INVOLVEMENT IN STANDARDS DEVELOPMENT AND PRODUCT EFFECTIVENESS

by

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in partial fulfillment of the requirements for the degree of
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ABSTRACT

The objective of this research is to develop and test a model that captures how standards activities influence product effectiveness and how company-level factors influence standards activities. The model developed in the thesis integrates the product development, standards management, and competitive aggressiveness literatures. I conceptualize standards activities as having five dimensions: number of contributions made to standards groups, number of standards-related alliances the company joins, contribution diversity, alliance diversity, and time-to-commitment. I used data on 44 new products that incorporated one of five standards to test a set of eight hypotheses. My results suggest that: i. the number of contributions a company makes to groups pushing a standard and the number of standard-related alliances the company joins increases the product's market share more than the other dimensions of standards involvement; ii. the company's early installed base increases the number of contributions it makes to standards groups and the number and diversity of alliances the company joins; and iii. a company's number of early customers shortens the company's time-to-commit, while the greater the share in other markets lengthens it.

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1. INTRODUCTION

The academic literature on standards has been concerned with the economic analysis of network externalities and compatibility, the role of standards as tools for competitive advantage, and the determinants of the use for, and supply of standards (Bailetti & Callahan, 1995).

Although standards have been an important focus of much research in the economic literature due to their effect on competition, an examination of standards in the product development literature has been noticeably lacking. Widely read reviews of the product development literature (Brown & Eisenhardt, 1995; Krishnan & Ulrich, 2001) do not recognize the importance of standards in product development

While the strategic importance of standards is well established and progress has been made in understanding it, less is known about how the company's involvement in the development of a standard affects the market performance of the company's products that subsequently incorporate such standard.

The objective of this research is to develop and test a model that:

- relates a company's involvement in standards activities with the market performance of the products that subsequently incorporate the standard, and
- identifies how standards involvement is influenced by company level factors.

To test the model, this research will use data on companies that sell communications networks. In the networking industry, standard development is critical to adoption. The nature of the networking market drives suppliers to collaborate to develop standards so that interoperability can be achieved between vendors.

The environment examined in this research differs from others that have been examined in the literature. Figure 1 shows that this research is positioned in the networked-legitimization cell. The research is concerned about networked products, not stand alone products and about the legitimization phase of the technology adoption life cycle, not the competition phase. Typically, the literature to date has examined standalone products during the competition phase.

Figure 1. Standard development in networked and legitimization market

This research will be of interest mostly to: i. researchers who contribute to the product development, standards management, and competitive aggressiveness literatures; ii. product managers who invest in standards activities, and iii. technical and marketing

personnel responsible for managing the consistency between product development and standards evolution.

This thesis makes three contributions. First, the research model used in this thesis integrates the product development, standards management, and business strategy literatures.

The second contribution that this research makes is that managers can use the model to assess investments in standards related actions such as the development of contributions and the participation in alliances. The model improves our understanding of what standards related actions improve product effectiveness and what company factors constrain standards activities.

The third contribution that this research makes is that it provides an approach to assess the aggressiveness of a competitor's standards involvement strategy that depends on readily available data.

The thesis is organized into seven chapters. Chapter 1 is the introduction. Chapter 2 provides the literature review and the lessons learned from it. Chapter 3 develops the research model and the hypotheses tested in this study. Chapter 4 explains the research method. Chapter 5 presents the results and Chapter 6 discusses them. Chapter 7 provides the conclusions, identifies the limitations of the study and makes suggestions for further research.

2. LITERATURE REVIEW

The literature that is relevant to this research includes three streams: product development, standards management, and competitive aggressiveness. Section 2.1, 2.2, and 2.3 review the literature in the three research streams. Section 2.4 summarizes the lessons learned from the literature review.

2.1 Product-development literature

Brown and Eisenhardt (1995) and Krishnan and Ulrich (2001) have provided excellent reviews of the product development literature. Brown and Eisenhardt (1995) organized the product development literature into three research streams: rational plan, communication web, and disciplined problem solving, while Krishnan and Ulrich (2001) reviewed the literature from a decision-making perspective.

The rational plan research stream emphasizes that proper product planning leads to product success. Cooper (1979), and Cooper & Kleinschmidt (1987, 1993) found that large and growing markets, and extensive preliminary market and technical assessments were strongly associated with new product success. Standards involvement was not identified as a success factor in these studies.

The communication web research stream considers that communication among team members and outsiders is an important factor to product success. Ancona and Caldwell (1992) identified that a proper external communication strategy helps a product-development team gain task-related information and increase product success. Communications anchored around standards involvement was not identified as being critical by those who contribute to this research stream.

The problem solving research stream emphasizes the coordination between senior management and development teams. Clark and Fujimoto (1991) concluded that heavyweight team leaders and product integrity determine product success. Heavy weight team leaders create product concepts with senior management and communicate with project teams. Product integrity suggests that senior manager's product vision needs to align to development efforts at the project level. Contributors to this literature do not identify standards involvement as a contributor to product integrity.

Krishnan and Ulrich (2001) organized the product development literature around the important decisions that need to be made in a development project. Contributors to this literature include Christensen and Bower (1996), Moorthy and Png (1992), Iansiti (1995), and Krishnan and Bhattacharya (1998). Decisions making in development projects examines conflicts with existing markets, timing and sequence of product introduction, concurrency between technologies development and product development. Christensen and Bower (1996) studied the disk drive industry. They found that established firms fail to recognize market shifts due to resource conflicts between its existing markets and the

new product opportunities they identify. Moorthy and Png (1992) studied the trade-off between cannibalization versus faster accrual of profits when making decisions of product introduction timing. Recent work suggests that product introduction timing may be affected by network externalities or technological improvements (Padmanabhan et al. 1997, Bhattacharya et al. 1998). Research on decisions making also found a firm has to develop new technologies and new products concurrently (Iansiti 1995, Krishnan & Bhattacharya 1998). Once again, standards involvement is not central to the literature focused on decision making in product development.

2.2 Standards management literature

The standards management literature argues that standards are key aspect of product development. This literature can be organized into three streams. The first stream focuses on the benefits that standards provide companies. Shapiro and Varian (1999b) studied how standards make information sharing easier and that how increases the value of user networks and generates greater return on investment. Researchers who studied competition in the VCR, TV, and software industries, concluded that vendors can enjoy large profits after their technologies become industry standards (Besen & Farrell 1994; Shapiro & Varian 1999a).

Companies benefit from standards by accessing larger user networks and reducing uncertainty (Besen & Farrell 1994; Farrell & Saloner 1988; Katz & Shapiro 1994).

Recently, Funk (2003) studied how DoCoMo and its four phone suppliers were actively involved in the development of digital phone standards in Japan and how this involvement helped DoCoMo and its suppliers dominate the cellular phone market that emerged as a result of the new standards.

Weiss and Spring (1992), Spring and Weiss (1994), and David and Monroe (1994) suggest that companies derive benefits from their active participation in standards activities in three ways. First, they increase the company's prestige and advance their industry leadership aspirations. Second, companies benefit from standards involvement because it enables their early entry to a new market that is based on a standard. The third benefit companies derive from standards participation is information sharing.

The second research stream in the standards management literature focuses on how companies recover what they invest in standards. Standard development is costly and time-consuming (Spring et al. 1995). Besen and Saloner (1989a, 1989b) and Shapiro and Varian (1999b) identified four types of contributions companies make to standards groups: financial support, standard group leadership, technology contributions, and standard promotions.

Spring and Weiss (1994) suggest that a firm can recover its standard investments by selling to customers that are willing to pay for products that incorporate the standard and by providing consulting services to other firms who need the knowledge about the standard.

The third research stream focuses on the competitive strategies anchored around standards that companies use. Shapiro and Varian (1999a, 1999b) studied strategies on standard management from industries such as transportation, electricity, broadcasting, telecommunications, banking, and software. They identified nine corporate strategies that used standards to compete. These strategies are 1. Increase installed base of users to make user networks more valuable; 2. Use intellectual property rights to control new technology or interfaces; 3. Innovate continuously to advance technology; 4. Bring product that incorporates a new standard to the market first; 5. Enhance manufacturing capabilities and produce low-cost standard components; 6. Develop complement product for established markets; 7. Form alliances; 8. Improve company reputation in the marketplace; and 9. Release product roadmap and manage users' expectations.

2.3 Competitive aggressiveness literature

Ferrier, a key contributor to the competitive aggressiveness literature, examined the relationship between a firm's competitive actions and its market performance (Ferrier 2001). Competitive actions refer to a sequence of activities that a firm carries out over time in order to enhance its competitive position in the market place. Ferrier developed a process model of competitive aggressiveness and then tested it using a sample that included 224 companies from 16 different industries. Ferrier's model posits that four dimensions of competitive aggressiveness affect a firm's performance. These dimensions are: volume, duration, complexity, and unpredictability. The model also recognizes that

company-level factors constrain and enable a firm's competitive aggressiveness. These factors include: top management team heterogeneity (TMT), past performance, organizational slack. Although attack complexity and attack unpredictability are partially supported by data, attack volume and attack duration are proved to contribute to market share gains.

Various researchers have examined the relationship between TMT heterogeneity and a firm's performance (Bantel & Jackson 1989; Bantel 1993; Carpenter & Frederickson 2001; Hambrick, Cho, & Chen 1996; Bunderson & Sutcliffe 2002). By sampling competitive actions and response of 32 U.S. airlines over eight years, Hambrick, Cho, and Chen (1996) found TMT heterogeneity increases firm's effectiveness when responding to competitive challenges.

2.4 Lessons learned from the literature review

The literature streams relevant to this research are three: product development, standards management, and competitive aggressiveness. This section provides the four key insights learned from reviewing the literature.

Literature streams have evolved independently from each other

Most firms that develop and market computer and telecommunications products are involved in standards setting. However, the product development, standard management, and competitive aggressiveness literatures have advanced quite independently from each other. For example, reviews of the product development literature (Brown & Eisenhardt 1995; Krishnan & Ulrich 2001) and the competitive aggressiveness literature (Ferrier 2001) make no mention of the importance of standards involvement.

Similarly, important frameworks used in the competitive strategy literature have not been incorporated by either the product development or standards strategy literatures. For example, Ferrier's competitive aggressiveness framework can be used to study the involvement of firms in standard setting at different levels of activity.

A lack of models that relate standards involvement with product effectiveness

How can we assess a company's involvement in standards setting? Top management teams are aware of the importance of standards involvement. Many companies fund their employees' active participation in standard setting organizations. However, they have no models to assess the return on investment in standards activities. A model that captures the relationship between standards involvement and the market performance of the products that incorporate these standards does not exist.

Company support for standards groups can be classified into four types

The contributions that companies make to standards groups can be classified into four types: financial support, standard group leadership, technology, and standard promotions (Besen & Saloner 1989a, 1989b; Shapiro & Varian 1999b). Financial support refers to the provision of funds to sponsor a standard group or operate a standard's organization. Standard group leadership refers to providing company employees to act as chairs or directors of standards groups. Technology contributions refer to funding employees to make technology presentations at standard group meetings and preparing drafts relevant to the standard. Standard promotion refers to the activities a company undertakes to promote one or more standards.

3. RESEARCH MODEL AND HYPOTHESES

3.1 Research model

The objective of this research is to develop and test a model that:

- relates a company's involvement in standards activities with the market performance of the products that subsequently incorporate the standard, and
- identifies how standards involvement is influenced by company level factors.

Figure 2 provides the research model used in the thesis. It is a two-part model that identifies the antecedents and consequences of aggressive standards involvement. The model builds on the work by Ferrier (2001) and describes how company-level factors influence the aggressiveness of standards involvement and how standards involvement influences product effectiveness. Aggressive standards involvement is related to better product effectiveness.

FIGURE 2. ANTECEDENTS AND CONSEQUENCES OF AGGRESSIVENESS IN STANDARDS INVOLVEMENT

On the left of Figure 2, I identify three factors expected to constrain and enable the company's aggressiveness towards standards involvement. These company-level factors are: i. number of early customers before standards were approved, ii. company's share in other markets, and iii. number of patents that are relevant to the standard and are owned by the company.

I conceptualize the aggressiveness of standards involvement has having five dimensions: i. number of contributions made to standards groups, ii. number of standard related

alliances to which the company is a part, iii. contribution diversity, iv. alliance diversity, and v. time-to-commit. The first two dimensions, number of contributions and number of alliances, correspond to the volume dimension used by Ferrier (2001). The next two dimensions, contribution diversity and alliance diversity correspond to Ferrier's diversity dimension. I introduce a new dimension of aggressiveness. Time-to-commit refers to the number of months between when the standards group is officially formed and when the company commits to the standard. The shorter the time-to-commit, the greater the standards involvement aggressiveness.

Brown and Eisenhardt distinguish between product effectiveness and product efficiency (Brown & Eisenhardt 1995). In this thesis, I am concerned about product effectiveness and not efficiency. On the right of Figure 2, I show that product effectiveness is measured as the market share of the company's products that incorporate the standard. Market share was the preferred measure of product effectiveness because data on market share is widely used and, for large markets, readily available from market tracking organizations.

3.2 Company-level factors and aggressiveness of standards involvement

Number of early customers

Number of early customers refers to the number of customers prior to standard implementation (Shapiro & Varian 1999a, 1999b; Funk & Methe 2001). Research on growth has identified the directions in which company growth can be pursued (Baghai et. al, 2000; Kotler, 1999). The sale of more of what the company makes to existing customers is an attractive path for growth. A large installed base allows the company to expand sales to existing customers, reduces the cost of finding customers for the products that incorporate the standards, makes it easier for the company's technical personnel to experiment with standard implementation, and increases the rapidity of customer feedback. This makes the payoff from making many contributions of various types to standards groups attractive. A small installed base, in comparison, inhibits the company's ability to invest in making many standards related contributions of various types. Accordingly, I predict that the size of the installed base increases the number of contributions a company makes to standards groups and the diversity of these contributions. Therefore,

Hypothesis 1a. Number of early customers is positively related to the number of contributions the company makes to standards groups.

Hypothesis 1b. Number of early customers is positively related to contribution diversity.

To push for the establishment of a new standard or a particular definition of a standard, companies form alliances (Shapiro & Varian, 1999a, 1999b). Success in establishing a large installed base may give rise to complacency and organizational routines that inhibit strategic change. Poor past performance provides the motivation for strategic change (Lant et al., 1992; Starbuck, 1983). The top management team of a company with a large installed base is more likely to believe that the company has the power in the market place to go at it alone and be less willing to join standards related alliances. In addition, the top management team may be unwilling to share its rich set of experiences with members of various alliances. Without the benefit of the company's experiences, competitors need to invest more time and money. Accordingly, I predict that size of the installed base reduces the company's motivation to join a large number of standards related alliances. Therefore,

Hypothesis 1c. Number of early customers is negatively related to the number of alliances a company joins.

A large installed base provides company employees with more opportunities to develop relationships with different types of organizations and a greater awareness to sense strategic problems. Accordingly, I predict that a large installed base increases the

company's motivation to join alliances that include different types of organizations. Therefore,

Hypothesis 1d. Number of early customers is positively related to alliance diversity.

A large installed base increases the potential for the firm to profit from early commitment to a new standard. It increases the potential to grow via additional sales to existing customers and reduces development and customer acquisition costs. A large installed base reduces the uncertainty associated with early commitment to a new standard. Accordingly, I predict that size of the installed base shortens the time a company takes to commit to a new standard. Therefore,

Hypothesis 1e. Number of early customers shortens the company's time-to-commit.

Share in other markets

The second set of hypotheses focus on the relationship between a firm's share in other markets and its contributions to standard groups working to define standards in new markets. TMTs of firms that enjoy large market shares in existing markets may be willing to support the activities of standard groups working to define standards in new markets to

keep open the option to invest heavily later for the purpose of leading it. However, these firms have experience in standards activities and will be more focused in the type of standards related activities in which they invest. Therefore,

Hypothesis 2a. Share in other markets is positively related to the number of contributions the company makes to standards groups.

Hypothesis 2b. Share in other markets is negatively related to contribution diversity.

Top management teams may be unwilling to join a large number of alliances anchored around standards that affect markets where the firm does not enjoy large market shares. If the firm does join an alliance it would probably be one comprised of homogenous members. Accordingly, I predict that a large share in markets other than those affected by the standard decreases the number of standard related alliances the company joins and increases the likelihood that the company will only join those that have homogeneous membership. Therefore,

Hypothesis 2c. Share in other markets is negatively related to the number of alliances the company joins.

Hypothesis 2d. Share in other markets is negatively related to alliance diversity.

A TMT of a firm that leads in existing markets may take longer to commit to new standards. Attention required by the markets their firm leads may detract from giving attention to the new standard. TMTs may be more preoccupied with issues that concern markets where the firm has larger market shares. Moreover, committing to a standard at an early stage is risky. Given that attention is required elsewhere, top management teams may be less willing to make risky decisions. Accordingly, I predict that the greater the share in markets other than those affected by the standard delays the timing of the company's decision to commit to the standard. Therefore,

Hypothesis 2e. Share in other markets lengthens the company's time-to-commit.

Number of patents

Patents affect the company's standards involvement (Weiss & Spring, 1992; Spring & Weiss, 1994; Shapiro & Varian 1999a, 1999b). Company employees who championed the filing of patents that are found to be related to new standards may be interested in participating in many different standards activities. They will seek to make contributions to standards groups and participate in alliances in order to increase the value of their patents. They will also pressure the company to commit to the new standards early. Accordingly, I predict that a larger number of patents are related with a larger number of standards related contributions and alliances, greater contribution and alliance diversity, and a shorter time-to commit. Therefore,

Hypothesis 3a. Number of patents is positively related to the number of contributions the company makes to standards groups.

Hypothesis 3b. Number of patents is positively related to standards contribution diversity.

Hypothesis 3c. Number of patents is positively related to the number of alliances the company joins.

Hypothesis 3d. Number of patents is positively related to alliance diversity.

Hypothesis 3e. Number of patents shortens the company's time-to-commit.

3.3 Aggressiveness of standards involvement and product effectiveness

Number of contributions to standards groups and number of alliances

Researchers in the competitive aggressiveness research stream, suggest that aggressive companies experience higher performance (Ferrier, 2001; Young, 1996). According to these researchers, companies that carry out more actions than their rivals will be exploiting more opportunities and closing off the potential for action on the part of their rivals. Accordingly, I predict that the number of contributions to standards groups and the number of alliances the company joins is positively related to market share of the new product that incorporates the standard. Therefore,

Hypothesis 4. The number of contributions a company makes to standards groups will be positively related to market share.

Hypotheses 5. The number of alliances the company joins will be positively related to market share.

Diversity

Companies that carry out a wide range of action types are more aggressive. These companies attack rivals on multiple fronts. Previous research suggests that companies

that carry out a complex repertoire of competitive actions experience higher levels of performance (Ferrier, 2001). Accordingly, I predict that greater contribution diversity and greater alliance diversity increase market share new product. Therefore,

Hypothesis 6. Contribution diversity will be positively related to market share.

Hypotheses 7. Alliance diversity will be positively related to market share.

Time-to-commit

Time-to-commit refers to the number of months between when the standards group is officially formed and when the company announces the introduction of a new product that complies with the standard (Besen & Saloner, 1989a, 1989b; Shapiro & Varian 1999a, 1999b). Early introduction of a product that complies with a standard allows the company to accumulate more knowledge on how to implement the standard and how to compete in the marketplace based on the standard. This allows the early adopter to attack more effectively those companies that adopt the standard at a later date. Accordingly, I predict that a short time-to-commit increases market share of new product. Therefore,

Hypotheses 8. Time-to-commit will be negatively related to market share.

4. RESEARCH METHOD

4.1 Unit of analysis

The unit of analysis is a product which is compliant with a networking standard and was introduced by a supplier of networks.

4.2 Time period

The time period of the study is from October 1995 to December 2000.

4.3 Sample selection

Three steps were followed to select the sample. The networking standards that were to be part of the study were identified first. In the second step, I identified those companies for which market share data was available two years after the standards were approved. In the third step, I identified the companies that had been involved in standards activities prior to the date the standard was approved.

The sample was comprised of new products, each of which

- had implemented one or more standards
- the companies that developed and introduced them had been involved in establishing the standards
- had market share data available two years after the standard they implemented was approved.

Step 1. Standard selection

Firms that track market share report market share data by market segment. Some of these market segments directly relate to one or more standards the products implement.

In the first step, I examined the market share reports issued by five market tracking firms: Dell'Oro, RHK, IDG, Synergy, and Infonetics during the second half of 2003 and identified those market segments that in my opinion were directly related to a standard implementation in the product.

I then discussed the list with seven individuals with expertise in networking standards.

The outcome of this step was a list of the networking standards to be used in this research.

I am satisfied that there is no other networking standard that could have been added to this list.

Step 2. Products for which market share was available

I used the reports issued by the five market tracking firms listed above to identify the products for which market share was reported two years after the standards were approved.

For each standard selected in step 1, I identified the products for which market-tracking firms reported market share data two years after the standard the products implemented was approved.

The outcome of the second step was a list that included the names of the products for which market share was available two years after the standard was established and the names of the companies that developed and introduced these products.

Step 3. Standards participation

In step 3, I used archives in official standard websites to identify which companies in the list prepared in step 2 had been involved in establishing the standards their products implement. The products that were included in the list developed by companies not involved in establishing the standard were eliminated from the sample.

The outcome of step 3 was a list of the companies to be used in the sample.

Appendix C includes the names of the 11 companies that were not involved in standards development but owned market share two years after the standards were approved.

4.4 Variable measurement

Of the nine variables in the model shown in Figure 2, three are company-level factors, five are dimensions of standards involvement aggressiveness, and one is a measure of product effectiveness. In this section we described how these variables were measured

Company-level Factors

Company-level factors include: number of early customers, share in other markets, and number of patents.

Number of early customers

Number of early customers was measured as the number of customers who purchased the standard-related products from the company that committed to implementing a standard before the standard was approved.

Share in other markets

Share in other markets was measured as the number of information communications market segments in which the company had a market share that ranked amongst the top five in the year the standard was approved. Some companies are market leaders in several industries. The share in other markets variable is a count of the number of market segments in the information communications industry where the company had one of the top five market share positions. For example, if company A is a market leader in market segments in the automotive industry, mining industry, manufacturing industry, and information technology industry, the variable Share in other markets only counts the number of market segments in the information technology industry where “Company A” had a market share in the top five positions.

Number of patents

Number of patents was measured as the number of U.S. patents relevant to the standard that were issued to the company.

Standards involvement aggressiveness

Standards involvement aggressiveness is comprised of: number of contributions to the standards forums, number of alliances in which the company is a part, contribution diversity, alliance diversity, and time-to-commit.

Number of contributions to standards groups

Number of contributions to standards groups was measured as the sum of the number of contributions made to the four contribution types: financial support, standard group leadership, technology, and promotion. The number of financial support contributions was measured as the number of times a company provided funds to sponsor a standard group or operate a standard's organization.

The number of standard group leadership contributions was measured as the number of the company's employees that were appointed chairman or director of standards groups.

The number of technology contributions was measured as the sum of the number of technology presentations company employees made at standard group meetings and the number of drafts relevant to the standard that were produced by company employees.

The number of promotion contributions was measured as the number of news releases, white papers, and leader speech related to the standard that the company published in its website and industry websites.

Number of alliances

Number of alliances was measured as the number of standard related alliances which the company formed before the standard was approved of which the company was a part.

Contribution diversity

Contribution diversity, CH, was measured using a variation of the Herfindal-Hirschman index,

$$CH = 1 - \sum P_i^2$$

Where P is the percentage represented by each of the four contribution types identified in the literature review: financial support, standard group leadership, technology, and promotion.

Alliances diversity

Alliance diversity, AH, was also measured using a variation of the Herfindal-Hirschman index,

$$AH = 1 - \sum P_i^2$$

where P is the percentage represented by each of six alliance types: i. Computer Software, ii. Computer Services, iii. Computer Hardware/Electronic Instruments & Controls/Semiconductors ; iv. Communications Equipment; v. Resellers; and vi. Others.

Time-to-commit

Time-to-commit was measured as the number of months between when a standard group is officially formed and when the company announces the introduction of its first product introducing the standard.

Market share

Market share was measured as the portion of worldwide shipments in a market segment that was accounted for by the company's shipments. It is company's market share in the market segment two years after the standard was approved.

4.5 Data collection

For each product in the sample, data on nine variables was collected.

Company-level factors

Data on number of early customers was first collected from industry news websites and then verified with information provided in companies' websites. Industry news websites are valuable sources of company information and make profits by providing accurate and up-to-date information. To collect the data, I used the search engines provided in the industry news websites and searched for key words related to the standards. I then counted the number of customer announcements made by the company. To increase data accuracy, I cross-referenced the data obtained from an industry news website with data in companies' websites.

Data on share in other markets was collected from marketing reports. The data reflects the annual ranking of company's market share. The data was collected from five marketing research firms: Dell'Oro, IDC, Infonetics, RHK, and Synergy. I counted number of market segments that the company's market share is ranked in the top five in the year when the standard was approved.

Data on number of patents was collected from U.S. Patent Full-Text and Full-Page Image Databases (<http://www.uspto.gov/patft/index.html>). I counted the number of issued patents related to the standard that were awarded to company from the time when a standard group was formed and when the standard was approved.

Standards involvement dimensions

Five dimensions measure standards involvement: number of contributions, number of alliances, contribution diversity, alliance diversity, and time-to-commit.

Data on the number of contributions is comprised of four categories: financial support, standard group leadership, technology, and promotion. I collected data on financial support, standard group leadership, and technology contributions from standard official websites. Data on standard promotion was collected from industry news websites. I counted the number of product trials, number of announcements about the product roadmap, and the number of speeches related to the standard made by the companies' leaders.

Data on the number of alliances was collected from industry news websites. I searched these websites looking for announcements about alliances related to the standards. Based on the contents of the alliance related announcements, I identified the role of the alliance

partners. Once again the announcements found in the industry news websites were validated with information provided in companies' websites.

Time-to-commit was calculated as the number of months between when the standards group was formed and when the company announced its commitment to implement the standard. The information was collected from industry news websites and company websites.

Product effectiveness

Data on market share was collected from the information published online by the following market tracking organizations:

- Dell'Oro
- IDC
- Infonetics
- RHK
- Synergy

4.6 Data analysis

In the first step of the data analysis I obtained descriptive statistics for the variables in Figure 2 and examined whether or not they were normally distributed. I determined that my variables were not normally distributed.

In the second step, I tested the null hypothesis that pairs of variables were associated. I first examined associations amongst company-level factors, then amongst standard involvement dimensions, then amongst company-level factors and standards involvement dimensions, and finally between standards-involvement dimensions and market share. I used these findings to build the structured equation model illustrated in Figure 2.

In the third step, I used stepwise regression analysis with forward selection to explore the relationships between each standard involvement dimension and the three company level factors and between market share and the five standard involvement dimensions.

In the fourth step, I used the results of the correlation tests and stepwise regressions to build the models that captured the relationships in Figure 2 and could be run with the AMOS software.

In the fifth step, I used the results from the AMOS regressions and correlation tests to reject or accept the hypotheses developed in section 3.

Descriptive statistics

Descriptive statistics for the nine variables shown in Figure 2 were calculated. I used the Skewness and Kurtosis statistics to evaluate if a variable was normally distributed.

A variable was considered normally distributed if the absolute value of the standard error of the Skewness statistic was less than 2 and the absolute value of the standard error of the Kurtosis statistic was less than 2.

Correlation tests

Spearman rank order correlation tests were used to measure the strength of the association between variables. This was done because examination of the variables' skewness and kurtosis statistics indicated that three of the nine variables were not normally distributed. If all the variables were normally distributed, their association would have been tested using Pearson's correlation coefficients. Moreover, when the sample size is large (more than 40 observations), the results obtained from testing Spearman and Pearson correlations are very similar.

The Spearman rank correlation coefficient is a nonparametric rank statistic. It replaces values of data with ranks and measures the linear relationship between the two sets of ranks (Norusis, 2002).

Null hypothesis of each association between two variables is:

H_0 : There is no association between the rank pairs.

When the direction of relationship is unknown, a two-tailed test is required. Alternative hypothesis of a two-tailed test is:

H_a : There is an association between the rank pairs.

When the direction of relationship is known, a one-tailed test is required. Alternative hypothesis of an one-tailed test is:

H_a : The association between the rank pairs is positive (or negative)

When $P > .10$, I considered that a null hypothesis is accepted and the association of two variables is not significant. When $P < .10$, I considered the null hypothesis to be not supported. Three levels of significance indicating the strength of an association will be shown in all tables. These are: $P < .01$, $P < .05$, and $P < .10$.

Stepwise regressions with forward selections

Stepwise regression is used to identify the smallest number of variables that explain the largest variance of the dependent variable. Stepwise regression is used as an exploratory tool. There was no intent to use stepwise regressions to develop an optimal regression equation with predictive purposes. The problems of making statistical inferences using stepwise regressions are discussed in Hays (1994).

Each of the five dimensions of standard involvement was regressed against the three company-specific variables. In each regression, an explanatory variable is entered one at a time, generally with the goal of accounting for the largest additional amount of variance of market share with each new company-specific factor added to the equation.

Structural Equation Models

The results of the correlation tests and the stepwise regressions were used to build a structural equation model for the variables in Figure 2. Structural Equation Modeling (SEM) is a statistical modeling technique that provides factor analysis, path analysis and regression. It is an extension to the general linear model and often used to test a set of regression equation simultaneously and discover relationships inside test model. (Benter & Chou, 1987; Hoyle, 1995; Information Technology Services, 2001)

A SEM model implies a structure of the covariance matrix of the measured variables. The relationships of variables inside test model are expressed as restrictions on the total set of possible relationships. (Information Technology Services, 2001)

Each SEM model consists of three types of variables: 1) independent variables, which are assumed to be measured without error, are called exogenous or upstream variables. 2) dependent variables or mediating variables are called endogenous or downstream variables. 3) Latent or unobserved variables are not directly measured but affect the relationships or correlations among measured variables in the analysis. (Information Technology Services, 2001)

Although normally distributed data are ideal to SEM, the criteria can't be fully met in practice. Generally, it recommends that large sample size should be collected when data are not normally distributed. Thus, the more data are collected, the better results are produced.

The chi-square test is used to measure the fitness of the model. If the probability value (P) of the chi-square is below .05, the model will be not be accepted. It indicates that the model does not fit the data.

The Tucker-Lewis Index (TLI), and the Root Mean Square Error of Approximation (RMSEA) are the two other statistics used to measure fitness of test model. They are used

to assess the overall fit of test model. Hu and Bentler (1999) recommend RMSEA values below .06 and Tucker-Lewis Index values of .95 or higher.

In this study, a model is fit if

- 1) The P of the chi-square test of absolute model fit is .05 or higher;
- 2) The TLI index is .95 or higher;
- 3) The RMSEA is .08 or less.

Hypotheses testing

Once a test model satisfies above criteria, the hypotheses were tested using the P of the regression estimates obtained using the AMOS software. A $P < .10$ indicated that the relationship between the dependent and independent variable was significant.

Results of correlation tests were also used to accept or reject hypotheses when the pair of variables of interest was not included in the structure equation models that met the goodness of fit criteria.

5. RESULTS

5.1 Sample

The sample is comprised of 44 products that implemented one or more of the five standards shown in Table 1. This table provides a brief description of the standards, the date when a group was formed to develop the standard, the date when the standard was approved, and the number of samples in the standard.

Thirty-three networking companies introduced the 44 products from October 1995 to December 2000.

TABLE 1. STANDARDS THAT WERE IMPLEMENTED IN THE PRODUCTS IN THE SAMPLE

Standard Name	Description	Date Formed	Date Approved	Number of products
Cable Lab - Cable Modem DOCSIS 1.0	A protocol supports high-speed data traffic over cable networks.	Nov-95	Mar-98	8
DSL Forum - ITU-T G. Lite ADSL	A protocol supports high-speed asymmetrical data traffic over a pair of copper lines.	Jun-96	Aug-98	12
Fibre Channel Association - T11.3 FC-HBA	A protocol allows systems and storage devices to connect more efficiently.	Jan-99	Nov-00	6
Gigabit Ethernet -IEEE P802.3z	A protocol supports Ethernet data to be transferred at 1000Mbps in Local Area Network(LAN).	Nov-95	Jul-97	11
Wireless LAN - IEEE P802.11a/b	A protocol family supports wireless data communications in Ethernet frame format.	Sep-97	Aug-99	7

5.2 Descriptive statistics

Table 2 presents the descriptive statistics for the nine variables in the study.

Examination of Skewness and Kurtosis indicates that three variables are not normally distributed: number of patents, number of alliances, and market share. Skewness statistics for these three variables are greater than +2 and their Kurtosis statistics are greater than +2. The other six variables in Table 2 are normally distributed.

TABLE 2. DESCRIPTIVE STATISTICS (SAMPLE SIZE = 44)

	Min	Max	Mean	Standard deviation	Skewness (Std.E=.36)	Kurtosis (Std.E=.70)
Number of early customers	0	8	1.72	2.06	1.38	1.42
Share in other markets	0	7	2.05	1.90	0.50	-0.64
Number of patents	0	17	1.96	3.15	3.27	12.76
Number of contributions	4	56	21.59	13.76	0.97	0.28
Number of alliances	1	33	5.89	5.81	2.84	10.74
Contribution diversity	0	0.72	0.43	0.14	-0.47	0.66
Alliance diversity	0	0.82	0.45	0.27	-0.82	-0.78
Time-to-commit	4	31	18.82	6.89	-0.14	-0.49
Market share	0.46	64.57	8.94	12.89	2.94	9.47

5.3 Spearman correlation coefficients

Company-level factors

Table 3 provides the Spearman correlation coefficients for the three company-level factors: Number of early customers, Share in other markets, and Number of patents. Two tailed tests of the alternative hypothesis at $P < .01$ show no association between the company-level factors. Number of early customers and number of patents are associated when $p < .10$.

TABLE 3. SPEARMAN CORRELATIONS FOR COMPANY-LEVEL FACTORS (SAMPLE SIZE = 44)

	Number of early customers	Share in other markets	Number of patents
Number of early customers	1.000 .		
Share in other markets	-.097 (.532)	1.000 .	
Number of patents	.271 (.076*)	.122 (.429)	1.000 .

* $p < .1$ (two tailed)

** $p < .05$ (two tailed)

*** $p < .01$ (two tailed)

Standards involvement dimensions

Table 4 provides the Spearman correlation coefficient for the five dimensions of standards involvement aggressiveness. Two tailed tests of the alternative hypothesis at $P < .10$ show the following associations:

- Number of contributions is associated with Number of alliances
- Number of contributions is associated with Contribution diversity
- Number of contributions is associated with Alliance diversity
- Number of alliances is associated with Contribution diversity
- Number of alliances is associated with Alliance diversity
- Number of alliances is associated with Time-to-commit
- Contribution diversity is associated with Alliance diversity

TABLE 4. SPEARMAN CORRELATION COEFFICIENTS FOR THE FIVE DIMENSIONS OF STANDARDS INVOLVEMENT AGGRESSIVENESS (SAMPLE SIZE = 44)

	Number of contributions	Number of alliances	Contribution diversity	Alliance diversity
Number of contributions	1.000 .			
Number of alliances	.528*** (.000)	1.000 .		
Contribution diversity	.553*** (.000)	.363** (.015)	1.000 .	
Alliance diversity	.623*** (.000)	.772*** (.000)	.553*** (.000)	1.000 .
Time-to-commit	-.108 (.486)	-.277* (.069)	-.196 (.201)	-.248 (.104)

* $p < .1$ (two tailed)

** $p < .05$ (two tailed)

*** $p < .01$ (two tailed)

Company-level factors and dimensions of standards involvement

Table 5 shows the Spearman correlation coefficients for the associations between the three company-level factors and the five dimensions of standards involvement aggressiveness.

TABLE 5. SPEARMAN CORRELATION COEFFICIENTS FOR THE ASSOCIATIONS BETWEEN COMPANY-LEVEL FACTORS AND DIMENSIONS OF STANDARDS INVOLVEMENT AGGRESSIVENESS (SAMPLE SIZE = 44)

	Hypothesis 1	Hypothesis 2	Hypothesis 3
	Number of early customers	Share in other markets	Number of patents
Number of contributions	.331** (.020)	.232* (.065)	.064 (.339)
Number of alliances	.509*** (.000)	-.055 (.361)	.173 (.130)
Contribution diversity	.278** (.034)	.154 (.159)	.004 (.489)
Alliance diversity	.424*** (.002)	.019 (.450)	.142 (.179)
Time-to-commit	-.514*** (.000)	.329** (.015)	-.080 (.304)

* $p < .1$

** $p < .05$

*** $p < .01$

One tailed tests of the alternative hypothesis at $P < 0.10$ show the following associations:

- Number of early customers is positively associated with Number of contributions
- Number of early customers is positively associated with Number of alliances
- Number of early customers is positively associated with Contribution diversity
- Number of early customers is positively associated with alliance diversity
- Number of early customers is negatively associated with Time-to-commit
- Share in other markets is positively associated with Number of contributions
- Share in other markets is positively associated with Time-to-commit

Dimensions of standard involvement and market share

Table 6 shows the Spearman correlation coefficients for the associations between the five dimensions of standards involvement aggressiveness and market share.

TABLE 6. SPEARMAN CORRELATION COEFFICIENTS FOR THE ASSOCIATIONS BETWEEN THE FIVE DIMENSIONS OF STANDARDS INVOLVEMENT AGGRESSIVENESS AND MARKET SHARE (SAMPLE SIZE = 44)

	Hypothesis 4	Hypothesis 5	Hypothesis 6	Hypothesis 7	Hypothesis 8
	Number of contributions	Number of alliances	Contribution diversity	Alliance diversity	Time-to-commit
Market share	.442*** (.001)	.627*** (.000)	.350** (.010)	.688*** (.000)	-.292** (.027)

* $p < .1$

** $p < .05$

*** $p < .01$

One tailed tests of the alternative hypothesis at $P < 0.10$ show the following associations:

- Number of contributions is positively associated with Market share
- Number of alliances is positively associated with Market share
- Contribution diversity is positively associated with Market share
- Alliance diversity is positively associated with Market share
- Time-to-commit is positively associated with Market share

5.4 Stepwise regressions with forward selection

Dimensions of standards involvement

Table 7, 8, 9, and 10 provides the results of regressing Number of contributions, Number of alliances, Alliance diversity, and Time-to-commit against the three company-level factors using the stepwise procedure with forward selection. No explanatory variable was entered in the regression with Contribution diversity as the dependent variable. Thus, no table corresponding to Contribution diversity is included in this section.

Number of early customers was entered as an explanatory variable in five of the four regressions (Number of contributions, Number of alliances, Alliance diversity and Time-to-commit), while Share in other markets was entered in the regression for Time-to-commit.

TABLE 7. STEPWISE REGRESSION WITH NUMBER OF CONTRIBUTIONS AS THE DEPENDENT VARIABLE AND COMPANY-LEVEL FACTORS AS THE POTENTIAL EXPLANATORY VARIABLES (SAMPLE SIZE = 44)

Explanatory Variables included	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Adjusted R square
	B	Std. Error	Beta			
(Constant)	17.899	2.587		6.919	.000	.084
Number of early customers	2.166	.973	.325	2.226	.031**	

* p < .1
 ** p < .05
 *** p < .01

TABLE 8. STEPWISE REGRESSION WITH NUMBER OF ALLIANCES AS THE DEPENDENT VARIABLE AND COMPANY-LEVEL FACTORS AS THE POTENTIAL EXPLANATORY VARIABLES (SAMPLE SIZE = 44)

Explanatory Variables included	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Adjusted R square
	B	Std. Error	Beta			
(Constant)	3.127	.945		3.308	.002	.315
Number of early customers	1.619	.356	.575	4.554	.000***	

* p < .1
 ** p < .05
 *** p < .01

TABLE 9. STEPWISE REGRESSION WITH ALLIANCE DIVERSITY AS THE DEPENDENT VARIABLE AND COMPANY-LEVEL FACTORS AS THE POTENTIAL EXPLANATORY VARIABLES (SAMPLE SIZE = 44)

Explanatory Variables included	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Adjusted R square
	B	Std. Error	Beta			
(Constant)	.352	.048		7.324	.000	.174
Number of early customers	.057	.018	.439	3.167	.003***	

* p < .1
 ** p < .05
 *** p < .01

TABLE 10. STEPWISE REGRESSION WITH TIME-TO-COMMIT AS THE DEPENDENT VARIABLE AND COMPANY-LEVEL FACTORS AS THE POTENTIAL EXPLANATORY VARIABLES (SAMPLE SIZE = 44)

Explanatory Variables included	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Adjusted R square
	B	Std. Error	Beta			
(Constant)	19.304	1.489		12.963	.000	.311
Number of early customers	-1.610	.423	-.483	-3.807	.000***	
Share in other markets	1.105	.459	.305	2.409	.021**	

* p < .1
 ** p < .05
 *** p < .01

Standards involvement aggressiveness and market share

Table 11 shows the results of regressing market share as the dependent variable and the dimensions of standards involvement as the dependent variables using the forward selection procedure. Two variables were entered into the regression: Number of alliances and Number of contributions.

TABLE 11. STEPWISE REGRESSION WITH MARKET SHARE AS THE DEPENDENT VARIABLE AND STANDARDS INVOLVEMENT DIMENSIONS AS THE POTENTIAL EXPLANATORY VARIABLES (SAMPLE SIZE = 44)

Explanatory Variables included	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Adjusted R square
	B	Std. Error	Beta			
(Constant)	-4.555	2.358		-1.932	.060	.585
Number of alliances	1.270	.261	.573	4.870	.000***	
Number of contributions	.279	.110	.298	2.534	.015**	

* p < .1
 ** p < .05
 *** p < .01

5.5 Structural Equation Models

I used AMOS to examine the models that capture the interactions amongst the nine variables in the research model shown in Figure 2. Model fitness was evaluated using the following criteria:

1. The probability of the model, P , should be greater than .05
2. The TLI index of the model should be greater than .95
3. The RMSEA of the model should be less than .08

Model 1

The results from the Spearman correlation tests shown in Table 5 and the stepwise regressions shown in Table 7, 8, 9, 10 support the specification of the following AMOS relations to capture how company-level factors affect dimensions of standards involvement aggressiveness:

- Number of early customers → Number of contribution
- Number of early customers → Number of alliances
- Number of early customers → Alliance diversity
- Number of early customers → Time-to-commit
- Share in other markets → Time-to-commit

The correlations for the variable-pairs shown in Table 5 are all significant at the $p < .10$ and the results of the stepwise regressions entered the variables shown on the left of the → as explanatory variables.

Table 5 indicated that Share in other markets was correlated with Number of contributions at $p < .10$. However, the results in Table 7 show that the stepwise regression with Number of contributions as the dependent variable did not enter Share in other markets as explanatory variable. Given the discrepancy, I decided to add another link to the AMOS software:

- Share in other markets → Number of contributions

The results from the Spearman correlation tests shown in Table 6 and the stepwise regression result shown in Table 11 both support the specification of the following AMOS relations to capture dimensions of standards involvement aggressiveness affect market share:

- Number of alliances → Market share
- Number of contributions → Market share

The results shown in Table 6 suggest that all five dimensions of standards involvement were correlated with market share at $p < .05$. Thus, I decided to add three more links to the AMOS software:

- Contribution diversity → Market share
- Alliance diversity → Market share
- Time-to-commit → Market share

Table 3 indicates that Number of early customers and Share in other markets are not correlated. Thus, I did not specify a correlation adjustment for these two variables in the AMOS software. Table 4 suggests that Number of contributions is correlated with Number of alliances, Contribution diversity and Alliance diversity; Number of alliances is correlated with Contribution diversity, Alliance diversity and Time-to-commit; and that Contribution diversity is correlated with Alliance diversity. Therefore, I specified correlation adjustments for all these associations in the AMOS software.

To summarize, Model 1 was specified as indicated below. A link on a path is denoted $\rightarrow$ and the correlation between two variables is denoted $\leftrightarrow$.

- Number of early customers $\rightarrow$ Number of contributions
- Number of early customers $\rightarrow$ Number of alliances
- Number of early customers $\rightarrow$ Contribution diversity
- Number of early customers $\rightarrow$ Alliance diversity
- Number of early customers $\rightarrow$ Time-to-commit
- Share in other markets $\rightarrow$ Number of contributions
- Share in other markets $\rightarrow$ Time-to-commit
- Number of contributions $\rightarrow$ Market share
- Number of alliances $\rightarrow$ Market share
- Contribution diversity $\rightarrow$ Market share
- Alliance diversity $\rightarrow$ Market share
- Time-to-commit $\rightarrow$ Market share
- Number of contributions $\leftrightarrow$ Number of alliances
- Number of contributions $\leftrightarrow$ Contribution diversity
- Number of contributions $\leftrightarrow$ Alliance diversity
- Number of alliances $\leftrightarrow$ Contribution diversity
- Number of alliances $\leftrightarrow$ Alliance diversity
- Number of alliances $\leftrightarrow$ Time-to-commit
- Contribution diversity $\leftrightarrow$ Alliance diversity

Figure 2 illustrates Model 1.

FIGURE 3. MODEL 1 DEVELOPED BASED ON RESULTS FROM SPEARMAN CORRELATION TESTS AND STEPWISE REGRESSIONS

Table 12 shows the AMOS results for Model 1. The goodness of fit statistics in Table 12 indicates that the model does not fit the data. The probability level for model 1 is less than .05, its TLI is less than .95 and its RMSEA is greater than .06.

TABLE 12. RESULTS OF USING AMOS TO OBTAIN REGRESSION ESTIMATES FOR MODEL 1

Model 1		Regression	p
Links in paths		estimate	
Chi-square = 23.590	Number of early customers → Number of contributions	.337	.014**
Degrees of freedom = 9	Number of early customers → Number of alliances	.576	.000***
Probability level = .005	Number of early customers → Contribution diversity	.295	.043**
TLI = .657	Number of early customers → Alliance diversity	.439	.001***
RMSEA = 0.194	Number of early customers → Time-to-commit	-.482	.000***
Squared multiple correlations	Share in other markets → Number of contributions	.278	.01**
Market share = .61	Share in other markets → Time-to-commit	.331	.007***
Number of contributions = .19	Number of contributions → Market share	.118	.028**
Number of alliances = .33	Number of alliances → Market share	.289	.000***
Contribution diversity = .08	Contribution diversity → Market share	.019	.871
Alliance diversity = .19	Alliance diversity → Market share	.037	.766
Time-to-commit = .34	Time-to-commit → Market share	.023	.813
* p < 0.10			
** p < 0.05			
*** p < 0.01			

Model 2

To improve the goodness of fit statistics, I specified model 2 without the three links in Table 12 that had the highest p values: Contribution diversity → Market share, Alliance diversity → Market share, and Time-to-commit → Market share.

The removal of the Contribution diversity $\rightarrow$ Market share link results in the removal of the Number of early customers $\rightarrow$ Contribution diversity link and three correlation associations: Number of contributions $\leftrightarrow$ Contribution diversity, Number of alliances $\leftrightarrow$ Contribution diversity, and Contribution diversity $\leftrightarrow$ Alliance diversity.

The removal of the Alliance diversity $\rightarrow$ Market share link, results in the removal of the Number of early customers $\rightarrow$ Alliance diversity link and two correlation associations: Number of contributions $\leftrightarrow$ Alliance diversity; Number of alliances $\leftrightarrow$ Alliance diversity.

The removal of the Time-to-commit $\rightarrow$ Market share link results in the removal of two links Number of early customers $\rightarrow$ Time-to-commit and Share in other markets $\rightarrow$ Time-to-commit as well as one association: Number of alliances $\leftrightarrow$ Time-to-commit.

Model 2 was specified as:

- Number of early customers $\rightarrow$ Number of contributions
- Number of early customers $\rightarrow$ Number of alliances
- Share in other markets $\rightarrow$ Number of contributions
- Number of contributions $\rightarrow$ Market share
- Number of alliances $\rightarrow$ Market share
- Number of contributions $\leftrightarrow$ Number of alliances

Figure 3 illustrates Model 2.

FIGURE 4. MODEL 2 DEVELOPED BY ELIMINATING LINKS FROM MODEL 1

Table 13 shows the results for model 2 obtained from the AMOS software.

TABLE 13. RESULTS OF USING AMOS TO OBTAIN REGRESSION ESTIMATES FOR MODEL 2

Model 2		Regression	p
Links in paths		estimate	
Chi-square = 13.164	Number of early customers → Number of contributions	.333	.013**
Degrees of freedom = 4	Number of early customers → Number of alliances	.575	.000***
Probability level = .011	Share in other markets → Number of contributions	.337	.003***
TLI = .726	Number of contributions → Market share	.304	.009***
RMSEA = .231	Number of alliances → Market share	.565	.000***
Squared multiple correlations			
Market share = .61			
Number of contributions = .22			
Number of alliances = .33			

* p < 0.10
 ** p < 0.05
 *** p < 0.01

The goodness of fit statistics in Table 10 does not meet the criteria. The probability level for model 2 is less than .05, its TLI is less than .95 and its RMSEA is greater than .06.

Model 3

There were two possible ways to improve the goodness of fit of model 2. I could eliminate the path starting with Number of early customers or eliminate the path starting with Share in other markets. Model 3 was specified by eliminating the path that started with Number of early customers in model 2.

Model 3 was specified as:

- Share in other markets → Number of contributions
- Number of contributions → Market share
- Number of alliances → Market share
- Number of contributions ↔ Number of alliances

Figure 4 illustrates Model 3.

FIGURE 5. MODEL 3 DEVELOPED BY ELIMINATING NUMBER OF EARLY CUSTOMERS FROM MODEL 2

TABLE 14. RESULTS OF USING AMOS TO OBTAIN REGRESSION ESTIMATES FOR MODEL 3

Model 3		Regression	p
Links in paths		estimate	
Chi-square = 1.478	Share in other markets → Number of contributions	.337	.003***
Degrees of freedom = 2	Number of contributions → Market share	.304	.009***
Probability level = .478	Number of alliances → Market share	.565	.000***
TLI = 1.027			
RMSEA = .000			
Squared multiple correlations			
Market share = .61			
Number of contributions = .11			
Number of alliances = .00			

* p < 0.10
 ** p < 0.05
 *** p < 0.01

The goodness of fit statistics in Table 14 meets the criteria. The probability level for model 3 is greater than .05, its TLI is greater than .95 and its RMSEA is less than .06.

Model 4

Model 4 was specified by eliminating the path that started with Share in other markets in model 2.

Model 4 was specified as:

- Number of early customers → Number of contributions
- Number of early customers → Number of alliances
- Number of contributions → Market share

- Number of alliances $\rightarrow$ Market share
- Number of contributions $\leftrightarrow$ Number of alliances

Figure 5 illustrates Model 4.

FIGURE 6. MODEL 4 DEVELOPED BY ELIMINATING SHARE IN OTHER MARKETS FROM MODEL 2

TABLE 15. RESULTS OF USING AMOS TO OBTAIN REGRESSION ESTIMATES FOR MODEL 4

Model 4		Regression estimate	P
Links in paths			
Chi-square = 11.673	Number of early customers → Number of contributions	.325	.024**
Degrees of freedom = 1	Number of early customers → Number of alliances	.575	.000***
Probability level = .001	Number of contributions → Market share	.298	.009**
TLI = .182	Number of alliances → Market share	.573	.000***
RMSEA = .498			
Squared multiple correlations			
Market share = .61			
Number of contributions = .11			
Number of alliances = .00			

* p < 0.10
 ** p < 0.05
 *** p < 0.01

The goodness of fit statistics in Table 15 does not meet the criteria. The probability level for model 4 is less than .05, its TLI is less than .95 and its RMSEA is greater than .06.

Model 3 fits the data much better than models 1, 2 and 4 do.

5.6 Testing hypotheses

Table 16 shows the results of testing the hypotheses. A hypothesis is supported when:

- the results from the Spearman's correlation analysis shown in Tables 5 and 6 support the hypothesis at $p < .10$
and
- the results from the stepwise regression analysis shown in Tables 7, 8, 9, 10 or the Model 3 results shown in Table 14 support the hypothesis at $p < .10$

A test outcome is denoted inconclusive if the results of Spearman correlation tests contradict Model 3 results or the stepwise regression results.

TABLE 16. RESULTS OF TESTING HYPOTHESES USING SPEARMAN CORRELATION ANALYSIS, REGRESSION ANALYSIS AND SEM

Hypothesis	Test Outcome	Rationale
Hypothesis 1a. Number of early customers is positively related to the number of contributions the company makes to standards groups.	Supported	Correlation coefficient in Table 5 is positive and significant at $p < 0.05$; regression coefficient in Table 7 is positive and significant at $p < .05$.
Hypothesis 1b. Number of early customers is positively related to contribution diversity.	Not supported	Correlation coefficient in Table 5 is positive and significant at $p < 0.05$; stepwise regression with contribution diversity as the dependent variable and the company-level factors as explanatory variables did not enter Number of early customers or any other variable.
Hypothesis 1c. Number of early customers is negatively related to the number of alliances a company joins.	Not supported, significant association is in the opposite direction	Correlation coefficient in Table 5 is positive and significant at $p < 0.1$; regression coefficient in Table 8 is positive and significant at $p < .001$.
Hypothesis 1d. Number of early customers is positively related to alliance diversity.	Supported	Correlation coefficient in Table 5 is positive and significant at $p < 0.1$; regression coefficient in Table 9 is positive and significant at $p < .001$.
Hypothesis 1e. Number of early customers shortens the company's time-to-commit.	Supported	Correlation coefficient in Table 5 is negative and significant at $p < 0.1$; regression coefficient in Table 10 is negative and significant at $p < .01$.

Hypothesis 2a. Share in other markets is positively related to the number of contributions the company makes to standards groups.	Supported	Correlation coefficient in Table 5 is positive and significant at $p < 0.1$; regression estimate in Model 3 in Table 14 is positive and significant at $p < 0.1$.
Hypothesis 2b. Share in other markets is negatively related to contribution diversity.	Not supported	Correlation coefficient in Table 5 is not significant at $p < 0.1$; stepwise regression with contribution diversity as the dependent variable and the company-level factors as explanatory variables did not enter Share in other market or any other variable.
Hypothesis 2c. Share in other markets is negatively related to the number of alliances the company joins.	Not supported	Correlation coefficient in Table 5 is not significant at $p < 0.1$.
Hypothesis 2d. Share in other markets is negatively related to alliance diversity.	Not supported	Correlation coefficient in Table 5 is not significant at $p < 0.1$.
Hypothesis 2e. Share in other markets lengthens the company's time-to-commit.	Supported	Correlation coefficient in Table 5 is positive and significant at $p < 0.05$; regression coefficient in Table 10 is positive and significant at $p < .05$.
Hypothesis 3a. Number of patents is positively related to the number of contributions the company makes to standards groups.	Not supported	Correlation coefficient in Table 5 is not significant at $p < 0.1$.
Hypothesis 3b. Number of patents is positively related to standards contribution diversity.	Not supported	Correlation coefficient in Table 5 is not significant at $p < 0.1$; stepwise regression with contribution diversity as the dependent variable and the

		company-level factors as explanatory variables did not enter Number of patents or any other variable.
Hypothesis 3c. Number of patents is positively related to number of alliances the company joins.	Not supported	Correlation coefficient in Table 5 is not significant at $p < 0.1$.
Hypothesis 3d. Number of patents is positively related to alliance diversity.	Not supported	Correlation coefficient in Table 5 is not significant at $p < 0.1$.
Hypothesis 3e. Number of patents shortens a company's time-to-commit.	Not supported	Correlation coefficient in Table 5 is not significant at $p < 0.1$.
Hypothesis 4. The number of contributions a company makes to standards groups will be positively related to market share.	Supported	Correlation coefficient in Table 6 is positive and significant at $p < 0.01$; regression estimate in model 3 in Table 14 are positive and significant at $p < 0.01$.
Hypotheses 5. The number of alliances a company joins will be positively related to market share.	Supported	Correlation coefficient in Table 6 is positive and significant at $p < 0.01$; regression estimate in Model 3 in Table 14 is positive and significant at $p < 0.01$.
Hypothesis 6. Contribution diversity will be positively related to market share.	Not supported	Correlation coefficient in Table 6 is positive and significant at $p < 0.05$; regression estimate in Model 1 in Table 12 is not significant at $p < 0.1$.
Hypotheses 7. Alliance diversity will be positively related to market share.	Not supported	Correlation coefficient in Table 6 is positive and significant at $p < 0.01$; regression estimate in Model 1 in Table 12 is not significant at $p < 0.1$.

Hypotheses 8. Time-to-commit will be negatively related to market share.	Not supported	Correlation coefficient in Table 6 is negative and significant at $p < 0.05$; regression estimate in Model 1 in Table 12 is not significant at $p < .10$.
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6. DISCUSSION OF RESULTS

This research is the first empirical study that examines the relationship between standards involvement and product market performance. A research model that integrates the literature on product development, standard management, and competitive aggressiveness was developed. Eight sets of hypotheses were derived from the research model. The hypotheses were tested using a sample of 44 new products introduced by 33 networking companies that participated in standards activities. Spearman's correlation analysis, regression analysis and SEM were used for the purpose of testing the hypotheses.

6.1 Company-level factors that affect standards involvement

Number of early customers

Shapiro and Varian (1999a, 1999b) suggested that building an early customer community is an effective strategy in standard competitions. Therefore, the first set of hypotheses stated that a company's Number of early customers:

- was positively related to the number of contributions the company makes to the standards groups, contribution diversity, and alliance diversity
- was negatively related to the number of alliances the company joins to push standards
- shortens the company's time-to-commit to the standard

My results support Hypothesis 1a, 1d and 1e. The greater the Number of early customers, the greater the number of contributions the company will make to support groups pushing the standard, the greater the variety of standard related alliances the company will join, and the shorter the time the company takes to commit to a standard. Table 16 provides the rationale for supporting these three hypotheses.

Based on the results I need to reject Hypothesis 1c. An association between Number of early customers and Number of alliances exists, however, it is in the opposite direction than the one I predicted. I had predicted that a larger installed base would decrease the number of standard related alliances the company joins. The results indicate the contrary. They suggest that a company's installed base is positively related to the number of alliances the company joins.

Share in other markets

The second set of hypotheses stated that share in other markets:

- was positively related to the number of contributions the company makes to standards groups
- was negatively related to contribution diversity, number of alliances the company joins and alliance diversity
- lengthens the company's time-to-commit

My results support hypotheses 2a and 2e. High share in other markets increases the number of contributions the company makes to standards groups and lengthens the company's time-to-commit.

In my research, share in other markets is not a proxy for company size. There is no reason to believe that large companies that are also market leaders in various market segments will also lead in new market segments.

My results suggest that share in other markets is not related to the number of alliances a company joins or contribution and alliance diversity.

Christensen (1997) argues that market leaders normally develop advanced technologies earlier than their competitors. My results support the argument that vendors who own high market shares in other market segments make a greater number of contributions to the development of a standard in a new market.

Number of patents

Weiss and Spring (1992), Shapiro and Varian (1999a, 1999b) suggested that intellectual property is an important asset in standard competitions. My research attempted to examine how intellectual property affects standards involvement aggressiveness. The

third set of hypotheses stated that the number of patents related to the standards that were owned by the company:

- was positively related to the number of contributions the company makes to standards groups and the number of standards-related alliances the company joins, and the diversity of contribution and alliances
- shortens time-to-commit

My results indicate that number of standards-related patents a company holds is not associated with any of the five dimensions of standards involvement aggressiveness. The hypotheses that were part of the third set of hypothesis were not accepted.

6.2 Dimensions of standards involvement that affect market share

Number of contributions to standards groups and number of alliances

Hypotheses 4 and 5 posited that the number of contributions the company makes to the groups pushing the standard and the number of standard related alliances the company joins, the better the product will perform in the market. My results support both hypotheses. The Spearman correlation coefficients measuring the association between number of contribution and market share and number of alliances and market share shown in Table 6 are positive and significant at $p < .01$. The regression estimates for number of contributions and number of alliances in model 3 shown in Table 14 are

positive and significant at $p < .01$. The SEM results indicates that number of contribution and number of alliances significantly affect market share with $R^2 = .61$. I believe that the R^2 is high because my research used data from networking industry. Networking standard affects end-user's attitude of new networking technologies. Vendors must co-operate in standard development and technology promotions so that massive technology adaptation can happen. I do not believe that similar results can be obtained when the sample is comprised of standalone products drawn from the competition phase of the technology adoption life cycle.

My findings support studies on standard management that standards activities affect new product sales (Spring & Weiss 1994; Shapiro & Varian 1999a, 1999b). Number of contributions to standards groups and number of alliances are the two measures that were used to evaluate how actively vendors participated in standards activities. Studies on standard management suggest that vendors can benefit from active standards involvement by accessing a larger number of potential customers and generating more sales leads.

Contribution diversity and alliance diversity

I expected that contribution diversity and alliance diversity to increase market share. Thus, hypotheses 6 and 7 were developed. Based on my results, I cannot conclusively state that diversity affects market share.

The results from the correlation analyses (shown in Table 6) support hypothesis 6 at $p < 0.05$ and hypothesis 7 at $p < .01$. However, the regression estimates in model 1 in Table 12 do not support these two hypotheses.

Shapiro and Varian (1999a, 1999b) argue that market complements can help a firm to attain advantages in standard competitions. Market complement is important to a new product because it implies the new product is viable to other businesses. Alliance diversity can be a measure that evaluates the degree of market complements. I classified alliances into six categories. Higher alliance diversity reflects the fact that a company has a broad complement of alliances anchored around the standard. From the results, I can't conclude that alliance diversity increases the market share of a new product. However, my results indicate that a relationship between alliance diversity and market share may exist.

Time-to-commit

Hypothesis 8 was developed to reflect the expectation that the time it takes a company to commit to a standard is negatively related to market share. I expected that the longer it takes a company to commit to a standard, the smaller the market share of the company's products that implement the standard. .

Testing of hypothesis 8 led to inconclusive results. In Table 6, I show that the association between time-to-commit and market share is negative at $p < .05$. This result supports hypothesis 8. The regression estimates shown in Model 1 in Table 12 are not significant at $p < 0.1$. This result would lead me to reject hypothesis 8.

6.3 Key findings

The key findings are:

- The number of contributions a company makes to groups pushing a standard and the number of standard-related alliances the company joins increases the product's market share more than the other dimensions of standards involvement.
- Number of early customers increases the number of contributions a company makes to standards groups and the number and diversity of alliances the company joins.
- A company's share in other markets increases its contributions that it makes to the standards groups.
- A company's Number of early customers shortens the time-to-commit, while the greater the share in other markets lengthens it.
- Number of standard-related patents held by the company does not affect the company's standards involvement aggressiveness.
- Contribution diversity, alliance diversity and time-to-commit *may* increase market share.

7. CONCLUSIONS, LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

7.1 Conclusions

My research used Ferrier's framework (Ferrier 2001) to study the relationship between a company's involvement in the activities that push the development of a standard and the market performance of the product that incorporates the standard. The model describes how company-level factors influence the standards activities and how standards involvement aggressiveness influences the market share of new products.

Data available online for 44 new products from 33 networking companies were used to test eight sets of hypotheses. The first three sets of hypotheses examined the relationship between company-level factors and standards involvement. Five sets of hypotheses examined the relationship between standards involvement and product's market share.

We used Spearman's correlation analysis and SEM to test the hypotheses. Results suggest that the number of contributions to the groups evolving the standard and the number of standard related alliances the company joins to push the standard affect market share and that Number of early customers and share in other markets affect standards involvement.

My study integrates research on product development, standards management and competitive aggressiveness. It offers a framework to assess investment in standards activities from a product effectiveness perspective.

7.2 Limitations

This study has three important limitations. First, the number of networking standards limited the size of the sample to 44 new products. I am confident that I included all the possible standards in this study. A sample of 44 limits the numbers of variables that can be examined simultaneously using techniques such as SEM.

The second limitation is that the researcher had to both collect online data and classify it into categories to calculate the measures of contribution and alliance diversity. This means that my biases may have affected how data was classified which then affected the measures of contribution and alliance diversity.

The third limitation is that the results may not be generalized to other industries. The most variables of my research model were identified from literature in information technology. The sample included only networking companies. No claims that the findings apply to other industries can be made.

7.3 Suggestions for future research

Future research could use the structure presented as Figure 2 as a framework to study the relationship between standards involvement and market share in other industries.

There are 11 companies that didn't involve in the whole cycle of standard definitions but their market shares were reported by market research reports in two years after the standards were approved. Future research can use data from these companies and study how company can succeed in the market segments that related to standards without active standard participation.

Sample size is a major limitation in my research. Future research can increase the sample size.

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Appendix A STANDARD GROUP LIST

TABLE 17. STANDARD GROUP INFORMATION

<p>Cable Labs - Cable modem DOCSIS 1.0</p> <ul style="list-style-type: none">• Official Website www.cablelabs.com
<p>Search key words: “Cable Modem” or “DOCSIS” between “1995-11-01” and “1998-04-01”</p> <ul style="list-style-type: none">• news.search.com• search.nwfusion.com• www.cabledatacomnews.com
<p>DSL forum - ITU-T G.Lite ADSL</p> <ul style="list-style-type: none">• Official Website www.dslforum.org
<p>Search key words: “ADSL” or “DSL” between “1996-06-01” and “1999-08-01”</p> <ul style="list-style-type: none">• news.search.com• search.nwfusion.com• www.telecommagazine.com• www.convergedigest.com
<p>Fibre Channel Association - T11.3 FC-HBA</p> <ul style="list-style-type: none">• Official Website www.fibrechannel.org
<p>Search key words: “Fibre Channel” between “1999-01-01” and “2000-12-01”</p> <ul style="list-style-type: none">• news.search.com• search.nwfusion.com• www.t11.org• www.storagenetworkingworld.com• www.snia.org

Gigabit Ethernet – IEEE P802.3z

- Official Website <http://grouper.ieee.org/groups/802/3/z/public/index.html>

Search key words: “**Gigabit Ethernet**” or “**GE**” between “**1995-11-01**” and “**1998-08-01**”

- news.search.com
- search.nwfusion.com

Wireless LAN - IEEE P802.11a/b

- Official Website <http://www.ieee802.org/11/>

Search key words: “**Wireless LAN**” or “**WiFi**” between “**1997-09-01**” and “**1999-09-01**”

- news.search.com
- search.nwfusion.com
- www.weca.net
- www.wi-fi.com
- www.wlana.org

Appendix B COMPANY INFORMATION

TABLE 18. CABLE LABS – CABLE MODEM DOCSIS 1.0

Company	Web site	Mkt Shr in the 2 nd year	Source
3Com	www.3com.com	11.45%	Dell'Oro
Cisco Systems	www.cisco.com	0.64%	Dell'Oro
COM21*	www.com21.com	10.10%	Dell'Oro
Motorola	www.motorola.com	36.05%	Dell'Oro
Samsung	www.samsung.com	7.73%	Dell'Oro
Terayon	www.terayon.com	13.21%	Dell'Oro
Thomson	www.thomson.net	7.76%	Dell'Oro
Toshiba	www.toshiba.com	9.02%	Dell'Oro

* COM21 filed bankruptcy in July 2003.

TABLE 19. DSL FORUM - ITU-T G.LITE ADSL

Company	Web site	Mkt Shr in the 2 nd year	Source
3Com	www.3com.com	6.66%	Dell'Oro
ADC	www.adc.com	0.70%	Dell'Oro
Alcatel	www.alcatel.com	19.63%	Dell'Oro
Cisco Systems	www.cisco.com	4.24%	Dell'Oro
Copper Mountain	www.coppermountain.com	1.42%	Dell'Oro
Lucent	www.lucent.com	1.19%	Dell'Oro
Netopia	www.netopia.com	1.87%	Dell'Oro

Nortel	www.nortelnetworks.com	2.46%	Dell'Oro
Orckit	www.orckit.com	5.00%	Dell'Oro
Paradyne	www.paradyne.com	0.46%	Dell'Oro
Efficient*	www.efficient.com	22.66%	Dell'Oro
Westell	www.westell.com	10.41%	Dell'Oro

* Efficient is a Siemens company.

TABLE 20. FIBRE CHANNEL ASSOCIATION - T11.3 FC-HBA

Company	Web site	Mkt Shr in the 2 nd year	Source
Brocade	www.brocade.com	64.57%	IDC
McData	www.mcdata.com	18.46%	IDC
QLogic	www.qlogic.com	8.91%	IDC
Vixel *	www.vixel.com	2.94%	IDC
Gadzoox	www.gadzoox.com	3.24%	IDC
INRANGE **	www.inrange.com	1.87%	IDC

* Vixel was acquired by Emulex in Oct. 2003.

** INRANGE was acquired by CNT in Apr. 2003.

TABLE 21. GIGABIT ETHERNET - IEEE P802.3z

Company	Web site	Mkt Shr in the 2 nd year	Source
3Com	www.3com.com	6.52%	Dell'Oro
Alcatel/Packet Engines*	www.alcatel.com	1.04%	Dell'Oro
Cabletron**	www.cabletron.com	3.26%	Dell'Oro
Cisco Systems	www.cisco.com	50.03%	Dell'Oro

Extreme Networks	www.extremenetworks.com	7.01%	Dell'Oro
Fore Systems***	www.foreswitches.com	0.66%	Dell'Oro
Foundry Networks	www.foundrynet.com	2.93%	Dell'Oro
HP	www.hp.com	1.28%	Dell'Oro
Intel	www.intel.com	5.51%	Dell'Oro
Lucent	www.lucent.com	0.98%	Dell'Oro
Bay networks****	www.baynetworks.com	5.59%	Dell'Oro

* Packet Engines was acquired by Alcatel in 1998.

** Cabletron became Riverstone and Enterasys in 2000.

*** Fore was acquired by Marconi in 1999.

**** Bay Networks was acquired by Nortel Networks in June 1998.

TABLE 22. WIRELESS LAN - IEEE P802.11A/B

Company	Web site	Mkt Shr in the 2 nd year	Source
3Com	www.3com.com	3.33%	Dell'Oro
Lucent*	www.lucent.com	15.01%	Dell'Oro
Cisco Systems	www.cisco.com	9.79%	Dell'Oro
Cabletron**	www.cabletron.com	2.85%	Dell'Oro
Intel	www.intel.com	2.18%	Dell'Oro
Proxim	www.proxim.com	1.23%	Dell'Oro
Symbol	www.symbol.com	1.64%	Dell'Oro

* Lucent spun its semi-conductor business off. Agere owns Lucent's wireless LAN business.

** Cabletron was spun-off and became Riverstone and Enterasys in 2000. Currently, Enterasys owns Cabletron's Wireless LAN business.

Appendix C COMPANIES NOT PASSED DATA EVLUATION CRITERIA

TABLE 23. COMPANY NOT PASSED DATA EVELUATION CRITERIA

Company	Web site	Standard Group
ADC	www.adc.com	CABLE MODEM DOCSIS 1.0
Ericsson	www.ericsson.com	CABLE MODEM DOCSIS 1.0
Polycom	www.polycom.com	ITU-T G.LITE ADSL
Sumitomo	www.sumitomo.com	ITU-T G.LITE ADSL
Accton/SMC	www.accton.com www.smc.com	IEEE P802.3Z
D-Link	www.d-link.com	IEEE P802.3Z
Buffalo	www.buffalotech.com	IEEE P802.11 A/B
Linksys	www.linksys.com	IEEE P802.11 A/B
Netgear	www.netgear.om	IEEE P802.11 A/B
SMC	www.smc.com	IEEE P802.11 A/B

Appendix D DATA EVALUATION

TABLE 24. DATA EVALUATION CRITERIA

Variables		Criteria
Number of early customers		<ul style="list-style-type: none"> Announcement was published on industry news website
Share in other markets		<ul style="list-style-type: none"> Company name was ranked in top five market share annually in the year when standard was approved by market research reports Dell'Oro, RHK, IDC, Synergy and Infonetics
Number of patents		<ul style="list-style-type: none"> Company name was in assignee field of U.S. patent that related to the standards
Number of contributions	Financial Contributions	<ul style="list-style-type: none"> Principle member Founder
	Standard Group Leadership	<ul style="list-style-type: none"> Appointed chair Appointed director
	Technology contributions	<ul style="list-style-type: none"> Submitted draft Technology presentation
	Standard promotions	<ul style="list-style-type: none"> New product information related to the standard Executive speech Product trails
Number of alliances	Computer software	<ul style="list-style-type: none"> Individual software vendors
	Computer Services	<ul style="list-style-type: none"> Solution providers System integrators

	Computer Hardware/Electronic Instruments & Controls/Semiconductors	<ul style="list-style-type: none"> • Semi-conductor providers • Chipset providers • Optical component providers
	Communications Equipment	<ul style="list-style-type: none"> • System integrators
	Resellers	<ul style="list-style-type: none"> • Product distributors • OEM buyers
	Other partners	<ul style="list-style-type: none"> • Other than above four categories
Time-to-commit		<ul style="list-style-type: none"> • Company announced product roadmap that promise standard compliance
Market Share		<ul style="list-style-type: none"> • Port shipment by vendors in percentage of overall market in the second year after standards were approved