Task and Environmental Uncertainty and Adoption of Technological Innovations by Home Builders

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by T. Michael Toole

An empirical investigation into two research questions pertaining to the adoption of technological innovations by small- and medium-sized home building firms was conducted by multiple regression analysis of data collected from interviewing over 100 home builders across the country.

How are home building firms that are more apt to adopt technological innovations before they are widely diffused different from those that are less apt to do so? The research showed that home builders who are more apt to adopt non-diffused innovations have superior information processing abilities related to building innovations. These builders were found to tap into more sources of information about new products from portions of their organizational environments than did non-adopters. Information processing significantly differentiates these builders from those who are less willing to adopt innovations that are not widely diffused because the uncertainty level of most building innovations is quite high due to the complexity of the home building task and the complexity of the organizational environment facing home builders. No significant relationships were found to exist between adoption behavior and either company size, number of years the company has been in business, or market segment served (i.e., average house price).

How are home building firms that are more apt to adopt high uncertainty technological innovations before they are widely diffused different from those that are more apt to adopt low uncertainty innovations before they are widely diffused? The data provided evidence that the two groups differ in the characteristics of the individuals involved in innovation-related activities. Propensity to adopt high uncertainty, non-diffused innovations is associated with having higher numbers of functions (e.g., top management, office administration, sales, design, site supervision) involved in making adoption decisions. Each function possesses intimate knowledge of one or more sectors of the environment and can therefore help to reduce the uncertainty of how well an innovation would fit with the firm's task process and environment. Propensity to adopt high uncertainty innovations is also associated with having at least one individual with a building trades background involved in innovation-related activities. These individuals likely apply their tacit knowledge about the construction process to reduce the uncertainty relating to how well an innovation will be assimilated into the existing task process.

Propensity to adopt low uncertainty, non-diffused innovations is associated with having at least one individual with an architectural or engineering background involved in innovation-related activities. These individuals apparently apply engineering principles to reduce the uncertainty of innovations related to physical performance, but cannot reduce the uncertainty of high uncertainty innovations related to market acceptance. Propensity to adopt low uncertainty innovations is also associated with having a more positive attitude about adoption of innovations and/or higher tolerance of uncertainty. This factor does not play a critical role in relatively early adoption of high uncertainty innovations apparently because it is overwhelmed by the need for effective gathering and processing of information about innovations.

The results of this research suggest that, contrary to the prevailing opinion within the home building industry, builders' adoption of technological innovations substantially reflects factors within their control. However, contrary to widespread public perception, the majority of home builders are neither apathetic nor excessively conservative about new building technologies. The results also suggest that the construct of uncertainty deserves a more prominent position within organizational diffusion theory.

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Finally, I would like to acknowledge that God played a big part in my research, as He does in all of our lives. *Unless the Lord builds the house, its builders labor in vain.* (Psalm 127:1)

This thesis is dedicated to my wife, Amy,
who supported me with love (and money and children...) throughout my research and who will always be the most important person in my life.

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CHAPTER 1: INTRODUCTION

The rate of technological change in the home building industry continues to be wrongly perceived by managers in other industries, academics, and the American public as a whole. In 1980, Ventre railed against the home building industry's reputation as a "backward industry," "a non-industry," "a headless monster," and "an army of pygmies" (Ventre, 1980). While these terms have not been used to describe the industry in recent years, I am confident that if the public was polled as to the perceived rates of technological progress in various industries, home building would be one of the lowest (Nelson & Winter, 1977; Oster & Quigley, 1977; U.S. Congress Office of Technology Assessment, 1986).

To examine the gap between the expected and the perceived rates of technical change in home building, first consider the expectations. It is generally assumed that in all industries: some firms should *generate* technological innovations through formal research and development (R&D); firms not attempting to generate innovations should quickly *adopt* innovations to maintain competitiveness; the set of innovations in an industry over time will include both incremental and radical innovations; and the result of innovations over time will be a visible pattern of technical progress, manifested in reductions in the costs and/or improvements in the performance of the industry's products or services.

Next, consider the perceived rate of technological change. U.S. home builders appear to violate all four of the above assumptions. Little formal R&D is performed even by the largest firms. Few firms appear to aggressively import technologies developed in other industries. Not only have there been no radical innovations adopted throughout the home building industry over the past few decades, but the flow of incremental improvements is typically so subtle and so constant that a net change is not obvious to individuals not familiar with the technical details of home building[1] (U.S. Congress, Office of Technology Assessment, 1986; NAHB, 1990).

Critics could probably understand an industry not meeting normative expectations about technical change if technology did not play a critical role in the industry (as is the case with taxi-cabs, truck driving, and other industries), but this is not perceived to be true in home building. From the normative technologists' view, successful home building

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[1] Moavenzadeh (1991) reports that nearly 90% of the materials and construction processes of houses built today are different from those of houses built in the 1950s.

results from effective application of engineering principles and processes during the design stage, followed by the managed application of a broad and deep base of tacit technologies—known as construction trade skills—during the construction stage. Since tacit and explicit technologies are critical in the design and construction stages, technological innovation should play a critical role in shaping competition within the home building industry.

If substantial technological change is not evident, so the view goes, there must be institutional or individual factors that are to blame. Until the past decade or so, the fragmented local building code system justifiably was blamed for hindering the diffusion of innovative building products. Recent evidence, however, has shown that the influence of building codes on innovation adoption has decreased (Duke, 1988). One explanation that remains popular for what is perceived as slow diffusion of building innovations is that home builders are excessively conservative and do not appreciate the benefits of technological innovation.

The goals of this thesis is to increase our understanding of technological innovation in home building and refute the perceptions that home builders are ignorant or irrationally resistant to new technology. I accomplish these goals by investigating the question: **How are home building firms[2] that are more apt to adopt technological innovations before they are widely diffused different from firms that are less apt to do so?**

The theme underlying my research is that uncertainty plays a key role in decisions on adopting innovative home building products. I furnish evidence that adoption of innovations that are not widely diffused reflects uncertainty reduction as a result of internal information processing. In other words, home building firms that adopt innovations before they are widely diffused process information about innovations better than firms that are less apt to adopt non-diffused innovations.

Because uncertainty plays such a pivotal role in the adoption behavior of home builders, I differentiate between high and low uncertainty innovations and focus on a second research question: **How do adopters of high uncertainty, non-diffused building innovations differ from adopters of low uncertainty, non-**

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[2] The theory and empirical findings presented in this thesis apply to small- and medium-sized home building firms, that is, firms building less than 200 homes per year. Large home building companies were also interviewed and observed as part of my research but were not included in my empirical analysis.

diffused building innovations?

Because so little effective research has been done on the home building industry, I feel it is important to take a *descriptive*, rather than a *prescriptive*, approach. My research questions do not ask what *should* builders do; they ask what *do* builders do. This thesis does not investigate whether the rate of technological innovation in home building is sufficient, nor does it assume that it is not. I neither analyze whether most new building products represent proven technological progress, nor assume that they do. Most importantly, <u>this thesis does not discuss whether builders should adopt non-diffused innovations</u> because this may lead to better financial performance. Instead, this thesis demonstrates that builders who are more apt to adopt innovative building products that are not widely diffused are indeed different from their competitors who are less apt to do so.[3]

WHY THIS TOPIC IS IMPORTANT

My research topic is important for several groups. When a home building firm typically starts using new building products relative to other builders is a key element of its technology strategy. Technology strategy may in turn play an important role in determining the overall success of a company. Builders who believe that adopting innovations may improve their sales and profit margins and help them better deal with shortages in traditional materials, will be interested in what firm characteristics facilitate relatively early adoption.

The research reported in this thesis may help building <u>material manufacturers</u> to better market innovative building products and to reduce the time required for effective innovations to diffuse throughout the industry.

My research topic is also important for <u>academics</u>. The broader question underlying my research is how organizational environments influence technological change. This question is being asked by academicians for other industries, as suggested by the following quote from a leading organizational theory journal (Tushman & Nelson, 1990: 3)

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[3] This thesis does <u>not</u> provide data or background information about the industry or the home building process other than what is necessary to communicate my hypotheses. Readers interested in general information on the industry should consult the President's Committee on Urban Housing (1968), Willis (1979), or Slaughter (1991).

> "Several broad research questions motivated this special issue: ... To what extent do organizational and social factors affect technological change? and What characteristics of organizations and environments shape the development of technological change and innovation?"

Government policy makers are aware of the critical need for reductions in the cost of housing. Housing accounts for a major portion of consumer budgets and therefore influences the overall quality of life. Although the significant drop in interest rates over the past two years has reversed the trend, the housing affordability index has substantially deteriorated over the past two decades (Harvard University Joint Center For Housing Studies, 1990). While the causes of decreasing affordability are due mostly to higher land prices, lower real incomes, and other factors unrelated to the actual construction process, many researchers continue to assert that technology has the potential for significantly reducing the cost of housing. If this potential is to be achieved, it is essential that we understand what factors hinder the successful application of improved building technology.

Home builder adoption behavior is also important in light of two goals that have been voiced in the federal government. One goal is to stimulate the diffusion of energy-efficient and environmentally-friendly innovations. A second goal is to transfer advanced materials and manufacturing systems developed in defense-related industries into civilian industries, including construction. Such a program would not be entirely new. Formal government programs to encourage the transfer of technology, capital, and management expertise from Fortune 500 firms into the housing industry were established immediately after World War II and in 1969. Neither of these programs, however, were more than marginally successful. And, as the following quote implies, it is not clear that our understanding of technological innovation in home building has advanced sufficiently since those periods to ensure a similar program would be more successful now.

> "Little is known, for example, about the characteristics of early adopters, the specific attributes of housing innovations that influence adoption, and how various actors in the housing industry make adoption decisions." (National Association of Home Builders Research Center, 1991: 38)

I show in Chapter Two that the existing home building innovation literature emphasizes institutional barriers to innovation and that few studies have investigated individual- and organizational-level factors. Yet it is on the latter levels that decisions concerning innovation are made. If we hope to promote the adoption of advanced technologies by home builders, we need to know more about what they think about innovations in general, how they decide whether to adopt specific innovations, and what aspects of their environment most influence when and how innovations are adopted. This thesis may therefore help government agencies make better decisions about funding innovative building technology research, development, and transfer programs in not-for-profit laboratories and universities.

BACKGROUND DEFINITIONS

Due to the lack of consistent and precise definitions in the literature, it is appropriate to provide up front definitions of key terms in this thesis.

Technological innovation in home building is the application of technology that is new to an organization and that significantly improves the design and construction of a living space by:

- decreasing installed cost (due to a greater volume of output resulting from a given level of input);
- increasing installed performance (i.e., qualitatively superior output from a given level of input); and/or
- increasing construction business performance (i.e., quantitatively or qualitatively superior process, such as reduced lead time and increased flexibility.)

Let me focus on a few elements of this definition because it is central to the thesis. The phrase "*that is new to an organization*" borrows from the extant diffusion research the notion that innovation is something new to an organization. It need not be new to the entire industry. Thus, when a company uses any significant product or process for the first time and continues to use it, we say that innovation has occurred, regardless if this first use represents no technical progress for the company's industry as a whole.

"*That significantly improves*" is intended to eliminate minor changes that are so inconsequential that most builders or home owners have little incentive to consider changing. For example, changes that result in cost savings of less than $10 per house or less than a few percentages of a performance parameter would not be considered significant.

"*The design and construction of a living space*" eliminates administrative changes that have no effect on the home building process or final product. Using a computer for job costing (that is, financial record keeping of past expenditures) is an administrative innovation, while using a computer for estimating or scheduling would be considered a technological innovation because it can significantly influence the sequencing of the individual work tasks and whether the proper quantities of materials were ordered.

"*Design*" does not refer to purely aesthetic design. Changes in living spaces or architectural features to accommodate lifestyle changes and aesthetic preferences are generally not considered technological innovations. If, however, such changes require changes in the technical design, the technical process, or new materials, then they are considered technological innovations. Breakfast nooks and pass-throughs would generally be considered only architectural changes because they require only minor modifications to the existing framing process. Bigger living rooms, on the other hand, often may be associated with a technological innovation because they require the second story floor joists span longer distances, which often requires the use of innovative framing materials or designs.

While the previous examples illustrate that changed appearance does not necessarily imply technological innovation, it is also true that an unchanged appearance does not necessarily imply that technological innovation has not occurred. There is an oriented strand board (OSB) siding product available that is nearly identical in appearance to traditional wood siding. Yet this product is a technological innovation because the underlying material—engineered reconstituted wood—is significantly different in cost, performance, and factor inputs from traditional sawn lumber.

Home builder adoption of a technological innovation occurs when a home building firm first uses a technological innovation that it subsequently uses in at least 25% of the cases *in which it has an opportunity to use the innovation.* The italicized portion of the previous sentence is an important part of the definition but rather difficult to ascertain. Aside from high volume speculative builders who rarely deviate from a standard portfolio of regional house designs, most builders construct a wide variety of homes. They may try a new product on a house, have success with it, yet not attempt to use it again on their next few houses because they consider it inappropriate (namely, not cost-effective) for the customer, design, or market. While it is clear that a builder who tries an innovation then never uses it again is not considered to have adopted it, it is not clear whether a builder who has not used an innovation recently should be considered a non-adopter.[4]

[4] While this definition may seem awkward or excessively vague, I mention in Chapter Three that very

The terms **"early adoption"** and "early adopter" are used in this thesis as they are used in the existing diffusion literature. That is, early adoption refers to adoption that occurs within the early stages of an innovation's diffusion. Early adoption does not necessarily imply that adoption occurs shortly after the innovation is first introduced. For example, steel studs (for framing light structures such as commercial and residential buildings) have been available for many decades, but their market share is currently less than 5%. Therefore, a builder who uses steel studs in his houses is considered an early adopter even though he might not have started using them until 20 or more years after they became available.

Organizational environments are the conditions in which organizations operate. They are the external factors that influence how an organization must behave if it is to be considered successful. The totality of these conditions are often divided into specific sectors, such as suppliers, customers, technology, socio-political, regulatory, and competitors. For example, important aspects of the customer sector of a home builder's environment might include the demand for rapid-construction, energy efficiency, or a specific architectural feature. Chapter Two summarizes the portions of home builders' environments that may influence their adoption behavior.

The term **risk** refers to decisions in which the individual knows both the subjective utility of possible outcomes and the probabilities associated with these outcomes (Luce & Raiffa, 1957). Thus, risky situations can be rationally evaluated by calculating expected value.[5] This academic definition is more narrow than the definition used by practitioners, the latter referring to a situation in which there are two or more possible outcomes to an event, of which at least one is not desirable.

Uncertainty is defined as the state when an individual perceives that she is missing information necessary for a decision or action. Specifically, information is missing that would allow the decision maker to know what outcomes are possible from her decision and the odds associated with each outcome. Uncertain situations are almost always

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few builders requested clarification when I asked them if they used an innovation "on a regular basis."

[5] Consider the simple example in which you are playing one-on-one basketball with your friend and he challenges you to bet $1 on the next game. Should you accept the bet? According to normative decision theory, it would be irrational for you to accept the bet unless you believe that the expected outcome of the bet is greater than your current situation. Let's say you believe that the chances of you winning are 55%. The expected value of the bet would be the probability of winning (.55) multiplied by the outcome of winning ($1 + $1 you already have = $2) plus the probability of losing (.45) multiplied by the outcome from losing (0), which equals $1.10. $1.10 is greater than the outcome of not taking the bet (1.00 multiplied by $1= $1.00), so you should take the bet. The bet is risky in that there is a possibility of you losing your dollar, but if you wish to maximize the amount in your wallet, you should take the bet.

perceived as being "risky" (using the common notion of risk) in that there is a possibility (albeit unknown) that the outcome of the situation will be undesirable.

Task uncertainty is uncertainty resulting from characteristics of the decision maker's work process or an organization's set of *value activities.*

Environmental uncertainty is uncertainty resulting from characteristics of the decision maker's external environment. In this thesis, environmental uncertainty does not refer to uncertainty resulting from a decision maker's internal environment, that is, conditions within the decision maker's organization (Duncan, 1972).

High uncertainty innovations differ from **low uncertainty innovations** in the amount of information that potential adopters are typically missing when they first hear about the innovation. High uncertainty building innovations are those in which potential adopters are missing substantial amounts information relating to, for example, long-term performance, total installed cost, or acceptance by home buyers, subcontractors, or local building officials. Low uncertainty innovations are those in which potential adopters are not missing substantial amounts of information pertaining to these criteria.

OVERVIEW OF THE THESIS

The structure of the thesis is as follows. Chapter Two reviews several sets of literature on my research topic and theoretically explains how the home building task and home builders' organizational environments contribute to high levels of uncertainty about many home building innovations. Chapter Two also suggests that home builders who are more apt to adopt non-diffused innovations are those who have superior abilities to gather and process information about innovations and higher tolerances of uncertainty.

Chapter Three presents nine hypotheses that follow directly from the perspectives on my research questions presented in Chapter Two. Chapter Three also includes a detailed discussion of the methodology used to gather empirical evidence for my hypotheses. Namely, I conducted telephone or in-person semi-structured interviews with 108 builders around the country.

Chapter Four discusses the multiple regression and probit analysis process that were used to analyze my data and that indicate at least partial statistical support for five of the nine hypotheses. Chapter Five summarizes my research and suggests implications for various groups associated with home building.

The appendices include the classification of high or low uncertainty of the twelve innovations used to measure the dependent variables, the questionnaire form that was used to record every interview, my raw data, and descriptive statistics.

CHAPTER 2: EXISTING AND NEW PERSPECTIVES ON THE ADOPTION OF TECHNOLOGICAL INNOVATIONS BY HOME BUILDERS

This chapter has two objectives. One objective is to draw from four sets of literature that are relevant to my research questions.[6] The four sets of literature are home building innovation, diffusion theory, organizational environments, and descriptive decision theory. The second objective is to show that uncertainty is a major factor influencing home builder adoption behavior and that builders more apt to adopt non-diffused innovations are better able to reduce uncertainty through effective information processing than are builders less apt to adopt non-diffused innovations.

HOME BUILDING INNOVATION

While no literature on home building innovation specifically addresses either of my research questions, many reports address a related question: What factors affect the diffusion of innovations in the home building industry?[7] Table 1 summarizes the answers to these questions most often found in the literature. All of the factors included in Table 1 are assumed to be <u>negatively</u> related to the generation or adoption of innovations. With few exceptions, all of the relationships suggested in Table 1 are based on intuitive analysis, usually by applying general theory to the home building industry.[8]

The existing literature focuses almost exclusively on industry-level factors. Not only does the literature emphasize institutional barriers to innovation (such as governmental regulations), the firm-level and individual-level characteristics that are seen as directly influencing diffusion of innovations are themselves seen as being determined by industry-level factors. For example, firm size, management intensity, and profit margins (shown

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[6] How are home builders who are more apt to adopt technological innovations that are not widely diffused different from home builders who are less apt to do so? And, how do adopters of high uncertainty non-diffused building innovations differ from adopters of low uncertainty non-diffused building innovations?

[7] Although there are exceptions—e.g., Ventre (1973, 1980), Moavenzadeh (1991), and Slaughter (1991, 1993)—it is interesting to note that the majority of literature on construction innovation seems to accept the assumption that the rate of technological innovation in home building is lower than it should or could be.

[8] The relationships suggested by NAHB Foundation (1972) and Ehrenkrantz Group/Gershon Meckler Assoc. (1979) are based on empirical investigation. Ventre (1973), Oster & Quigley (1977), and Slaughter (1991) are also empirical pieces, but the factors that they suggest influence the rate of technical progress in home building are based on intuitive analysis.

in Table 1) are firm-level factors that result from variation among local building codes, cyclical sales, and horizontal and vertical fragmentation.

Table 1: Factors Discouraging Innovation in Home Building

Factor	Source	Typical Explanation
variations among building codes	NAHB Research Foundation, 1972; Ventre, 1973; Ehrenkrantz Group/Gershon Meckler Assoc., 1979; Oster & Quigley, 1977; Tatum, 1986; U.S. Congress OTA, 1986; Slaughter, 1991; NAHBRC, 1989b, 1991; Toole & Tonyan, 1992	Inconsistent local building codes limit the potential market of innovations.
cyclical sales	President's Committee on Urban Housing, 1968; Oster & Quigley, 1977; Tatum, 1986; U.S. Congress OTA, 1986; Moavenzadeh, 1991; Slaughter, 1991; NAHBRC, 1989b, 1991; Toole & Tonyan, 1992	Volatile demand makes it harder to carry the relatively large fixed costs typically associated with generating or adopting innovations.
conservative home buyers	President's Committee on Urban Housing, 1968; Ventre, 1973, 1980; Ehrenkrantz Group/Gershon Meckler Assoc., 1979; U.S. Congress OTA, 1986; NAHBRC, 1989b, 1991; Toole & Tonyan, 1992	Home buyers reject innovations and insist builders offer traditional materials and designs.
vertical fragmentation	President's Committee on Urban Housing, 1968; Ventre, 1973; U.S. Congress OTA, 1986; Moavenzadeh, 1991; NAHBRC, 1989b, 1991; Toole & Tonyan, 1992	The vertical disjointedness of the home building value system (i. e., designers, general contractors, subcontractors, and others are all involved in each project but no one group dominates the process, and the typical lack of cooperation among these groups) prevents the joint problem solving and acceptance necessary for innovation.
horizontal fragmentation	Ventre, 1973; U.S. Congress OTA, 1986; Moavenzadeh, 1991; NAHBRC, 1989b, 1991	The disjointedness between the different building trades involved on each project prevents the systems integration that is necessary for innovation.

Table 1, continued

small size of firms	Oster & Quigley, 1977; Ehrenkrantz Group/Gershon Meckler Assoc., 1979; U.S. Congress OTA, 1986; Moavenzadeh, 1991; Slaughter, 1991; NAHBRC, 1989b, 1991	Small firms rarely have the human and financial resources to pursue innovation.
variation in housing not related to codes	President's Committee on Urban Housing, 1968; Slaughter, 1991; NAHBRC, 1989b, 1991	Local variation limits potential sales of innovations, which makes it more difficult to amortize investment.
labor resistance	NAHB Research Foundation, 1972; Ventre, 1973; NAHBRC, 1989b, 1991	Labor resists innovations that might reduce labor requirements or cross (trade) jurisdictional boundaries.
low profit margins on total contract value	Tatum, 1986; NAHBRC, 1989b, 1991	Builders interpret the uncertainty inherent in innovations as higher risk. Risk (unless compensated by significant benefits) must be minimized because low margins are so low that failure of any sort could result in a net loss on a project.
management intensity	NAHBRC, 1989b, 1991	The day to day operations of home building require intense management, leaving little time to consider or initiate innovation.

Although the literature mentioned in Table 1 does not directly address my specific research questions, it does provide information and theory that allow us to infer answers. If the overall rate of technological progress in home building and the diffusion rates of individual innovations reflect institutional characteristics of the industry, home builders who are willing to adopt non-diffused innovations must somehow manage to overcome such barriers. Thus, referring back to Table 1, we might infer that such adopters have sufficient staffing to reduce management intensity, broad vertical and horizontal scopes of operations, etc. Unfortunately, most of these are associated with large firm size. They do not help us to predict what characteristics of small home building companies might determine whether they typically adopt innovations earlier than other builders.

Only one report has taken the issue one step further and addresses what firm–level and individual-level factors influence when a company typically adopts technological innovations. An unpublished report by the National Association of Home Builders Research Center (NAHBRC) (1989b) includes an exploratory multiple regression analysis of data from the "1987 NAHB Builders Survey." The variables included in the initial full (i.e., not stepwise) model are total employees, amount of work subcontracted, percentage of company that is direct labor, age of the owner/CEO, education of the owner/CEO, years in business, whether the firm engages in any multi-family construction, and whether the firm uses any "industrialized construction technologies." The exploratory analysis indicates that variables associated with total employees, subcontracting, multi-family construction, and industrialized technologies were significant at the $p<.05$ level. However, the contribution of this study to my own research is limited by the fact that the regression model did not include many potentially important independent variables. (This is not surprising given that the data were collected for purposes other than exploring potential determinants of firm adoption behavior, and may explain why the multiple R squared of the stepwise equation was only 0.08.) The NAHB study is also limited by the fact that pre-regression and post-regression analyses was not included in the report to confirm that multiple regression was an appropriate analysis tool. (Chapter Four of this thesis discusses the issue of appropriate pre-regression analysis further.)

DIFFUSION THEORY

Diffusion theory is a topic within the field of the management of technology and innovation that the diffusion of innovations within communities and the adoption of innovations by individual units. The seminal work on diffusion theory is *The Diffusion of Innovations* by Everett Rogers (1983). He identifies five elements found in many diffusion or adoption studies:

- Diffusion has four basic elements: innovations, social systems, communication channels, and time.
- There are two primary types of communication channels: mass media and interpersonal.
- The innovation-decision process can be conceptualized as having five stages: knowledge, persuasion, decision, implementation, and confirmation.
- There are three important aspects of the social system: social structure, norms, opinion leaders and change agents.
- The rate of diffusion of an innovation is influenced by five characteristics of the innovation: Relative Advantage, Compatibility, Complexity, Trialability, Observability.

The Diffusion of Innovations (Rogers, 1983) includes a chapter expressly on organizational innovation. He suggests three sets of factors that influence when an organization adopts innovations: individual personality characteristics of management, characteristics of organizational structure, and characteristics related to the organization's interconnectedness with its environment. Figure 1 contains a compilation of generalizations about what factors influence the typical adoption timing of organizations. The ten individual (leader) characteristics were compiled from Rogers' (1983) Chapter 7, which discusses the individual attributes of early adopters. Structural characteristics are explicitly listed and discussed in some detail in Rogers' Chapter 10. Unfortunately, external characteristics of the organization are neither listed nor discussed anywhere in the book. In Figure 1, the plus and minus signs in parentheses indicate whether the factor typically positively or negatively influences organizational innovativeness.

Figure 1: Independent variables related to organizational innovativeness (compiled from Rogers, 1983)

Individual (Leader) Characteristics

1. Years of education (+)
2. Exent of dogmatism (–)
3. Ability to deal with abstractions (+)
4. Attitude toward change (+)
5. Ability to cope with uncertainty and risk (+)
6. Attitude toward science (+)
7. Fatalistic attitude (–)
8. Exposure to mass communication (+)
9. Exposure to interpersonal communication (+)
10. Intensity of information seeking (+)

Internal Characteristics of Organizational Structure → **Organizational Innovativeness**

1. Centralization (–)
2. Complexity (+)
3. Formalization (–)
4. Interconnectedness (+)
5. Organizational Slack (+)
6. Size (+)

External Characteristics of the Organization

1. System openness (+)
2. Etc.

DIFFUSION THEORY DOES NOT ADEQUATELY CAPTURE THE UNCERTAINTY IN ORGANIZATIONAL ADOPTION DECISIONS

Although the literature on the diffusion of innovations is one of the most voluminous in social science, the vast majority of it focuses on adoption by individuals in a community-based social system, rather than adoption of technological innovations by industrial organizations (Baldridge & Burnham, 1975; Gatignon & Robertson, 1986; Van de Ven & Rogers, 1988). Much of the theory developed for individual adoption does not adequately apply to the organizational adoption context because the latter is inherently more complex.

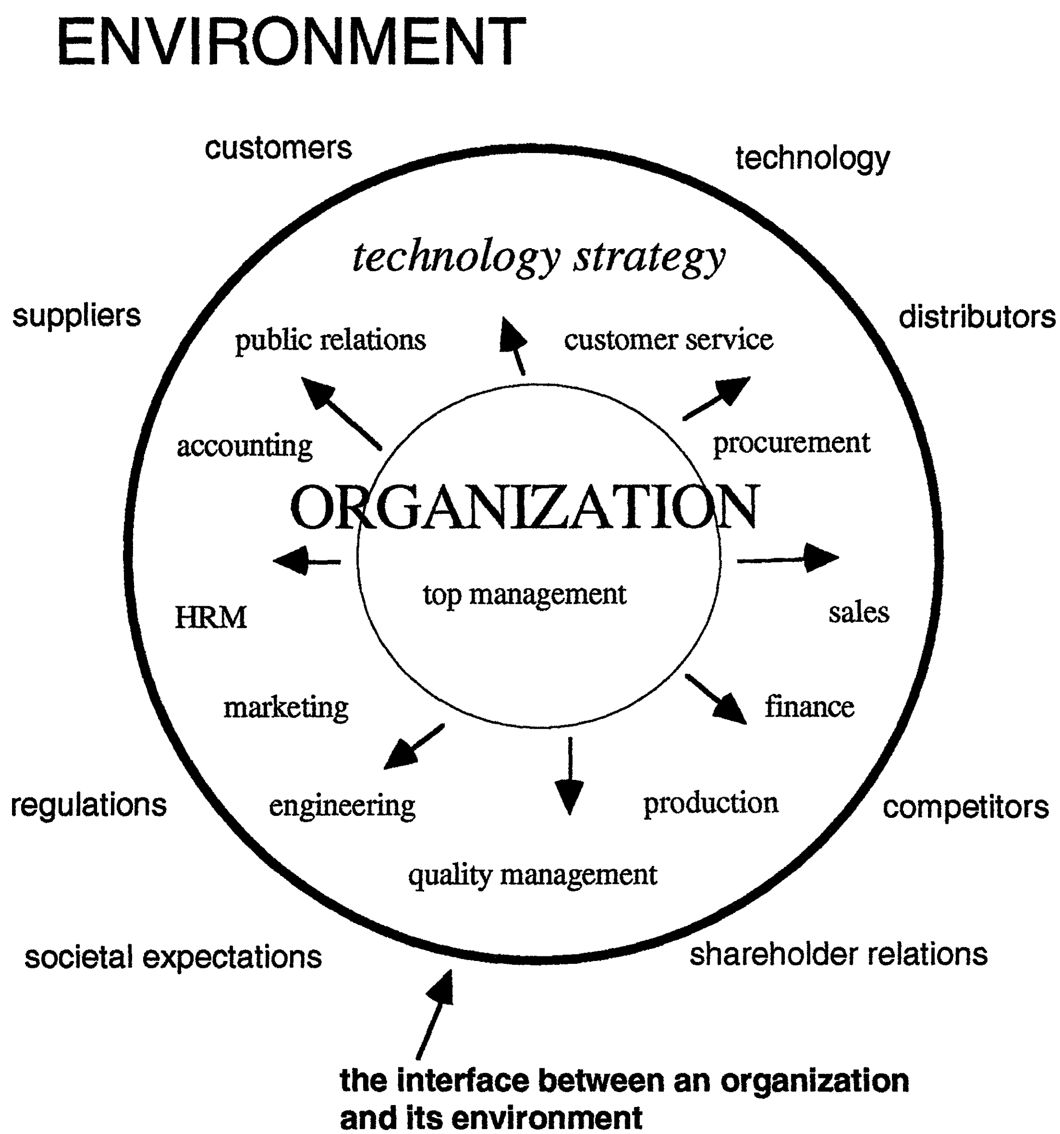
Three characteristics of organizational adoption contribute to its complexity. First, there are many organizational variables that act over and above the aggregate of individual variables (Ven de Ven & Rogers, 1988). For example, the outcome of an organizational adoption decision may reflect organizational inertia or political struggles more than the characteristics of the individuals making the decision or the characteristics of the innovation.

Second, the task process in which technological innovations are introduced is typically more complex, reflecting multiple sets of distinct technical skills applied in many interdependent activities. Furthermore, the products of the completed tasks are often composed of numerous interrelated subsystems, which may exhibit dynamic, counter-intuitive behavior (Forrester, 1969). This characteristic suggests that the implicit assumption in existing diffusion theory, that potential adopters have the ability to obtain nearly complete knowledge of the characteristics of an innovation (e.g., how it would match with the adopter's task), is inappropriate.

The third characteristic of organizational adoption decisions that make them significantly more complex than individual adoption decisions is that the number, diversity, and volatility of individuals and organizations with which organizations typically interact is much greater than is the case with individuals. This point is discussed further in the section of this chapter entitled, "Environmental uncertainty of home building innovations."

The latter two characteristics suggest the need for theoretical links between an organization's task and environment and its adoption behavior. Specifically, they suggest that the *relative advantage* of an innovation is not strictly a function of how an innovation matches with the internal characteristics of an organization, such as norms or structure. The relative advantage of an innovation is also a function of how the innovation can be expected to fit with an potential adopter's task, and a function of how the innovation allows the organization to match with its environment. Figure 2 illustrates that adoption behavior, which is an important component of technology strategy, thus fits naturally with the emerging concept of strategy as guiding an organization's match to its environment (Bourgeois, 1980; Venkatraman & Prescott, 1990).

Figure 2: The concept of strategy as matching an organization with its environment



To evaluate an innovation's relative advantage, individuals making organizational adoption decisions need tremendous amounts of information related to the innovation and to their environments. Yet, task complexity and environmental complexity and volatility can result in potential adopters missing information necessary to effectively analyze how adopting the innovation within their organization will effect their organization's match with its environment. Consequently, **uncertainty**—which was defined in Chapter One as the state when an individual is missing information relevant to a decision—plays a critical role in the adoption of technological innovations by organizations.

Existing diffusion theory does not sufficiently address uncertainty. Rogers (1983) includes only a few passing references to the uncertainty inherent in innovations. Existing diffusion theory also has not sufficiently addressed how organizational environments and task characteristics influence adoption behavior or how organizations gather and process information to reduce uncertainty. Gatignon and Roberts (1989) included hypotheses that pertained to each of these constructs, but their conceptualizations and measurements are not helpful for understanding the home building industry, and many of their hypotheses were not supported. Ettlie and Bridges (1982) report that the few studies of how environmental uncertainty influences adoption have yielded contradictory results.[9]

In short, while the existing diffusion theory is satisfactory for predicting diffusion of innovations in an individual consumer context, significant gaps develop when it is applied to many organizational adoption contexts. Furthermore, even the organizational characteristics that have been shown to predict innovativeness in other industries (see Figure 1) seem to be of little use for understanding the adoption behavior of small home building companies. Generic constructs such as formalization and centralization are difficult to define and even more difficult to measure in firms with few employees.

Before considering the uncertainty of most building innovation adoption decisions, it might be helpful to elaborate on the concept of uncertainty in adoption decisions in general. It was stated in Chapter One that normative decision theory holds that decision makers should endeavor to make choices that offer the highest expected value. In other words, decision makers should make choices that provide the best chances of an outcome meeting their goals. In the case of adoption decisions, decision makers must judge whether the technological innovation they are considering using offers a better set of potential outcomes than that offered by the product or method they currently use.

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9 Their own results appear to support the hypothesis that uncertainty and early adoption are positively related; however, I question the contribution of this study given that the sample consisted of graduate and undergraduate students.

In order to identify the choice offering highest expected value, it is necessary to know all possible outcomes associated with each choice and the probabilities associated with each outcome. Five distinct elements are required. A decision maker must: 1) know the goals that are relevant to the decision; 2) know the variables that influence potential outcomes and the states of these variables; 3) know the cause and effect relationships between the variables (Schrader, Riggs & Smith, 1993); 4) have the ability to calculate the potential outcomes that result from elements 1) through 3); and 5) know the reversibility the decision. If a decision maker can reverse a choice that led to an undesirable outcome with little effort or tangible cost, the set of potential outcomes associated with that choice will clearly be viewed more positively than if the consequences of a decision were costly or impossible to reverse.

Except in the case of pure gambles, decision makers are always missing one or more of the five elements listed above and thus cannot identify the possible outcomes associated with each choice and the probabilities associated with each outcome. Herbert Simon made a major contribution to organizational theory with his picture of managers as satisficers who constantly make decisions under at least some degree of uncertainty (March & Simon, 1958). Psychologists have since theorized and furnished empirical evidence for heuristics[10] and other cognitive mechanisms that humans routinely use to make decisions without having all of the desired information (Tversky & Kahneman, 1974).

The previous paragraph does not imply that individuals are always comfortable with and effective at making decisions under uncertainty. Psychological research over the past two decades has shown that individuals facing highly uncertain decisions frequently avoid the decisions altogether or demonstrate extreme decision biases. This point will be discussed further at the end of the chapter, after discussing how the task and environmental characteristics of home building causes most adoption decisions to be highly uncertain.

TASK UNCERTAINTY OF HOME BUILDING INNOVATIONS

It was suggested in the previous section that potential organizational adopters of innovations frequently have difficulty evaluating how an innovation will match with their task. This section elaborates on this point in the context of the home building industry.

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[10] Heuristics are cognitive shortcuts that people use to make decisions without undue mental effort or the need to have all information available at the time of the decision (Tversky & Kahneman, 1974; Hogarth, 1980).

Five distinct characteristics of the home building process make it difficult for potential adopters to analyze how innovations may effect their operations. Three of the five characteristics relate to Perrow's (1967) two dimensions for categorizing organizational tasks: variety and analyzability. The former refers to "the degree to which stimuli is familiar or non familiar" while the latter refers to whether the search necessary to solve unfamiliar stimuli can be logical, analytical, and systematic. The first characteristic discussed below—the variety of the end product—pertains to task variety. The second and third characteristics pertain to task analyzability. Due to the complex interaction of multiple subsystems installed by groups possessing distinct, tacit skills, the task of designing and installing all but the simplest homes is fairly unanalyzable.

The end products vary considerably. It is obvious that houses are not like consumer goods in which a limited number of product variations are mass produced and marketed around the country. The variations in size, layout, materials, living spaces, and style of houses around the country due to local tastes, climate, and regulations are tremendous (Slaughter, 1991). The variation even within geographic regions is considerable. A substantial portion of the single family detached (SFD) homes in the U.S. are considered custom homes, that is, they have designs that are at least partially custom tailored to the desires of the future buyer. Since the concrete benefits of an innovation depend on the characteristics of the house in which it is used, weighing the expected benefits versus the switching or fixed costs associated with adopting the innovation can be difficult.

The end products of the task consist of many interacting parts and/or dynamic subsystems. Houses are assembled from thousands of parts which comprise at least six distinct but interrelated subsystems (Oster & Quigley, 1977; Tatum, 1986): structural, building envelope, interior and exterior finishes, plumbing, HVAC (heating, ventilating, and air conditioning), and electrical. This fact influences innovation adoption decisions in two ways. First, it makes it harder to analyze how an innovation itself will perform and how interrelated systems will perform. An innovation that ostensibly is part of only one subsystem may change the performance of another subsystem in an unpredictable way. For example, through a series of incremental improvements over the past five decades, air leakage through the building envelope has been significantly reduced, thereby reducing uncomfortable drafts and energy usage. Unfortunately, this technological "progress" has caused excessive moisture, poor indoor air quality, and other problems to develop (Slaughter, 1991). Oriented strand board, which is a sheathing product used in lieu of plywood, is another example. Some builders believe that it swells more than plywood and does not hold nails as well, which requires changes in how finish materials are typically installed.

The second way in which the interrelated systems characteristic of houses influence adoption decisions is to make the consequences of poor adoption decisions potentially severe. A new building product that does not perform as expected could have short- or long-term health and safety implications for the occupants. Replacing many building products requires removing and replacing adjacent materials in order to gain access. For example, replacing defective structural, building envelope, or utility systems requires that finish materials be removed and replaced. The cost of such work can easily exceed the profit generated on the entire house.

Long time frame and wide range of conditions associated with output. As mentioned above, few houses are exactly alike in design and materials. When installation, regulation, site conditions, and end users are also considered, every house is to some extent unique. Even two houses with identical designs located next to one another may differ in non-trivial ways due, for example, to variation in the following areas during the construction process: the weather; the skills, attitudes, and energy levels of the tradesmen; when the local building inspector happened to be on site; whether the specified materials were actually ordered, delivered, and installed correctly; and whether there was a vein of clay underlying one of the footings. Once the house is built and occupied, the range of extreme weather, unusual living habits, and other conditions under which the house must perform over a lifetime of twenty or more years is also largely unknown.[11]

Although governmental regulations and the market demand that building material manufacturers test new products before marketing them, the testing that is performed often falls short of approximating the range of field conditions. Also, expected service lives of most innovations are considerably longer than pre- or post-introduction testing periods and accelerated testing methods are often dubious. In short, it is difficult for a home builder to be completely confident that every portion—particularly those that include one or more innovations—of every new house he or she builds will stand up to a wide range of design, installation, and occupancy conditions over many years.

The task requires high levels of tacit knowledge and skills. By definition, tacit knowledge and skills are those that are not easily articulated or transferred to others. The

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[11] A local building official told me in an interview that this is the reason why local code officials have the authority to reject innovative building materials and systems that have been approved by the state building code or have a National Evaluation Report issued them by the three model code agencies.

building trades includes high levels of tacit knowledge and skills that are gained through many years of on-the-job training and socialization (Stinchcombe, 1959). The tacit nature of construction trade skills make it difficult for an individual without a trades background to understand the nuances of the construction task process. The tacit nature also makes it difficult for an individual to articulate to someone without his specific trades background the consequences of changes resulting from the introduction of an innovation. The many sets of tacit knowledge necessary to build houses thereby contribute to the uncertainty of building innovations.

The task requires interaction with a large number of diverse entities. For a complex set of reasons, the entire process of building a home is performed by many organizations other than home building companies. The uncertainty their involvement contributes to the adoption decision is discussed in the next section.

As a result of the five characteristics of the home building task summarized above, potential adopters of building innovations that have not been widely diffused are typically missing a tremendous amount of information relevant to their decision. Unless the organization is able to gather and process a substantial portion of the missing information, the assessment of "relative advantage" becomes difficult and unstable. The information missing as a result of task complexity might not be viewed as so critical if builders perceived that nearly all building innovations have been eventually shown to provide a net economic advantage. Unfortunately, the history of the home building industry is full of examples of innovations that were adopted by some builders but eventually shown not to be able to accommodate the range of conditions to which they were subjected. Fire-retardant plywood and early in-slab plastic pipe systems are two examples of products that eventually failed in the field, causing irreparable damage to many home builders.

ENVIRONMENTAL UNCERTAINTY OF HOME BUILDING INNOVATIONS

It was stated earlier in this chapter that the relative advantage of an innovation is in part a function of how the innovation allows the organization to match with its environment. This section discusses the uncertainty prevalent in the adoption decisions of home builders that is related to their organizational environments. It is first useful to review the organizational environments literature because it provides a useful framework for analyzing an organization's environment, the organization's ability to predict future states of the environment, and how an inability to predict future characteristics of the environment may influence the organization's behavior.

Organizational environments may be conceived as "those external actors or conditions relevant or potentially relevant to goal setting and goal attainment" or "the primary set of forces to which the organization must respond" (Miles & Snow, 1978: 252). Organizational environments have traditionally been seen as consisting of five sectors: technology, supplier, regulatory, competitor, and customer. It is the "match" between these sectors and an organization that determines an organization's performance. Thus, the five sectors—individually and as a group—influence what a company must do to achieve profitability, growth, and other organizational goals.

Much of the organizational environments literature focuses on the characteristics of the environment that induce uncertainty within organizations about how to best match the environment. The higher the amount of **perceived environmental uncertainty**, the more difficult it is for managers to make decisions concerning what actions are most appropriate for achieving organizational goals.

Miles and Snow (1978: 252–253) summarize well the prominence of environmental uncertainty in organization theory:

> "Although theory and research on organizational environments have employed numerous dimensions, the uncertainty dimension has received by far the most attention. March and Simon (1958) suggested that uncertainty absorption is one of the most fundamental functions of an organization. Weick (1969) and Galbraith (1973) argued that organization structure largely arises from attempts to remove equivocality from external information and to process this information during performance of internal tasks. Finally, Thompson (1967, p. 159) claimed: 'Uncertainty appears as the fundamental problem for complex organizations and coping with uncertainty, as the essence of the administrative process.'"

Concepts and causal theory related to environmental uncertainty help to supplement our understanding of the uncertainty of home building innovations gained from the construction innovation and diffusion theory literatures. Empirical research has shown that environmental uncertainty influences organizational structure, strategy, and performance (Lawrence & Lorsch, 1967; Miles & Snow, 1978; Tung, 1979; Bourgeois, 1985). Since each of these constructs have been shown to correlate with organizational innovation and because uncertain environments imply it is more difficult to predict how an innovation would allow an organization to match its environment, it seems likely that environmental uncertainty may directly influence organizational adoption behavior. To date, the relationship between environmental uncertainty and adoption behavior has not been sufficiently researched. As mentioned in the previous section, Ettlie & Bridges (1982) state that the research results to date have been contradictory.[12]

The dimensions of the environment that contribute to environmental uncertainty have been debated for two decades (Duncan, 1972; Sharfman & Dean, 1991). Dess and Beard (1984) build on the work of Child (1972), Pfeffer and Salancik (1978), Aldrich (1979) and others in theorizing that three dimensions of the environment contribute most to environmental uncertainty.

Munificence refers to "the extent to which the environment can support sustained growth" (Dess & Beard, 1984: 55). Munificence can be thought of as the degree of *hostility*. Organizations in industries that are fragmented, have low profit margins, or pursue stable or shrinking markets face environments with low munificence. Low munificence contributes to uncertainty because it implies that organizations face stiff competition in achieving organizational goals relating to revenue and profit growth. In addition, low munificence also implies that the consequences of improper decisions may threaten organizational survival.

Dynamism refers to unpredictable volatility in demand, prices, product characteristics, technologies, and other important industry characteristics. Unpredictable change contributes to uncertainty because managers do not know on what assumptions they should base their decisions. The contribution of dynamism to perceived uncertainty is heightened when organizational response requires a significant amount of time and resources.

Complexity refers to "the heterogeneity of and range of an organization's activities" (Child, 1972: 3; cited in Dess & Beard, 1984: 56). The more inputs required for an organization's operations, the more outputs it produces, the more organizations and industries that it interacts with, or the more regulated it is, the higher the complexity of an organization's environment. Complexity contributes to perceived uncertainty by increasing the number of variables that managers must take into account when making decisions about organizational actions.

Home builders face extremely high perceived environmental uncertainty (PEU), which

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[12] To the best of my knowledge, Ettlie & Bridges (1982) is the most recent article to research this relationship.

influences adoption behavior. The dynamism of the industry is high in that it faces extreme swings in demand (Rosen, 1979; NAHBRC, 1991), perhaps more than any other American industry. Volatile demand influences innovation because it is difficult for managers to determine their company's ability to amortize capitalization and fixed costs necessary for generating and adopting innovations. The industry also faces extreme swings in material prices. For example, the cost of lumber needed to frame a typical house has increased over 50% over the past two years.

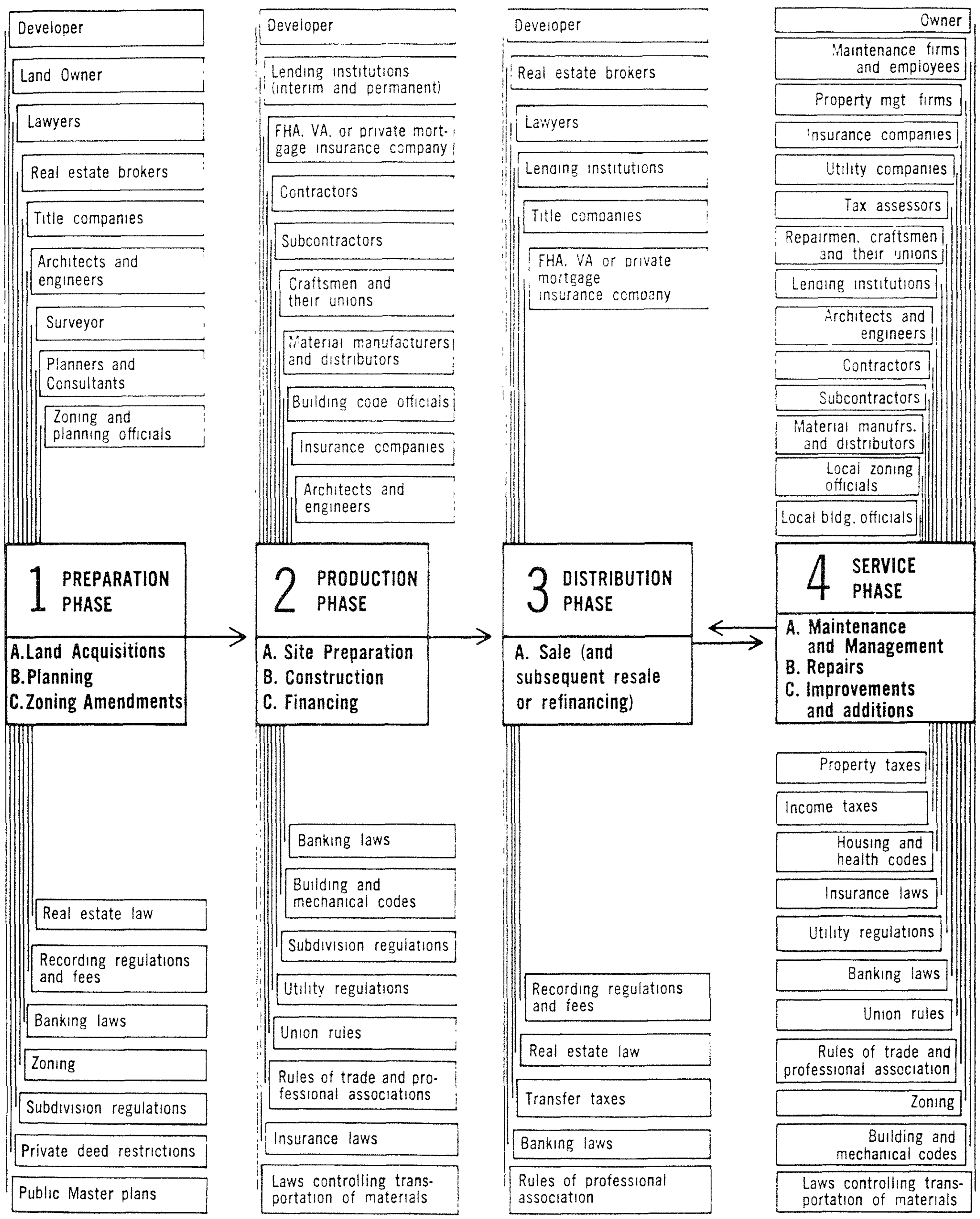
The munificence of the home builder industry is very low as a result of low profit margins, fragmentation (NAHBRC, 1991), and not having sustained market growth in decades. (Housing starts have fluctuated between 1.0 and 1.9 million since the 1950s.) Low munificence results in very few home building firms having sufficient resources to invest in generating or adopting innovations while also ensuring sufficient organizational slack to survive drastic drops in demand.

The complexity of builder's organizational environment is due to the number and diversity of external groups and industries which may influence the effectiveness of the adoption decision. Figure 3 indicates the groups and organizations associated with the entire home building process.

The home building innovation literature listed at the beginning of this chapter suggest that the following groups and industries often influence or are influenced by builders' adoption decisions:

- architects and other house designers
- banks
- building material or component manufacturers
- building material retailers
- developers
- home buyers
- local building departments and planning boards
- realtors
- subcontractors
- local and national trade associations

Figure 3: Groups and organizations associated with the entire home building task. (source: President's Committee on Urban Housing, 1968)



There is considerable diversity among these groups, which makes communication and anticipation of their actions difficult, thereby increasing the uncertainty of the adoption decision. Most of the groups are in the private sector (e.g., developers, banks, contractors), while several are in the public sector (e.g., code agencies, building departments). Some have national or international operations (e.g., raw material suppliers); others typically operate only in a small local area (e.g., architects, contractors). Some of the organizations are product-oriented (e.g., suppliers, manufacturers); others are service-oriented (e.g., architects, banks). Several of the groups have distinct professions or occupational trades associated with them.

Three of the groups listed above are particularly significant sources of uncertainty in innovation adoption decisions.

Home buyers.

> "The function of the home is to conserve, to protect privacy, family life, cultural and social values, traditions. It is a reflection of very deep needs, for security, continuity, conformity, in an area of emotional intensity, dealing as it does with one's personal immediate environment, rich in symbolic meaning." (Herbert, 1984:19)

For reasons implied in the quote above, most buyers approach the buying decision for a new home very differently from other purchases, often with a very strong bond to tradition. At the same time, buyers today seek higher levels of physical performance (e.g., thermal efficiency, low maintenance) and more architectural features (e.g., large open spaces, cathedral ceilings) than in the past, which often demands materials and components superior to traditional construction. Walking the fine line between tradition and progress is exceedingly difficult for builders, particularly for small builders who often must obtain information on buyer needs through outside real estate agents.

Home building is a localized business in which home buyers respond to word-of-mouth effects more than to mass media or other types of advertising. A builder's reputation is therefore critically important to his success. It was mentioned in the previous section that the cost of a poor adoption decision can be severe in home building because the direct costs of replacing a failed portion of the house can be high. The importance home buyers place on a builder's reputation suggests that the indirect costs of a poor adoption decision can be even more severe than the direct costs.

The regulatory system. There is intense but non-uniform regulation of the home building process. Home builders not only must comply with a hierarchy of building codes (federal, regional, state, local) but often face wide variation among zoning ordinances, the enforcement of local building codes, and the permitting and inspection process. It is often difficult to determine whether an innovation might delay a project or require additional management effort to satisfy regulatory officials (NAHBRC, 1991). Builders are also faced with changing federal and local regulations pertaining to environmental protection, access for the disabled, and other areas that influence their daily operations.

Subcontractors. Construction of a house typically involves 15 to 20 subcontractors (NAHB, 1990). Home builders and subcontractors have established a system of socialized skills, norms, and implicit contracts that help coordinate the efforts of so many firms working sequentially or simultaneously in relatively small spaces. Some innovations disrupt this system, resulting in construction delays, reduced quality, disputes between trades, and require additional coordination costs.

THE RESULT: UNCERTAINTY DOMINATES HOME BUILDER ADOPTION DECISIONS

The task and environmental characteristics of the home building industry result in two salient phenomena relating to adoption of technological innovations. First, home builders are typically missing key information related to how an innovation will allow them to match their task and environment. Typical questions implicitly and explicitly voiced by builders include:

- Will it perform as promised in all of my homes over a long period of time?
- How much will money will it actually save or cost me?
- How much will potential home buyers value or resist it?
- To what extent will it affect and/or be resisted by subcontractors?
- To what extent will it be resisted by the local regulatory system?

The second salient phenomenon is that the consequences of poor adoption decisions can be severe. The industry characteristics of volatile demand and low profit margins leave most builders with very low cash reserves. Yet, as stated earlier, the direct costs alone of replacing a portion of a home that failed can exceed the total profit that a builder made on a house, and the resulting damage to his reputation can limit his sales for years afterward.

In light of the severe consequences of poor adoption decisions and the fact that so many innovations in the past have physically failed or been resisted by home owners or other groups, the vast majority of builders seek convincing proof that a new building product will provide significant advantages over an existing product. If a builder has not adopted an innovation, it is rarely because he is confident the innovation will not provide a net economic advantage; rather, its net economic advantage has not been convincingly demonstrated. Innovations are considered guilty until proven innocent. "Uncertainty is avoided like the plague, while the certainty of historical information is accorded such a premium that it dominates the managers' mental processes completely" (Woods, 1966:95).

Table 2: Constraints to the use of cost saving innovations reported by builders

Rank Order	Constraint	Aggregate Weighted Value
1	Not considered using	.45
2	Poor performance risk	.44
3	May damage reputation	.39
4	Building code prohibits	.34
5	Not enough technical information	.32
6	Building officials frown	.30
7	Not applicable to design	.30
8	Not marketable	.26
9	Expect too many callbacks	.26
10	Appraisal penalty	.21
11	Cost more	.21
12	Lenders frown	.20
13	Unsatisfactory experience	.19
14	Material not available	.17
15	Requires sub to change	.16
16	Not worth extra training	.13
17	Union rules prohibit	.11
18	Licensing system prevents	.09
19	Lack of management/supervision	.09
20	Not heard of item	.08

(source: NAHB Research Foundation, 1972)

Preliminary evidence that uncertainty plays a key role in the adoption behavior of home builders and that the three groups mentioned above contribute to home builder uncertainty can be found in the results of an empirical study conducted over twenty years ago. Table 2 summarizes the results of a survey of hundreds of builders by the NAHB Research Foundation in 1971. Note how many of the high ranking responses indicate a suspicious lack of information pertaining to how the innovation would perform or how it would allow potential adopters to match with portions of their environment.

DECISION MAKING UNDER UNCERTAINTY

The previous sections have shown that many home building innovations are at least initially highly uncertain for most builders. Up until this point, we have not theorized an answer to my research question, how do builders who are more apt to adopt non-diffused innovations differ from builders who are less apt to do so? To do so, let us consider descriptive decision theory on both the individual and organizational levels.

When decision makers are missing information that they feel is necessary to make the best decision, they may take one of two paths. They can postpone the decision until they have gathered at least some of the information that they are missing, or they can make the decision based on the information they already have, using heuristics. In general, the more information a decision maker is missing, the more the decision is likely to be biased, that is, the more likely it is that the alternative chosen will not have the highest expected value (Tversky & Kahneman, 1974; Hogarth, 1980).

Several of the theories that have been formulated to explain typical decision making behavior can be applied to decisions about adopting technological innovations. Prospect theory explains why most individuals are risk-adverse with respect to gains (that is, they prefer choices with higher probabilities, even if they offer lower expected values than alternative choices), but are risk-seeking with respect to losses (Kahneman & Tversky, 1979). The possible outcomes associated with adopting a non-diffused innovation are more difficult to identify than the possible outcomes associated with not adopting an innovation because the potential adopter can draw on experience to envision the latter, but not the former. Since the possible outcomes of adopting and their corresponding probabilities are rather fuzzy, prospect theory can be used to explain the observation that most potential adopters of non-diffused building innovations choose not to adopt.

Decision theorists suggest that anticipated regret in conjunction with norms and the status quo may play a strong role in decision making under uncertainty (Bell, 1982; Kahneman

& Miller, 1986; Samuelson & Zeckhauser, 1988; Ritov & Baron, 1992). Rather than carefully comparing the benefits of alternatives to a decision maker's current situation, individuals compare the levels of future regret that each alternative could cause. Alternatives linked with possible high levels of regret are avoided, especially if they require action. Alternatives that are more uncertain are typically associated with higher levels of potential regret. If a more uncertain alternative was chosen and an undesirable outcome occurred, the decision maker would have a high level of regret (e.g., "I knew that was too risky!"). On the other hand, if the less uncertain alternative is chosen and an undesirable outcome occurred, the regret level would be low (e.g., "I really didn't have any choice since I didn't know what the other alternative was about.").

Whether an alternative that offers higher utility but is more uncertain is chosen over an alternative that offers lower utility but is more certain (such as the status quo), depends on the level of uncertainty of the more uncertain alternative and the decision maker's tolerance of uncertainty. If the uncertainty level is low or if the decision maker has a relatively high tolerance of uncertainty, it is likely that status quo or regret bias will not cause the decision maker to reject the superior but more uncertain alternative. If, on the other hand, the uncertainty level is high, then status quo or regret bias will likely cause the decision maker to reject the more uncertain alternative.

The previous paragraphs discuss individual decision making under uncertainty. Uncertainty has also been theorized to play a key role in organizational behavior. Indeed, a key premise of organizational theory for the past 35 years is that missing information is more the norm in organizations than the exception, and that collecting information from their environments to reduce uncertainty is one of the most salient characteristics of organizations (March & Simon, 1958; Thompson, 1967; Galbraith, 1973; Miles & Snow, 1978).

Three more recent articles add to our understanding of uncertainty reduction in organizations. Daft and Macintosh (1981) and Daft and Weick (1984) suggest that what happens to information once it is brought into an organization is just as important as the quantity and quality of information that is brought in. Information relevant to decisions that is collected from an organization's environment is worthless data until it is interpreted and given meaning within the organization. Furthermore, the set of information apparently relevant to a decision is often equivocal, that is, it can be interpreted in multiple ways to yield differing conclusions. Part of the task of management and other employees involved in information processing is to reduce the equivocality of the information in order to reduce the uncertainty of the decision.

Schrader, Riggs and Smith (1993) clarify the construct of uncertainty by differentiating it from ambiguity. An uncertain decision is one in which the decision maker does not know the probabilities associated with the outcomes but does know the cause and effect relationships that determine the possible outcomes. An ambiguous decision is one in which the decision maker does not even know the underlying cause and effect relationships, that is, the decision maker lacks an adequate mental model of the situation at hand. These authors theorize that whether or not an attempt is made to gain additional information (versus basing the decision on the information that the organization already possesses) depends on: whether the decision is framed as uncertain or ambiguous; whether the organization has successfully reduced uncertainty in similar situations; and whether information can be gained from existing communication networks using specific problem-solving skills available within the organization.

The decision theory summarized above can be directly applied to help understand the adoption of technological innovations by home builders. When a builder hears about a new building product that is not highly uncertain, he may either attempt to obtain at least some of the missing information before making the decision, or he may make the decision without gaining more information using heuristics. If the uncertainty of the innovation is low or if he has a relatively high tolerance of uncertainty, he is more apt to try the new product.

On the other hand, if the adoption decision is perceived to be highly uncertain, it is very unlikely that the decision maker will decide to adopt the innovation without gathering more information because the decision would probably reflect status quo or regret bias. Specifically, a builder may reject a new building product that provides superior performance and has the same chance of failure as the product he currently uses because he would have an extreme level of regret if he used the new product and it failed. ("I knew I shouldn't have tried using that thing!") On the other hand, if he took no action, used the conventional product and it failed, he would have low regret since he did what he and other builders have always done. ("These things happen.")

If the information gathering process is ineffective—that is, not enough information is collected or it is not effectively interpreted—he will be forced to make his decision based on missing or misinterpreted information and will probably not adopt due to status quo bias. If the information gathering process is effective, then adoption is more likely to occur.

In short, we should expect to find that adopters of non-diffused innovations—particularly of high uncertainty innovations—have superior abilities to effectively gather missing information for their adoption decisions. In addition, these relatively early adopters are also expected to have higher tolerances of uncertainty. Four hypotheses presented in Chapter Three suggest what factors influence the effectiveness of the information gathering process.

CHAPTER 3: HYPOTHESES AND METHODOLOGY

This chapter presents nine hypotheses pertaining to my research questions that follow directly from the perspectives provided in Chapter Two. This chapter also summarizes the methodology used to test the hypotheses.

Recall it was asserted in Chapter Two that most home building product innovations are highly uncertain. That is, as a result of the complexity of the home building task and home builders' organizational environment, potential adopters of building innovations are initially missing tremendous amounts of information necessary for the adoption decision. The information that is missing can be divided into two sets. One set pertains to how well the innovation really works. The other set pertains to whether the innovation matches well with portions of the home builders' environment. If an attempt is not made to gather at least a portion of the missing information, a potential adopter is likely to reject an innovation due to ambiguity avoidance or status quo bias.

If this picture of the adoption process is valid, what would we expect to find about builders who are more apt to adopt home building innovations that are not widely diffused? Also, what differences would we expect to find between adopters of high uncertainty, non-diffused innovations and adopters of low uncertainty, non-diffused innovations? The rest of this chapter presents specific expectations about the uncertainty reducing characteristics of companies that lead to relatively early adoption. Four of the hypotheses pertain to structural, procedural, and staffing characteristics that result in effective information gathering. One hypothesis relates to attitude or tolerance of uncertainty. The remaining hypotheses pertain to the relationships between adoption and firm size, market segment, company age, and geographic location. These variables are included in hypotheses primarily to prevent them from being viewed as plausible alternative explanations for findings associated with the first five hypotheses. Assume, for example, that it was found that the number of functions active in innovation-related activities is significantly related to adoption behavior. If an indicator of firm size was not included in the multiple regression model, it would be difficult to dismiss the possibility that the relationship really reflected the fact that larger firms (which may have more functions involved in various decision making processes than smaller firms) are more innovative.

With the exception of H7, all of the hypotheses address adoption of non-diffused innovations in general. That is, all but H7 suggest the same direction in the relationship between the independent variable and adoption of high uncertainty, non-diffused innovations as in the relationship between the independent variable and adoption of low uncertainty, non-diffused innovations. As is discussed under the Methodology section of this chapter, the sets of data pertaining to the two sets of innovations are analyzed separately in order to answer the thesis' second research question.

A general theme underlying the first four hypotheses is that adopters of non-diffused building innovations adopt earlier than other builders because they have established superior abilities to gather information that is missing. This conflicts with the presumption of overwhelming environmental determinism found in the home building innovation literature. For example, NAHBRC (1991) cites the conclusions of NAHB Research Foundation (1972) that only 15% of home builder adoption behavior can be attributed to factors under builders' control. This suggests the Research Foundation authors assume if a builder is missing information necessary to adopt an innovation, it certainly is not the fault of the builder. While not denying the strong determinism of the home building environment, the hypotheses that follow suggest that a significant portion of home builder adoption behavior is a result of internal characteristics of firms.

HYPOTHESES

H1: Adoption of non-diffused innovations is facilitated by tapping into many sources of information about innovations.

Reaching out into the environment for information about innovations that are being considered for adoption helps potential adopters reduce both task-related and environment-related sources of uncertainty associated with innovations. Potential sources of information include: architects and other house designers, home buyers, local material suppliers, trade magazines, manufacturers' literature and service representatives, other builders, seminars and trade shows, and subcontractors.

Each external source of information can provide information about the innovation itself or about how the innovation will allow the organization to match with its environment. The more sources of information that an organization taps into, the more it reduces the uncertainty of an innovation, and, thus, the more likely it is to adopt innovations earlier than other builders. For example, builders who talk with manufacturers' sales representatives, or view and touch an innovation at a lumberyard or home show, are more apt to understand how the product works than are builders who just see pictures of the product in trade magazines. Builders who ask one or two home owner customers for their opinion of an innovation are less likely to be uncertain about whether future customers will reject the use of the product in their homes. Reducing uncertainty through gathering of external information is hypothesized to be important for both high and low uncertainty innovations, but more so for the former.

> ***H2: Adoption of non-diffused innovations is facilitated by higher numbers of employees who participate in innovation-related activities and/or higher percentages of employees who participate in innovation-related activities.***

The more employees considered to be involved in suggesting innovations or gathering or processing information on innovations, the greater the chances that the company will hear about a new product and gather sufficient information about it to allow relatively early adoption. An employee is more likely to suggest that management look into a new building product if the employee is explicitly assigned this responsibility or if he knows that management considers him to be an important source of information about new building products.

The hypothesized relationship between an organization and its environment can be likened to that between a tree and its environment. Each portion of a tree draws in a necessary resource from its environment. The roots draw in water and nutrients. The leaves capture sunlight and carbon dioxide. The more roots and the more leaves, the higher the total flow into the tree. The roots and leaves of organizations are the individuals and groups who interact with different portions of their environment, gathering information to increase the likelihood that it will be able to adapt to changes in its environment, such as new technology. The more people involved in innovation-related activities, the higher the total amount of information flowing into the organization.

Note that the construct of the numbers of individuals active in innovation-related activities is different from the construct of company size (H6), although you would expect the two to be positively correlated. Going back to the tree analogy, if you conceptualize the total size of a tree to be composed of the total volume of roots, leaves, and trunk, you would expect that trees with high volumes of roots and leaves would have high total size; however, this need not be the case because some trees have unusually thin trunks. Thus, this hypothesis refers to the number of employees active in gathering and processing information, not to the total number of employees (which is hypothesized in H6).

The second construct included in this hypothesis—the percentage of employees active in innovation related activities—is very different from firm size. In fact, there is probably a negative correlation between the two constructs.

It should also be noted that the hypothesized directions of the relationships between numbers and percentages of employees active in innovation-related activities and relatively early adoption behavior are opposite what would be hypothesized for larger companies. As IBM, GM, and other large organizations have experienced, too many information gatherers and decision makers can lead to ineffective bureaucracy. In large companies, hypothesizing a positive relationship between early adoption and high numbers and percentages of employees involved in making the decisions could mean that tens or even hundreds of people are involved. This would almost certainly lead to excessive lengths of time and perhaps poor decisions as well (Wheeler & Janis, 1980). In a sample of home building companies with employees typically less than 10, however, organizational inertia and other phenomena that would have a negative influence on early adoption behavior are not expected to be present.

> ***H3: Adoption of non-diffused innovations is facilitated by a greater number of functions involved in innovation-related activities.***

The tree analogy may help explain this hypothesis. It was stated above that the more leaves a tree has, the more it can capture sunlight and carbon dioxide. Leaves alone, however, are not sufficient for a tree's survival. Roots are also essential because they draw in water and nutrients from a different portion of a tree's environment.

The same type of relationship is hypothesized for home builders needing information from their environment. It is not enough merely to have multiple people in the company active in innovation-related activities; such individuals must be associated with multiple functions within the company for effective information processing. Small home builders typically have four functions within the company: top management, office administration, sales, and field supervision. Additionally, some builders have in-house trades crews or professional design capability, while others subcontract out the sales function to realtors. Each function interacts with a different portion of the company's environment. Superintendents interact with subcontractors, sales employees interact with customers, office staff often interact with suppliers, etc.

Since employees in each function are the company experts on one or more areas of the company's environment, the more functions represented by those active in suggesting, gathering information on, or deciding whether to use innovations, the better we expect the information gathering, equivocality reduction, and processing to be. Thus, the more functions involved in innovation-related activities, the more the organization is able to reduce the uncertainty of how the innovation might change the company's match with each portion of its environment, making relatively early adoption more likely.

The comment made for H3 about the direction of the relationship being opposite that hypothesized if the sample included larger companies may <u>not</u> apply to this hypothesis. As stated above, having higher numbers of employees involved in innovation-related activities could mean that tens or even hundreds of people are involved in making a single decision, which would be dysfunctional. The number of functions within companies, however, is typically conceptualized as no more than eight, which is probably not excessive for effective decision making.

> ***H4: Adoption of non-diffused innovations is facilitated by having multiple professional backgrounds active in innovation-related activities.***

Individuals in home building companies who participate in decision making typically have one of three professional backgrounds: building trades, architecture or engineering, or a college degree in an area other than architecture or engineering. Each of these backgrounds is associated with a unique and valuable set of analytical skills. Companies with individuals who are active in making adoption decisions and have one or more of these backgrounds will be more apt to adopt non-diffused innovations because such individuals help the company process different sets of information and reduce uncertainty and equivocality more than in companies who lack these backgrounds. For example, an individual with an architectural or engineering background is more apt to understand the engineering principles underlying engineered wood products or be more confident of the properties of synthetic materials. An individual with a building trades background would be more able to predict how an innovation will be installed and whether it will disrupt the subcontracting sequence. Since the third category represents a wide range of backgrounds, it is not clear what analytical skills individuals in this category share. Nevertheless, it is hypothesized that degrees in business, science, and even liberal arts provide valuable perspectives that non-college graduates and engineers lack, and that such perspectives can help reduce uncertainty about the home building environment.

H5: Adoption of non-diffused innovations is facilitated by a positive attitude about early adoption of technological innovations.[13]

Having a positive attitude about adoption of non-diffused technological innovations can be thought of as perceptions (or culture) within a company that technological innovations are important to their company's success and that early adoption does not always present excessive risk. Having a positive attitude facilitates relatively early adoption by influencing all stages of the adoption decision. An organizational culture which embraces innovations as important to the company's success may encourage employees to be on the lookout for innovations during the *knowledge* stage and to seek information about innovations that are being considered during the *evaluation* stage. A positive attitude implies a certain tolerance of the uncertainty associated with innovations, which makes it more likely that low uncertainty innovations will be accepted in the *decision* stage without the need to gather further information. Higher tolerance of uncertainty will also make it more likely that high uncertainty innovations will not be rejected due to status quo bias or regret bias.

H6: Adoption of non-diffused innovations is related to company size.

Unlike the previous five hypotheses, this hypothesis is included not because it is suggested by the perspectives related to uncertainty that underlie this thesis, but because its inclusion strengthens the findings of the other hypotheses. Diffusion theory holds that larger firms are more apt to be early adopters (Rogers, 1983). If an indicator of company size was not included in the multiple regression analysis, critics could argue that some or all of the relationships found to be statistically significant were spurious or indirectly related to company size.

Plausible hypotheses concerning the relationship between early adoption behavior and company size could be made in either direction. As just mentioned, numerous empirical studies have documented a positive relationship between company size and innovativeness. It could be hypothesized that large home builders are more apt to adopt

[13] It may be tempting to downplay the significance of this hypothesis with the thought, "Of course you should expect a relationship between an attitude about a behavior and actual behavior." There are, however, many examples in organizational literature in which embraced attitudes are not reflected in behavior, as well as examples in which actual behavior would not be predicted by espoused attitudes.

non-diffused innovations for many reasons. They are more apt to hear about innovations because there are more employees to interact with the environment and because employees are more apt to be formally assigned to scan for innovations. Large firms typically have the resources to investigate innovations, including individuals with an architectural or engineering background, and to have the financial resources to survive an occasional failure of an adopted innovation. Also, larger firms may be more motivated to pursue incremental innovations because the net result of even a small cost savings per unit is substantial with high volumes of houses.

On the other hand, it could be hypothesized that the relationship may be in the opposite direction. A negative relationship between size and adoption behavior might be expected because larger firms are more apt to be bureaucratic and conservative. Also, many consumers seek homes built by larger firms because they anticipate receiving more consistent quality (but not necessarily higher quality). The uncertainty inherent in many innovations could cause large builders to avoid high uncertainty innovations. Another reason why large builders might be less apt to adopt non-diffused innovations is that small builders might be more aggressive about trying cost saving or differentiating innovations as a means of competing against larger builders who enjoy economies of scale.

In light of the conflicting plausible directions of the relationship between company size and adoption behavior, it is hypothesized only that a relationship exists. The direction is not specified.

> ***H7: Adoption of high uncertainty, non-diffused innovations is negatively related to average house price while adoption of low uncertainty, non-diffused innovations is positively related to average house price.***

Existing diffusion theory (Rogers, 1983) might suggest that builders serving the high end of the market—that is, those typically building luxury homes rather than starter or average homes—would be more apt to adopt all building innovations early because their customers would tend to be more cosmopolitan, educated, and connected with social and information networks. The uncertainty inherent in many building innovations, however, suggests a different relationship. I hypothesize that the relationship between a builder's market segment and adoption behavior depend on the uncertainty level of the innovation. Builders serving primarily the high end of the market will avoid innovations with high levels of uncertainty because quality absolutely cannot be compromised with their customers. That is, builders of high cost homes will avoid innovations that they are not confident will perform as promised because their business critically depends on positive word-of-mouth effects. However, high end builders may be more apt to adopt low uncertainty, non-diffused innovations that they perceive offer high performance with little risk of failure.

Early adoption behavior of builders serving the lower end of the market is hypothesized to be in the opposite direction. Because in this segment profit margins are typically lower, buyers are less choosy about the details of their homes, and word of mouth is not as critical to builders' success, builders building starter and average homes will be more apt to adopt cost saving non-diffused innovations, even if the innovations at least initially have high uncertainty associated with them.

H8: Adoption of non-diffused innovations is positively related to the age of the company.

Several builders I spoke with during the formative stages of my research suggested that builders who are more apt to adopt non-diffused innovations are inexperienced builders who have not learned the hard way that early adoption does not provide sufficient payoff to outweigh the many risks. To preclude the possibility of this view serving as a plausible rival explanation for any significant findings related to H1–H5, company age was included in the multiple regression model. Although existing diffusion theory holds that early adopters are no different in age than later adopters (Rogers, 1983), it is hypothesized that propensity to adopt non-diffused innovations is positively related to age of the company. Adoption decisions in older companies are apt to be made by individuals possessing more years of building experience than in younger companies. The more years of experience an individual has, the better he or she is able to analyze how well an innovation will perform or whether his or her customers, local inspection officials, or subcontractors will reject it.

H9: Adoption of non-diffused innovations is related to the geographic location of the company.

As shown in Table 1, the existing literature on home building innovation suggests that local building codes and the permitting/inspection process influences the diffusion of innovations. Since codes and inspection vary across geographic areas, it is likely that a builder's adoption behavior is significantly influenced by the location in which he operates.

OVERVIEW OF METHODOLOGY

To test the nine hypotheses presented in this chapter, I performed a self-report, observation study[14] of 100 randomly selected[15] builders around the country. My dependent variables—propensity to adopt high/low uncertainty innovations that are not widely diffused—were measured by the number of innovations that a builder reported using regularly from a list of twelve innovations. Since these twelve innovations were thought to be between 2% and 40% diffused through the industry, if a builder reported using them regularly, it was considered early adoption. Six innovations each were classified as high uncertainty or low uncertainty using the framework shown in Appendix 1. The pilot stage of the survey occurred in October through December of 1993. The remainder of the survey occurred in January 1994. After performing diagnostics to confirm that regression analysis was appropriate, inferential statistical analysis was performed through multiple regression analysis of each dependent variable and all hypothesized independent variables. The multiple regression models were confirmed using multinomial probit analysis.

SURVEY PROCESS

Table 3 summarizes the numbers of firms included in my sample and the contact experience that led to a final sample of 100 companies building 180 homes per year or less. Eleven of the firms contacted were identified through friendly sources. The remaining firms were identified randomly from the Yellow Pages of 7 areas around the country: Boston, MA; Boulder, CO; Chicago, IL; Nashville, TN; Princeton, NJ; Rochester, NY; and Seattle, WA.

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[14] The term "self-report" indicates that I obtained data from each firm by asking participants rather than through observation or archival study. The term "observation study" does not imply that I visually observed 100 builders. The term is used in social science to connote any study that is not experimental or quasi-experimental in nature. While the latter are clearly preferable because they allow possible confounding effects to be controlled, they are extremely difficult to execute using home builders or any other groups from industry.

[15] 11 (11%) of the builders in the sample were contacted as a result of a mutual acquaintance. Since data analysis indicated that these firms were not atypical, there is little chance that including non-random firms in the sample biased the findings.

Table 3: Summary of sample contacts.

Number of firms	Description
191	Number of firms that build at least one new home per year that were contacted by telephone and asked to participate in a telephone survey[16]
31	Number of firms that never returned two messages left on answering machines
35	Number of firms that never returned at least two messages left with secretaries or faxed to them
19	Number of firms that stated they would not help
106	Number of firms that agreed to participate[17]
6	Number of firms whose data was discarded *before analysis*[18]
100	Number of firms whose data were analyzed to test hypotheses
55%	Response rate if builders that never returned messages are counted as non-respondents as well as those that were contacted and stated they were not willing to help.
85%	Response rate if only builders that were contacted and stated they were not willing to help are counted as non-respondents.

The interview process typically occurred as follows. When someone in the company answered my call, I introduced myself as a doctoral student writing a thesis on how builders decide to use new building products and asked to speak with the owner of the company for "just a few minutes." Often the phone was answered by a secretary or office administrator who asked for my name and number so the appropriate person could return my call. (I believe that many of them suspected I was really a salesman.) I would then ask if I could send a fax that provided information about my research, which was always answered affirmatively. If no one called me back within 24 hours of receiving my fax, I would call again at least one more time before recording them as a non-respondent. Every phone call—successful or not—was dialed and documented using a contact

[16] This figure does not include wrong or disconnected numbers or firms performing only remodeling who were inadvertently contacted.

[17] Six of these firms were surveyed and interviewed in-person during the pilot stage of my survey.

[18] Four of these firms were discarded because they built between 275 and 2000 homes per year, while the 100 firms that were analyzed built between 1 and 180 homes per year, with a mean of 21. Since the number of homes built per year is one of the variables included in the multiple regression models and since regression analysis is highly sensitive to values significantly different from the bulk of a sample, it was decided to delete the four larger companies from the sample before the data was analyzed. Another firm was discarded because I discovered it was the sales office of a subdivision in which four home building firms were active. The sixth firm was discarded because it was discovered that the company had effectively ceased operations several years ago.

manager software program.

When I did manage to speak with an appropriate individual, I typically began by asking how they hear about and decide to use innovative building products. Since most builders were not sure what I meant by this term even after I gave a brief definition, I illustrated my definition and jogged their memory about specific innovations by reading the list of twelve innovations used to measure my dependent variables. I would proceed through a written questionnaire[19] that served as the basis for my "script" and as the hardcopy on which I recorded interviewees' answers. (A copy of the questionnaire is provided in Appendix 2.) Builders frequently elaborated on their answers or provided opinions related to my questions, which I scribbled in the margins of my questionnaire.

INDICATORS OF DEPENDENT VARIABLES

As I mentioned above, I measured propensity to adopt innovations that are not widely diffused by reading builders a list of twelve innovations and asking which of them their company used on a regular basis. All respondents seemed comfortable with my clarification of "on a regular basis" as meaning they used them in at least 25% of the occasions in which they had an opportunity to do so.

Appendix 1 provides detailed analysis on how the twelve innovations used to establish the dependent variables were classified as high- or low-uncertainty innovations. High uncertainty innovations are those for which potential adopters are at least initially missing significant amounts of information necessary to answer the questions below.

- Will it perform as promised in all of my homes over a long period of time?
- How much will money will it actually save or cost me?
- How much will potential home buyers value or resist it?
- To what extent will it affect and/or be resisted by subcontractors?
- To what extent will it be resisted by the local regulatory system?

The six innovations listed below were used to measure propensity to adopt high uncertainty, non-diffused innovations.

- composite floor joists or floor trusses

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[19] A written questionnaire was drafted because I initially intended to collect data using a written instrument once I had completed a telephone pilot study. I decided to complete the study using telephone surveys due to the advantages of high response rate and the ability to obtain rich data.

- computer aided design/drafting (CADD)
- oriented strand board (OSB)
- steel studs
- plastic plumbing supply pipe
- vinyl siding

Low uncertainty innovations are those for which builders are at least initially missing less information to answer the questions below. The six innovations listed below were used to measure propensity to adopt low uncertainty, non-diffused innovations.

- estimating or scheduling software
- house wrap (often referred to by the brand name "Tyvek")
- insulating concrete wall forms
- composite wood beams or headers
- non-wood trim
- vinyl-clad or all-vinyl windows

Each innovation reported to be used regularly was scored as one. The indicator for adoption of high uncertainty, non-diffused innovations was calculated by summing the scores for the six high uncertainty variables, thereby creating a discrete ratio variable between 0 and 6. The indicator for adoption of low uncertainty, non-diffused innovations was calculated by summing the scores for the six low uncertainty variables, thereby creating a discrete ratio variable between 0 and 6.

INDICATORS OF INDEPENDENT VARIABLES

H1: Adoption of non-diffused innovations is facilitated by tapping into many sources of information about innovations.

The independent construct in this hypothesis was measured by asking interviewees, "How do you hear about new building products, or, once you have heard about one, what helps you decide whether to use it?" The sources they mentioned as a response to this open-ended question were checked off on the third of the questionnaire. I then asked them whether each of the potential sources of information shown below and on the third page of my questionnaire that they had not mentioned were important to them.

- Architects / house designers
- Homeowners / customers

- Local material suppliers
- Magazines, newspapers, and newsletters
- Manufacturers literature and service reps
- Other builders
- Results of your own testing (such as laboratory or field tests other than trying it in one of your houses)
- Seminars and trade shows
- Subcontractors

I varied the order in which I mentioned the potential source such that architects and home designers were not always the first one I mentioned, home owners not second, etc.

Each source of information that they stated was important to them received a score of 1. Sources that were not affirmed as being important received a score of 0. If I sensed that their reply to whether a source was important was rhetorical or normative, I would respond with a statement that was negative about the source. For example, if when I asked, "How about subs, are they an important source of information about new products?" the builder responded with just a short "yeah," I would say, "Some builders have told me that their subs are not very helpful on new products because they don't like to try new things." I would then assign a score of 1 to subcontractors only if the interviewee clearly affirmed their importance to his company. I then summed the scores for the nine sources into a discrete ratio variable between 0 and 9 that represented the number of sources that the builder reported were important.

H2: Adoption of non-diffused innovations is facilitated by higher <u>numbers</u> of employees who participate in innovation-related activities and/or higher <u>percentages</u> of employees who participate in innovation-related activities.

The first independent construct in this hypothesis was measured by asking how many people worked in each of the job categories shown below and on the bottom of the third page of my questionnaire.

- Top Managers
- Office Staff
- Sales Staff

- Design Staff
- Superintendents And Other Field Managers
- Tradesmen And Other Field Employees

I would then total these numbers up and confirm the total with the interviewee. I then asked how many of the company's employees were "somehow involved in new products, that is, suggesting new products or helping to decide whether to use a new product." This variable was discrete and ranged between 1 and 10. The percent of employees who are active in innovation-related activities was calculated by dividing the number of active employees by the total employees, resulting in a continuous ordinal variable between 5 and 100.

H3: Adoption of non-diffused innovations is facilitated by a greater number of functions involved in innovation-related activities.

I chose to test this hypothesis using two indicators of the independent construct, neither of which were not as simple as the previous indicators. One indicator pertained to the number of functions involved in all innovation-related activities, that is, the number of job categories active in suggesting specific innovations for the company to consider using, gathering information on innovations, or deciding whether to use innovations. The other indicator pertained expressly to the functions involved in deciding whether to use innovations. It was straight forward to ask each respondent how many individuals from each function were involved in each of these activities, however, it was not clear whether and how to modify their answers to reflect individuals with multiple functions. Recall that having multiple functional roles involved in decision making was hypothesized to facilitate relatively early adoption because individuals in each function possessed valuable information about the portion of the company's environment that they most interacted with. It would not be appropriate to count multiple-function individuals in each of their functions (for example, many top managers in small companies also perform the sales function) because it is likely that their knowledge of specific portions of the environment would be diluted by their multiple responsibilities. On the other hand, it would not seem appropriate to count multiple-function decision makers only in one of their functions.

It was decided to split the difference. By referring back to the information on the number of individuals in the company who worked in the job categories shown on the bottom of the third page of my questionnaire, I could identify which, if any, employees reported to be active in innovation-related activities performed multiple roles within the company. The number of functions involved in decision making was then taken as the average of 1) the number of functions involved when each function of a multiple-role decision maker was counted as one function and 2) the number of functions involved when multiple-role decision maker were counted as only one function. For example, if a small builder reported that he performed the top management, office administration, and sales functions and that he and his superintendent jointly decided which new products to use, his firm would be scored as 3, which is the average of 4 and 2. This indicator was a discrete variable ranging from 1 to 5.

The number of functions considered active in all innovation related activities (i.e., gathering information as well as making decisions) was calculated the same way. This indicator was a discrete variable ranging from 1 to 6 (which is one more than decision-making variable because some firms had non-supervisory field employees who were considered to be active in innovation-related activities).

H4: Adoption of non-diffused innovations is facilitated by having multiple professional backgrounds active in innovation-related activities.

The independent construct in this hypothesis was measured by asking what were the professional backgrounds of the individuals reported to be active in innovation-related activities for H2. Most interviewees did not understand this open-ended (and vague) question, so I then asked about each of the three backgrounds listed below and at the top of the fourth page of my questionnaire:

- One or more has field experience in the building trades
- One or more has an architectural or engineering background
- One or more has a college degree in other than architecture or engineering.

Each of the backgrounds were scored as a 1 if any of the individuals active in adopting innovations had such a background and a 0 if they did not. I then summed the scores from the three variables to create a discrete ordinal variable between 0 and 3.

H5: Adoption of non-diffused innovations is facilitated by a positive attitude about early adoption of technological innovations.

The independent construct in this hypothesis was measured using three Likert scales that capture three specific attitudes related to technological innovations: whether deviating from standard industry behavior can be beneficial, whether technological innovations are important to their company's success, and whether new building products represent excessive risk. I introduced the scales by saying, "I would like to read three statements and have you tell me whether you strongly or somewhat agree, you are neutral, or strongly or somewhat disagree." I then read each statement and response question exactly as shown below and on the second page of my questionnaire.

> In general, there is little to be gained from being the first to do anything in the home building business. *Do you agree with this statement?*
> I strongly disagree _______
> I somewhat disagree _______
> I am neutral _______
> I somewhat agree _______
> I strongly agree _______

> Using new building products does not make much of a difference in the cost or performance of a house and does not improve profits or sales. *Do you agree with this statement?*
> I strongly disagree _______
> I somewhat disagree _______
> I am neutral _______
> I somewhat agree _______
> I strongly agree _______

> In general, the benefits from using new building products right after they are introduced are outweighed by the risks of using them. *Do you agree with this statement?*
> I strongly disagree _______
> I somewhat disagree _______
> I am neutral _______
> I somewhat agree _______
> I strongly agree _______

Each scale was scored -2 for "strongly agree," -1 for "somewhat agree," 0 for "I am neutral," +1 for "somewhat disagree," and +2 for "strongly disagree." I then summed the scores from the three scales to calculate a combined attitude score, which was a discrete ordinal variable between -6 and +6.

I should note that achieving stable and meaningful measures of attitudes is particularly problematic in all areas of social science, which is why most questionnaires include multiple measures of each construct or subconstruct. Multiple measures for each of the three subconstructs listed above were created and used during the pilot stage of my research; however, all but one scale each had to be dropped because interviewees got impatient with the longer set of attitude scales.

H6: Adoption of non-diffused innovations is related to company size.

Company size is a difficult construct to operationalize in the home building industry. I considered three measures that are commonly used to measure firm size in other industries: total employees, annual revenues, and number of units (homes) produced per year. Each of these have problems in home building. Revenues are troublesome for four reasons. First, some firms have sister companies that perform subcontracting, development, or design, and it is unclear whether to include these employees or not. Second, companies with large revenues may actually build few homes because they derive most of their revenues from commercial construction. Third, large revenues do not imply either large net income or high number of employees because the firm may subcontract all activities. Fourth, many companies consider this confidential information. Total employees is problematic due to the problem of sister companies mentioned above. The number of homes has the problem of low correlation with revenues and employees. It was decided to gather data on total employees as well as number of homes.

H7: Adoption of high uncertainty, non-diffused innovations is negatively related to average house price while adoption of low uncertainty, non-diffused innovations is positively related to average house price.

The independent construct in this hypothesis was measured by asking interviewees what percentages of their homes typically fall into the starter, average, and luxury categories. Interviewees would occasionally respond with the price range of their homes, which would require me to discuss with them where their houses stood in relation to median prices in their areas. For example, a $150,000 home in Nashville is considered an average home, while in nearly all other areas it would be considered a starter. The indicator was calculated by multiplying the typical percentages of homes considered starter, average, or luxury by 1, 2 and 3, respectively, resulting in a discrete ordinal variable between 100 and 300 that was referred to as SEGMENT.

As discussed in Chapter Four, the resulting variable was decidedly non-normal because the majority of the sample built luxury homes. Some, but not all, statisticians believe that non-normally distributed variables are not appropriate for parametric analysis (Bryman & Cramer, 1990). It was decided to be conservative and transform the continuous variable relating to market segment to a dichotomous variable. A company received a score of 1 if its score for SEGMENT was above 220 and a 0 if its score was 220 or below. 220 was chosen as the cutoff because it resulted in approximately one-third of the sample receiving a score of 0.

H8: Adoption of non-diffused innovations is positively related to the age of the company.

Company age was measured by asking interviewees how many years the company had been in business, as shown the fifth page of Appendix 2. Because multiple regression is sensitive to extreme values, this variable was capped at 60 years.

H9: Adoption of non-diffused innovations is related to the geographic location of the company.

The location of the company was identified by the Yellow Pages that contained the builder's name. Since the seven regions represented in the sample are hundreds of miles apart, there is no chance of a company being listed in more than one set of Yellow Pages used to identify the sample. Location indicators were included in the multiple regression and probit models by including 0/1 dummy variables for all but one location (Colorado).

CHAPTER FOUR: DATA ANALYSIS AND FINDINGS

This chapter provides detailed analysis of my hypotheses using data collected from a telephone survey of 100 home builders. Using multiple regression analysis, confirmed by probit analysis, five of the nine hypotheses presented in Chapter Three were found to be statistically significant.

QUALITATIVE DATA

The data presented in this chapter provide systematic, objective evidence for my hypotheses but are sterile and lacking in richness. Before turning to the data analysis, it might be helpful to consider a few quotes by home builders that illustrate the broad hypothesis underlying my research that many technological innovations in home building are highly uncertain. These quotes were volunteered by home builders immediately after I began my interviews by stating that I was researching how home builders decide to use new building products.

The following remarks indicate that builders typically are missing information necessary to determine how well innovations will perform in their houses, that is, how well innovations will match with the home building task:

> "I just like to see it perform first. I don't want to have to go back and replace anything."
>
> "Lab tests only go so far. We don't like to be guinea pigs."
>
> "Some people like to take risks, but we like proven. Will people like it? Will it work?
>
> "We get lots of opportunity to try new things. You can take little risks, but how dangerous can you let yourself be? We are mostly a proven product builder."
>
> "There's no way of judging...[whether a new product will work. We]...don't need to try anything that is not proven."
>
> "You've got to remember that these new products are all prototypes. You don't know. You don't know how long it will last. How're you going to feel if it comes down and hurts somebody?"
>
> "We like to see it used by somebody else. Nobody wants to be first. So many

products have come and gone."

"You have to prove the product—takes 2-5 years. Lab tests don't cut it."

The next set of remarks indicate that builders typically are missing information necessary to determine how well innovations will be received by portions of their organizational environments, particularly by home owners.

"Buying a house is the biggest investment of their life, so they don't want to take any risks."

"People see OSB [oriented strand board] and think, 'more like cardboard than plywood.'"

"Market perception is screwy, but key."

"People don't understand how and why many new products are better."

"If the marketplace is not educated enough, you are really taking a risk. Take vinyl siding. It's a good product but customers drive by, see it going up, and think, 'there's a cheap house.'"

"What we are really talking about is trying to reach the buyer. There are times when we don't want anything new. They want tradition, nothing different."

"We're market driven. We wait for a customer to ask for something new."

"It's hard to be the first to do something. ...bankers, sales—there's lots of resistance."

"There's no question about it. Building codes limit the rate of innovation. Inspectors are cover-their-ass bureaucrats, each with his own pet peeve and own interpretations."

"Real estate agents can kill my ability to differentiate my homes, my ability to sell our use of new products."

Appendix 5 provides additional quotes by builders during my interviews that help convey the uncertainty builders typically perceive about innovations and how they reduce uncertainty through gathering information.

PRE-ANALYSIS PROCEDURES

The simplest way to furnish statistical evidence for my hypotheses would be to divide the sample based on numbers of high and low uncertainty innovations adopted and compare the means for each of the independent variables. Another simple analysis would be to perform univariate regression between each dependent variable and each independent variable. The problem with these approaches is that they provide evidence of association but do not imply causality. That is, if Y is shown through univariate analysis to be statistically related to both X_1 and X_2, we cannot be sure whether X_1 and X_2 each influence Y directly, whether X_2's influence on Y is a result of X_1's influence on X_2, or whether the relationship between Y and both Xs are the result of the influence between a fourth variable and both X_1 and X_2. Multiple regression, on the other hand, inherently controls for the influence of other independent variables included in the model. The regression coefficients represent the slope of the line of Y on X_i after the effects of the other Xs are "partialed out".

The theory underlying multiple regression makes several significant assumptions about the distributions of the dependent variables and independent variables and the nature of the relationships between them. Specifically, it is assumed that 1) dependent variables are continuous and approximate a normal distribution, 2) independent variables approximate a normal distribution or are categorical, and 3) the relationships between dependent and independent variables are linear in nature. Multiple regression textbooks suggest the need to perform various procedures before and after performing multiple regression analysis to confirm that the underlying assumptions are not violated by the data or the model. In addition, the independent variables should be analyzed to confirm that collinearity is not excessive (Belsley, Kuh, and Welsch, 1980; Weisberg, 1982).

The raw data used to test my hypotheses apparently violated the first two assumptions listed above. Specifically, although their distributions were bell shaped, my dependent variables were clearly discrete (not continuous) and had a relatively narrow range. It was decided the prudent course of action would be to confirm the results of the multiple regression with an analysis technique that did not require dependent variables to be continuous and normally distributed.

Many of the raw independent variables were also discrete. Furthermore, several were not even bell-shaped and were therefore probably inappropriate to include in multiple regression models in their raw forms. I corrected this problem through a combination of transformations and deletions. Specifically, I transformed the variables associated with the percentage of employees considered active in innovation-related activities (H2) and the number of homes typically built per year (H6) to a log form since this made them more normally distributed. I dropped three variables because even after various transformations their distributions were still fairly non-normal and because they were found to have excessive collinearity.[20] The three dropped variables were those relating to total employees (H6), the number of individuals considered active in innovation-related activities (H2), and the functions of individuals considered active in innovation-related activities (H3). As mentioned in Chapter Three, I transformed the variable relating to market segment (H7) into a dichotomous variable since its distribution was highly non-normal.

ORDINARY LEAST SQUARES MULTIPLE REGRESSION PROCEDURE

I performed a full (i.e., not stepwise) ordinary least squares regression of each of my two dependent variables against all of my (remaining) independent variables. The software used was SYSTAT for the Macintosh. I then performed residual and other diagnostics to verify that linear modeling was indeed appropriate, as discussed below.

1) Normal probability plots of the residuals indicated that the errors are normally distributed.

2) Scatter plots of residuals versus estimates indicated that the model has approximately constant variance.

3) Scatter plots of Cook distances and Student values versus estimates and the relatively minor diagnostic warnings shown on the regression output indicated that all members of sample were adequately described by the same linear model. I rechecked the raw data for the cases indicated as either outliers or exerting large leverage. Although these cases are slightly unusual in some respects (for example, the individual who decides whether to adopt new products in case 89 has a Ph.D. in engineering), their data contained no typographical errors and I did not feel it was appropriate to permanently remove them from the analysis. To be sure that these cases were not exerting excessive helpful influence on my data (i.e., increasing the significance of my findings), I removed the cases and re-analyzed the data. The results were found to be even more significant. That

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[20] As suggested by Weisberg (1982), I tested for collinearity by regressing each of the independent variables against all (i.e., multiple regression) of the other independent variables. The three independent variables that were dropped had multiple R-squared values exceeding 0.80.

is, the squared multiple R values were slightly higher and significant variables were found to be even more significant. Thus, leaving the outlier and high leverage cases in my sample actually has a conservative effect on my findings.

4) Scatter plots of residuals versus the interview sequence number indicated the errors were independent, i.e., not serially correlated.

5) Scatter plots of residuals versus independent variables with Lowess line smoothing confirmed the relationships between independent variables and dependent variables were linear in nature.

The Findings section in this chapter presents which hypothesized independent variables were found to be statistically related ($p<0.05$) to adoption of innovations that are not widely diffused. It is important to note that statistical significance is not the same as theoretical significance. A multiple regression model can have half of its independent variables statistically significant, yet the results are trivial because the model only captures a very small portion of the variance of the dependent variable. The amount of variance captured by my two regression models—as measured by multiple R squared values—are substantial for exploratory organizational research. The multiple R squared of the high and low uncertainty models were 0.44 and 0.41, respectively.

PROBIT PROCEDURE

It was decided to confirm the results of the regression analysis with a technique that did not assume continuous, normally distributed dependent variables. Probit and logit analyses are both variations of the standard multiple regression procedure which allow for dichotomous dependent variables, such as discrete choices. Judge *et al.* (1985) state that the differences between the two are slight and that the choice of which to use is usually based on convenience. Aldrich and Nelson (1984) state that the two techniques are essentially identical unless there are many cases at extreme probability values. Gatignon and Robertson (1986) performed both probit and logit analyses on adoption data and found only slight variation between the two sets of results.

The independent variables for the probit model were the same as those for the multiple regression model, but the dependent variables were slightly different. Instead of ranging from 0 to 5, the dependent variables in the probit model were made dichotomous. Builders who adopted 0 or 1 innovation in a set of high or low uncertainty innovations were scored as 0 for that set. Builders who adopted 2 or more innovations in a set were scored as 1 for that set. This grouping scheme resulted in approximately one-half of the sample considered to have a high propensity to adopt non-diffused innovations for each set of innovations. Aggregating the entire sample into two groups for each dependent variable in effect discards data because the analysis does not differentiate between cases included within groups. Probit is therefore inherently more conservative than multiple regression in estimating inferential statistical significance .

FINDINGS

The output from the multiple regression and probit analyses are shown on the following four pages.[21] Descriptions of the variable codes shown are provided in Appendix 3. Note that the p values shown on the regression output are for two-tailed t tests. Therefore, independent variables that are in the hypothesized direction can be considered significant if the value in the right column is $p<0.10$ or less.

Sources of information

Four of my hypotheses pertained to factors that influence the effectiveness of information gathering and processing. My first hypothesis was that adoption of non-diffused innovations was facilitated by tapping into higher numbers of external sources of information about innovations. This hypothesis was probably the most important element of uncertainty reduction and therefore the most important test of the themes underlying the thesis. How many employees are active in gathering or processing information about innovations (H2) and the functional responsibilities (H3) and analytical skills (H4) of these employees are probably meaningless if a company does not gather information from a number of different sources.

Table 4 indicates that the relationship between the number of information sources about innovations that builders considered important and the number of non-diffused innovations adopted is positive and significant for both high and low uncertainty innovations. Builders more apt to adopt both high and low uncertainty, non-diffused innovations tap into more sources of information about innovations than do non-adopters.

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21 The results shown on these pages and again as each hypothesis is discussed include the three individual professional backgrounds but not the variable for total professional backgrounds, as explained in the discussion of H4.

MULTIPLE REGRESSION ANALYSIS FOR HIGH UNCERTAINTY ADOPTION

VAR: DVHIGH
N: 100
MULTIPLE R: 0.664
SQUARED MULTIPLE R: 0.440
ADJUSTED SQUARED MULTIPLE R: 0.333
STANDARD ERROR OF ESTIMATE: 0.77

VARIABLE	COEF-FICIENT	STD ERROR	STD. COEF.	TOLER-ANCE	T	P (2TAIL)
CONSTANT	-0.41	0.87	0.00	.	-0.47	0.64
TOTINFO	0.28	0.08	0.37	0.64	3.65	0.00
TRADEBAK	0.70	0.28	0.23	0.78	2.52	0.01
AEBAK	-0.19	0.19	-0.09	0.84	-0.97	0.33
COLBAK	-0.19	0.19	-0.10	0.73	-1.01	0.32
LPERCEMP	-0.10	0.13	-0.08	0.56	-0.76	0.45
LHOMES	0.13	0.08	0.18	0.56	1.63	0.11
LYEARS	-0.09	0.11	-0.08	0.81	-0.83	0.41
FUNDM2	0.19	0.12	0.16	0.61	1.51	0.13
ATTITU	-0.01	0.03	-0.03	0.78	-0.36	0.72
SEG220	-0.02	0.19	-0.01	0.76	-0.12	0.91
MA	-0.85	0.34	-0.34	0.36	-2.47	0.02
IL	-0.52	0.33	-0.22	0.34	-1.58	0.12
NJ	0.03	0.37	0.01	0.41	0.07	0.94
NY	-1.10	0.37	-0.36	0.44	-2.93	0.00
TN	0.05	0.35	0.02	0.36	0.15	0.88
WA	-0.39	0.34	-0.15	0.40	-1.13	0.26

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	39.19	16	2.45	4.08	0.00
RESIDUAL	49.80	83	0.60		

WARNING: CASE 89 IS AN OUTLIER (STUDENTIZED RESIDUAL = 4.677)
WARNING: CASE 92 HAS LARGE LEVERAGE (LEVERAGE = 0.356)

DURBIN-WATSON D STATISTIC 2.129
FIRST ORDER AUTOCORRELATION -0.070

RESIDUALS HAVE BEEN SAVED

MULTIPLE REGRESSION ANALYSIS FOR LOW UNCERTAINTY ADOPTION

DEP VAR: DVLOW
N: 100
MULTIPLE R: 0.643
SQUARED MULTIPLE R: 0.414
ADJUSTED SQUARED MULTIPLE R: 0.301
STANDARD ERROR OF ESTIMATE: 0.88

VARIABLE	COEF-FICIENT	STD ERROR	STD. COEF.	TOLER-ANCE	T	P (2TAIL)
CONSTANT	1.57	0.99	0.00	.	1.59	0.12
TOTINFO	0.23	0.09	0.28	0.64	2.65	0.01
TRADEBAK	0.24	0.32	0.07	0.78	0.75	0.46
AEBAK	0.43	0.22	0.18	0.84	1.99	0.05
COLBAK	0.09	0.21	0.04	0.73	0.44	0.66
LPERCEMP	-0.04	0.15	-0.03	0.56	-0.28	0.78
LHOMES	-0.05	0.09	-0.06	0.56	-0.53	0.60
LYEARS	-0.02	0.13	-0.01	0.81	-0.15	0.88
FUNDM2	-0.08	0.14	-0.06	0.61	-0.58	0.56
ATTITU	0.09	0.04	0.24	0.78	2.49	0.01
SEG220	-0.01	0.21	-0.01	0.76	-0.07	0.95
MA	-0.35	0.39	-0.13	0.36	-0.91	0.36
IL	-0.50	0.38	-0.19	0.34	-1.32	0.19
NJ	0.30	0.42	0.09	0.41	0.71	0.48
NY	-0.48	0.42	-0.14	0.44	-1.13	0.26
TN	-0.86	0.40	-0.30	0.36	-2.13	0.04
WA	-0.53	0.39	-0.18	0.40	-1.37	0.18

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	45.13	16	2.82	3.66	0.00
RESIDUAL	63.91	83	0.77		

WARNING: CASE 33 IS AN OUTLIER (STUDENTIZED RESIDUAL = 3.125)
WARNING: CASE 92 HAS LARGE LEVERAGE (LEVERAGE = 0.356)

DURBIN-WATSON D STATISTIC 2.097
FIRST ORDER AUTOCORRELATION -0.052

RESIDUALS HAVE BEEN SAVED

PROBIT ANALYSIS FOR HIGH UNCERTAINTY ADOPTION

DEPENDENT VARIABLE: PDVHIGH
NUMBER OF INPUT CASES PROCESSED: 100
INDEPENDENT VARIABLE MEANS

VARIABLE	MEAN FOR D=0	MEAN FOR D=1
1 CONSTANT	1.00000	1.00000
2 TOTINFO	4.25000	4.91667
3 TRADEBAK	.807692	.979167
4 AEBAK	.307692	.229167
5 COLBAK	.634615	.583333
6 LPERCEMP	3.74271	3.52620
7 LHOMES	2.17140	2.37079
8 LYEARS	2.71464	2.59069
9 FUNDM2	2.02885	2.30208
10 ATTITU	-.221154	1.01042
11 SEG220	.692308	.645833
12 MA	.230769	.104167
13 IL	.230769	.166667
14 NJ	0.576923E-01	.187500
15 NY	.192308	0.208333E-01
16 TN	.134615	.187500
17 WA	.153846	.145833

CONVERGENCE ACHIEVED AFTER 6 ITERATIONS.
TOL = 0.100000E-02 % CHANGE IN LIKELIHOOD IS 0.367352E-03
NUMBER OF OBSERVATIONS: 100
NUMBER WITH DUMMY = 0 : 52
NUMBER WITH DUMMY = 1 : 48
-2 TIMES LOG LIKELIHOOD RATIO (CHI SQUARED) : 55.940
WITH 16. DEGREES OF FREEDOM
RESULTS OF ESTIMATION
LOG LIKELIHOOD: -41.2648

PARAMETER	ESTIMATE	STANDARD ERROR	T-STATISTIC
1 CONSTANT	-3.94752	2.14442	-1.8408
2 TOTINFO	.440032	.179023	2.4580
3 TRADEBAK	1.64722	.677064	2.4329
4 AEBAK	-.548901	.411285	-1.3346
5 COLBAK	-.427669	.383093	-1.1164
6 LPERCEMP	-.310902	.279058	-1.1141
7 LHOMES	.322976	.198763	1.6249
8 LYEARS	-.107068	.253655	-.42210
9 FUNDM2	.531783	.271016	1.9622
10 ATTITU	0.738495E-01	0.752880E-01	.98089
11 SEG220	.213881	.425730	.50239
12 MA	-3.78726	3.86491	-.97991
13 IL	3.33080	3.86462	.86187
14 NJ	-2.74458	3.88064	-.70725
15 NY	-4.81601	3.90269	-1.2340
16 TN	2.16341	3.87199	-.55873
17 WA	-3.07758	3.86518	-.79623

PROBIT ANALYSIS FOR LOW UNCERTAINTY ADOPTION

DEPENDENT VARIABLE: PDVLOW
NUMBER OF INPUT CASES PROCESSED: 100
INDEPENDENT VARIABLE MEANS

VARIABLE	MEAN FOR D=0	MEAN FOR D=1
1 CONSTANT	1.00000	1.00000
2 TOTINFO	3.93617	5.13208
3 TRADEBAK	.872340	.905660
4 AEBAK	.191489	.339623
5 COLBAK	.574468	.641509
6 LPERCEMP	3.68419	3.59853
7 LHOMES	2.41127	2.13927
8 LYEARS	2.63396	2.67394
9 FUNDM2	1.98936	2.31132
10 ATTITU	-.521277	1.16038
11 SEG220	.680851	.660377
12 MA	.148936	.188679
13 IL	.276596	.132075
14 NJ	0.212766E-01	.207547
15 NY	0.851064E-01	.132075
16 TN	.255319	0.754717E-01
17 WA	.170213	.132075

CONVERGENCE ACHIEVED AFTER 4 ITERATIONS.
TOL = 0.100000E-02 % CHANGE IN LIKELIHOOD IS 0.802304E-03
NUMBER OF OBSERVATIONS: 100
NUMBER WITH DUMMY = 0 : 47
NUMBER WITH DUMMY = 1 : 53
-2 TIMES LOG LIKELIHOOD RATIO (CHI SQUARED) : 43.901
WITH 16. DEGREES OF FREEDOM
RESULTS OF ESTIMATION
LOG LIKELIHOOD: -47.1842

PARAMETER	ESTIMATE	STANDARD ERROR	T-STATISTIC
1 CONSTANT	-.487560	1.71351	-.28454
2 TOTINFO	.395874	.154529	2.5618
3 TRADEBAK	-.477404	.498001	-.95864
4 AEBAK	.572562	.380910	1.5031
5 COLBAK	0.381609E-02	.366212	0.10420E-01
6 LPERCEMP	-.251326	.265347	-.94716
7 LHOMES	-0.619401E-01	.166365	-.37231
8 LYEARS	-.165878	.252239	-.65762
9 FUNDM2	0.309257E-01	.258779	.11951
10 ATTITU	.149698	0.648095E-01	2.3098
11 SEG220	.105444	.359006	.29371
12 MA	-.189057	.689729	-.27410
13 IL	-.831840	.668143	-1.2450
14 NJ	.930883	.908040	1.0252
15 NY	-.392788	.734825	-.53453
16 TN	-1.03849	.695504	-1.4932
17 WA	-.766535	.656019	-1.1685

Table 4: Multivariate analysis of the relationship between the number of information sources typically consulted and propensity to adopt non-diffused innovations.

		adoption of high uncertainty innovations	adoption of low uncertainty innovations
multiple regression	standard. coefficient	0.37	0.28
	t statistic	3.65	2.65
probit	estimate	0.44	0.40
	t statistic	2.46	2.56
finding		significant ($p<0.005$)	significant ($p<0.006$)

An interesting question related to this hypothesis is, Which sources of information best predict relatively early adoption? In other words, What sources of information do builders who are more apt to adopt non-diffused innovations tend to consider important that builders less apt to adopt early do not consider important? This question was answered by substituting the individual indicators for the nine sources of information for the indicator for total number of sources into the multiple regression models. The results of these analyses were that adoption of high uncertainty, non-diffused innovations were best predicted ($p<0.05$) by builders who considered other builders, in-house testing, and subcontractors important sources of information on innovations (see Figure 4). Adoption of low uncertainty, non-diffused innovations was best predicted by builders who considered architects, home owners, manufacturers, and subcontractors important sources of information (see Figure 5).

These findings are intuitively logical. Builders considering high uncertainty innovations seek information that they can trust. Asking a source of information that may be biased or wrong will not reduce uncertainty as well as will asking an unbiased source. Conducting their own testing programs and talking with other builders provide unbiased information. (It is not clear whether subcontractors provide unbiased information.) Some readers may be surprised that builders would share unbiased, helpful information with direct competitors. Schrader (1991), however, shows that employees in other industries frequently trade information because it best serves the economic interests of their firms.

Figure 4: Sources of information about innovations that best predict adoption of high uncertainty, non-diffused innovations.

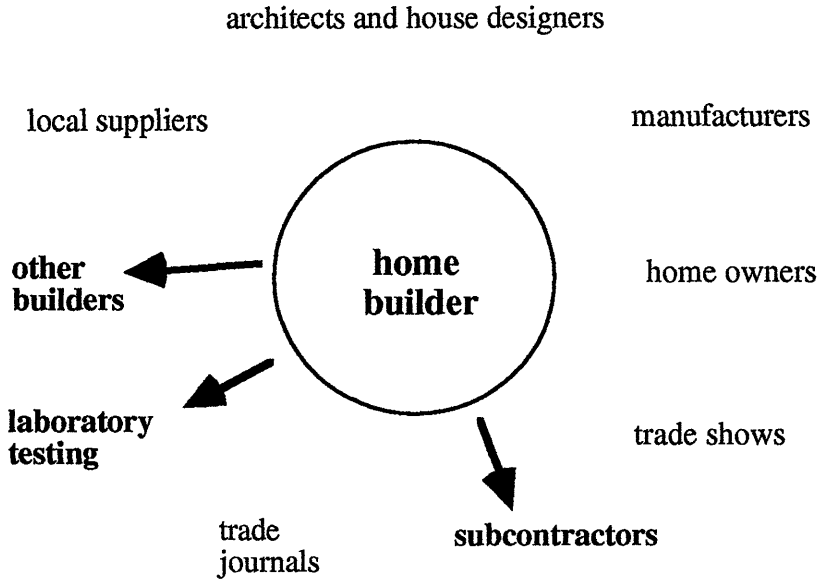
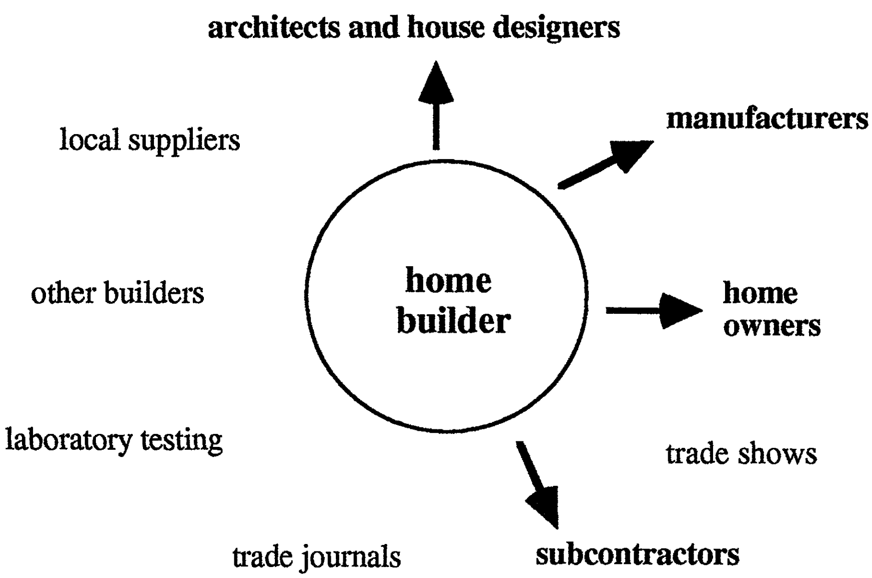


Figure 5: Sources of information about innovations that best predict adoption of low uncertainty, non-diffused innovations.



With low uncertainty innovations, the accuracy of the information is not as critical, so builders are comfortable seeking information from sources with whom they come into contact on a regular basis, yet who may not have full or unbiased information: architects, homeowners, manufacturers, and subcontractors. Of course, testing innovations and asking other builders could also provide helpful information on low uncertainty innovations, but both of these sources require more effort than necessary. Most of the builders I spoke with reported that unless they were active in the local builders association, they had little contact with other builders.

Numbers and percentages of employees gathering information

My second hypothesis suggested that adoption of non-diffused innovations is facilitated by higher <u>numbers</u> of employees and/or higher <u>percentages</u> of employees who participate in innovation-related activities. As each root and each leaf of a tree brings in certain amounts of water or carbon dioxide, each employee considered active in innovation-related activities was thought to bring in or process information that could be used to reduce uncertainty.

It was mentioned earlier in this chapter that the relationship between the number of employees active in innovation-related activities and relatively early adoption behavior was not analyzed because the independent indicator was found to be not normally distributed and to have excessive collinearity with the other independent variables.[22]

As shown in Table 5, there appears to be no relationship between the percentage of employees involved in innovation-related activities and adoption of either high or low uncertainty, non-diffused innovations. Apparently, the ability of builders to gain sufficient information in order to reduce the level of uncertainty to tolerable levels is not influenced by the portion of the workforce who contribute information or help in adoption decisions.

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[22] For the sake of completeness, I performed limited analysis on this indicator any way. The *univariate* relationship between the number of individuals active in innovation-related activities and adoption of high uncertainty innovations was positive and significant (t statistic = 2.09, p<.02). The *univariate* relationship with adoption of low uncertainty innovations was positively and significant (t statistic = 2.01, p<.03). I also inserted this indicator into the multiple regression models. With both models (corresponding to adoption of high and low uncertainty non-diffused innovations), the number of individuals active in innovation-related activities was not even close to being statistically significant, which implies that the significant univariate relationship were spurious or indirect.

Table 5: Multivariate analysis of the relationship between the percentage of employees active in innovation-related activities and propensity to adopt non-diffused innovations.

		adoption of high uncertainty innovations	adoption of low uncertainty innovations
multiple regression	standard. coefficient	-0.08	-0.03
	t statistic	-0.76	-0.28
probit	estimate	-0.31	-0.25
	t statistic	-1.11	-0.95
finding		not significant	not significant

Number of functions involved in adoption decisions

In light of the underlying premise that uncertainty reduction requires information be brought into the organization from the organization's environment, it was hypothesized that the more functions active in innovation-related activities, the more information gathering and processing are effective, which facilitates adoption. Multiple functions were theorized to be important for information processing and uncertainty reduction because individuals from each function are most closely connected with a specific portion of the environment. For example, sales staff—not superintendents top management, or other functions—should be most effective at providing information and analysis on how potential home buyers would respond to an innovation.

It was mentioned earlier in this chapter that the variable measuring the number of functions among the individuals considered active in *any* innovation-related activity was dropped due to high collinearity and non-normal distribution.[23] The variable measuring

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[23] For the sake of completeness, I performed limited analysis on this indicator any way. The *univariate* relationship between the number of functions among the individuals considered active in *any* innovation-related activity and adoption of high uncertainty innovations was positively and significantly related (t statistic = 1.65, $p<.05$). The *univariate* relationship early adoption of low uncertainty innovations was not significantly related (t statistic = 1.02). I also inserted this indicator into the multiple regression models. With the high uncertainty model, the number of functions active in any innovation-related activities was highly significant (t statistic = 2.25, $p<0.02$) when the indicator relating to the number of functions active in innovation adoption decisions was removed from the model. With the low uncertainty model, the number of functions active in any innovation-related activities was not significant (t statistic = -1.24, $p<0.22$).

the number of functions among the individuals active in adoption decisions (which is a subset of the individuals active in any innovation-related activity) was included in the multivariate analysis.

Table 6: Multivariate analysis of the relationship between the number of functions involved in adoption decisions and propensity to adopt non-diffused innovations.

		adoption of high uncertainty innovations	adoption of low uncertainty innovations
multiple regression	standard. coefficient	0.16	-0.06
	t statistic	1.51	-0.58
probit	estimate	0.53	0.03
	t statistic	1.96	0.12
finding		significant ($p<.05$)	not significant

As shown in Table 6, the relationship between the number of functions involved in making adoption decisions and adoption of high uncertainty, non-diffused innovations was found to be positively and significantly related, while no significant relationship was found with adoption of low uncertainty, non-diffused innovations. While the independent variable was hypothesized to significantly influence low uncertainty adoption as well as high, the lack of the relationship for low uncertainty innovations fits the underlying theory. Effective information gathering and processing are not as critical for adoption of low uncertainty innovations because potential adopters are not missing as much information as they are about high uncertainty innovations. Consequently, it is not essential that multiple functions are involved in low uncertainty adoption decisions.

The positive relationships between adoption and the number of functions involved and the number of external information sources consulted are analogous to what Allen (1977) found in his groundbreaking investigation of communication in R&D laboratories. The amount of information gathered (which leads to higher problem-solving performance) was found to be positively related to the number and diversity of external and internal sources of information that were consulted.

Professional backgrounds involved in innovation-related activities

Following the argument introduced for H3 that the characteristics of the individuals gathering and processing information about innovations influences adoption behavior, it was hypothesized in H4 that adoption of non-diffused innovations is facilitated by having multiple professional backgrounds active in innovation-related activities. The initial multiple regression models included one indicator that represented the number of professional backgrounds from a pre-established list of three. As shown in Table 7, this variable was not found to be statistically significant for either high or low uncertainty innovations.

Table 7: Multivariate analysis of the relationship between the number of professional backgrounds involved in innovation-related activities and propensity to adopt non-diffused innovations.

		adoption of high uncertainty innovations	adoption of low uncertainty innovations
multiple regression	standard. coefficient	-0.03	0.15
	t statistic	-0.26	1.59
probit	estimate	-0.18	0.22
	t statistic	-0.74	0.96
finding		not significant	not significant

It was decided to further analyze the relationship between adoption behavior and professional backgrounds. The regression model was re-analyzed with the individual indicators for the three backgrounds substituted into the multivariate model for the indicator for total backgrounds. (The revised hypothesis was that each professional background was independently and positively related to adoption of non-diffused innovations.) Tables 8, 9, and 10 indicate the findings from the multivariate analyses of the revised hypothesis.

Table 8 indicates that having at least one individual with a building trades background involved in innovation-related activities was found to be positively and significantly related to adoption of high uncertainty, non-diffused innovations. Table 9 indicates that having at least one individual with an architectural or engineering (AE) background involved in innovation-related activities was found to be positively and significantly related to adoption of low uncertainty, non-diffused innovations.[24] Table 10 indicates that having at least one individual with a college degree other than architecture or engineering involved in innovation-related activities was not found to be significantly related to adoption of either high uncertainty or low uncertainty, non-diffused innovations.

Table 8: Multivariate analysis of the relationship between having an individual with a building trades background involved in innovation-related activities and propensity to adopt non-diffused innovations.

		adoption of high uncertainty innovations	adoption of low uncertainty innovations
multiple regression	standard. coefficient	0.23	0.07
	t statistic	2.52	0.75
probit	estimate	1.65	-0.48
	t statistic	2.43	-0.96
finding		significant ($p<0.007$)	not significant

Table 9: Multivariate analysis of the relationship between having an individual with an architecture or engineering background involved in innovation-related activities and propensity to adopt non-diffused innovations.

		adoption of high uncertainty innovations	adoption of low uncertainty innovations
multiple regression	standard. coefficient	-0.09	0.18
	t statistic	-0.97	1.99
probit	estimate	-0.55	0.57
	t statistic	-1.33	1.50
finding		not significant	significant ($p<0.05$)

24 The probit t-statistic was actually below the one-tail critical t value for the appropriate degrees of freedom, however, this relationship will be accepted as statistically significant due to the high multiple regression t-statistic.

Table 10: Multivariate analysis of the relationship between having an individual with a college degree other than architecture or engineering involved in innovation-related activities and propensity to adopt non-diffused innovations.

		adoption of high uncertainty innovations	adoption of low uncertainty innovations
multiple regression	standard. coefficient	-0.10	0.04
	t statistic	-1.01	0.44
probit	estimate	-0.43	0.04
	t statistic	-1.12	0.10
finding		not significant	not significant

These findings are interesting in that two of the three backgrounds were each significant for adoption of innovations associated with one level of uncertainty but not the other. The fact that having at least one individual with a building trades background involved in innovation-related activities was significantly related to adoption of high uncertainty innovations but not to adoption of low uncertainty innovations fits with the underlying theme of the thesis: information processing characteristics facilitate adoption of all non-diffused innovations, but they are particularly critical to adoption of high uncertainty innovations. The data therefore support the idea mentioned in Chapter Three that individuals with a building trades background possess a unique ability to reduce a portion of the uncertainty associated with innovations. This ability is particularly important for adoption of high uncertainty innovations. For adoption of low uncertainty innovations, the uncertainty-reducing skills of individuals with a building trades background are not as critical and the building trades indicator is apparently lost in the noise of other variables.

The finding related to AE background is not so easily explained. It was suggested in Chapter Three that individuals with AE backgrounds possess unique skills that can help reduce the uncertainty of innovations. For example, individuals with an AE background might be more apt to adopt floor trusses or headers because they could understand the engineering principles underlying these products. This is illustrated by the following quote volunteered by a builder during an interview: "If you know enough about the products, the engineering principles, you can reduce the risk." It was therefore hypothesized that having at least one individual with an AE background involved in innovation-related activities facilitated adoption of non-diffused innovations. We would thus expect to find that this relationship was significant for adoption of high uncertainty innovations alone, or for both adoption of high uncertainty innovations and adoption of low uncertainty innovations. Instead the data indicated a significant positive relationship with adoption of low uncertainty innovations but a negative, not-significant relationship with adoption of high uncertainty innovations.

A plausible explanation for these findings relates to the tolerance of uncertainty of individuals with AE backgrounds and the uncertainty that they cannot reduce. Architectural or engineering knowledge can be applied to reduce the uncertainty of innovations associated with physical performance but not with market acceptance. If much of the uncertainty of high uncertainty innovations stems from the latter, we would expect to find a positive but weak relationship between AE background and adoption of high uncertainty, non-diffused innovations. However, since the education and professional norms of architects and engineers emphasize highly deterministic analysis and decision making, we might expect to find individuals with AE backgrounds to be less tolerant of uncertainty. Consequently, it is plausible that individuals with AE backgrounds can help gather and processes information to facilitate adoption of low uncertainty innovations, but actually hinder adoption of high uncertainty innovations due to strong status quo bias.

Positive attitude about early adoption

It was suggested in Chapter Two that in situations of low uncertainty, decision makers with a relatively high tolerance of uncertainty are more apt to decide to try a new building product without gathering additional information. It was thus hypothesized that having a positive attitude about early adoption of innovations—which implies a tolerance of uncertainty—would be positively related to adoption of low uncertainty, non-diffused innovations. It was also hypothesized that having a positive attitude would be positively related to adoption of high uncertainty, non-diffused innovations because it is less likely that high uncertainty innovations will be rejected due to status quo bias or regret bias.

Table 11 shows that the relationship between builders' attitudes and actual behavior regarding adoption of high uncertainty innovations is not statistically significant. The relationship between attitude and adoption of low uncertainty, non-diffused innovations, however, is positive and highly significant.

Table 11: Multivariate analysis of the relationship between positive attitude and propensity to adopt non-diffused innovations.

		adoption of high uncertainty innovations	adoption of low uncertainty innovations
multiple regression	standard. coefficient	-0.03	0.24
	t statistic	-0.36	2.49
probit	estimate	0.07	0.15
	t statistic	0.98	2.31
finding		not significant	significant (p<0.01)

As was the case with H3, finding statistical significance with adoption of non-diffused innovations with one level of uncertainty but not with the other does not contradict the underlying theory. A positive attitude or tolerance of uncertainty can directly influence adoption behavior of low uncertainty innovations because potential adopters are not missing so much information that information gathering is essential. On the other hand, with high uncertainty innovations, a positive attitude is not sufficient to lead to adoption, and variables more directly relating to information gathering outweigh the importance of a positive attitude.

It should be noted that if a hypothesized relationship in social science is not found to be statistically significant, it is possible that the theorized relationship is present but that the indicators are poor. As mentioned in Chapter Three, establishing attitude scales that are stable across individuals is quite difficult. It is possible that the three Likert scales adequately measured the attitudes of adopters of low uncertainty, non-diffused innovations but not of adopters of high uncertainty innovations. It is also possible that the attitude scales used inadequately captured tolerance of uncertainty.

Firm size

As stated in Chapter Three, the primary reason company size was included in the multiple regression models was to prevent size from being a plausible alternative explanation for significant findings related to other hypothesized variables. For example, it is plausible that larger companies are more apt to tap into more sources of information about innovations and to have formal decision making committees composed of multiple functions than are smaller firms. Without including an indicator of company size in the models, the significant findings related to H1, H3, H4, and H5 could have been dismissed as indirect effects of company size. It was also stated in Chapter Three that plausible theories pertaining to the relationship between company size and adoption behavior can be in either a positive or negative direction. Consequently, the direction of the relationship was not hypothesized.

As mentioned earlier in this chapter, data was collected on company size using two indicators: number of homes typically built per year and total employees. The latter was deleted from the analysis due to excessive collinearity.[25]

Table 12: Multivariate analysis of the relationship between (log) number of homes built each year and propensity to adopt non-diffused innovations.

		adoption of high uncertainty innovations	adoption of low uncertainty innovations
multiple regression	standard. coefficient	0.01	-0.02
	t statistic	0.10	-0.18
probit	estimate	-0.42	0.24
	t statistic	-0.31	0.18
finding		not significant	not significant

Table 12 indicates the data were inconclusive regarding whether company size—as measured by the number of homes built per year—is related to adoption of either high or low uncertainty, non-diffused innovations. It is important to remind the reader that only companies building 180 homes per year or less were included in the sample. Thus, the finding associated with this hypothesis should most accurately be stated as: "Among small and medium-sized home builders, company size was not found to be significantly related to early adoption." The data and analysis do not test whether the adoption behavior of large companies (i.e., those building between 300 and 2000 homes per year)

[25] For the sake of completeness, I performed limited analysis on this indicator any way. The *univariate* relationship between the total number of employees and adoption of high uncertainty innovations was positive and significant (t statistic = 2.15, p<0.02). The *univariate* relationship with adoption of low uncertainty innovations was not significant (t statistic = 1.18, p<0.12). I also inserted this indicator into the multiple regression models. The total number of employees was not significant in either the high uncertainty or the low uncertainty models.

is different from that of smaller companies.

Market segment

It was stated in Chapter Three that existing diffusion theory would suggest that builders building higher priced homes would tend to adopt both high and low uncertainty innovations earlier than would builders of affordable homes. It was hypothesized, however, that the relationship between average house price and adoption was positive only for low uncertainty adoption decisions. In light of the low tolerance of uncertainty theorized to exist among builders of high-end homes, it was hypothesized that adoption of high uncertainty, non-diffused innovations would be negatively related to average house price.

Table 13 shows that the indicator pertaining to market segment (starter, average, or luxury homes) was found to be not significant for either high or low uncertainty innovations. It is possible but unlikely that a significant relationship exists but was partially hidden when the raw variable pertaining to market segment was transformed into a dichotomous variable due to non-normal distribution. A more likely explanation is that the twelve innovations used to measure the dependent variables were equally balanced between cost-saving and performance-enhancing. The former tends to be adopted by the lower end of the market while the latter tends to be adopted by the high end of the market.

Table 13: Multivariate analysis of the relationship between average house price and propensity to adopt non-diffused innovations.

		adoption of high uncertainty innovations	adoption of low uncertainty innovations
multiple regression	standard. coefficient	-0.01	-0.01
	t statistic	-0.12	-0.07
probit	estimate	0.21	0.11
	t statistic	0.50	0.29
finding		not significant	not significant

Number of years in business

It was stated in Chapter Three that the primary reason company age was included in the multiple regression models was to prevent this variable from being a plausible alternative explanation for findings related to other hypothesized variables. Age was hypothesized to be related to adoption behavior but a direction was not specified. Table 14 indicates that company age was not found to be significantly related to adoption of either high uncertainty or low uncertainty, non-diffused innovations.

Table 14: Multivariate analysis of the relationship between years in business and propensity to adopt non-diffused innovations.

		adoption of high uncertainty innovations	adoption of low uncertainty innovations
multiple regression	standard. coefficient	-0.08	-0.01
	t statistic	-0.83	-0.15
probit	estimate	-0.11	-0.17
	t statistic	-0.42	-0.66
finding		not significant	not significant

Several builders I spoke with in the course of my investigation sincerely believe that adoption of new building products that are not widely diffused is so risky that builders who do so are mostly inexperienced fools who soon go out of business. While the results of my study cannot be used to convincingly reject this proposition (this would have required collecting data from builders who had indeed gone out of business), the lack of a significant relationship between company age and adoption behavior suggests that it is not accurate.

Geographic location

As stated in Chapter Three, indicators relating to the geographic location were included in the multiple regression and probit analyses primarily to prevent location serving as a rival explanation for findings associated with other hypotheses. The only theoretical link between location and uncertainty reduction/information processing is that some of the innovations included in the sample used to measure adoption behavior are more diffused in some regions than in others. The more diffused the innovation, the less information potential adopters are likely to be missing.

The output from the multiple regression and probit analyses provided at the beginning of this chapter indicates that geographic location is significantly related to adoption behavior for several of the regions. The analyses were performed by including dummy variables associated with all regions except Boulder, Colorado. Thus, the standardized coefficients and t statistics pertaining to location shown in the analyses output are relative to the Boulder area. (The coefficients and t statistics of the variables unrelated to location are not influenced by which location is chosen as the reference location.) For example, compared to Boulder, Rochester (NY) and Boston (MA) are negatively and significantly related to adoption of high uncertainty, non-diffused innovations.

The squared multiple R values of the high uncertainty and low uncertainty multiple regression models were 0.44 and 0.41, respectively, with the location dummy variables included in the models and 0.34 and 0.29, respectively, without them. This implies that location contributes approximately 25% of the explained variance in adoption behavior.

CHAPTER FIVE: CONCLUSIONS

This chapter first summarizes the theory, hypotheses, measurement methods, data collection techniques, analysis process, and findings that were discussed in Chapters One through Four. Implications of these findings for various groups associated with the home building industry and suggested research needs are then discussed.

SUMMARY

Research questions and background definitions

This thesis has presented theory and empirical data that contribute to answering two related research questions. The first question is, how are home builders who are more apt to adopt technological innovations that are not widely diffused different from home builders who are less apt to do so? The second question is, how are adopters of high uncertainty, non-diffused building innovations different from adopters of low uncertainty, non-diffused building innovations?

Chapter One introduced these questions, discussed why they are important for a number of groups and industries, and provided working definitions of key terms necessary to answer the questions. Technological innovations were defined as significant, technology-based improvements to the design, construction, or living space of homes. Uncertainty was defined as the state when an individual or organization is missing information necessary to make a decision. An organizational environment was defined as the unique set of conditions surrounding an organization—its competitors, customers, suppliers, technology, and regulatory sectors.

Existing and new theory

Chapter Two reviewed existing literature that helped answer the research questions of this thesis. The home building innovation literature is helpful in that it documents the environmental factors that influence generation and diffusion of technological innovations within the home building industry, but it does not address what internal factors influence adoption behavior of a given firm. Diffusion theory addresses what factors influence individual adoption behavior, but offers limited insight into organizational contexts. It was discussed how existing diffusion theory largely ignores the uncertainty permeating adoption decisions that results when the underlying tasks and organizational environments of potential adopters are highly complex.

It was also suggested in Chapter Two that five distinct characteristics of the home building task cause it to be highly complex and, thus, cause many adoption decisions to be highly uncertain:

- End products vary considerably.
- End products consist of many interacting parts and/or dynamic subsystems.
- End products face wide ranges of conditions over a long time frame.
- Task requires high levels of tacit knowledge and skills.
- Task requires interaction with a large number of diverse entities.

In light of the significant amount of uncertainty associated with home building innovations, it was surmised that response to uncertainty is a key behavior that differentiates builders who are more apt to adopt innovations that are not widely diffused from builders who are less apt to do so.

Descriptive decision theory that suggests how individuals and organizations respond to uncertainty was briefly reviewed relative to the thesis topic. When an individual is missing information necessary to make an optimal decision, she may take two paths: postpone the decision and gather some of the missing information, or make the decision based on existing information using heuristics. Which of these paths she takes depends on the amount of information that is missing and her tolerance of uncertainty. Consequently, we would expect adopters of non-diffused building innovations to have either superior abilities to gather and process information about innovations to reduce uncertainty, or to have higher tolerances of uncertainty.

Prospect theory (Kahneman & Tversky, 1979), status quo bias (Samuelson & Zeckhauser, 1988), and regret theory (Bell, 1988) provide similar theoretical explanations for why people often are biased against choices that offer higher expected outcomes but are more uncertain. These theories suggest that potential adopters of high uncertainty innovations would rarely adopt without gathering additional information. The bias against a high uncertainty innovation would be so excessive that the existing product or method would always be judged to offer higher relative advantage. It follows that information processing capabilities would be more important for adoption of high uncertainty, non-diffused innovations than for low uncertainty, non-diffused innovations.

Hypotheses and Methodology

The first half of Chapter Three presented nine hypotheses associated with the new perspectives on home building adoption behavior presented in Chapter Two. Five of these hypotheses pertain to structural, staffing, or cultural characteristics of home building firms which influence their ability to effectively process information about innovations in order to reduce uncertainty. Adopters of non-diffused innovations were hypothesized to tap into a greater number of different sources of information about innovations, to have greater numbers and percentages of employees active in innovation-related activities, to have greater numbers of functions[26] and professional backgrounds active in innovation-related activities, and to have a more positive attitude about early adoption of innovations.

Four of the hypotheses were not directly related to information processing but were included to eliminate plausible rival explanations for findings associated with the first five hypotheses. Company age was hypothesized to be positively related to propensity to adopt non-diffused innovations. Company size was hypothesized to be related to adoption behavior. The direction of the relationship was not specified due to conflicting plausible explanations. The relationship between market segment served (that is, the average house price of a firm) was hypothesized to depend on the level of uncertainty of the innovation. Adoption of high uncertainty, non-diffused innovations was hypothesized to be negatively related to average house price since builders serving high-end customers would be less tolerant of the risk of something going wrong with a new product. Conversely, adoption of low uncertainty innovations was hypothesized to be positively related because high end builders seek products that offer superior performance but with low perceived risk. Finally, company geographic location was hypothesized to influence adoption behavior for many reasons.

The second part of Chapter Three discussed how each hypothesis was tested, that is, how the dependent and independent constructs were measured, how data were collected from over 100 builders through semi-structured in-person and telephone interviews[27], and how the data were analyzed using ordinary least squares multiple regression analysis and

[26] Home building firms were conceptualized as having six functional areas: top management, procurement and administration, sales, design, site supervision, and field labor.

[27] The response rate was 55% if builders who never returned messages are counted as non-respondents, and 85% if only builders who were contacted and stated they were not willing to help are counted as non-respondents.

confirmed through probit analysis.

Findings

The results of the multiple regression and probit analyses of the data collected from 100 home building companies provide strong evidence for the general hypothesis that builders who are more apt to adopt non-diffused innovations are those who reduce uncertainty by gathering and processing information about innovations. One set of evidence is provided by the hypotheses that were found to be statistically significant. Four out of the five hypotheses that related to uncertainty reduction/information processing were significant for at least one of the two sets of innovations (high or low uncertainty) investigated. Out of the four hypotheses that did not relate directly to information processing, only one (geographic location) was found to be significantly related to adoption of either set of innovations. The beliefs held by many home builders that a firm's use of new building products reflects the firm's size, number of years in business, and market segment (price) were not borne out by the data.

A second and cruder set of evidence is provided by the multiple squared R values of the multiple regression models, which indicate how much of the variances in the dependent variable are explained by the independent variables included in the models. The multiple squared R values were 0.44 and 0.41 for adoption of high and low uncertainty non-diffused innovations, respectively. Approximately 75% of the explained variance was attributable to information processing characteristics while the remaining 25% of explained variance was attributable to geographic location. If uncertainty was not a key attribute of most building innovations, we should not have found that variables relating to information processing or tolerance of uncertainty would be so significantly related to adoption behavior.

The data therefore provides an answer to the first research question of this thesis: How are home builders who are more apt to adopt technological innovations that are not widely diffused different from home builders who are less apt to do so? Builders who are more apt to adopt non-diffused innovations are those who gather and process more information about innovations. Specifically, both adopters of high uncertainty, non-diffused innovations and adopters of low uncertainty, non-diffused innovations consult more sources of information about innovations found outside of their companies and consider this information in their adoption decisions.

The previous paragraph stated how adopters of high uncertainty non-diffused innovations and adopters of low uncertainty non-diffused innovations are alike. The second research question of this thesis was, how are these two groups different? Let me first review the findings associated with each set of innovations, then compare the two sets of findings.

Three of the nine hypotheses were found to be statistically significant ($p<0.05$) for high uncertainty innovations. The most statistically significant ($p<0.005$) and most theoretically important finding was already mentioned: Adoption of high uncertainty non-diffused innovations is strongly predicted by the number of information sources that a home builder consults in order to reduce uncertainty about specific innovations. Two other variables were also found to be statistically related to propensity to adopt high uncertainty non-diffused innovations. The number of functions (e.g., top management, sales, etc.) active in making adoption decisions was found to be positively related to adoption of non-diffused innovations as hypothesized. This finding, together with the finding regarding the number of information sources consulted, suggest that adoption of high uncertainty non-diffused innovations requires perspective and information associated with multiple sectors of the organization's environment. Each source of information that builders reported was important for gathering information about innovations is associated with a different portion of the environment.[28] Likewise, each of the functions in a home building company is most knowledgeable about one or more sectors of the organization's environment.

While the total number of professional backgrounds active in innovation-related activities was not found to be significant, having at least one individual with a building trades background active in gathering information or making adoption decisions was found to be positively related to propensity for relatively early adoption. Apparently, such individuals have tacit knowledge that allows them to process information related to how well the innovation will fit with the construction process.

Neither the percentage of employees considered active in innovation-related activities, whether a positive attitude about early adoption exists in the company, company size, market segment, nor the number of years a company has been in business were found to be significantly related to adoption of high uncertainty, non-diffused innovations.

Three of the six hypotheses concerning adoption of low uncertainty, non-diffused

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[28] The nine important sources of information about innovations reported by builders were architects or house designers, homeowners, local material suppliers, trade magazines, manufacturers literature and service representatives, other builders, trade shows, and subcontractors.

innovations were found to be statistically significant. Propensity to adopt low uncertainty, non-diffused innovations was found to be most strongly predicted ($p<0.006$) by the number of information sources about innovations that a home builder taps into in order to reduce uncertainty. Having a positive attitude about home building technological innovations in general—that is, believing that innovations are important to competitive success, that early adoption does not *always* present excessive risk, and that doing something first in the business can be beneficial—was also found to positively influence adoption behavior. In addition, having at least one individual with an architectural or engineering background active in innovation-related activities was found to be positively and significantly related to adoption of low uncertainty non-diffused building innovations. Apparently, such individuals apply their knowledge of materials and structural principles to reduce the uncertainty related to how well innovations may perform.

The percentage of employees considered active in innovation-related activities, the number of functions involved in adoption decisions, company size, market segment, and company age were found not to be significantly related to adoption of low uncertainty non-diffused innovations.

How are adopters of high uncertainty, non-diffused building innovations different from adopters of low uncertainty, non-diffused building innovations? While adopters of both high and low uncertainty non-diffused innovations obtain information about innovations from more sources of information than do builders less apt to adopt non-diffused innovations, the amount and quality of the information needed to facilitate adoption of high uncertainty innovations is higher than is needed for adoption of low uncertainty innovations. Consequently, having a positive attitude about innovations and/or a higher tolerance of uncertainty play a significant role in adoption of low uncertainty innovations, but not in adoption of high uncertainty innovations because it is overwhelmed by the need for effective gathering and processing of information about innovations.

Builders more apt to adopt high uncertainty innovations that are not widely diffused also differ from adopters of low uncertainty innovations in terms of the important characteristics of the individuals involved in innovation-related activities. While having at least one individual with an architectural or engineering background involved in innovation-related activities facilitates adoption of low uncertainty innovations, it does not facilitate adoption of high uncertainty innovations, apparently because such individuals are less tolerant of and cannot reduce high uncertainty related to market acceptance.

Adoption of high uncertainty non-diffused innovations is, however, facilitated by having someone with a building trades background to help evaluate how the innovation would fit with the company's house designs and subcontracting procedures.

Adoption of high uncertainty, non-diffused innovations also requires intimate knowledge of multiple sectors of the environment, which is provided by having multiple functions involved in adoption decisions. The functional duties of the individuals involved in innovation related activities characteristics are apparently not as important for adoption of low uncertainty innovations because the amount and nature of information is not so critical that knowledge about specific sectors of the environment is needed.

Figure 6 illustrates how adopters of high uncertainty, non-diffused innovations and adopters of low uncertainty, non-diffused innovations are alike and how they are different.

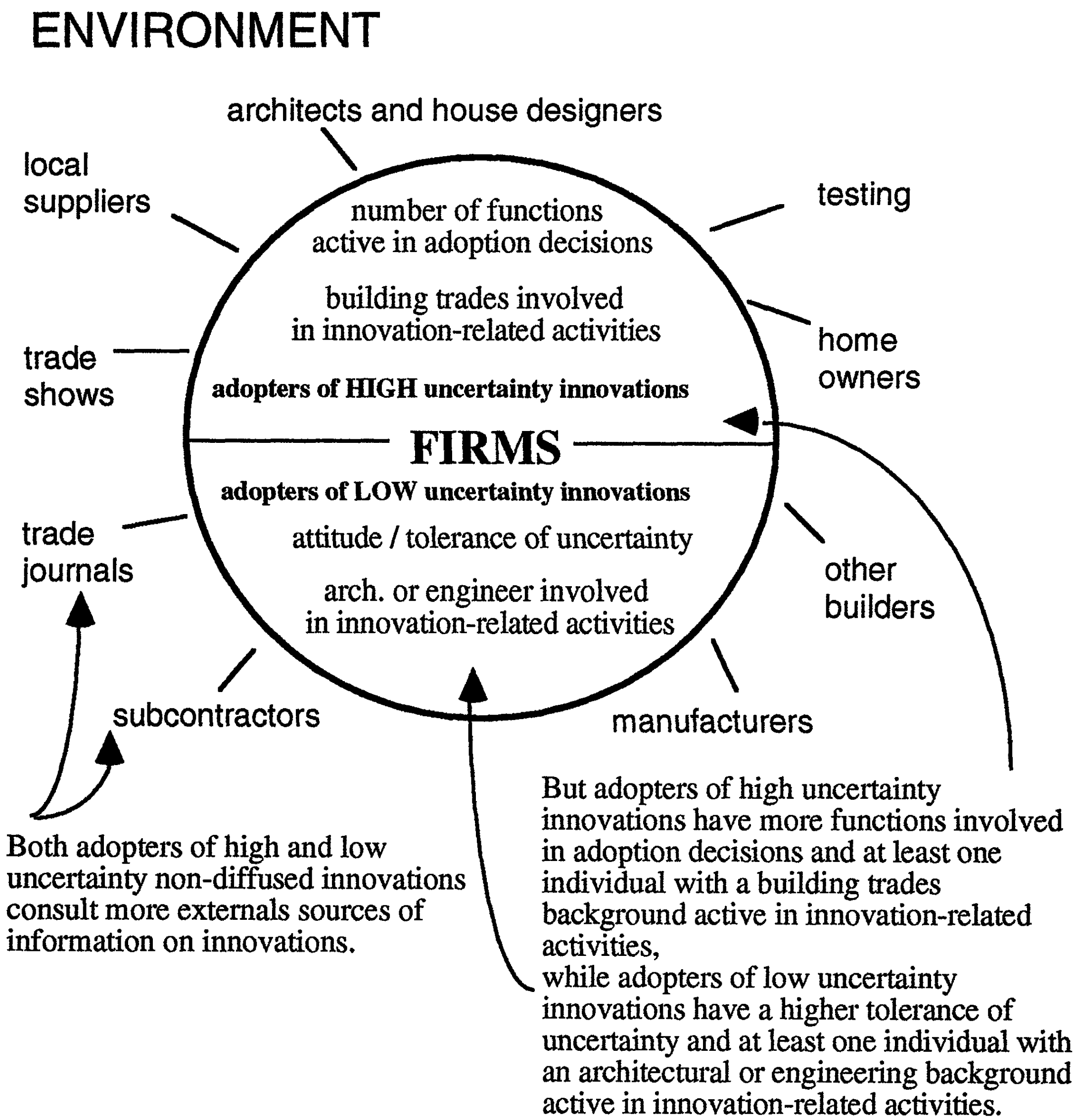
INFERENCES AND RESEARCH NEEDS

Although it was stated in Chapter One that this thesis was intended to be purely descriptive, most readers would be frustrated if the findings of any research did not have prescriptive implications—that is, point to what builders and other industry groups *should* do. This section extends the findings of my empirical research to infer what things builders and other industry groups should do differently.

Home builders

For the purpose of discussing the implications of this thesis, home builders can be divided into two groups: builders who believe that starting to use some new building products before they are widely diffused can pay off (that is, provide competitive advantage) and builders who believe that early adoption of building innovations can never pay off. For the first group, this thesis suggests they should establish appropriate staff, procedures, and norms within their organizations to more effectively gather and process information about innovations. Suggesting that information processing could be made more effective does not imply that builders should adopt more frequently adopt innovations before they are widely diffused. Rather, I am suggesting that builders improve the information processing within their companies to ensure the innovations that *are* adopted early are appropriate, that is, are more apt to be accepted by home owners, subcontractors, and local building departments and less apt to fail.

Figure 6: Comparison of adopters of high uncertainty, non-diffused innovations and adopters of low uncertainty, non-diffused innovations.



The findings suggest that vaguely assigning any one employee or *all* employees to be on the look out for new products probably will not be effective. An effective staffing plan should consider the number, professional backgrounds, and functional responsibilities of those assigned to gather information or make adoption decisions. Procedures should be established for collecting meaningful input about individual innovations from home buyers, subcontractors, retailers, and manufacturers, and for incorporating such input into timely adoption decisions.

Many of the builders I spoke with believe that early adoption of some innovations could be beneficial, yet had a company policy never to do it because identifying these innovations is too difficult and costly. This thesis suggests such builders should re-evaluate their policy in conjunction with improving the information processing within their organizations as summarized in the previous paragraphs.

For the second group of builders—those who believe that early adoption can never pay off—this thesis suggests that they too should reconsider their position. The empirical research presented in this thesis did not include a direct investigation of whether builders who are more apt to adopt non-diffused innovations are more successful than builders who are less apt. However, indirect evidence for the idea that relatively early adoption can pay off is provided by the finding in this thesis that adopters of non-diffused innovations are apparently more knowledgeable about innovations than are builders who do not adopt until an innovation is widely diffused. If decisions to adopt innovations relatively early were bad decisions, we would expect to find that early adopters made the decisions out of ignorance, i.e., that they did "not know what they were getting into." Instead, this thesis showed the opposite to be true. Builders who adopt relatively early know more about innovations because they seek information about them from more sources of information outside their companies and get more functional areas of their companies involved in the adoption decision.

Further evidence that early adoption may prove effective is provided by the relationship found between adoption behavior and the number of years firms have been in business. If relatively early adoption is always too costly or too risky, we would expect that builders more apt to adopt non-diffused innovations are young firms who have not yet "learned their lesson." We should have thus found the relationship between early adoption and firm age to be strongly negative. The data analysis indicated that this was not the case.

National Association of Home Builders

Detailed recommendations about what builders should do to improve their processing of information about innovations cannot be made without further research, which suggests that issues related to adopting building innovations should be added to the agenda of the research subsidiary of the industry's trade association, the National Association of Home Builders Research Center (NAHBRC). To better serve their constituency, NAHBRC should perform research to determine: what factors facilitate efficient information processing/uncertainty reduction among builders; what are the circumstances in which adoption of non-diffused innovations can pay off for a builder; and how builders can influence the acceptance of building innovations by home buyers, real estate agents, subcontractors, and local inspection officials.

This thesis did not attempt to empirically investigate the benefits in home building of adoption of technological innovations theorized in Toole (1990) and elsewhere, but there is clearly a need for such research. Unfortunately, the reluctance of home builders and other small businesses to reveal profits and the confounding effects of cyclical demand makes even a simple correlation study between adoption behavior and firm performance difficult.

The NAHBRC should consider establishing a clearinghouse to provide builders with information on specific innovations, either within NAHBRC or in conjunction with an independent organization. A database containing detailed information on projects in which specific innovations were used could reduce builder uncertainty about whether the innovation will perform well in the context of similar designs, site conditions, and other project factors.

Building material manufacturers

The findings of this thesis strongly suggest that material manufacturers should re-evaluate their marketing programs in light of the overwhelming influence of uncertainty on the adoption decisions of builders. In particular, manufacturers need to work closer with each of the industries and groups that contribute to builder uncertainty about new products.

Demand-pull marketing is risky and expensive in many industries, but it would seem to be warranted in home building since many custom builders will continue to look to customers to suggest new products. Marketing directly to home buyers will be more effective if market research is able to clarify confusing trends among homeowners. On one hand, home buyers are more educated about new products and more demanding about what is in their houses than they were in years past. On the other hand, most homeowners continue to be conservative about new products and very cost conscious. If material manufacturers already know, through market research, in which home elements mainstream home buyers still seek traditional design and materials and in which they are open to innovation, this information should be communicated to small builders.

Manufacturers need to work with retailers to ensure retail employees are as knowledgeable about new products as they are about existing products. Retailers will not sufficiently train their employees on new products without incentives from manufacturers. Sweaney, Meeks and Swagler (1992) show that builders' responses to an innovation based on text and pictures are considerably different than responses to viewing and touching it. Manufacturers should therefore also work with retailers to create shelf displays, in-store demonstrations, and take-home literature or samples that reduce uncertainty through visual and tactile exposure to the product and how it works.

Sales calls on builders by manufacturers representatives and demonstration house programs would also seem to be effective marketing tools for reducing uncertainty about performance. These methods also provide a valuable means for manufacturers to obtain direct feedback from builders. Trade shows provide hands-on exposure and opportunity for direct dialogue with builders, but many builders I spoke with told me that they avoid trade shows because they are too crowded and have excessive hype.

Manufacturers need to consider whether product design or product packaging can be improved to reduce the chances that contractors will store or install innovations improperly. Manufacturers also need to consider actual subcontractor installation costs (which may be highly localized) when pricing products and need to communicate this information to builders. Builders will then be more confident that promised cost savings will actually be achieved. To that end, manufacturers should perhaps even consider guaranteeing installation costs.

A final implication of my findings for manufacturers is that effective warranties should be part of the marketing mix of all innovative building products. Many of the warranties that come with new building products do not sufficiently alleviate the uncertainty of builders, installers, home owners, and local regulatory officials.

Academic theory

The empirical findings presented in this thesis indicate that the suggestions for improving diffusion theory discussed in Chapter Two deserve serious consideration. Although the empirical research reported here was not intended to adequately test whether variables directly related to uncertainty predict adoption behavior better than variables found in existing theory, the significant multiple squared R values of the multiple regression models indicate that the construct and effects of uncertainty may deserve more prominence in diffusion theory than they currently hold. The static research design used in this research was satisfactory for exploratory research, but future empirical studies must include direct measures of uncertainty and longitudinal and process research (Van de

Ven & Rogers, 1988) that more directly capture uncertainty reduction processes.

This thesis also suggests that diffusion theory needs to be expanded for organizational adoption, in particular to reflect task and environmental context. Unfortunately, although Conrath (1967), Duncan (1972), Miles and Snow (1978), Dess and Beard (1984), and others are helpful, no satisfactory, generalizable theoretical frameworks exist for categorizing task or environmental characteristics. Indeed, fundamental issues concerning the nature, measurement, and effects of organizational environments remain unresolved (Dess & Rasheed, 1991).

Closing Thoughts

It was suggested very early in this thesis that a significant portion of the public believe that home builders are either apathetic or excessively conservative about new building technologies. It is hoped that the theoretical perspectives on home builders' adoption of technological innovations presented in Chapter Two, the responses to the Likert scale items in my survey that measured builders' attitudes summarized in Chapter Four, and the quotes by builders included in Appendix 5 demonstrate that this belief is wrong. Most builders believe innovative building products are important for their competitive success and for best serving their customers. However, due to the many physical failures of new products in the past and the frequent resistance to new products by home owners and building regulatory officials, the vast majority of builders are highly suspect of using new products before they are widely diffused. Builders' behavior concerning new building products can therefore be viewed as a "rational" response to the challenging task and environmental characteristics of their industry.

This thesis began by pointing out the widespread belief that the American home building industry is not as innovative as it should be. This thesis has shown that if this belief is accurate, the problem does not lie solely with home builders or any other single group associated with the industry. If the rate of technical change in home building is to be increased, builders' uncertainty about new building products must be reduced. Individual home building firms can make a significant contribution toward this end by improving their abilities to gather and process information about innovations, but they cannot do it alone. The industries and groups that play key roles in the home building task and comprise home builders' organizational environments must also help builders process information and reduce the uncertainty of non-diffused building innovations.

APPENDICES

APPENDIX 1: CLASSIFICATION OF INNOVATIONS USED IN DEPENDENT VARIABLES

This appendix provides information on how the twelve innovations that were used to establish the dependent variables were classified as high or low uncertainty innovations. NAHBRC (1989b, 1991), Slaughter (1991), and articles from various trade magazines served as sources of data for this appendix. High uncertainty innovations are those for which builders are typically missing significant amounts of information necessary to answer the questions below. Low uncertainty innovations are those for which builders are typically missing less information to answer the questions below.

- Will it perform as promised in all of my homes over a long period of time?
- How much will potential home buyers value or resist it?
- To what extent will it affect and/or be resisted by subcontractors?
- To what extent will it be resisted by the local regulatory system?
- How much will money will it actually save or cost me?

HIGH UNCERTAINTY INNOVATIONS

Composite floor joists or trusses

Description: This term refers to two different products, wood I beams and trusses composed of laminated veneer lumber (LVL) or sawn lumber. Both replace sawn lumber, such as 2x10s or 2x12s, as the structural members holding up the subflooring and flooring.

Advantages: They are more dimensionally consistent and stable, giving the floor a more solid feeling and reducing the chance of squeaks developing. They can span longer distances while still meeting deflection criteria, thereby allowing larger open spaces.

Composite floor joists or trusses, continued

Criteria question	Amount of uncertainty and comments
Will it perform as promised in all of my homes over a long period of time?	HIGH: Squeaky and sagging floors are common and salient problems so builders are attuned to floor systems. Builders may be skeptical of performance because they do not trust or understand glue-based flaked engineered lumber and do not understand the principles underlying truss or I-beam design.
How much will potential home buyers value or resist it?	MEDIUM–HIGH: On one hand, home owners are attuned to potential causes of squeaky or sagging floors and are not apt to understand or trust the materials or design principles underlying these products. They may also think that these products cost less than sawn lumber and suspect a builder is just trying to save money. On the other hand, floor framing systems are not visible once framing is completed, so some home owners will not pay any attention to them.
To what extent will it affect and/or be resisted by subcontractors?	MEDIUM: Some framing subcontractors have never installed these products. Some electrical, plumbing, and HVAC subcontractors do not know how to work around these products.
To what extent will it be resisted by the local regulatory system?	MEDIUM: Some building inspectors are not familiar with the products and have concerns about their long-term performance and proper connection details.
How much will money will it actually save/cost me?	HIGH: Builders are often concerned about changes in local pricing and availability and whether subcontractors will charge more because they are not familiar with the products.

Computer-aided design/drafting (CADD)

Description: Computer software programs which produce printer/plotter-generated drawings ("blueprints").

Advantage: A set of plans can be stored in a computer file, allowing modifications to be made quickly and easily and a new set of plans to be printed. Also, drawings are more legible, cleaner and more uniform than hand-drawn plans.

Criteria question	**Amount of uncertainty and comments**
Will I achieve the expected performance benefits?	HIGH: CADD systems have gotten mixed reviews in the construction industry, with frequent reports of equipment and training costs outweighing productivity or marketing gains. Builders who typically hire out design and view CADD as a tool for including this service as part of their company's work scope have particularly high uncertainty about whether they will be able to effectively adopt this tool.
How much will potential home buyers value or resist it?	MEDIUM–HIGH: It is difficult to gauge whether home owners will appreciate the performance advantages. While CADD drawings look more professional, they lack the personality of hand-rendered drawings. Custom home owners may lose the sense that their home design is unique.
To what extent will it affect and/or be resisted by subcontractors?	LOW: Subcontractors are rarely affected.
To what extent will it be resisted by the local regulatory system?	LOW: The building permitting and inspection processes are rarely affected.
How much will money will it actually save/cost me?	HIGH: The investment in hardware and software required to perform CADD is substantial. Even builders who already own and use personal computers typically must upgrade their systems in order to run CADD programs. The time and costs required to make CADD operators productive are difficult to estimate but substantial.

Oriented strand board (OSB)

Description: Structural sheathing product made out of oriented strands of wood (similar to wafer board) that replaces plywood in walls, roofs, and perhaps floors.

Advantages: Less expensive than plywood.

Criteria question	**Amount of uncertainty and comments**
Will it perform as promised in all of my homes over a long period of time?	HIGH: Many builders associate OSB with earlier generations of waferboard or particleboard, which deteriorated when wet. Even some of the builders who are not concerned about wetness failure claim OSB is not dimensionally stable under moisture (i.e., it swells) or that it does not hold nails as well as plywood.
How much will potential home buyers value or resist it?	HIGH: Most home owners perceive OSB to be a cheap substitute for plywood and also associate OSB with earlier generations of waferboard.
To what extent will it affect and/or be resisted by subcontractors?	MEDIUM–LOW: Only the framing and siding subcontractors are affected.
To what extent will it be resisted by the local regulatory system?	MEDIUM: Many local inspectors share builders' concerns over long-term performance.
How much will money will it actually save/cost me?	HIGH: The price difference between OSB and plywood has fluctuated, as has OSB availability. Many builders fear that the $400 or so that they would save on a house by using OSB would be more than offset by the need to lower the price of the house due to home owner resistance.

Steel studs

Description: Steel studs (which are lightweight steel channel) most directly replace 2X wood studs and are part of an overall steel framing system (with metal top plates, headers, etc.).

Advantage: The price per linear foot of steel studs has dropped to below that of wood studs. Also, steel studs are more dimensionally uniform and stable than wood studs.

Criteria question	**Amount of uncertainty and comments**
Will it perform as promised in all of my homes over a long period of time?	LOW: Steel studs have a proven track record in commercial construction.
How much will potential home buyers value or resist it?	HIGH: Steel framing in houses is a totally foreign concept to most home owners. Home owners seem content with the idea of steel studs in commercial walls, but view an underlying wood frame as the essence of a home.
To what extent will it affect and/or be resisted by subcontractors?	HIGH: Steel framing would require most builders to start working with entirely new sets of framing subcontractors.
To what extent will it be resisted by the local regulatory system?	MEDIUM: Some building inspectors are not familiar with steel framing.
How much will money will it actually save/cost me?	HIGH: Although the price per linear foot of steel studs is currently less than that of wood studs, builders fear that the total material and labor costs of the framing system will not be lower. Also, builders fear that steel manufacturers will raise the price of steel studs.

Plastic freshwater piping

Description: Freshwater plumbing (i.e., supply rather than waste) pipe made out of polybutylene or polyvinyl chloride instead of copper.

Source and type of advantage: The price is both less expensive and less volatile than the price of copper pipe.

Criteria question	Amount of uncertainty and comments
Will it perform as promised in all of my homes over a long period of time?	MEDIUM–HIGH: Earlier versions of plastic pipe cracked over time and current plastic pipe is still more apt to crack if frozen.
How much will potential home buyers value or resist it?	MEDIUM–HIGH: Plastic pipe is still viewed as a cheap substitute for copper pipe. Plastic pipe is noisier than copper.
To what extent will it affect and/or be resisted by subcontractors?	MEDIUM: Some plumbing subcontractors do not install plastic freshwater pipe.
To what extent will it be resisted by the local regulatory system?	MEDIUM: Many building codes do not allow plastic freshwater pipe within the house. Even in areas that allow it, local inspectors are often leery of its long-term performance.
How much will money will it actually save/cost me?	LOW

Vinyl siding

Description: Exterior finish material for walls that is made out of vinyl instead of wood.

Advantages: More durable and requires less maintenance than wood.

Criteria question	Amount of uncertainty and comments
Will it perform as promised in all of my homes over a long period of time?	MEDIUM–HIGH: Earlier generations of vinyl siding cracked and warped over time. Builders in some regions of the country fear deterioration due to ultraviolet exposure.
How much will potential home buyers value or resist it?	HIGH: Most home owners still view vinyl siding as a cheap and less desirable alternative to wood, probably because early versions did not provide satisfactory performance and exhibited a distinctive sterile appearance.
To what extent will it affect and/or be resisted by subcontractors?	MEDIUM: Some builders would be required to start working with installers who currently perform mostly remodeling.
To what extent will it be resisted by the local regulatory system?	MEDIUM: Some local inspection officials share builders' concerns about performance.
How much will money will it actually save/cost me?	LOW: Material and installation costs are relatively predictable.

LOW UNCERTAINTY INNOVATIONS

Computer-aided estimating or scheduling

Description: Computer software programs that facilitate scheduling or cost-estimating of future homes.

Advantage: Scheduling programs allow rapid and easy calculation of expected completion dates, activity float, resource utilization, and other sets of information that help builders manage subcontractors and keep future home owners appraised of progress. Estimating programs allow rapid calculation of costs to improve cash management and the transfer of information gained from one project to another.

Criteria question	**Amount of uncertainty and comments**
Will I achieve the expected performance benefits?	MEDIUM: Many builders have set up spreadsheets or word processing templates to help them document and track construction costs as they occur; however, dedicated estimating and scheduling programs are decidedly less flexible and less intuitive but more powerful. Some builders perceive that costing information from one home cannot be effectively applied to other homes due to various aspects of the design, size, or site layout that make each home unique.
How much will potential home buyers value or resist it?	LOW
To what extent will it affect and/or be resisted by subcontractors?	LOW
To what extent will it be resisted by the local regulatory system?	LOW
How much will money will it actually save/cost me?	MEDIUM: Some builders fear the time necessary to enter information about each home into the programs may outweigh the tangible benefits.

House wrap

Description: A layer of synthetic material that is stapled into the sheathing over the entire building envelope much like building paper. This product is often referred to by the brand name "Tyvek."

Advantages: The material is formulated to repel wind and water but allow water vapor to migrate from inside the house to the outside. As a result, a house is "tighter" (i.e., less drafts and more energy efficient) without causing moisture buildup on or inside walls.

Criteria question	**Amount of uncertainty and comments**
Will it perform as promised in all of my homes over a long period of time?	MEDIUM–LOW: Some builders question whether the product really works better than traditional building papers. The benefits of a "tight" houe are lost if design and construction near the sill and around windows are not effective.
How much will potential home buyers value or resist it?	MEDIUM–LOW: Most builders apparently perceive that home owners like the idea of the product but may not be willing to pay extra for it.
To what extent will it affect and/or be resisted by subcontractors?	LOW
To what extent will it be resisted by the local regulatory system?	LOW
How much will money will it actually save/cost me?	LOW

Composite wood beams or headers

Description: Structural beams made out of LVL flanges and an oriented strand board (OSB) web that replace sawn 2x lumber.

Advantages: Due to the I-beam design and use of engineered materials, they can span longer distances and are more dimensionally stable.

Criteria question	**Amount of uncertainty and comments**
Will it perform as promised in all of my homes over a long period of time?	MEDIUM: Some builders are skeptical of these products' performance because they do not understand the underlying I-beam principle.
How much will potential home buyers value or resist it?	MEDIUM–LOW: Home owners are less apt to understand or trust the materials or design principles underlying these product than are builders; however, many homeowners have seen them used before. Also, many homeowners pay little attention to headers.
To what extent will it affect and/or be resisted by subcontractors?	MEDIUM–LOW: Many framing subcontractors have used these products. Using them usually does not affect the work of other subcontractors.
To what extent will it be resisted by the local regulatory system?	LOW: Most building inspectors are familiar with these products.
How much will money will it actually save/cost me?	MEDUM: Builders are often concerned about changes in local pricing and availability.

Insulating concrete wall forms

Description: Blocks or panels made out of expanded polystyrene or similar polymeric material that serve both as a forming material for concrete and thermal barrier. Most often used in foundations, but can be used in walls also.

Advantage: Provide superior thermal insulation, may increase the speed of construction, and may allow concrete be placed on days that would otherwise be too cold.

Criteria question	Amount of uncertainty and comments
Will it perform as promised in all of my homes over a long period of time?	MEDIUM–LOW: Many builders already install rigid insulation sheeting over their concrete walls.
How much will potential home buyers value or resist it?	MEDIUM: Most home owners do not think about thermal performance of foundation walls as much as they do about above-grade walls.
To what extent will it affect and/or be resisted by subcontractors?	MEDIUM–HIGH: Most foundation contractors are not familiar with the product and would incur training costs. Also, they have invested substantially in conventional forming systems.
To what extent will it be resisted by the local regulatory system?	MEDIUM: Local building inspectors may not be familiar with the product.
How much will money will it actually save/cost me?	LOW

Non-wood trim

Description: Outside trim or molding for baseboard or ceiling that is made out of either vinyl or a plastic-wood composite.

Advantage: Either less expensive and more uniform than comparable wood or allows more ornate patterns.

Criteria question	**Amount of uncertainty and comments**
Will it perform as promised in all of my homes over a long period of time?	MEDIUM–LOW: Some builders fear that outside vinyl trim will crack or warp and that the veneer-over-plastic-wood composites may de-laminate.
How much will potential home buyers value or resist it?	MEDIUM: Some home owners may reject materials other than real wood as cheap substitutes.
To what extent will it affect and/or be resisted by subcontractors?	LOW
To what extent will it be resisted by the local regulatory system?	LOW
How much will money will it actually save/cost me?	LOW

Vinyl windows (clad or all–vinyl)

Description: Windows with frames that are made nearly entirely out of vinyl or are made of vinyl-clad wood.

Advantages: More attractive than aluminum-clad windows. Less expensive than all-wood windows and do not require painting.

Criteria question	Amount of uncertainty and comments
Will it perform as promised in all of my homes over a long period of time?	MEDIUM: Some builders fear the vinyl will crack or warp, particularly in regions of high ultraviolet exposure.
How much will potential home buyers value or resist it?	MEDIUM: Some home owners view the products as a cheap substitute for all-wood windows and/or have concerns about the vinyl deteriorating.
To what extent will it affect and/or be resisted by subcontractors?	LOW
To what extent will it be resisted by the local regulatory system?	LOW
How much will money will it actually save/cost me?	LOW

APPENDIX 2: QUESTIONNAIRE USED AS SCRIPT IN TELEPHONE SURVEY

Massachusetts Institute of Technology, Center for Construction Research and Education
77 Massachusetts Ave, Room 1-041, Cambridge, MA 02139. 617-648-4466. Fax 617-641-2980.

QUESTIONNAIRE ON NEW BUILDING TECHNOLOGIES

Company: ______________________________ Date: ______________

Name of individual completing the questionnaire: ______________________________

Which of the innovative building products listed below does your company use on a regular basis? Let's say that "on a regular basis" means using it in 1/4 of the cases in which you have an opportunity to do so. *Please circle the answer that best describes your company for each product. Feel free to comment on any or all of the products you don't use.*

Composite floor joists or trusses	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT
Composite wood beams or headers	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT
Computer-aided design/drafting (CADD)	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT
Computer-aided estimating or scheduling	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT
House wrap (e.g., Tyvek)	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT
Insulating concrete wall forms	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT
Non-wood trim	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT
Oriented strand board (OSB)	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT
Polybutylene or CPVC freshwater pipe	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT
Steel studs	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT
Vinyl siding	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT
Vinyl windows (clad or all vinyl)	USE IT REGULARLY	TRIED IT BUT DON'T USE IT REGULARLY	NEVER USED IT

We are interested in your attitudes relating to new building products and technologies. *Please place a check next to the answer which best describes your company or how you feel.*

In general, when do you start to use a new building product relative to other builders in your area?

We are generally one of the first	________
We generally start shortly after the first	________
We generally start about the same time as most other builders	________
we generally start after most other builders	________
we are generally one of the last	________

Are there exceptions to what you typically do? Have there been one or more new building products in which you started to use it right after it came out? *If you check "yes", please list the products.*

No ________
Yes ________ *PLEASE LIST THEM*
____
____

In general, there is little to be gained from being the first to do anything in the home building business. *Do you agree with this statement?*

I strongly disagree	________
I somewhat disagree	________
I am neutral	________
I somewhat agree	________
I strongly agree	________

Using new building products does not make much of a difference in the cost or performance of a house and does not improve profits or sales. *Do you agree with this statement?*

I strongly disagree	________
I somewhat disagree	________
I am neutral	________
I somewhat agree	________
I strongly agree	________

In general, the benefits from using new building products right after they are introduced are outweighed by the risks of using them. *Do you agree with this statement?*

I strongly disagree	________
I somewhat disagree	________
I am neutral	________
I somewhat agree	________
I strongly agree	________

Which of the following groups frequently suggest a new product or provide you with information that helps you decide whether to try a new product?

Potential source of information	*Please check all important sources of information*
1. Architects / house designers	________
2. Homeowners / customers	________
3. Local material suppliers	________
4. Magazines, newspapers, and newsletters	________
5. Manufacturers literature and service reps	________
6. Other builders	________
7. Results of your own testing (such as laboratory or field tests other than trying it in one of your houses)	________
8. Seminars and trade shows	________
9. Subcontractors	________

Please indicate below the total number of people who work in the following job categories in your company.

JOB CATEGORY	Number of people in this job category in the company
TOP MANAGERS	________
OFFICE STAFF	________
SALES STAFF	________
DESIGN STAFF	________
SUPERINTENDENTS AND OTHER FIELD MANAGERS	________
TRADESMEN AND OTHER FIELD EMPLOYEES	________

Please indicate below the number of people in each job category who at least occasionally suggest new building products or gather information about them.

JOB CATEGORY	Number of people somehow involved in considering new products
TOP MANAGERS	_______
OFFICE STAFF	_______
SALES STAFF	_______
DESIGN STAFF	_______
SUPERINTENDENTS AND OTHER FIELD MANAGERS	_______
TRADESMEN AND OTHER FIELD EMPLOYEES	_______

What are the backgrounds of the people of who are active in suggesting new building products or gathering information about them? *Please check all that apply*

One or more has field experience in the building trades.	____
One or more has an architectural or engineering background.	____
One or more has a college degree in other than architecture or engineering.	____

Of the individuals who suggest or help evaluate new building products, how many spend more than 25% of their workday on these activities?

NONE	____
1–2	____
3–5	____
6 OR MORE	____

What is the position(s) of the individual(s) who decides whether to try a new building product? *Please check all that apply*

TOP MANAGERS	______
OFFICE STAFF	______
DESIGN STAFF	______
SALES STAFF	______
SUPERINTENDENTS AND OTHER FIELD MANAGERS	______

Does your company perform non-residential construction?

Yes	____
No	____

Please check the portions of your houses that you typically perform with in-house crews rather than subcontracting out the activities.

Excavation	_____
Paving	_____
Foundation	_____
Framing	_____
Doors/windows	_____
Drywall	_____
Painting	_____
Finish carpentry	_____
Flooring	_____
Insulation	_____
Plumbing	_____
Electrical	_____
HVAC	_____
Other *(PLEASE SPECIFY)*	______________
	______________

It is important that we know a few more things about your company. Please don't skip this section. The information requested below is as critical to our research as the questions you have already answered!

How many homes do you typically build a year?

homes per year ______

Of the total number of homes that you build each year, approximately what percentage are built speculatively, that is, construction is started before the owner is known?

built speculatively ______%

Of the total number of homes that you build each year, approximately what percentage are built on your own land, that is, on land not owned by some one else at the time of construction?

built on own land ______%

Of the total number of homes that you build each year, approximately what percentages are typically single family detached versus multi-family?
single-family detached (SFD) ______%
multi-family ______%

Of the total number of homes that you build each year, approximately what percentages are typically in the following market segments:
Starter ______%
Average ______%
Luxury ______%

How many years has your company been in business?

years in businesses ______

Have I missed anything? Are there factors influencing builders' use of new building products that I haven't asked?

____

____

____

Thank you very much for taking the time to complete this survey. If you would like to talk about new building technologies and products or about any of the questions in this survey, please feel free to call Mike Toole at 617–648–4466 or write your name and number below. I will call you shortly.

____

APPENDIX 3: RAW DATA

This appendix includes the raw data used to empirically investigate my hypotheses. It is provided to allow other researchers to perform meta-analysis. Home building companies (n=100) are grouped by rows, with the dependent and independent variables grouped by columns. This appendix also includes data on several variables that were collected during the telephone interviews but not included in the hypotheses or data analysis.

Key to the variable codes used in my analysis

CODE	DESCRIPTION	DATA CHARACTERISTIC
num	Case number assigned to each builder.	integer variable ranging from 1 to 100.
floors	Composite floor joists or trusses; used to measure adoption of high uncertainty, non-diffused innovations (dependent variable for H1–H9).	dummy variable scored as 1 if the innovation was reported to be used on a regular basis, 0 if not used on a regular basis.
cadd	Computer-aided design/drafting (CADD); see estsched	same as floors
osb	Oriented strand board (OSB); see floors	same as floors
pipe	Polybutylene or CPVC freshwater pipe; see floors	same as floors
studs	Steel studs; see floors	same as floors
siding	Vinyl siding; see floors	same as floors
estsched	Computer-aided estimating or scheduling; used to measure adoption of low uncertainty, non-diffused innovations (dependent variable for H1–H9).	same as floors
wrap	House wrap; see estsched	same as floors
forms	Insulating concrete wall forms; see estsched	same as floors
headers	Composite wood beams or headers; see estsched	same as floors

trim	Non-wood trim; see estsched	same as floors
windows	Vinyl windows (clad or all vinyl); see estsched	same as floors
arch	Architects and house designers; used to measure the number of sources of information about innovations that a builder taps into (independent variable for H1)	dummy variable scored as 1 if the source was considered an important source of information on new building products, 0 if not.
buyer	Home owners; see arch	same as arch
suppl	Local material suppliers; see arch	same as arch
mags	Trade journals and newsletters; see arch	same as arch
mfrs	Manufacturers literature and service representatives; see arch	same as arch
bldrs	Other builders; see arch	same as arch
test	Laboratory testing; see arch	same as arch
show	Trade shows and seminars; see arch	same as arch
subs	Subcontractors; see arch	same as arch
totinfo	Number of information sources that company regularly taps into concerning new products; calculated by summing the scores assigned to the nine variables listed above (independent variable for H1)	discrete variable with maximum range of 0 to ∞ and actual range between 3 and 7
totempl	Total number of employees in the company. (not used)	discrete variable ranging from 1 upward
numind	Number of individuals considered active in gathering information about or deciding to use new building products. (not used)	discrete variable ranging from 1 and up

state	Region in which the builder's name was found in the Yellow Pages (used to create dummy variables for each region; which were independent variables for H9)	nominal variable using standard state abbreviations, transformed into 0/1 dummy variables for each region
first	Used to measure attitude about early adoption; Likert scale response to: "In general, there is little to be gained from being the first to do anything in the home building business." (independent variable in H5)	5-point Likert scale ranging from -2 to +2.
import	Used to measure attitude about early adoption; Likert scale response to: "Using new building products does not make much of a difference in the cost or performance of a house and does not improve profits or sales." (independent variable in H5)	5-point Likert scale ranging from -2 to +2.
risks	Used to measure attitude about early adoption; Likert scale response to: "In general, the benefits from using new building products right after they are introduced are outweighed by the risks of using them." (independent variable in H5)	5-point Likert scale ranging from -2 to +2.
attitu	Attitude about early adoption of innovations; calculated by summing the scores from the three above attitude scales. (independent variable in H5)	discrete variable ranging from -6 to +6
percemp	The percentage of employees considered to be active in innovation-related activities (independent variable in H2)	continuous variable with maximum range of 0–100 and actual range of 7–100 (before log transformation)
numfunm	Number of functions considered active in gathering information about or deciding to use new building products, counting multi-functional individuals in all of their roles. (not used)	discrete variable ranging from 1 to 6
numfuns	Number of functions considered active in gathering information about or deciding to use new building products, counting multi-functional individuals in only one of their roles. (not used)	discrete variable ranging from 1 to 6

fundmm	Number of functions considered active in deciding to use new building products, counting multi-functional individuals in all of their roles. (used to calculate fundm2)	discrete variable ranging from 1 to 6
fundms	Number of functions considered active in deciding to use new building products, counting multi-functional individuals in only one of their roles. (used to calculate fundm2)	discrete variable ranging from 1 to 6
tradebak	Whether at least one individual involved in making adoption decisions has building trades experience. (independent variable in H4)	dummy variable scored as 1 if at least one individual having this background was reported to be active in adoption decisions, 0 if not.
aebak	Whether at least one individual involved in making adoption decisions has an architectural or engineering background. (independent variable in H4)	same as TRADEBAK
colbak	Whether at least one individual involved in making adoption decisions has a college degree other than architectural or engineering. (independent variable in H4)	same as TRADEBAK
totbak	Number of different professional backgrounds involved in making adoption decisions; calculated by adding scores for TRADEBAK, AEBAK, and COLBAK. (independent variable in H4)	discrete variable between 0 and 3
inhouse	Number of portions of the house that company performs with company crews. (not used)	discrete variable between 0 and 12
comm	Whether the company performs commercial construction as well as residential construction. (not used)	dummy variable scored as 1 if it was reported that the company at least occasionally performed commercial construction, 0 if not

lhomes	The (log of) the number of homes typically built per year. (independent variable in H6)	continuous variable with maximum range of 0–200 and actual range of 1.5–180 (before log transformation)
spec	The percentage of homes that the company typically builds speculatively. (not used)	continuous variable between 0 and 100
mf	The percentage of multi-family homes that the company typically builds. (not used)	continuous variable between 0 and 100
years	Number of years the company has been in business. (independent variable in H8)	continuous variable between 1 and 60 (capped)
start	The percentage of homes that the company typically builds considered in the Starter market segment. (independent variable in H7)	continuous variable between 0 and 100
aver	The percentage of homes that the company typically builds considered in the Average market segment. (independent variable in H7)	continuous variable between 0 and 100
luxur	The percentage of homes that the company typically builds considered in the Luxury market segment. (independent variable in H7)	continuous variable between 0 and 100
seg220	Whether the builder typically builds home in the upper half or the lower half of the market; calculated by multiplying the percentages of homes built in the Starter, Average, and Luxury segments by 1, 2, and 3, respectively, then splitting the sample at the 220 level. (independent variable in H7)	dichotomous (dummy) variable scored as 1 if the calculated segment score >220, 0 if not
numfun2	Number of functions involved in any innovation-related activity, calculated by averaging numfunm and numfuns (not used)	discrete variable with maximum range of 1–6

fundm2	Number of functions involved in making adoption decisions, calculated by averaging fundmm and fundms (independent variable in H3)	discrete variable with maximum range of 1–6
dvhigh	Number of high uncertainty, non-diffused innovations that the builder has adopted (dependent variable)	discrete variable with maximum range of 0–6 and actual range from 0–5.
dvlow	Number of low uncertainty, non-diffused innovations that the builder has adopted (dependent variable)	discrete variable with maximum range of 0–6 and actual range from 0–5
pdvhigh	High uncertainty adopter or non-adopter classification used in Probit analysis (dependent variable)	dichotomous variable scored as 2 if DVHIGH>2, otherwise 0
pdvlow	How uncertainty adopter or non-adopter classification used in Probit analysis (dependent variable)	dichotomous variable scored as 2 if DVLOW>2, otherwise 0

num	floors	headers	cadd	estsched	wrap	forms	trim	osb	pipe	studs	siding	windows
1	1	1	0	0	0	0	1	1	0	0	0	0
4	0	1	1	0	1	0	0	0	0	0	0	0
6	1	1	0	0	1	0	0	0	0	0	0	0
7	0	1	0	0	1	0	0	0	0	0	0	1
8	0	1	0	0	1	0	1	1	0	0	1	1
9	0	1	0	0	1	0	0	0	0	0	0	1
10	0	0	0	0	1	0	0	0	0	0	0	0
11	1	1	0	0	1	0	0	0	0	0	0	1
13	1	1	1	1	0	0	0	1	0	0	0	0
15	0	1	0	1	0	0	0	1	1	0	0	1
16	1	1	0	0	1	0	0	0	0	0	1	1
17	0	1	0	1	1	0	1	1	0	1	0	0
18	0	0	1	1	0	0	0	1	0	0	0	0
19	0	0	0	0	1	0	0	0	0	0	0	1
20	0	1	0	1	1	0	0	1	0	0	0	1
21	0	1	0	1	1	0	0	1	0	0	0	1
22	0	1	0	1	0	0	0	0	0	0	0	1
23	0	1	0	1	1	0	0	0	0	0	0	1
25	0	1	0	0	1	0	0	0	0	0	0	1
26	0	0	1	1	1	0	1	1	0	0	0	1
27	0	1	0	1	1	0	0	0	0	0	0	1
28	1	1	0	0	1	0	0	1	0	0	0	0
29	1	0	1	1	1	0	0	1	0	0	0	1
30	0	1	0	0	1	0	0	1	0	0	0	0
32	0	1	0	0	1	0	0	1	0	0	0	0
33	0	1	1	0	1	0	0	1	0	0	0	0
34	0	1	1	1	1	0	0	1	0	0	0	0
35	0	1	0	1	0	0	0	1	0	0	0	0
36	1	1	0	1	1	0	0	1	0	0	0	1
37	1	1	0	1	1	0	0	1	0	0	0	0
38	0	0	0	0	1	0	0	1	0	0	0	0
39	0	0	0	1	1	0	0	0	0	0	0	0
40	1	1	0	1	1	1	0	1	0	0	0	1
41	1	1	0	1	0	0	0	1	0	0	0	1
43	0	1	1	1	0	0	1	1	0	0	0	1
44	0	0	0	1	1	0	0	1	0	0	1	0
45	1	1	0	1	1	0	0	0	0	0	0	1
46	0	0	1	1	1	0	0	0	0	0	0	0
47	1	1	0	0	1	0	0	0	0	0	0	1
48	1	1	0	1	0	0	0	1	0	0	0	0
49	1	1	0	0	0	0	0	0	0	0	1	1
50	0	1	0	1	0	0	0	0	0	0	0	0
51	1	1	0	0	0	0	1	0	0	0	0	1
52	0	0	0	1	0	0	0	1	1	0	0	0
53	1	1	0	1	0	0	1	0	0	0	0	0
54	1	1	0	0	1	0	0	0	0	0	0	1
55	0	1	0	0	0	0	0	1	0	0	1	1
56	0	0	1	0	0	0	0	1	0	0	1	0
57	0	1	0	0	0	0	0	1	0	0	0	1
58	1	1	0	1	0	0	0	0	1	0	1	1
59	0	1	0	0	0	0	1	1	0	0	0	1
60	0	0	0	0	1	0	0	1	0	0	0	0

num	floors	headers	cadd	estsched	wrap	forms	trim	osb	pipe	studs	siding	windows
61	0	0	1	1	1	0	1	1	0	0	1	1
62	0	0	0	1	0	0	0	0	0	0	0	1
63	0	1	0	0	1	0	0	1	1	0	1	1
64	1	1	0	0	1	0	0	1	0	0	0	1
65	1	1	0	0	1	0	0	0	0	0	0	1
66	0	0	0	1	0	0	1	1	1	0	1	0
67	1	1	0	1	1	0	0	1	0	1	0	1
68	1	1	0	1	1	0	0	0	0	0	0	0
69	0	0	1	1	1	0	0	0	0	0	1	1
70	0	0	0	0	0	0	0	1	0	0	1	1
71	1	1	0	1	1	0	0	0	0	0	0	1
72	0	1	0	0	1	0	1	0	0	0	0	1
74	1	1	1	1	1	0	0	0	0	0	1	1
76	0	0	0	1	0	0	0	0	0	1	1	1
77	0	0	0	1	0	0	0	0	0	0	1	0
78	0	0	0	0	0	0	0	1	0	0	0	0
79	0	1	0	0	1	0	0	0	0	0	1	1
80	0	1	0	0	0	0	0	0	0	1	0	1
81	0	1	0	0	1	0	0	0	0	0	1	1
82	0	1	0	0	0	0	0	1	0	0	1	1
83	0	1	0	0	1	0	0	1	1	0	0	0
84	0	0	0	0	1	0	0	0	0	0	0	0
85	1	1	0	1	0	0	0	0	0	0	0	1
86	1	1	0	0	0	0	0	1	0	0	0	1
87	1	1	0	1	1	0	0	1	0	0	1	1
88	0	1	0	0	0	0	0	1	0	0	0	1
89	0	0	0	1	0	0	0	0	1	0	0	1
90	0	1	0	0	1	0	0	1	0	0	0	0
91	1	1	0	0	0	0	0	0	0	0	0	1
92	0	1	0	0	1	0	0	0	1	0	0	0
93	1	1	0	1	1	0	0	0	0	0	1	1
94	1	1	0	0	1	0	1	1	0	0	1	1
95	0	1	0	1	0	0	0	0	0	0	0	0
96	1	1	1	1	1	0	0	0	0	0	1	1
97	0	1	0	0	1	0	0	1	0	0	1	0
98	1	1	1	1	0	0	0	0	0	0	0	0
99	1	1	1	1	0	1	0	1	0	0	1	1
100	0	0	0	0	1	0	0	0	0	0	1	0
101	0	0	0	0	1	0	0	0	0	0	1	1
102	0	1	1	0	1	0	0	1	0	0	1	1
103	1	1	0	1	1	0	1	1	0	0	0	0
104	1	1	0	1	0	0	0	0	0	0	0	1
105	1	1	1	1	0	0	0	0	0	0	1	1
106	0	0	0	0	0	0	0	0	0	0	1	1
107	0	1	0	0	1	0	1	0	0	0	1	0
108	1	1	0	1	1	0	1	1	0	0	1	1
5	1	1	0	0	1	0	0	0	0	0	1	1
12	0	0	1	1	0	0	0	0	0	0	0	1

num	arch	ho	suppl	mags	mfrs	bldrs	test	show	subs	totinfo	totemp	numind
1	0	1	1	1	1	0	0	0	1	5	20	4
4	0	1	0	1	0	1	0	0	1	4	15	6
6	0	1	0	1	1	1	0	1	1	6	4	4
7	0	0	1	1	1	0	0	0	0	3	1	1
8	1	1	1	1	0	1	0	1	1	7	3	2
9	1	0	1	1	0	0	0	0	1	4	3	2
10	0	0	1	1	1	0	0	1	0	4	2	1
11	1	0	1	1	1	0	0	1	1	6	5	3
13	0	1	0	1	0	1	0	0	0	3	12	4
15	1	0	1	1	1	1	0	1	0	6	60	6
16	1	1	1	1	0	1	0	0	0	5	4	3
17	0	0	1	1	1	0	0	1	1	5	3	1
18	0	0	1	1	1	0	0	1	0	4	11	4
19	0	0	0	0	1	1	0	1	0	3	18	2
20	0	1	1	1	1	0	0	1	1	6	7	3
21	0	1	1	1	1	1	0	1	1	7	16	3
22	0	1	1	1	0	0	0	1	1	5	12	2
23	1	0	0	1	1	0	0	1	0	4	50	2
25	0	0	1	1	1	0	0	1	1	5	2	1
26	0	1	0	1	1	0	0	0	1	4	8	1
27	0	1	1	1	1	1	0	0	0	5	6	3
28	0	1	0	1	1	1	0	0	0	4	2	2
29	1	0	1	1	1	1	0	1	1	7	18	5
30	0	0	1	0	0	1	0	0	1	3	2	2
32	0	0	1	1	1	1	0	0	1	5	4	3
33	0	1	1	1	0	0	0	0	0	3	5	2
34	0	0	1	1	0	1	0	1	1	5	1	1
35	0	0	0	1	1	1	0	1	0	4	1	1
36	0	1	1	1	0	1	0	1	1	6	3	1
37	1	0	1	1	1	1	0	0	0	5	3	2
38	0	0	1	1	0	0	0	0	1	3	5	1
39	0	1	1	0	0	0	0	0	1	3	5	1
40	0	1	0	1	1	0	0	0	1	4	13	2
41	0	1	1	1	0	1	0	0	1	5	1	1
43	0	1	1	1	1	1	0	0	0	5	7	2
44	0	1	0	1	1	0	0	1	1	5	20	3
45	0	0	1	1	1	1	0	0	1	5	44	9
46	0	0	0	0	1	1	0	1	0	3	14	3
47	1	0	1	1	1	0	0	1	0	5	4	3
48	0	0	1	1	0	1	0	1	1	5	6	1
49	0	0	1	0	1	1	0	0	1	4	4	2
50	0	0	1	1	0	0	0	0	1	3	2	2
51	1	1	1	1	1	0	0	1	1	7	1	1
52	1	1	0	1	0	1	0	0	1	5	11	2
53	1	0	1	1	1	1	0	0	1	6	5	1
54	0	0	1	1	1	0	0	1	0	4	15	5
55	0	0	1	1	0	1	0	0	1	4	6	3
56	0	0	0	1	0	1	0	1	0	3	18	1
57	0	0	1	1	1	0	0	0	1	4	16	3
58	0	0	1	1	1	1	0	0	1	5	6	3
59	0	0	1	1	1	1	0	0	1	5	3	1
60	0	0	0	0	0	1	0	1	0	2	7	1

num	arch	ho	suppl	mags	mfrs	bldrs	test	show	subs	totinfo	totemp	numind
61	1	0	1	1	1	1	1	1	0	7	49	9
62	1	0	0	0	0	0	0	1	0	2	2	1
63	0	0	0	0	0	0	0	1	1	2	9	1
64	0	0	0	1	1	1	0	1	1	5	10	4
65	1	0	1	0	1	1	0	1	0	5	13	6
66	1	0	1	1	0	0	0	1	1	5	8	5
67	1	0	1	1	1	1	0	0	0	5	7	3
68	0	0	1	1	0	1	0	1	1	5	4	2
69	0	0	1	0	1	0	0	1	0	3	7	1
70	0	0	1	0	0	1	0	1	1	4	60	3
71	1	1	0	1	0	1	0	0	0	4	2	1
72	0	1	0	1	0	0	0	1	0	3	3	1
74	1	0	1	1	1	1	0	0	0	5	9	1
76	0	0	1	0	1	1	0	1	1	5	12	3
77	0	0	1	1	1	0	0	1	1	5	1	1
78	0	0	1	1	1	0	0	0	0	3	1	1
79	0	0	0	1	1	0	0	1	1	4	3	1
80	1	0	1	1	0	1	0	0	1	5	6	4
81	0	0	1	0	1	1	0	1	1	5	1	1
82	0	1	1	1	1	1	0	0	1	6	5	1
83	1	0	0	1	0	1	0	0	0	3	7	4
84	0	1	0	1	0	1	0	1	0	4	3	1
85	1	0	1	1	0	0	0	1	0	4	2	1
86	0	0	0	1	1	1	0	1	0	4	1	1
87	0	0	1	0	1	1	0	1	1	5	2	1
88	0	0	1	1	1	1	0	1	1	6	6	2
89	0	0	1	0	1	1	0	0	1	4	2	1
90	0	0	0	1	1	1	0	1	1	5	1	1
91	1	0	1	1	1	0	0	0	0	4	6	1
92	0	0	0	0	0	0	0	1	0	1	2	2
93	1	0	1	1	1	1	0	0	1	6	5	5
94	1	0	1	1	1	1	0	1	0	6	6	3
95	0	0	0	1	0	0	0	1	0	2	8	3
96	0	1	1	1	1	1	0	1	1	7	4	2
97	0	0	1	1	1	1	0	0	1	5	2	2
98	0	0	0	1	1	1	0	0	1	4	1	1
99	0	1	1	1	0	0	1	1	1	6	7	2
100	0	0	1	0	1	1	0	1	0	4	7	3
101	0	0	1	1	0	1	0	1	0	4	4	2
102	1	0	0	1	1	1	0	1	0	5	5	2
103	0	0	1	1	1	1	0	0	1	5	8	3
104	0	0	0	1	1	1	0	1	0	4	2	1
105	1	0	1	1	1	1	0	0	1	6	3	1
106	1	0	1	1	0	0	0	1	0	4	2	2
107	0	1	1	1	1	1	0	0	1	6	5	3
108	1	1	0	1	1	1	0	1	1	7	8	7
5	0	0	1	1	1	1	0	1	1	6	20	2
12	0	1	1	1	0	0	0	1	0	4	10	1

num	state	first	import	risks	attitu	percemp	numfunm	numfuns	fundmm	fundms
1	MA	-2	1	0	-1	20	3	3	2	2
4	MA	-2	-1	-2	-5	40	5	3	3	3
6	MA	-1	0	0	-1	100	5	3	5	3
7	MA	-1	1	1	1	100	4	1	4	1
8	MA	2	0	2	4	67	4	1	4	1
9	MA	0	0	0	0	67	4	2	4	2
10	MA	1	1	-2	0	50	3	1	3	1
11	MA	1	1	0	2	60	4	1	4	1
13	CO	-2	0	-1	-3	33	3	3	3	2
15	OH	0	2	0	2	8	4	4	4	4
16	MA	1	1	1	3	75	4	3	4	3
17	CO	2	2	1	5	33	3	1	3	1
18	MA	0	1	-1	0	64	5	5	1	1
19	NY	0	-1	-1	-2	11	2	2	1	1
20	NY	-1	-1	-1	-3	43	2	2	1	1
21	NY	1	1	1	3	19	2	2	1	1
22	NY	2	1	0	3	17	3	3	3	3
23	NY	0	1	-1	0	4	2	2	1	1
25	NY	1	0	1	2	50	3	1	3	1
26	CO	2	0	2	4	13	1	1	1	1
27	IL	2	1	0	3	50	3	2	3	2
28	IL	1	0	0	1	100	4	2	4	2
29	IL	1	1.50	1	4	28	3	3	3	3
30	IL	-1	1	0	0	100	4	2	4	1
32	IL	1	1.50	1	4	75	4	1	4	1
33	IL	1	-2	-1	-2	40	3	1	3	1
34	IL	-2	0	2	0	100	3	1	3	1
35	IL	-1	1	-1	-1	100	1	1	1	1
36	CO	2	1	0	3	33	2	1	2	1
37	CO	2	-1	2	3	67	3	2	3	2
38	IL	-2	1	-2	-3	20	1	1	1	1
39	IL	-1	-1	0	-2	20	1	1	1	1
40	IL	1	1	-1	1	15	1	1	1	1
41	WA	-1	1	-1	-1	100	4	1	4	1
43	CO	-1	2	2	3	29	3	1	3	2
44	IL	1	-1	-1	-1	15	3	3	2	2
45	MA	2	2	1	5	20	4	3	2	1
46	MA	-2	-2	-2	-6	21	1	1	2	1
47	IL	-1	2	-1	0	75	3	2	3	2
48	CO	2	1	-1	2	17	1	1	1	1
49	TN	0	1	-2	-1	50	3	1	3	1
50	TN	-1	0	-1	-2	100	4	2	1	1
51	TN	1	-1	-1	-1	100	4	1	4	1
52	WA	0	0	0	0	18	2	2	2	1
53	WA	-1	1	-1	-1	20	3	1	3	1
54	IL	2	-1	1	2	33	2	2	1	1
55	TN	1	1	2	4	50	2	1	2	1
56	TN	-1	-1	-2	-4	6	2	1	2	1
57	TN	0	1	1	2	19	2	1	1	1
58	TN	1	1	-1	1	50	3	2	2	2
59	WA	-1	1	-1	-1	33	2	1	2	1
60	IL	-2	0	-1	-3	14	3	1	3	1

num	state	first	import	risks	attitu	percemp	numfunm	numfuns	fundmm	fundms
61	IL	0	0	0	0	18	4	4	3	3
62	WA	-1	1	1	1	50	2	1	2	1
63	TN	0	-1	1	0	11	2	1	2	1
64	WA	2	1	2	5	40	2	2	2	2
65	NJ	1	1	1	3	46	3	2	3	2
66	TN	1	1	-1	1	63	3	2	2	1
67	NJ	0	0	0	0	43	4	2	4	2
68	NJ	1	1	-2	0	50	1	1	1	1
69	NJ	-2	-2	-2	-6	14	3	1	3	1
70	WA	1	1	1	3	5	1	1	1	1
71	MA	-1	0	0	-1	50	3	1	3	1
72	MA	-1	0	0	-1	33	4	1	4	1
74	NJ	1	1	-1	1	11	3	1	3	1
76	TN	2	-1	0	1	25	3	1	3	1
77	NY	-2	1	0	-1	100	5	1	5	1
78	TX	-2	-2	-2	-6	100	5	1	5	1
79	NJ	-1	0	0	-1	33	4	1	4	1
80	WA	-1	-1	-1	-3	67	4	3	4	3
81	CT	1	1	1	3	100	4	1	4	1
82	NJ	-2	-1	-1	-4	20	3	1	3	1
83	IL	2	2	0	4	100	4	4	5	3
84	IL	-1	1	0	0	33	2	1	2	1
85	TN	-2	0	-1	-3	50	4	1	4	1
86	WA	0	1	0	1	100	4	1	4	1
87	WA	-2	0	-2	-4	50	3	1	3	1
88	WA	2	0	0	2	33	3	1	3	1
89	WA	-1	2	0	1	50	3	1	3	1
90	IL	-1	-1	-1	-3	100	4	1	4	1
91	WA	-2	2	-2	-2	17	3	1	3	1
92	IL	1	2	0	3	100	4	1	4	1
93	NJ	2	0	0	2	100	4	4	4	4
94	NJ	1	1	1	3	50	4	2	4	3
95	TX	0	0	0	0	38	3	2	3	2
96	NJ	1	2	1	4	50	4	2	4	2
97	TN	2	2	0	4	100	4	1	4	1
98	TN	-1	0	-1	-2	100	3	1	3	1
99	NY	1	2	0	3	28	3	2	2	1
100	NY	2	1	0	3	43	3	2	2	1
101	NY	1	1	0	2	50	3	2	2	1
102	NJ	0	1	0	1	40	4	2	4	2
103	WA	0	2	0	2	38	4	3	4	3
104	WA	-2	1	0	-1	50	3	1	3	1
105	CO	-1	-2	-1	-4	33	3	1	3	1
106	TN	-2	2	-2	-2	100	4	1	4	1
107	NY	1	2	-1	2	60	3	2	3	2
108	NJ	1	2	2	5	88	4	4	4	4
5	MA	0	2	0	2	10	4	2	4	2
12	MA	0	-1	-2	-3	10	1	1	1	1

num	tradebak	aebak	colbak	totbak	inhouse	comm	homes	spec	mf	years
1	1	0	1	2	1	0	12	50	60	19
4	1	1	1	3	1	0	6	75	0	46
6	1	0	1	2	5	1	3	85	0	15
7	1	0	0	1	1	0	2	0	0	8
8	1	1	1	3	3	1	6	50	0	8
9	0	1	1	2	2	0	2	0	0	60
10	1	0	0	1	4	0	4	0	0	23
11	1	0	0	1	4	1	2	0	0	30
13	1	0	1	2	0	0	50	95	0	12
15	1	1	1	3	12	0	75	10	25	43
16	1	1	1	3	4	1	2	0	0	14
17	1	0	1	2	6	1	8	25	0	12
18	1	0	0	1	1	0	40	0	0	19
19	1	0	0	1	0	0	25	45	0	20
20	1	1	1	3	0	0	50	50	0	48
21	1	1	1	3	0	0	17	50	0	18
22	1	1	1	3	0	1	40	50	0	44
23	1	0	1	2	4	1	150	50	0	29
25	1	1	0	2	0	1	6	40	0	20
26	1	0	0	2	2	0	12	13	0	19
27	1	1	1	3	0	0	10	50	0	20
28	1	0	1	2	0	0	2	25	0	10
29	1	0	1	2	0	0	100	45	0	14
30	1	0	1	2	0	0	20	45	0	21
32	1	0	1	2	0	0	5	50	0	7
33	1	0	1	2	0	0	17	38	0	15
34	1	0	1	2	0	0	10	0	0	10
35	1	0	0	1	0	0	45	45	0	25
36	1	0	1	2	0	1	3	50	0	13
37	1	0	1	3	2	1	10	10	0	21
38	1	0	0	1	1	0	20	50	0	28
39	1	0	1	2	0	0	6	45	0	12
40	1	0	1	2	3	0	12	5	0	6
41	1	0	1	2	0	0	4	43	0	5
43	1	0	1	2	1	0	35	10	0	2
44	1	1	1	3	0	0	65	8	0	6
45	1	1	1	3	6	1	35	0	0	22
46	1	1	0	2	1	0	12	50	0	9
47	1	1	1	3	0	0	4	100	0	2
48	1	0	0	1	0	0	35	70	0	22
49	1	0	1	2	6	0	3	0	0	30
50	1	0	1	2	0	0	4	0	0	9
51	0	0	1	1	0	0	3	0	0	8
52	1	0	1	2	0	0	8	25	0	17
53	0	0	0	1	0	0	6	70	0	6
54	1	0	1	3	0	0	50	10	20	25
55	1	0	0	1	0	1	17	50	0	24
56	1	0	0	2	3	1	3	0	5	9
57	1	0	1	2	6	1	3	0	0	21
58	1	1	1	3	3	1	4	0	0	7
59	0	0	0	0	0	0	18	80	20	15
60	1	0	0	1	0	0	35	10	0	14

num	tradebak	aebak	colbak	totbak	inhouse	comm	homes	spec	mf	years
61	1	1	1	3	8	1	120	10	20	60
62	0	1	0	1	0	0	4	75	0	28
63	1	0	0	1	0	0	65	0	30	20
64	1	0	1	2	0	0	37	95	0	12
65	1	0	1	3	4	1	1	25	0	25
66	1	0	1	2	0	0	55	50	0	12
67	1	0	0	1	4	0	1	0	0	11
68	1	0	0	1	3	1	2	50	0	40
69	1	0	0	1	3	1	17	0	10	56
70	1	0	0	1	2	0	180	75	50	22
71	1	0	1	2	7	0	1	50	0	10
72	1	0	0	1	0	0	12	0	0	8
74	1	0	1	2	0	0	12	20	0	8
76	1	1	0	2	6	1	5	60	0	12
77	0	0	1	1	0	0	3	60	0	13
78	0	0	1	1	0	0	10	66	0	15
79	1	0	0	1	7	1	1	0	0	5
80	1	1	1	3	0	0	6	0	0	15
81	1	0	1	2	0	1	10	15	0	15
82	1	0	0	1	4	1	4	0	0	33
83	1	0	0	1	3	1	11	0	0	4
84	0	0	1	1	0	0	11	10	20	14
85	0	0	1	1	0	0	5	0	0	12
86	0	0	1	1	0	0	7	25	0	11
87	1	0	0	1	0	1	10	100	100	20
88	1	0	1	2	2	1	30	90	0	13
89	1	0	1	2	0	0	10	100	70	9
90	1	0	1	2	0	0	4	25	0	3
91	1	1	0	2	4	0	8	88	0	14
92	1	0	1	2	0	0	10	10	0	10
93	1	0	1	2	0	1	2	100	20	38
94	1	1	0	2	0	1	3	33	0	18
95	1	1	0	2	0	0	50	50	0	21
96	1	0	0	1	4	0	3	25	40	21
97	1	0	0	1	0	0	10	25	0	2
98	1	0	0	1	0	1	3	25	0	14
99	1	1	0	2	0	0	12	70	0	60
100	1	0	1	2	0	1	27	10	0	20
101	1	0	1	2	0	1	17	10	0	10
102	1	1	1	3	0	0	10	20	0	1
103	1	1	0	2	6	0	3	0	0	12
104	1	1	0	2	0	1	11	33	0	9
105	1	0	0	1	4	0	2	0	0	4
106	0	1	1	2	0	1	60	100	0	12
107	1	0	1	2	0	1	30	5	10	13
108	1	0	1	2	0	0	50	5	70	35
5	1	0	1	2	2	1	17	99	0	23
12	1	0	0	1	1	0	13	0	0	18

num	start	aver	luxer	seg220	numfun2	fundm2	dvhigh	dvlow	pdvhigh	pdvlow
1	0	0	100	1	3	2	3	1	2	0
4	0	0	100	1	4	3	2	1	0	0
6	0	80	20	0	4	4	2	1	0	0
7	0	90	10	0	3	3	1	2	0	0
8	0	100	0	0	3	3	3	3	2	2
9	0	0	100	1	3	3	1	2	0	0
10	0	0	100	1	2	2	0	1	0	0
11	0	0	100	1	3	3	2	2	0	0
13	0	50	50	1	3	3	4	1	2	0
15	0	25	75	1	4	4	2	3	0	2
16	0	50	50	1	4	4	3	2	2	0
17	0	0	100	1	2	2	3	3	2	2
18	0	100	0	0	5	1	2	1	0	0
19	0	0	100	1	2	1	0	2	0	0
20	0	100	0	0	2	1	2	3	0	2
21	0	0	100	1	2	1	2	3	0	2
22	0	0	100	1	3	3	1	2	0	0
23	40	60	0	0	2	1	1	3	0	2
25	0	100	0	0	2	2	1	2	0	0
26	0	100	0	0	1	1	2	4	0	2
27	0	0	100	1	3	3	1	3	0	2
28	0	0	100	1	3	3	3	1	2	0
29	0	100	0	0	3	3	3	3	2	2
30	0	0	100	1	3	3	2	1	0	0
32	0	50	50	1	3	3	2	1	0	0
33	0	50	50	1	2	2	3	1	2	0
34	0	0	100	1	2	2	3	2	2	0
35	50	50	0	0	1	1	2	1	0	0
36	0	0	100	1	2	2	3	3	2	2
37	0	0	100	1	3	3	3	2	2	0
38	0	0	100	1	1	1	1	1	0	0
39	0	0	100	1	1	1	0	2	0	0
40	0	20	80	1	1	1	3	4	2	2
41	0	0	100	1	3	3	3	2	2	0
43	0	30	70	1	2	3	3	3	2	2
44	0	70	30	1	3	2	2	2	0	0
45	0	0	100	1	4	2	2	3	0	2
46	0	0	100	1	1	2	1	2	0	0
47	0	0	100	1	3	3	2	2	0	0
48	0	30	70	1	1	1	3	1	2	0
49	30	50	20	0	2	2	3	1	2	0
50	0	0	100	1	3	1	1	1	0	0
51	0	0	100	1	3	3	2	2	0	0
52	0	0	100	1	2	2	1	2	0	0
53	0	0	100	1	2	2	2	2	0	0
54	0	0	100	1	2	1	2	2	0	0
55	0	30	70	1	2	2	3	1	2	0
56	0	30	70	1	2	2	3	0	2	0
57	0	10	90	1	2	1	2	1	0	0
58	0	35	65	1	3	2	3	3	2	2
59	60	40	0	0	2	2	2	2	0	0
60	0	20	80	1	2	2	1	1	0	0

num	start	aver	luxer	seg220	numfun2	fundm2	dvhigh	dvlow	pdvhigh	pdvlow
61	30	30	40	0	4	3	3	4	2	2
62	0	0	100	1	2	2	0	2	0	0
63	0	100	0	0	2	2	3	3	2	2
64	0	20	80	1	2	2	3	2	2	0
65	0	0	100	1	3	3	2	2	0	0
66	0	100	0	0	3	2	2	3	0	2
67	0	0	100	1	3	3	4	3	2	2
68	0	0	100	1	1	1	2	2	0	0
69	0	60	40	1	2	2	2	3	0	2
70	30	70	0	0	1	1	2	1	0	0
71	0	100	0	0	2	2	2	3	0	2
72	0	30	70	1	3	3	1	3	0	2
74	0	0	100	1	2	2	4	3	2	2
76	0	100	0	0	2	2	2	2	0	0
77	0	20	80	1	3	3	1	1	0	0
78	0	0	100	1	3	3	1	0	0	0
79	0	50	50	1	3	3	2	2	0	0
80	0	50	50	1	4	4	2	1	0	0
81	40	40	20	0	3	3	2	2	0	0
82	0	100	0	0	2	2	3	1	2	0
83	0	0	100	1	4	4	2	2	0	0
84	0	50	50	1	2	2	0	1	0	0
85	0	0	100	1	3	3	2	2	0	0
86	0	0	100	1	3	3	3	1	2	0
87	0	50	50	1	2	2	4	3	2	2
88	0	100	0	0	2	2	2	1	0	0
89	100	0	0	0	2	2	0	3	0	2
90	0	100	0	0	3	3	2	1	0	0
91	0	50	50	1	2	2	2	1	0	0
92	0	0	100	1	3	3	1	2	0	0
93	20	60	20	0	4	4	3	3	2	2
94	0	30	70	1	3	4	4	3	2	2
95	0	100	0	0	3	3	1	1	0	0
96	30	50	20	0	3	3	4	3	2	2
97	0	100	0	0	3	3	3	1	2	0
98	0	0	100	1	2	2	3	1	2	0
99	60	40	0	0	3	2	5	3	2	2
100	0	50	50	1	3	2	1	1	0	0
101	0	100	0	0	3	2	1	2	0	0
102	20	50	30	0	3	3	4	2	2	0
103	0	20	80	1	4	4	3	3	2	2
104	0	20	80	1	2	2	2	2	0	0
105	0	100	0	0	2	2	4	2	2	0
106	0	100	0	0	3	3	1	1	0	0
107	70	30	0	0	3	3	2	2	0	0
108	0	50	50	1	4	4	4	4	2	2
5	0	0	100	1	3	3	3	2	2	0
12	0	0	100	1	1	1	1	2	0	0

APPENDIX 4: DESCRIPTIVE STATISTICS

This appendix provides descriptive statistics on the variables included Appendix 3. The names in parentheses after the variable descriptions are the codes used in the computer analyses and in Appendix 3.

Percentages of sample who reported to use the following innovations regularly:

composite floor joists or floor trusses (floors)	39
composite wood beams or headers (headers)	74
CADD (cadd)	19
estimating or scheduling software (estsched)	50
house wrap (wrap)	61
insulating concrete wall forms (forms)	2
non-wood trim (trim)	15
oriented strand board (osb)	49
plastic plumbing supply pipe (pipe)	8
steel studs (studs)	4
vinyl siding (siding)	32
vinyl-clad or all-vinyl windows (windows)	62

Percentages of sample who reported that the following are important sources of information about new building products:

Architects / house designers (arch)	29
Homeowners / customers (buyer)	30
Local material suppliers (suppl)	70
Magazines, newspapers, and newsletters (mags)	83
Manufacturers literature and service reps (mfrs)	64
Other builders (bldrs)	63
Results of your own testing (test)	2
Seminars and trade shows (show)	58
Subcontractors (subs)	58

Percentages of sample who reported that the following professional backgrounds are involved in suggesting, gathering information on, or deciding whether to use new building products:

Building Trades (tradebak)	89
Architecture or Engineering (aebak)	27
College other than AE (colbak)	61

Other independent variables

	Minimum	Maximum	Mean
number of sources of information about innovations considered important (totinfo)	1	7	4.57
number of individuals active in innovation-related activities (numind)	1	9	2.38
percentage of employees active in innovation-related activities (percemp)	4	100	48.91
number of functions active in making decisions about new products (fundm2)	1	4	2.16
% of houses in the starter market segment (start)	0	100	5.80
% of houses in the average market segment (aver)	0	100	35.90
% of houses in the luxury market segment (luxur)	0	100	58.30
overall market segment (segment)	100	300	252.50
attitude concerning being benefits of being one of the first in the industry to do something (first)	-2	2	0.06
attitude concerning the importance of new building products to their success (import)	-2	2	0.51
attitude concerning the risks of new building products (risks)	-2	2	-0.16
overall attitude score (attitu)	-6	5	0.41
number of homes typically built per year (homes)	1	180	20.81
total number of employees	1	60	8.65

Dependent Variables, by region

region	**mean number of high uncertainty innovations adopted**	**mean number of low uncertainty innovations adopted**
CO	2.22	3.22
IL	1.35	2.40
MA	1.06	2.71
NJ	2.25	3.50
NY	0.91	2.82
TN	1.69	1.94
WA	1.47	2.47
total sample	1.51	2.64

Univariate relationship between hypothesized variables

The table below indicates the t statistics from univariate regression of the independent variables listed below against the two dependent variables. T statistics above 1.67 are considered significant ($p<0.05$) for one tailed tests (that is, if in the hypothesized direction), and 2.00 for two tailed tests.

	univariate relationship with adoption of:	
independent variable	**high uncertainty innovations**	**low uncertainty innovations**
number of sources of information about innovations considered important (totinfo)	+5.28	+4.05
number of individuals active in innovation-related activities (numind)	+1.72	+2.48
percentage of employees active in innovation-related activities (percemp)	-0.32	-1.92
number of functions active in any innovation-related activities (numfun2)	+1.98	+0.57
number of functions active in making decisions about new products (fundm2)	+2.72	+0.79
total number of professional backgrounds active in innovation-related activities (totbak)	+1.02	+2.61
some one with building trades background active in innovation-related activities (tradebak)	+2.72	+2.06
some one with architectural or engineering background active in innovation-related activities (aebak)	-0.33	+1.89
some one with a college degree other than architecture or engineering active in innovation-related activities (colbak)	-0.07	+0.72
overall attitude score (attitu)	+2.04	3.94
log number of homes typically built per year (lhomes)	-0.79	+0.99
log total number of employees (ltotemp)	+0.87	+2.61
market segment (average house price)	-0.67	-1.09

Pearson correlation matrices

(A key to the variable codes shown below is in Appendix 3.)

The following variables were used in H1–H7.

	totinfo	tradebk	aebak	colbak	totbak	lperce	lhomes	fundm2	attitu	seg220	dvhigh
totinfo	1.00										
tradebak	0.06	1.00									
aebak	0.15	-0.00	1.00								
colbak	0.23	-0.08	0.02	1.00							
totbak	0.27	0.36	0.58	0.64	1.00						
lpercem	0.06	-0.21	-0.05	0.21	-0.03	1.00					
lhomes	-0.06	0.11	0.07	0.11	0.15	-0.40	1.00				
fundm2	0.29	-0.07	0.20	0.22	0.20	0.41	-0.23	1.00			
attitu	0.35	0.21	0.03	0.18	0.26	0.09	0.11	0.15	1.00		
seg220	-0.21	-0.11	-0.00	0.09	0.04	-0.06	-0.19	0.05	-0.08	1.00	
dvhigh	0.47	0.27	-0.03	-0.01	0.10	0.03	-0.08	0.26	0.20	-0.07	1.00
dvlow	0.38	0.20	0.19	0.07	0.25	-0.19	0.10	0.08	0.37	-0.11	0.25

The following variables were not used in any hypotheses but are included for meta-analyis or other analysis by other researchers.

	totempl	numind	numfunm	numfuns	inhouse	comm	spec	mf	lyears	dvhigh
totempl	1.00									
numind	0.56	1.00								
numfunm	-0.15	0.24	1.00							
numfuns	0.40	0.76	0.37	1.00						
inhouse	0.46	0.29	0.12	0.17	1.00					
comm	0.07	0.12	0.08	0.05	0.29	1.00				
spec	0.00	-0.01	-0.12	-0.05	-0.24	-0.01	1.00			
mf	0.20	0.15	-0.04	0.13	-0.00	-0.04	0.19	1.00		
lyears	0.30	0.28	-0.15	0.24	0.17	0.19	0.09	0.18	1.00	
dvhigh	0.00	0.17	0.16	0.17	0.12	0.10	-0.03	0.16	-0.11	1.00
dvlow	0.20	0.24	-0.08	0.20	0.21	0.06	-0.11	0.23	0.08	0.25

APPENDIX 5: QUOTES BY BUILDERS

This appendix features quotes by builders volunteered during in-person interviews or telephone surveys. They are grouped by the themes presented in Chapter Two.

'You just don't know if it will work'

The quotes in this section illustrate the uncertainty builders perceive about new building products that is related to the complexity of the task in which innovations are introduced. Because building products are subjected to a wider range of conditions than is possible in pre-release testing and because there have been so many failures of new building products in the past, builders understandably are extremely cautious about adoption of innovations that are not widely diffused.

"They have to be proven before I will use it."

"If it's working, I don't want to change. If you have to go back and repair it..."

"I've been burned many times. Why do I keep trying new things? I'm dumb, I guess. I mean, I want to be smart and keep up, but I keep getting burned."

"You are definitely taking a risk."

"I used to be on the forefront, but I've had a lot of bad experiences. Now we like to see a product tested for a while."

"Manufacturers are biased. They will tell you how wonderful it is, but it is not always so great."

"A lot of new products don't come with installation or protection literature. They get stored in the mud then installed improperly."

"Half the time new products end up failing, so we have to go back and fix it. But the other half, they work well and we end up setting the pace for other builders."

"Many new products compromise durability ...."

New products are an "inherent risk."

"We don't like to stick our necks out."

"We're ahead of most builders.... We continue to do it but we get burned."

"If you are interested in new products, you are crazy."

"Warranty is your problem. Is the manufacturer going to be around for a long time?"

"It's got to prove itself."

"We are slow to switch. Let someone else take the risk first."

"I want to be up near the front of the pack, but not necessarily first. Litigation is so common. You can get sued for anything. We don't do anything that could lead to a problem."

"You've got to know the down side of each new product, how to use it properly."

"I don't trust a product that depends entirely on glue."

'You just don't know if buyers will go for it'

The quotes in this section illustrate the uncertainty builders perceive about technological innovations that is related to the most critical area of the home builder environment: home buyer acceptance.

"If we don't have the information to educate the buyer, we don't use it."

(vinyl siding) "Excellent product but you can't get it accepted except in low end."

"Buying a house is the biggest investment of their life, so they don't want to take any risks."

"People see OSB and think, 'more like cardboard than plywood.'"

"If you know enough about the products, the engineering principles, you can reduce the risk. But you still got sellability risks."

"We let someone else do the testing, so the public comes to accept it."

"You have to worry about buyer's perception if it is visible."

"It has to be accepted by the public first before we'll try it."

"I wait for a customer to ask for something. Hey, 'if it ain't broke...', right?"

"You've really got to do a lot of marketing to get something new accepted. There is usually a margin of safety with existing products, so there isn't a lot of incentive."

"Selling a steel house is totally different. There's a lot of learning, education involved. Using steel studs when everyone else is using wood is like committing suicide."

"We are not really innovators. We've been in business since 1965 and we sell that we will be around for a long time. A lot of guys are willing to try anything for price. We are not."

"My goal is to differentiate my product from the standing inventory. The more I differentiate my product, the better I do, which may require new products or new designs."

"I'm willing to try a new product when a customer asks for it, but not until then."

(Homeowners) "are helping us to become more educated. They ask about things we don't even know about."

"First movers don't get appreciated" in this business. We are here to serve the niche that exists, not to create a new one."

Uncertainty related to other environmental sectors

The quotes in this section illustrate that builders adoption behavior reflects other areas of their environment, particularly building codes.

"Codes are screwy."

"It's also an educational process with inspectors."

"Unions and codes very restrictive. As a result of that mentality, we are not going to pioneer through" (every municipality the company builds in).

"A lot of this stuff is governed by codes."

"Local interpretation of building codes is really bad—fire blocking, etc. Also, the inspector asks for things not in the codes.... Codes are builders' worst enemy."

"You carry subs kicking and screaming."

"Real estate agents need to be educated about new products."

Information reduces uncertainty

The key assumption underlying many of my hypotheses was that builders who are more apt to adopt innovations that are not widely diffused reduced the uncertainty of innovations through gathering information. This point is illustrated in the following quotes.

"We use it only if we are absolutely sure it will work."

"We wait for acceptance, avoid using something right away. And we definitely get buyer input."

"If I use something first, I have made damn sure it is going to work."

"It has got to be proven" before we use it."

"You've got to do a little research first. We might try it on a spec home or model first."

"The kind of information you need" about new products "depends on the product."

"I'm not worried about new products needing to be fixed more often, not as long as they are installed properly and you've talked with the manufacturer about it."

Do new products typically cost more or less?

It is the author's opinion that some product innovations are high cost, high performance while others are lower cost, equal or higher performance. The quotes included in this section illustrate that many builders have strong perceptions on this issue that go one way or the other.

"That's the problems with new products. Every time they come out with something new, it costs more."

"Sometimes they help sell, but they never save money."

"Most new products are cost-saving, which are most important in lower-end homes. They look like real products at first, but eventually you get what you pay for."

"New products drive up costs, but they provide better sales."

"Your subs usually want more money for something new, so it really doesn't pay."

"Some new products make sense, but you can't get the customer to pay for it."

"All customers are cost conscious. New products let us offer more features for the same money."

"In the $250-300 range, we are very reluctant to try anything new. In the $100-125 range, we will try anything to keep the price down."

"Manufacturers say, 'this costs more but there are labor savings.' But subs say they want more to install it."

"We've considered steel studs. They are supposed to cost less, but our carpenter subs haven't had a raise in a few years, so they'd use it as an excuse to get more money."

Miscellaneous

The quotes in this section pertain to various issues associated with adoption of home building technological innovations that are not widely diffused.

"There is a bottom line that you can measure and one you can't. You can't know the cost of not keeping current."

"It is only risk if you can't identify a fault, a problem to solve, a void to fill."

"I see a product in a magazine that fills a hole in the market. I think, 'If we had this product, we could have done a better job with Mr. ...."

"Who uses a lot of new products? The guys who aren't around anymore, or they're just barely hanging on."

"Manufacturers don't support their new products like they should. Anderson came out with these new types of windows. I went whole-hog on them in a development, then Anderson just discontinued them. Made me look bad. Owens-Corning introduced this new type of insulation, kind of like thermaply. I fought the city to use it, then Owens-Corning just pulled it, probably because sales were going fast enough for them. You have enough of these experiences, and it blunts your pioneering spirit."

"I'm a risk-taker, a gambler. I have to fight myself to keep from being the first one. The rewards just aren't there, takes too much time and energy to be first."

"Pioneers get shot, arrows in their necks, and stuff like that."

"Financial strength is important. Innovation takes time, which I wouldn't have if I was always worried about cash flow."

"It's an educational process. It's cheaper to copy than to pioneer."

"The small builder is consumed with running his business. He's a lawyer, accountant, backhoe operator. He's too busy to learn about new products. During the weekdays you're building. On weekends you're selling. At nights you're planning meetings, running through your numbers..."

APPENDIX 6: BIOGRAPHY OF AUTHOR

After receiving a B.S. in Civil Engineering from Bucknell University in 1983, Mike Toole served five years as an officer in the U.S. Navy Civil Engineers Corps. His tours of duty included serving as a Company Commander in Naval Mobil Construction Battalion Three (aka "the Seabees") and serving as a construction contract administrator at Mare Island Naval Shipyard in Vallejo, California.

In 1988 and 1989, Toole worked as a project manager for Brown & Root Services Corp. on indefinite quantity construction contracts in San Diego and Hawaii.

He began his graduate studies at M.I.T. in 1989 and received an S.M. in Civil Engineering in 1990. The title of his thesis was "Strategic issues in stresskin foam panels for residential construction." Toole developed the curriculum for and twice served as the sole Instructor of a graduate course in the Department of Civil and Environmental Engineering, "Strategy for Engineering and Construction Management."

Other professional experiences include extended consulting relationships with Brown & Root Services Corp., the College of the Atlantic, and Insulspan Inc. He is President of Tonyan Composites Corporation, a start up firm designing, manufacturing, and marketing innovative building panels. He is a registered professional civil engineer in the states of California and Massachusetts.

Publications include: "A case study of introducing system dynamics for solving community planning issues" (co-authored with J.D. Nyhart, Sloan School of Management working paper, M.I.T.); "'Discovery exchanges:' a human ecology tool for interdisciplinary trust and problem-solving in home building" (*Proceedings from the Sixth Meeting of the Society for Human Ecology*, Snowbird, Utah, October 1992); and "The adoption of building systems: a case study" (co-authored with T. D. Tonyan, *Building Research Journal*, January 1992, pp. 21-26);

Honors include the 1993 Civil and Environmental Engineering Teaching Award at M.I.T., Sigma Xi Scientific Research Honorary Society, Tau Beta Pi Engineering Honor Society, Omicron Delta Kappa Leadership Honor Society, Mortar Board Scholarship Honor Society, the S. A. Baronowsky and M. B. Ridgeway Prizes at Bucknell, and a Navy Achievement Medal.

Toole is married to Amy Pettibone Toole and has two children, Rebecca Ellen and Thomas John.

REFERENCES

Aldrich, H. (1979). *Organizations and Environments.* Englewood Cliffs, NJ: Prentice Hall.

Aldrich, J. H. and F. D. Nelson (1984). *Linear probability, logit, and probit models.* Bevery Hills, CA: Sage.

Allen, T. J. (1977). *Managing the flow of technology.* Cambridge, MA: MIT Press.

Baldridge, J. V. and R. A. Burnham (1975). "Organizational innovation: individual, organizational, and environmental impacts." *Administrative Science Quarterly* 20:165–176.

Bell, D. E. (1982). "Regret in decision making under uncertainty." *Operations Research* 30:961–981.

Belsley, D. A., E. Kuh, and R. E. Welsch (1980). *Regression diagnostics.* New York: John Wiley & Sons.

Bourgeois, L. J. III (1985). "Strategic goals, perceived uncertainty, and economic performance in volatile environments." *Academy Of Management Journal* 28(3):548–573.

Bryman, A. and D. Cramer (1990). *Quantitative data analysis for social scientists.* London: Routledge.

Child, J. (1972). "Organizational structure, environment and performance: the role of strategic choice." *Sociology* 6:1–22.

Conrath, D. W. (1967). "Organizational decision making behavior under varying conditions of uncertainty." *Management Science* 13(8):B487–B500.

Curley, S. P., J. F. Yates, and R. A. Abrams (1986). "Psychological sources of ambiguity avoidance." *Organizational Behavior and Human Decision Processes* 38:230–256.

Daft, R. L. and N. B. Macintosh (1981). "A tentative exploration into the amount and equivocality of information processing in organizational work units." *Administrative Science Quarterly* 26:207–224.

Daft, R. L. and K. E. Weick (1984). "Towards a model of organizations as interpretation systems." *Academy of Management Review* 9(2):284–295.

Dess, G. G. and D. W. Beard (1984). "Dimensions of organizational task environments." *Administrative Science Quarterly* 29:52–73.

Dess, G. G. and A. M. A. Rasheed (1991). "Conceptualizing and measuring organizational environments: a critique and suggestions." *Journal of Management* 17(4):701–710.

Duncan, R. B. (1972). "Characteristics of organizational environments and perceived environmental uncertainty." *Administrative Science Quarterly* 17:313–327.

Duke, R. (1988). "Local building codes and the use of cost-saving methods." Staff Report of the Bureau of Economics to the Federal Trade Commission. Washington, DC.

Ehrenkrantz Group/Gershon Meckler Assoc. (1979). *A study of existing processes for the introduction of new products and technology into the building industry*. Washington: U.S. Institute of Building Sciences.

Ellsberg, D. (1961). "Risk, ambiguity, and Savage's axiom." *Quarterly Journal of Economics* 75:643–669.

Ettlie, J. E. and W. P. Bridges (1982). "Environmental uncertainty and organizational technology policy." *IEEE Transactions on Engineering Management* EM–29(1):2–10.

Forrester, J. W. (1969). "Notes on complex systems." In Urban Dynamics:107–114. Cambridge, MA: MIT Press.

Frisch, D. and J. Baron (1988). "Ambiguity and rationality." *Journal of Behavioral Decision Making* 1:149–157.

Galbraith, J. R. (1973). *Designing complex organizations*. Reading, MA: Addison-Wesley.

Gatignon, H. and T. S. Robertson (1986). "Technology diffusion: an empirical test of competitive effects." *Journal of Marketing* 53(January):35–49.

Gatignon, H. and T. S. Robertson (1989). "Technology diffusion: an empirical test of competitive effects." *Journal of Marketing* 53(January):35–49.

Harvard University Joint Center For Housing Studies (1990). *The state of the nation's housing*. Cambridge, MA: Harvard University Press.

Henderson, R. M. and K. B. Clark (1990). "Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms." *Administrative Science Quarterly* 34(1):9–30.

Herbert, G. (1984). *The dream of the prefabricated house*. Cambridge, MA: The MIT Press.

Hogarth, R. M. (1980). *Judgment and choice: the psychology of decision*. New York: Wiley.

Judge, G. G., W. E. Griffiths, R. C. Hill, H. Lutkepohl, and T-C. Lee (1985). *The theory and practice of econometrics*. New York: John Wiley & Sons.

Kahneman, D. and A. Tversky (1979). "Prospect theory: an analysis of decision under risk." *Econometrica*. 47(2):263–291.

Luce, R. D. and H. Raiffa (1957). *Games and decisions*. New York: John Wiley & Sons.

March, J. G. and H. A. Simon (1958). *Organizations*. New York: John Wiley & Sons.

Miles, R. E. and C. C. Snow (1978). *Organizational strategy, structure and process*. New York: McGraw-Hill.

Moavenzadeh, F. (1991). "Innovation in housing." *Construction Business Review* 1(July/August 1991):60–77.

National Association of Home Builders (1990). "Strategic issues for home builders: 1990–1992 and beyond." unpublished report, NAHB, Washington DC.

National Association of Home Builders Research Center (1989A). "Historical review of housing innovation." unpublished report prepared for Martin Marietta Energy Systems Inc. NAHBRC, Upper Marlboro, MD.

National Association of Home Builders Research Center (1989B). "Diffusion of innovation in the housing industry." unpublished report prepared for U.S. Department of Energy. NAHBRC, Upper Marlboro, MD.

National Association of Home Builders Research Center (1991). "Final report of the advanced housing technology program." unpublished report submitted to the Oak Ridge National Laboratory. NAHBRC, Upper Marlboro, MD.

National Association of Home Builders Research Foundation (1972). "Constraints to builders adoption of cost-saving innovations." unpublished report submitted the U.S. Dept. of Housing and Urban Development. NAHB Research Foundation, Upper Marlboro, MD.

Nelson, R. R. and S. G. Winter (1977). "In search of useful theory of innovation." *Research Policy* 6:36–76.

Oster, S. M. and J. M. Quigley (1977). "Regulatory barriers to the diffusion of innovation: some evidence from building codes." *Bell Journal of Economics.* 8(2):361–377.

Pfeffer, J. and G. Salancik (1978). *The external control of political organizations.* New York: Harper & Row.

President's Committee on Urban Housing (1968). "A decent home." Washington: Government Printing Office. (also referred to as "The Kaiser Commission")

Ritov, I. and J. Baron (1992). "Status-quo and omission biases." *Journal of Risk and Uncertainty* 5:49–61.

Rogers, E. M. (1983). *The diffusion of innovations.* New York: The Free Press.

Rosen, K. T. (1979). *Seasonal cycles in the housing market.* Cambridge, MA: The MIT Press.

Samuelson, W. and R. Zeckhauser (1988). "Status quo bias in decision making." *Journal of Risk and Uncertainty* 1:7–59.

Schrader, S. (1991). "Informal technology transfer between firms: cooperation through information trading." *Research Policy* 20:153–170.

Schrader, S., W. M. Riggs, and R. P. Smith (1993). "Choice over uncertainty and ambiguity in technical problem solving." *Journal of Engineering and Technology Management 10:73–99.*

Sharfman, M. P. and J. W. Dean, Jr. (1991). "Conceptualizing and measuring the organizational environment: a multidimensional approach." *Journal of Management* 17(4):681–716.

Slaughter, E. S. (1991). "'Rapid' innovation and integration of components: comparison of user and manufacturer innovations through a study of residential construction." unpublished doctoral dissertation, Dept. of Civil Engineering, M.I.T.

Slaughter, E. S. (1993). "Innovation and learning during implementation: a comparison of user and manufacturer innovations." *Research Policy* 22:81–95.

Stinchcombe, A. L. (1959). *Administrative Science Quarterly* 4:168–187.

Sweaney, A. L., C. B. Meeks, and R. M. Swagler (1992). "Building professionals' views of adopting new technology: the case of electrical plugs and receptacles." *Building Research Journal* 2:49–56.

Tatum, C. B. (1986). "Potential mechanisms for construction innovation." ASCE *Journal of Construction Engineering and Management.* 112(2):178–191.

Thompson, J. D. (1967). *Organizations in action.* New York: McGraw-Hill.

Toole, T. M. (1990). "Strategic issues in stresskin foam panels for residential construction." unpublished S. M. thesis, Dept. of Civil Engineering, Massachusetts Institute of Technology.

Toole, T. M. and T. D. Tonyan (1992). "The adoption of innovative building systems: a case study." *Building Research Journal.* 1(1):21-26.

Tushman, M. L. and R. R. Nelson (1990). "Introduction: technology, organizations, and innovation." *Administrative Science Quarterly* 35:1–8.

Tung, R. L (1979). "Dimensions of organizational environments: an exploratory study of their effect on organization structure." *Academy Of Management Journal* 22:672–693.

Tversky, A. and Kahneman, D. (1974). "Judgment under uncertainty: heuristics and biases." *Science* 185:1124–1131.

Tversky, A. and Kahneman, D. (1986). "Rational choice and the framing of decisions." *Journal of Business* 59(4):S250–S2???.

U.S. Congress, Office of Technology Assessment (1986). "Technology, trade, and the U.S. residential construction industry—special report, OTA-TET-315.

U.S. Dept. of Housing and Urban Development, Office of Policy Development and Research (1976). "Factors involved in the transfer of innovations: a summary and organization of the literature." Washington, DC, January 1976.

Van de Ven, A. H. and E. M. Rogers (1988). "Innovations and organizations: critical perspectives." *Communication Research* 15(5):632–651.

Venkatraman, N. and J. E. Prescott (1990). "Environment-strategy coalignment: an empirical test of its performance implications." Strategic Management Journal 11:1–23.

Ventre, F. T. (1973). "Social control of technological innovation: the regulation of building construction." unpublished Ph.D. thesis, Dept. of Urban Studies and Planning, Massachusetts Institute of Technology.

Ventre, F. T. (1980). "On the blackness of kettles: inter-industry comparisons in rates of technological innovation." *Policy Sciences* 11:309–328.

Weick, K. (1969). *The social psychology of organizing.* Reading, MA: Addison-Wesley.

Weisberg, S. (1982). *Applied linear regression.* New York: John Wiley & Sons.

Wheeler, D. D. and I. L. Janis (1980). A Practical Guide for Making Decisions. New York: Free Press,.

Willis, M. A. (1979). "The effects of cyclical demand on industry structure and on the rate of technological change: an international comparison of the house builder sectors in the United States, Great Britain, and France," unpublished Ph.D. Dissertation, Yale University.

Woods, D. H. (1966). "Improving estimates that involve uncertainty." *Harvard Business Review*. 44:91–98.

BIBLIOGRAPHY

Barnes, J. H. (1984). "Cognitive biases and their impact on strategic planning." *Strategic Management Journal* 5:129–137.

Beardsworth, A. D., E. T. Keil, M. Bresnen, and A. Bryman (1988). "Management, transience and subcontracting: the case of the construction site." *Journal Of Managerial Studies* 25:603–625.

Bernhardt, A. D., et al. (1980). *Building tomorrow: the mobile/manufactured housing industry*. Cambridge: The MIT Press.

Bigoness, W. J. and W. D. Perreault (1981). "A conceptual paradigm and approach for the study of innovators." *Academy of Management Journal* 24(1):68–82.

Boulton, W. R., W. M. Lindsay, S. G. Franklin, and L. W. Rue (1982). "Strategic planning: determining the impact of environmental characteristics and uncertainty." *Academy of Management Journal* 25(3):500–509.

Bourgeois, L. J., III (1980). "Strategy and environment: a conceptual integration." *Academy Of Management Review* 5:25–40.

Brockhaus, R. H. Sr. (1980). "Risk taking propensity of entrepreneurs." *Academy of Management Journal* 23(3):509–520.

Business Roundtable (1982). "Technological progress in the construction industry." report B–2. The Business Roundtable, 200 Park Ave, New York, NY.

Butler, J. E. (1988). "Theories of technological innovation as useful tools for corporate strategy." *Strategic Management Journal* 9:15–29.

Carroll, J. S. and E. J. Johnson (1990). *Decision research: a field guide*. Newbury Park, CA: Sage.

Covin, J. G. and D. P. Slevin (1989). "Strategic management of small firms in hostile and benign environments." *Strategic Management Journal* 10:75–87.

Daft, R. L. and R. H. Lengel (1986). "Organizational information requirements, media richness and structural design." *Management Science* 32(5):554–571.

Daft. R. L. (1978). "A dual-core model of organizational innovation." *Academy of Management Journal* 21:193–210.

Damanpour, F. (1987). "The adoption of technological, administrative, and ancillary innovations: impact of organizational factors." *Journal of Management* 13:675–688.

Damanpour, F. and W. M. Even (1984). "Organizational innovation and performance: the problem of `organizational lag'." *Administrative Science Quarterly* 29:392–409.

Dess, G. G. and N. K. Origer (1987). "Environment, structure, and consensus in strategy formulation: a conceptual integration." *Academy of Management Review* 12:313–330.

Dess, G. G., R. D. Ireland, and M. A. Hitt (1990). "Industry effects and strategic management research." *Journal of Management* 16:7–28.

Downey, H. K. and J. W. Slocum, Jr. (1975). "Uncertainty: measures, research and sources of variation." *Academy of Management Journal* 18(3):564–578.

Downey, H. K. and R. D. Ireland (1979). "Quantitative versus qualitative: environmental assessment in organizational studies." *Administrative Science Quarterly* 24:630–637.

Downey, H. K., D. Hellriegel, and J. W. Slocum, Jr. (1975). "Environmental uncertainty: the construct and its applications." *Administrative Science Quarterly* 20:613–629.

Downs, G. W., Jr. and L. B. Mohr, (1976). "Conceptual issues in the study of innovation." *Administrative Science Quarterly* 21:700-714.

Eccles, R. G. (1981). "Bureaucratic and craft administration revisited." *Administrative Science Quarterly* 26:449–469.

Eccles, R. G. (1981). "The quasi firm in the construction industry." *Journal of Economic Behavior and Organization* 2:335–357.

Eichler, N. (1982). *The merchant builders*. Cambridge, MA: MIT Press.

Einhorn, H. J. and R. M. Hogarth (1986). "Decision making under ambiguity." *Journal of Business* 59(4):S225–S250.

Fichman, R. G. (1992). "Information technology diffusion: a review of empirical research." forthcoming in ???

Freeman, C. (1986). *The Economics of Industrial Innovation*, 2nd Ed. Baltimore: Penguin.

Gatignon, H. and T. S. Robertson (1985). "A propositional inventory for new diffusion research." *Journal of Consumer Research* 11(March):849–867.

Gerloff, E. A., N. Kanoff, W. D. Bodensteiner (1991). "Three components of perceived environmental uncertainty: an exploratory analysis of aggregation." *Journal of Management* 17(4):749-768.

Gifford, W. E., H. R. Bobbitt and J. W. Slocum, Jr. (1979). "Message characteristics and perceptions of uncertainty by organizational decision makers." *Academy of Management Journal* 22:458–481.

Hambrick, D. C. (1982). "Environmental scanning and organizational strategy." *Strategic Management Journal* 3:159–174.

Hansen, K. L. and Tatum, C.B., "Technology and Strategic Management in Construction." ASCE *Journal of Management in Engineering*. 5(1):,67–83.

Hrebiniak, L. G. and C. C. Snow (1980). "Industry differences in environmental uncertainty and organizational characteristics related to uncertainty." *Academy of Management Journal* 23:750–759.

Huber, G. P., M. J. O'Connell (1975). "Perceived environmental uncertainty: effects of information and structure." *Academy of Management Journal* 18:725–740.

Ireland, R. D., M. A. Hitt, R. A. Bettis, and D. A. De Porras (1987). "Strategy formulation processes: differences in perceptions of strength and weaknesses indicators and environmental uncertainty by managerial level." *Strategic Management Journal* 8:469–485.

Jones, D. A. (1992). "Roadblocks to technology." *Builder*. June 1992, pp. 170–175.

Jurkovich, R. (1974). "A core typology of organizational environments." *Administrative Science Quarterly* 19:380–394.

Kahneman, D. and D. T. Miller (1986). "Norm theory: comparing reality to its alernatives." *Psychological Review* 93:136–153.

Kelly, H., (1986). "Technology and the Construction Industry." Technology and the U.S. Construction Industry (Proceedings. on Technical Change and the U.S. Building Construction Industry), Office of Technology Assessment, AIA Press, Washington, DC, March, 1986, 1–10.

Kendall, S. H. (1986). "Who's in charge of housing innovation?" *Architecture* 15(10):87–90.

Kimberly, J. R. and M. J. Evanisko (1981). "Organizational innovation: the influence of individual, organizational, and contextual factors on hospital adoption of technological and administrative innovations." *Academy of Management Journal* 24(4):689–713.

Koch, J. A. and Moavenzadeh, F. (1979) "Productivity and Technology in Construction." ASCE *Journal of the Construction Division*. 105(C04):351–366.

Kopp, D. G. and R. J. Litschert (1980). "A buffering response in light of variation in core technology, perceived environmental uncertainty, and size." *Academy of Management Journal* 23:252–266.

Lawrence, P. R. and J. W. Lorsch (1967 or 9?). *Organization and environment.* Homewood, IL: Richard D. Irwin.

Leblebici, H. and G. R. Salancik (1981). "The effect of environmental uncertainty on information and decision processes in banks." *Administrative Science Quarterly* 26:578–596.

Leifer, R. and G.P. Huber (1977). "Relations among perceived environmental uncertainty, organization structure, and boundary-spanning behavior." *Administrative Science Quarterly* 22:235–247.

Lenz, R. T. and J. L. Engledow (1986). "Environmental analysis: the applicability of current theory." *Strategic Management Journal* 7:329–346.

Leonard-Barton, D. (1988). "Implementation characteristics of organizational innovations." *Communication Research* 15(5):603–631.

Lawrence, P. R. and J. W. Lorsch (1967). *Organization and environment.* Homewood, IL: Richard D. Irwin.

Lyles, M. A. and H. Thomas (1988). "Strategic problem formulation: biases and assumptions embedded in alternative decision-making models." *Journal Of Managerial Studies* 25:131–145.

March, J. G. (1978). "Bounded rationality, ambiguity, and the engineering of choice." *The Bell Journal of Economics* 9(2):587–608.

March, J. G. and J. P. Olsen (1976). *Ambiguity and choice in organizations*. Bergen, Norway: Universitetsforlaget.

March, J. G. and Z. Shapira (1987). "Managerial perspectives on risk and risk taking."

Management Science 33(11):1404–1418.

McCall, M. W., Jr. and R. E. Kaplan (1985). *Whatever it takes: decision makers at work.* Englewood Cliffs, NJ: Prentice-Hall.

McCaskey, M. B. (1982). *The executive challenge: managing change and ambiguity.* Marshfield, MA: Pitman Publishing Inc.

McCaskey, M.B. (1976). "Tolerance for ambiguity and the perception of environmental uncertainty in organization design." Chapter 3 in Kilmann, R.H., L.R. Pondy, and D.P. Slevin, *The Management of Organization Design*, North-Holland.

McCrimmon, K. R. and D. A. Wehrung (1986). *Taking risks: the management of uncertainty.* New York: Free Press.

Meyer, J. W. and W. R. Scott (1983). *Organizational environments: ritual and rationality.* Beverly Hills, CA: Sage.

Meyer, M.W. and Assoc. (1978). *Environments and organizations.*" San Francisco: Jossey-Bass.

Miller, A. (1988). "A taxonomy of technological settings, with related strategies and performance levels." *Strategic Management Journal* 9:239–254.

Miller, C. C., W. H. Glick, Y. D. Wang, and G. P. Huber (1991). "Understanding technology-structure relationships: theory development and meta-analytic theory testing." *Academy of Management Journal* 34(2):370–399.

Miller, D. (1987). "The structural and environmental correlates of business strategy." *Strategic Management Journal* 8:55–76.

Miller, D. and P. H Friesen (1983). "Strategy-making and environment: the third link." *Strategic Management Journal* 4:221–235.

Miller, D. and P. H Friezen (1982). "Innovation in conservative and entrepreneurial firms: two models of strategic momentum." *Strategic Management Journal* 3:1–25.

Milliken, F. J (1987). "Three types of perceived uncertainty about the environment: state, effect, and response uncertainty." *Academy of Management Review*12:133–143.

Milliken, F. J (1990). "Perceiving and interpreting environmental change: an examination of college administrators interpretation of changing demographics." *Academy of Management Journal* 33:42–63.

Mintzberg, H. (1981). "What is planning anyway?" *Strategic Management Journal* 2:319–324.

Mintzberg, H. (1990). "The design school: reconsidering the basic premises of strategic management." *Strategic Management Journal* 11:171–195.

Mintzberg, H., D. Raisinghani, and A. Theoret (1976). "The structure of `unstructured' decision processes." *Administrative Science Quarterly* 21:246–275.

Norusis, M. J. (1982). *SPSS introductory guide.* New York: McGraw-Hill.

Onkvisit, S. and J. J. Shaw (1989). "The diffusion of innovations theory: some research questions and ideas." *Akron Business and Economic Review* 20(1):46–55.

Pierce, J. L. and A. L. Delbecq (1977). "Organization structure, individual attitudes and innovation." *Academy of Management Review* 2(1):27–37.

Pondy, L. R., R. J. Boland, and T. Howard (Eds.). *Managing ambiguity and change*:93–125. New York: John Wiley.

Qualls, W. J. and C. P. Puto (1989). "Organizational climate and decision framing: an integrated approach to analyzing industrial buying decisions." *Journal of Marketing Research* 26:179–192.

Riemer, J. W. (1979). *Hard hats: the work world of construction workers*. Beverly Hills, CA: Sage.

Schwenk, C. R. (1984). "Cognitive simplification processes in strategic decision making." *Strategic Management Journal* 5:111–128.

Schwenk, C. R. (1988). "The cognitive perspective on strategic decision making." *Journal Of Managerial Studies* 25:41–56.

Schwenk, C. R. (1989). "Linking cognitive, organizational and political factors in explaining strategic change." *Journal Of Managerial Studies* 26:177–188.

Sharfman, M.P. and J.W. Dean, Jr. (1991). "Dimensions and constructs: a response to Dess and Rasheed." *Journal Of Management* 17(4):711–715.

Shaw, M. (1987). "Anticipating the market for technological innovations in the home building industry." unpublished S. M. thesis, Dept. of Civil Engineering, M.I.T.

Shoemaker, J. H. (1992). "Determinants of risk-taking: behavioral and economic views." *Journal of Risk and Uncertainty* 6:49–73.

Simon, H. A. (1979). "Rational decision making in business organizations." *American Economic Review* 69:493–513.

Sims, H.P., Jr, A. Gioia and Associates (Eds.) *The thinking organizations*. San Francisco: Jossey-Bass Publishers.

Singh, J. (1986). "Performance, slack, and risk taking in organizational decision making." *Academy of Management Journal* 29(3):562–585.

Stubbart, C. I. (1989). "Managerial cognition: a missing link in strategic management research." *Journal Of Managerial Studies* 26:325–349.

Sumichrast, M., G. Ahluwalia, and R. J. Sheehan (1979). *Profile of the Builder*. Washington, DC: National Association of Home Builders.

Sutherland, J. W. (1977). *Administrative decision making: extending the bounds of rationality*. New York: Van Nostrand Reinhold Co.

Tatum, C. B. (1984). "What prompts construction innovation?" ASCE *Journal of Construction Engineering and Management*. 110(3):11–323.

Tatum, C. B. (1986). "Potential mechanisms for construction innovation." ASCE *Journal of Construction Engineering and Management*. 112(2):178–191.

Tatum, C. B. (1987). "Process of innovation in construction firm." ASCE *Journal of Construction Engineering and Management*. 113(4):648–663.

"To Keep America Competitive." *Engineering News Record,* 1986, 217(5), 23–31.

Tornatzky, L.G. and K. J. Klein (1982). "Innovation characteristics and innovation adoption-implementation: a meta-analysis of findings." *IEEE Transactions on Engineering Management* EM–29(1):28–45.

Tosi, H., R. Aldag, and R. Storey (1973). "On the measurement of the environment: an assessment of the Lawrence and Lorsch environmental uncertainty subscale." Administrative Science Quarterly 18:27-36.

Usdiken, B., Z. Sozen, and H. Enbiyaoglu (1988). "Strategies and boundaries: subcontracting in construction." *Strategic Management Journal* 9:633–637.

Van de Ven, A. H. (1990). "Scholarship in Technology and Innovation Management" unpublished lecture.

Ventre, F. T. (1979). "Innovation in residential construction." *Technology Review.* (November):51–59.

Wholey, D. R. and J. Brittain (1989). "Characterizing environmental variation." *Academy of Management Journal* 32(4):867–882.

Williams, J. R. (1983). "Technological evolution and competitive response." *Strategic Management Journal* 4:55–65.