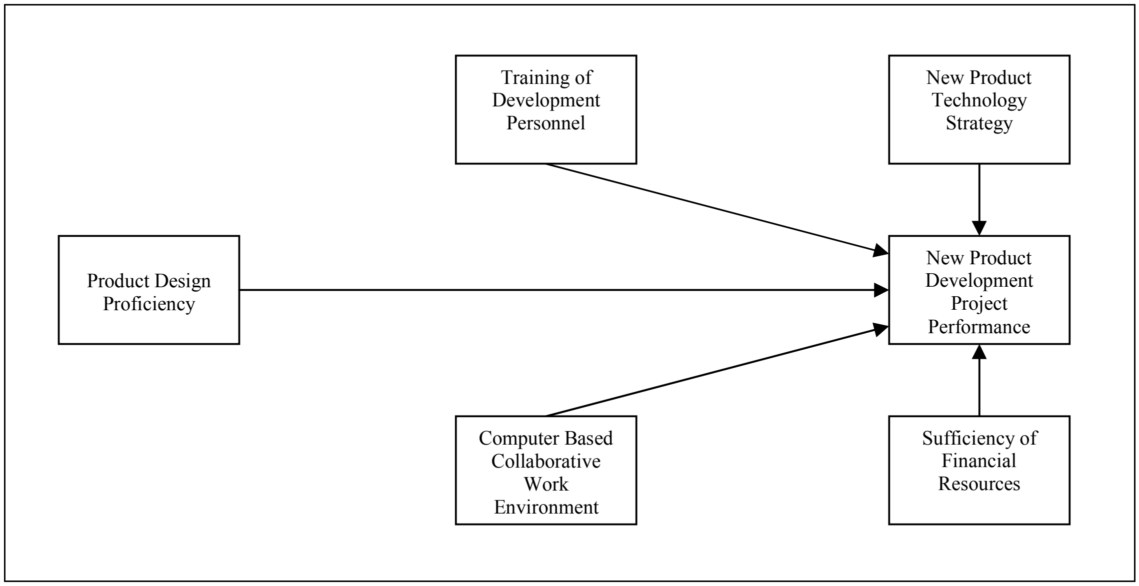


FIGURE 4.5.1 The project performance model with significant findings

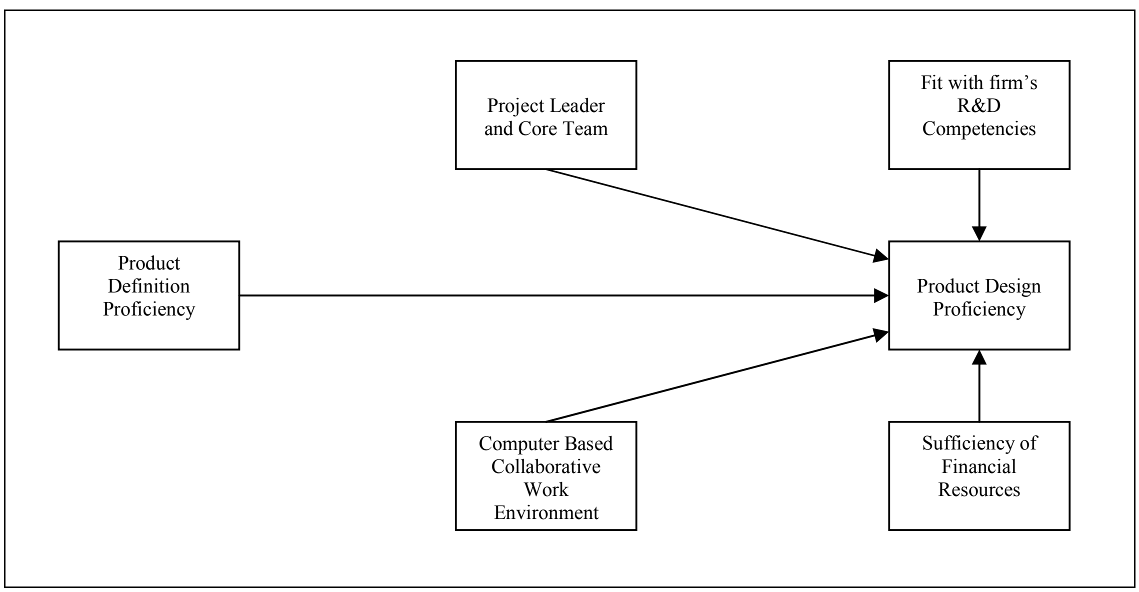
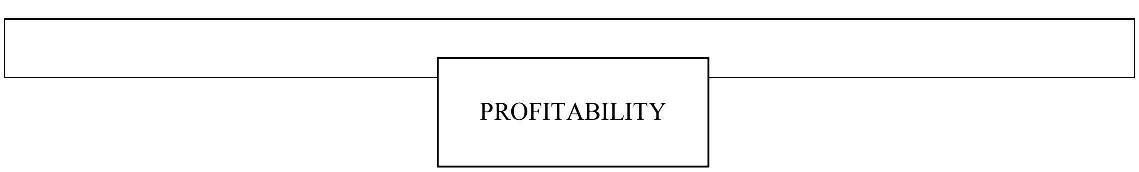


FIGURE 4.7.1. The design proficiency model with significant findings



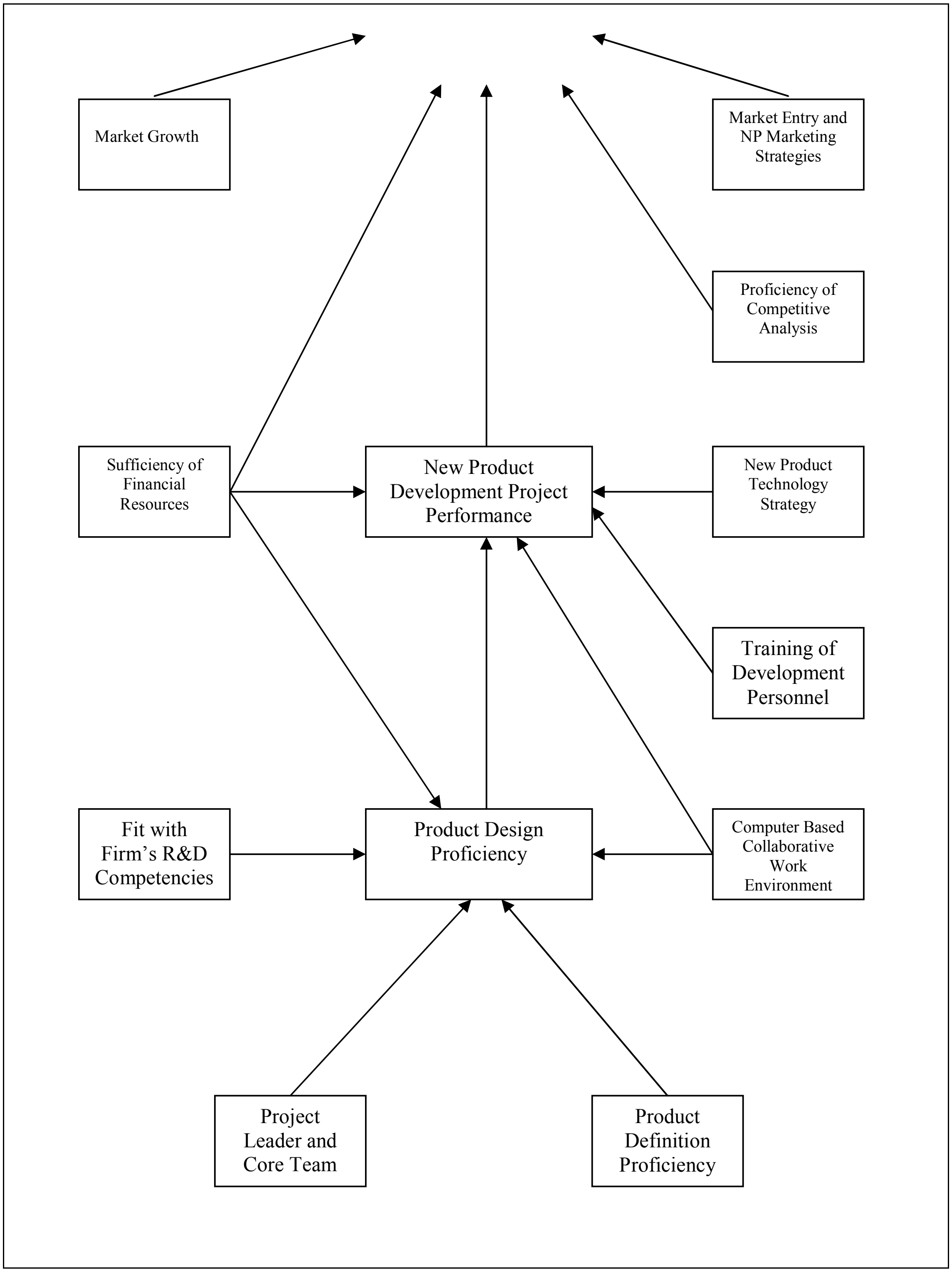


FIGURE 5.1. The integrated new product development model with significant findings