The Diffusion of Innovation in the Residential Building Industry

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Disclaimer

Preface

The U.S. Department of Housing and Urban Development (HUD) and the Partnership for Advancing Technology in Housing (PATH) present this report in direct support of ongoing efforts to understand the home building industry's means and methods. While construction of homes has reached record highs in the United States over the last decade, many home product manufacturers and home builders still rely on traditional materials and practices, and today's housing is increasingly unaffordable. At the same time, homebuyers are requiring higher performance and better quality in their homes. Technological innovations have the potential for producing valuable housing at decreased or constant cost. Many of these techniques already exist in the market, while others have yet to be developed. For all innovations, though, America's home builders ultimately become the most practical judges for what goes into the nation's housing stock. The ability to know how, why, and where builders adopt new technologies is critical for future technological research and research dissemination. Until now, there have been no thorough and concise surveys or measures of these practices.

There is much to be done, and there is much that all of the home building industry would like to see done. This is an especially critical concern for PATH—the public-private partnership aimed at dramatically improving the cost and quality of housing through the development and application of advanced technologies in the American housing industry. Despite the importance of the housing industry to the national economy, there is very little investment in residential technologies. This is especially true of the single-family homes that make up most of America's housing stock; it can take 10 to 25 years for a new housing technology to achieve full market penetration. PATH looks at the issues and barriers related to technology development in the housing industry, as well as provides tools and services to address them.

For PATH, then, these survey results pose innumerable opportunities for additional research and exciting interventions for promoting technological change: How can early adopters of technology receive adequate and timely information to make innovative choices? How can institutions foster the development of technology advocates within all home building enterprises? How can government intervene in educating homebuyers about the value and performance of the homes that they buy? The results of this study will directly assist PATH and any other organizations promoting innovation in determining the most effective and viable solutions.

Clearly, this survey will generate similarly exciting consequences for all parties involved in housing production. This initial exploration opens an entirely new approach to helping home builders and building trades understand how their work is structured, and how it can be improved. Ultimately, these improvements will also benefit America's homeowners. Research initiatives and results like these directly support the home building industry's future production capacity and the quality and cost of American homes for years to come. We invite you to read this report and all of the reports in this series, as well as to look out for more advanced research from HUD in this field.

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SUMMARY

Purpose and Significance of Study

The successful diffusion of innovations in the residential home building industry can have substantial social, economic, and environmental benefits to Americans. By incorporating new technologies, techniques, and materials into construction practices, it is possible to:

- Create more affordable housing.
- Improve energy efficiency and conserve energy resources.
- Improve the quality of U.S. housing stock by reducing the need for frequent repair and maintenance.
- Increase the longevity of the housing stock.
- Reduce the flow of scrap materials into the waste stream.
- Conserve scarce natural resources.

By knowing how and why innovations diffuse within the residential industry, it is possible to accelerate the technology adoption process through more effectively designed programs, demonstration projects, channels of distribution, marketing strategies, and policy incentives.

Adoption of innovation is a highly complex behavior. Adoption patterns vary across industries, and home building as an industry is significantly different from other industries, where more research has been conducted on the diffusion of innovation. Consequently, research specifically focused on home building is required before applying any of the findings from studies of adoption and diffusion in other industries. Although research in other industries has shown that the firm's size, industry concentration, human resources, organizational structure, culture, decision processes, market context, information channels, and social networks are important contributors to the adoption of innovation, along with supplier-vendor characteristics and the technical and economic attributes of the innovation, the role and importance of these characteristics in the diffusion of innovation in home building must be clearly established.

We wish to know how and under what circumstances residential housing innovations become standard industry practices.… This study is a major step forward in advancing our knowledge about innovation in residential construction.

Ultimately we wish to know how and under what circumstances residential housing innovations become standard industry practices. Toward this end, we first conducted a literature review to summarize established theory and research on the diffusion of innovations generally—and in the construction industry specifically. We then designed a questionnaire to establish how home builders make decisions about using new building products, materials, and practices. We mailed the questionnaire to a sample of U.S. home builders and collectively analyzed their responses. In addition, we analyzed the innovation adoption patterns by home builders across several years as tracked by the National Association of Home Builders Annual Builder Practices Survey. We intentionally focused our data collection on home builders who adopted particularly products and materials at an early stage of market penetration, as these "early adopters" are a small percentage of all builders but are critically important in demonstrating the benefits of these products and materials to other builders. Nonetheless, middle-stage adopters warrant greater research attention, as they are the lynchpin to significant market penetration. Late-stage adopters are heavily influenced by the "bandwagon" effect and pressure to adopt products, materials, and practices that are rapidly becoming industry standards.

Any one study by itself cannot address all of the complexity that surrounds the adoption of new construction materials, products or practices. Consequently, this study is one of several needed to help establish a deeper and sounder understanding about innovation in residential construction. At the same time, this study is a major step forward in advancing our knowledge about innovation in residential construction.

Synopsis of Findings

At the early stage of diffusion, national and regional firms, multifamily and modular builders, and custom builders are more likely to adopt innovations than are single-family production builders. Although sales and supplier representatives, subcontractors, and trade shows are important sources of information about new products and materials for all builders, early-stage adopters rely on technology transfer programs and universities more than middle or late-stage adopters do. Although small, less established manufacturers often are the first to introduce new products, residential building construction relies heavily on established manufacturers who stand behind their products. This behavior likely reflects the substantial financial and market risks associated with innovation in residential building. Product failures can cost builders dearly, both in direct losses and in damage to the firm's reputation. Establishing a reputation for high quality and durable homes, and for quickly addressing problems in new homes, was a key business strategy for over two-thirds of the builders in this survey.

This study found the following characteristics associated with *higher* levels of adoption of new products, materials, and practices in home building.

The types of home building firms most likely to be early adopters were:

- Modular builders and multifamily builders.
- Single-family custom home builders.
- National and regional builders.

These more innovative firms were also more likely to:

- Have a technology advocate within the building firm.
- Stress the importance of being creative and the first to use new products.
- Use technology transfer programs like the Partnership for Advancing Technology in Housing (PATH) and universities.
- Use union labor at least sometimes.

These firms also stressed the importance of:

- Homebuyers who are aware of and want new products and materials.
- Reliance on established manufacturers standing behind their building and construction products.

The types of home building firms that wait until new products, materials, and practices have been around much longer were more likely to be local firms and single-family production builders.

These later adopters also were more likely to:

- Emphasize marketability and profit.
- Associate the firm's success with land development.
- Emphasize the "tried and true" and the risks of new materials and products (marginal statistical significance).

In surveys about innovation among home builders, the homebuyer is often identified as an impediment to innovation in residential construction. Homebuyers are supposedly risk-adverse and want the "tried and true." Consequently, the reasoning goes, builders have no choice other than to avoid innovation. Although we did not collect any data on homebuyers, our findings suggest that this perception among home builders plays an important role in the diffusion of residential construction technology. Builders are less likely to be innovative if they emphasize that their customers prefer the "tried and true" and don't like nontraditional products or features and if they stress marketability and profit. They are also less likely to be innovative if their business strategy emphasizes acquiring and developing land with better locations than that of their competitors. Innovative builders, by contrast, emphasize educating their customers about new technologies.

Technology diffusion and adoption research often identifies the importance of technology advocates within firms. Technology advocates are also important in the diffusion of residential building technologies. Two-thirds of the respondents in this study identified a technology advocate—usually the owner—within the firm. Additionally, innovation among home builders is associated with firms that establish innovation and creativity as part of their corporate culture.

The importance of the firm's culture is highly important. Some firms, probably as a result of their owners' advocacy of innovation, see themselves as creative and innovative. They are less concerned about the immediate impact of innovation on profits and stress the contributions of innovation to productivity. They do not look to their competitors or to market trends before deciding to innovate.

These innovative firms are the best targets for technology transfer programs. They learn about technology from the government (through programs like PATH), the National Association of Home Builders (NAHB) seminars, universities, and the Internet. Middle- and late-stage adopters are more likely to learn about new technologies from other builders and trade shows. Further research on middle-stage adopters could reveal strategies to quicken the diffusion of new materials and practices in residential construction to this group. Late-stage adopters are inappropriate targets for technology diffusion programs. They are too risk-adverse and will wait for others to show that the benefits and costs of new technologies are proven. By that time, competitive bandwagon effects are sufficiently powerful to bring them along.

The diffusion of residential building technologies is highly complex, and diffusion mechanisms likely vary for particular types of technologies and for different stages of diffusion. An analysis of annual diffusion rates for specific technologies from 1995 to 2001, measured by the Annual Builder Practices Survey (ABPS) of the National Association of Home Builders Research Center, provided greater insight into these differences.

Diffusion of some of the technologies we reviewed began among smaller builders, while others began with larger builders. Some saw first acceptance in more expensive homes and others in low-cost homes. Acceptance of new technologies and materials ultimately depends on whether they meet the needs of the consumer and the builder better than existing technologies and materials. The needs for high- and low-end markets and for large and small builders are not always the same. Additionally, geographic differences also help shape the needs of both builder and buyer. New construction technologies follow multiple diffusion paths depending on characteristics of the technology related to competitive advantage, ease of use, and consumer preference.

Large builders seem to be first to adopt new materials that offer a cost savings, improvements in production, reduced call-backs, or reduced exposure to liability. Smaller builders are often first to adopt technologies where high consumer awareness of a material exists, the price of the new technology is significantly higher than what it replaces, or the home construction process must be substantially altered. Home builders in geographic areas where both builders and homebuyers have an increased awareness of a new technology or find a technology most useful are likely to be first to adopt. Consumer preference and the tendency of innovative builders to be less concerned about competitive advantage related to factors other than price might explain the greater acceptance by small builders of new technologies that cost more than alternatives.

Product-specific characteristics help explain some of the variations in diffusion patterns. Clearly these patterns are dynamic. Competitive advantage changes as products are modified, prices of both the new and the older technologies change, and builders and consumers learn more about the benefits of new technologies. The analyses of diffusion processes and trends presented here provide significant insights into the diffusion of new technologies in residential construction, while at the same time identifying important directions for new research. Additional analysis of these data can provide even more insights into the diffusion of residential construction technologies. Improved knowledge about diffusion of residential construction technologies will help improve the design of technology transfer programs and quicken the pace of technology development to improve the affordability, quality, and durability of housing.

DIFFUSION OF INNOVATION LITERATURES

Many disciplines study diffusion of innovation, including management (organization theory, innovation and diffusion theory), communications, sociology, geography, marketing (consumer theory, new product acceptance), economics (especially industrial organization, microeconomics, economic history), and agricultural economics. The literature addresses a wide range of topics, which Wolfe (1994) classified into three streams: diffusion of innovation, organizational innovativeness, and process theory models. Process theory investigates the origination of innovations rather than their diffusion and focuses on their refinement and adaptation during their life cycles.

These literatures deal with two distinct phenomena relevant to this study:

1. What causes organizations and entrepreneurs to adopt innovations invented by others?
2. What determines the rate of diffusion of an innovation within an industry?

A thorough understanding of the diffusion process in an industry requires insights into both the adoption decision on the part of an individual or organization and the overall timing and rate of diffusion within the industrial sector. For the purposes of this study, the following definitions and assumptions are used:

- "**Adoption** is the acceptance and continued use of a product, service, or idea. The adoption process refers to a series of mental and behavioral states that a person passes through leading to the adoption or rejection of an innovation." (Howard and Moore, 1988, p. 344)
- "**Diffusion** is the spread of an innovation throughout a social system." (Howard and Moore, 1988, p. 345)
- **Innovation** is "any idea, practice, or material artifact perceived to be new to the relevant adopting unit." (Czepiel, 1974, p. 173)
- "The diffusion pattern at the industry level is the outcome of the distribution of individual firm adoption decisions." (Robertson and Gatignon, 1986, p. 2)
- "The linkage between the micro-adoption process and the aggregate diffusion process needs to be more firmly established to achieve a clearer understanding of diffusion patterns." (Feder and Umali, 1993, p. 215)
- "Diffusion studies do not consider the innovation process, but begin at the time when the innovation is [introduced to the market]." (Feder and Umali, 1993, p. 215)

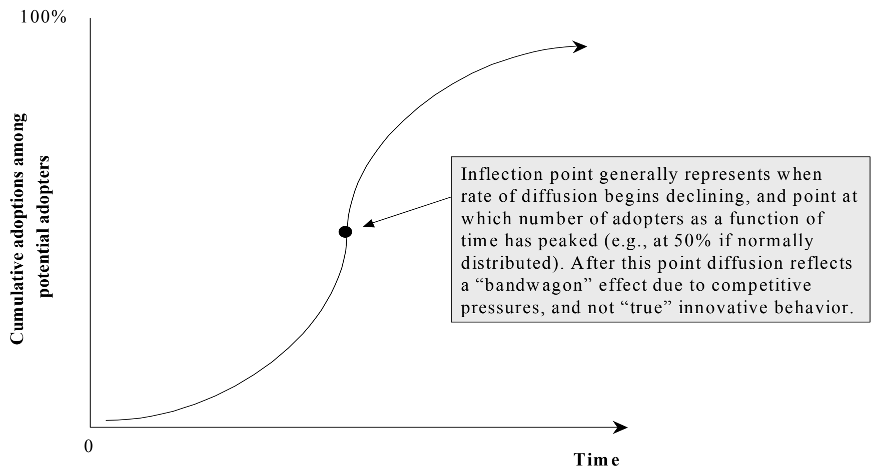
Modeling the Diffusion Process

In the research literature, diffusion is modeled extensively as either the ***diffusion process*** or the ***adoption process***. Diffusion models focus on the overall rate and timing of the diffusion of an innovation within a specific industrial sector, while adoption models focus on the characteristics of the person or firm adopting an innovation and the decision to adopt. As has been well documented, the acceptance and use of innovations is not instantaneous, but can instead take a considerable period of time to become standard industry practice. What has long puzzled economists and marketing analysts are the causes of this time delay.

Diffusion models focus on the overall rate and timing of the diffusion of an innovation within a specific industrial sector. Adoption models focus on the characteristics of the person or firm adopting an innovation and the decision to adopt.

Diffusion models are empirical, logistic S-curve models that estimate the spread of an innovation as a function of time (see Figure 1). Extensive reviews of the generic model, its variations, and its estimation procedures may be found in Feder and Umali (1993); Mansfield (1968); Mahajan, Muller, and Bass (1990); and Zettlemeyer and Stoneman (1993). Frank Bass (marketing) and Edwin Mansfield (economics) initially introduced the S-curve diffusion model, which Davies (1979) identified as an application of the epidemic model long used to describe the spread of contagious diseases. "If knowledge of existence and profitability are increasing functions of prevalence of use of a technology then use of that technology can be expected to spread like a disease: the probability that a non-user will adopt in any time period will be an increasing function of the fraction of the population that has already adopted." (Jaffee and Stavins, 1995)

Fig. 1 – The Logistics (S)-Curve Model of the Diffusion Process



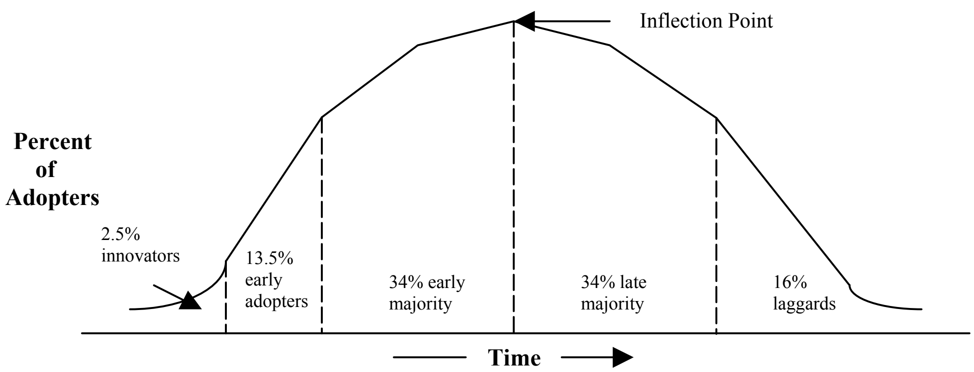
Research has refined the mathematical specification of the models and worked on industry-specific applications, with variants of the Bass or epidemic model referred to as probit, density dependence, substitute technologies, cusp catastrophe, and multiple sequence pattern models (Geroski, 2000; Gopalakrishnan and Damanpour, 1994; Islam and Meade, 1997; Herbig, 1991). Davies (1979) related the mechanistic diffusion model with behaviors that cause diffusion to follow the general S-curve pattern. He also demonstrated that "no single curve can satisfactorily describe the diffusion of all innovations" because different conditions lead to different diffusion curves. Understanding those conditions, rather than mathematical simulation, is the key to developing better explanations of the diffusion process from this stream of the diffusion research. If adopters were homogeneous, diffusion would occur along the same path with only communication and market failures influencing the speed of adoption. Research has consistently demonstrated that adopters are heterogeneous, with the degree of heterogeneity depending on industry characteristics such as size, concentration, and integration (Kelly and Brooks, 1991; Robertson and Gatignon, 1986; Jaffee and Stavins, 1995).

Although the mathematical foundation of the S-curve is the same in both economics and marketing, they are based on different parameter estimates and assume different determinants of diffusion. The Bass model focuses on innovation and imitation and assumes adopters are influenced either by the mass media (innovators) or word-of-mouth (imitators). The Bass model is used in marketing to forecast the rate of market penetration of new products (new product acceptance) and is often applied to consumer products to develop pricing, advertising, and market entry strategies (Mahajan, Muller, and Bass, 1990; Zettlemeyer and Stoneman, 1993). In contrast, the Mansfield model is often used to explain retroactively the industrial diffusion of an innovation, and its parameter estimates focus on profitability, the adoptability of innovations, industry size and growth, and other economic criteria as determinants of the rate of diffusion.

Adoption models[1] are solidly anchored to the work of Everett Rogers, who categorizes the innovative character of adopters as a function of time and as a probability distribution (see Figure 2). Research that uses the Rogers model tends to focus on individual socioeconomic and demographic attributes and has a long history of being applied to *consumer* behavior. Different types of innovators have distinctive individual profiles in terms of age, education, income, risk tolerance, and so on; research has generally established the empirical validity of the Rogers typology. Some critics say a simpler framework of fewer categories (such as innovators, late adopters, nonadopters) may be more realistic and fit the research better (Anderson and Ortinau, 1988; Arndt, 1967). In contrast, Moore (1999) argued that there are distinct separations between categories of adopters ("cracks in the bell curve") due to psychological differences between these categories. Taylor et al. (1994), however, found the benefits-price model of adoption superior to Moore's psychographic model.

Late majority, laggards, and nonadopters behave in the bandwagon effect, while innovators, early adopters, and early majority adopters represent truly innovative behavior.

Fig. 2 – Rogers' Model of Innovation Adoption



The model is based on a probability distribution. Note that the mean, or point of inflection on the normal curve, corresponds to the inflection point on the Logistics Curve.

Innovation is inherently risky and disruptive. Rationales for both first-mover advantage and second-mover advantage can be found, with advantage tipped to the second-mover under conditions of uncertain profitability.

The logistics diffusion model and the Rogers adoption model can be blended by concentrating on their mathematical properties. Because of the character of the logistics curve and the normal curve, *the point of inflection on both represents the same phenomenon*. As a consequence, the late majority, laggards, and nonadopters in the Rogers model may be understood to behave in the bandwagon effect of the logistics model, while the innovators, early adopters, and early majority of the Rogers model represent truly innovative behavior. The implication for this study is that only "the first half" of innovative behavior needs to be studied (innovators through the early majority) because competitive bandwagon effects are likely to take over the diffusion process once the number of adopters has peaked.

Diffusion stages reflect individual decisions about the timing of adoption. Independent of the probability of exposure to information that increases as more organizations adopt an innovation, the timing of adoption

[1] Adoption of technology includes both acquisition and deployment (Fichman and Kemerer, 1999), but the literature has generally focused on acquisition as a point-in-time event. Deployment or implementation is done over a period of time and includes discontinuation, which has been studied less extensively.

reflects assessments of risk and cost. Innovation is inherently risky and disruptive. Rationales for both first-mover and second-mover advantage can be found, with advantage tipped to the second-mover under conditions of uncertain profitability (Hoppe, 2000; Tellis and Golder, 1996; Jensen, 1982). Late movers, however, run the risk of losing competitive position (Bryant et al., 1990). Stoneman and Kwon (1996) estimated annual gross profit gain to adopters of one or more new technologies of 11% above the mean.

♦ Information Awareness and the Adoption Process

A parallel model to the adoption decision model developed by Rogers is the information awareness model of Rogers and Shoemaker (1971). It reflects the concept that the decision to adopt an innovation is a function of various stages of information gathering and decision making; as Burt states, "During the course of this communication activity, the potential adopter reaches a psychological decision regarding adoption of the innovation" (Burt, 1973:126). This model assumes that access to information is the principal determinant of the adoption decision, which is sequenced as follows:

1. Awareness.
2. Interest.
3. Evaluation.
4. Trial.
5. Adoption.

Research conducted using this model tends to focus on the role of different information and communication channels in each stage of the process. These information sources include the following:

- Mass media (e.g., popular press, trade press, government publications, TV, radio).
- Word-of-mouth (e.g., peers, neighbors, extension agents, sales reps).
- Opinion leaders (e.g., known innovators in field; set of opinion leaders may be unique to each adopter).

Communication from informal networks, supplier-adopter communications, technology demonstrations, and communication with other adopters increase the probability of adoption.

Communication channel behavior has been found to vary across adopter categories (Rogers, 1995), with both external and internal communications important to innovation (Damanpour, 1991). Communication from informal networks, supplier-adopter communications, technology demonstrations, and communication with other adopters increase the probability of adoption (Frambach, 1993; Beatty, 1992; Midgley et al., 1992). Similar to the strength of weak ties in economics, a diversity of indirect communication links benefits diffusion (Midgley et al., 1992). At the same time, communication intensity has been found to increase adoption (Meyers et al., 1999). Additionally, information an adopter has about competitors' actions increases profitability estimates of innovations (Oliva, 1991).

♦ The Determinants of Diffusion

Research on the determinants of the diffusion process may incorporate the Bass/Mansfield logistics model, the Rogers adoption model, or the Rogers and Shoemaker information awareness model. Other analysts simply seek to isolate diffusion and adoption factors without integrating them into a broader theoretical framework. When considered as a whole, the body of empirical work on innovation diffusion and adoption suggests a variety of contingencies to both processes: the same factors are not at work at all times in all industries or among all decision makers. The challenge is to identify those variables that are most influential for a particular sector, type of innovator, or type of innovation.

A substantial literature addresses the factors that influence adoption. These include macroeconomic and cultural variations (pertinent to international comparisons), manufacturer characteristics, industry characteristics, buyer-adopter characteristics, technology characteristics, decision process characteristics, and regional variations. Wolfe's 1994 review concluded that the "most *consistent* theme found in the organization innovation literature is that its research results have been *inconsistent*" and that the "current state of the literature offers little guidance to those who want to influence organizational innovation." Damanpour's 1991 meta-analysis of the literature, however, found substantial consistency in statistically significant associations "for specialization, functional differentiation, professionalism, centralization, managerial attitude toward change, technical knowledge resources, administrative intensity, slack resources, and external and internal communication. Results suggest that the relations between the determinants and innovation are stable, casting doubt on previous assertions of their instability." Seemingly inconsistent results are often related to uncontrolled differences between industries (most studies are industry specific).

The determinants of innovation and diffusion as identified in the literature tend to fall out into several broad categories (Figure 3):

- The adopter's human resources.
- Organizational structure.
- Organizational culture and decision process.
- Market context.
- Industry characteristics.
- Communication channels and social networks.
- Technical attributes of the innovation.
- Economic attributes of the innovation.
- Supplier/vender characteristics.

Fig. 3 – Determinants of Adoption and Diffusion

Adopter's Human Resources	Adopter's Organizational Structure	Adopter's Organizational Culture and Decision Process
▪ Skills ▪ Motivation ▪ Commitment ▪ Specialization and professionalism ▪ Technical knowledge resources ▪ Managerial attitudes and support	▪ Size and resources ▪ Centralization ▪ Flexibility ▪ Communication/ administrative intensity ▪ Complexity ▪ Formalization	▪ Innovation proneness ▪ Organizational support for innovation ▪ Technology champions ▪ Cooperation and openness ▪ Orientation (outward v. inward) ▪ Organizational position and role of decision maker
Adopter's Market Context	**Industry Characteristics**	**Communication Channels and Social Networks**
▪ Location ▪ Competitive strategy ▪ Market scope ▪ Growth strategy ▪ Knowledge of competitors' behavior ▪ Unionization	▪ Regionalization ▪ Concentration ▪ Heterogeneity ▪ Inter-firm competitiveness ▪ Growth rate ▪ Wage rates ▪ Government regulation	▪ Mass media ▪ Word-of-mouth ▪ Opinion leaders ▪ Professional and trade associations ▪ Boundary spanners ▪ Informal and indirect links
Technical Attributes of the Innovation	**Economic Attributes of the Innovation**	**Supplier/Vender Characteristics**
▪ Divisibility ▪ Learning by doing ▪ Complexity-crudeness ▪ Type of innovation (process or product) ▪ Complementarities required ▪ Relative improvements in old technologies ▪ Compatibility (values and practice) ▪ Communicability ▪ Relation to innovator product class schemas ▪ High, medium, and low tech ▪ Radical v. incremental	▪ Profitability ▪ Uncertainty/risk ▪ Expectations about future prices ▪ Expectations about future tech trajectory of innovation ▪ Labor saving v. materials saving ▪ Scale neutral v. lumpy ▪ Initial cost ▪ Continuing cost ▪ Rate of recovery of cost ▪ Time savings ▪ Start-up investment	▪ Technical capabilities and support ▪ Communications skills ▪ Expertise in monitoring deployment ▪ Public relations

♦ Further Categorization of Adopter Characteristics

Brown et al. (1981) developed a supply-oriented framework in which channels of distribution mechanisms (structure, policy, strategy) are used to explain adoption patterns, since the channels control the availability of innovation to potential adopters. Meyers et al. (1999) found that adoption was greater when sellers had a higher level of technical capabilities, stronger communication skills, and greater expertise in project management. They argue that a cooperative and effective interface between sellers and buyers is particularly important for the diffusion of industrial process innovations.

Market context includes location, competitive strategy, market scope, growth strategy, knowledge of competitors' behavior, and unionization. Traditional logistic diffusion models pattern the aggregate potential adopter population and rate of diffusion but do not account for spatial variations in adoption behaviors. However, because of adopter heterogeneity, diffusion does not spread evenly across time and geography. Geographic variation can affect a variety of factors, some of which are specific to the technology being diffused (e.g., variation in energy costs and regulations). Adopter categories (innovators, early, mid, late) can exhibit distinct spatial characteristics (Brown et al. 1976). Populations tend to be geographically stratified, and there is asymmetrical communication between cities and outlying areas (Gore and Lavaraj, 1987). Regional variations in building practices, only partly a reflection of climate, are well known. Suppliers might have regional targets and availability. Consequently, location is important to consider in diffusion research.

> *Diffusion does not spread evenly across time and geography. Geographic variation can affect a variety of factors, some of which are specific to the technology being diffused (e.g., variation in energy costs and regulations). Regional variations in building practices, only partly a reflection of climate, are well known.*

Technical and economic attributes of the innovation collectively compose what is referred to as the "adoption potential" or "adoptability" of an innovation (Tornatsky and Klein, 1982; Berry and Bronfman, 1981; Perry and Danziger, 1980). For example, Dalle (1997) identifies "network externalities" where the number of agents adopting a technology affects its utility, such as in communications networks where blocks of communicators need to adopt the technology in order for it to have increased utility for individual adopters. Similarly, Markus (1987) identified threshold effects in adoption.

Diffusion theory and research tend to focus on adoption behaviors of individual consumers or entrepreneurs and thus might not explain the adoption behavior of large, complex organizations. Individual characteristics (sex, age, attitudes) are not important determinants of innovative behavior of people in complex organizations (Baldridge and Burnham, 1975; Bobrowski and Bretschneider, 1994), although organization position and role for the individual does matter. Power, sanctions, communication linkages, and boundary roles are more important than individual characteristics.

♦ Diffusion of Construction Technology

As a process industry, construction faces certain challenges both in terms of introducing new technology and in studying the diffusion of technology. Relatively few studies have been conducted on the diffusion of construction technology, whether for commercial or residential uses. In general, the literature on innovation and diffusion in the construction industry addresses:

- Construction as a "laggard industry" relative to innovation.
- Impediments to innovation in construction.
- Competitive advantage and increased profit associated with innovation.
- Migration of innovation from commercial to residential construction.
- Organizational and social factors influencing innovation adoption by builders.

Much of the literature is exhortatory and descriptive. Some studies assume that a problem exists and prescribe approaches for construction firms to become more innovative (Tatum, 1987; Laborde and Sanvido, 1994; CERF, 1996a and 1996b). Others describe the diffusion of particular products and technologies, highlighting the problems encountered. Much can be learned from these case studies, but their lack of theoretical and methodological rigor restricts their lessons to suggestions rather than conclusions.

♦ *The "Laggard Industry" Argument*

> *Arguments that the construction industry lags in innovation have been based on aggregate expenditures on research and development, but such expenditures do not clearly measure the development and deployment of new technologies in construction. Studies specifically focused on technology innovation in construction have found more innovation than suggested by a "laggard" industry.*

The construction industry has often been described as a laggard in the introduction and diffusion of new technology (Tatum, 1987; Dibner and Lemer, 1992; CERF, 1996a and 1996b). Justification for this conclusion, however, has not been clearly established. Arguments that the construction industry lags in innovation (e.g. Building Research Board, 1988; CERF, 1996b) have been based on aggregate expenditures on research and development (R&D), but such expenditures do not clearly measure the development and deployment of new technologies in construction (Ventre, 1980).

A significant amount of technology development introduced in construction comes from other sectors, primarily manufacturing, and consequently does not get credited to the construction industry. Manufacturing firms develop products and materials for construction, but their R&D expenditures are counted in manufacturing and rarely attributed to the construction sector. For example, innovation in the forest and wood products industry (Bengston and Gregersen, 1991/92) undoubtedly has direct benefits for construction. One estimate of R&D spending on construction in the United States attributed roughly two-thirds of the total to building-related research by manufacturers (Dibner and Lemer, 1992, citing Building Research Board, 1988).

Studies specifically focused on technology innovation in construction have found more innovation than suggested by a "laggard" industry. Ventre reported in 1973 that diffusions of 14 innovations in residential construction were similar in process and speed to comparable innovations in other industries. Additionally, Slaughter (1991) reported much more innovation in residential construction than suggested by previous studies that focused on industrywide R&D expenditures and impediments to innovation rather than on adoption of actual innovations. Later, Slaughter (1993a and 1993b) found 34 innovations among seven manufacturing firms and six construction companies in a detailed study of innovation in the use of stressed-skin panels in residential construction. Dibner and Lemer (1992) caution that any conclusion that construction is a technological laggard rests on sparse evidence. Nonetheless, they also tacitly accepted this very conclusion and focus on "impediments" to diffusion in construction.

♦ ***Impediments to Innovation in Construction***

Reflecting the "laggard industry" assumption, much of the discussion in the research literature has focused on identifying various barriers to efficient and effective diffusion in construction. The NAHB Research Center's 1989 study of innovation in home building identified several of the same impediments to innovation that were reported in studies conducted in the early 1960s:

- Cyclical nature of construction.
- Dominance of small firms.
- Lack of integration of the industry, particularly the heavy reliance on subcontractors.
- Diverse building codes with local peculiarities in details and administration.
- Lack of product approval systems that establish and certify to well-recognized performance criteria.
- Lack of access to information about new products.
- Inadequate education and training on products and materials, installation techniques, and methods of operation and maintenance.
- Exposure to liability.
- Required acceptance by the finance and insurance industries.
- Limited funding for research.
- Resistance to innovations from homebuyers.

Other impediments to innovation suggested to exist in the U.S. building industry (Dibner and Lemer, 1992; CERF, 1996a and 1996b; Jaffee and Stavins, 1995; NAHB Research Center, 1991; Koebel, 1999; Ball, 1999) include:

- Lack of clear means for moving new technology from government and university research labs to field-testing.
- Poorly developed links between universities and the construction industry.
- Low levels of government support for technology development.
- Changes in ownership over the long service lifetimes of buildings.
- Inadequate flow of information within the industry and between the industry and manufacturers.
- Adversarial relations in design and construction related to fixed-price contracts.
- Inadequate capital for deployment.
- The high cost of deployment.
- Management ingenuity.
- High discount rates.
- Low impact of technology on profit.

> *Reflecting the "laggard industry" assumption, much of the discussion in the research literature has focused on identifying various barriers to efficient and effective diffusion in construction. . . . Several of these factors very clearly characterize . . . residential construction. However, their role and importance in influencing the adoption and diffusion of innovation in construction are much less clear.*

Several of these factors very clearly characterize the construction industry, particularly residential construction. However, their role and importance in influencing the adoption and diffusion of innovation in construction are much less clear. The motivation for a firm to adopt an innovation is assumed to relate to gaining competitive advantage that increases profits, which has been the focus of a few studies of the construction industry.

- ***Competitive Advantage and Increased Profit Associated with Innovation***

Tatum (1987) has argued that innovation is essential for the on-going competitive success of construction firms for two reasons: the push of competitive advantage and the pull of increasingly complex construction required by building owners. Both price and performance can influence competitive advantage. Substitution among wood products in residential construction, specifically the shift to engineered wood products, was initially related to increases in softwood lumber prices (Eastin et al., 2000). Although initial shifts were prompted by price advantage, the higher performance of engineered wood products sustained continued use even after softwood lumber prices declined. Price advantage might be required for initial adoption of a building innovation, after which performance and familiarity can sustain use. High cost and rapid growth markets led to early adoption and greater diffusion of innovations in the cement industry (Rosenbaum, 1989), as did industry concentration.

> *The motivation for a firm to adopt an innovation is assumed to relate to gaining competitive advantage that increases profits. . . . However, innovation is not a clear path to competitive advantage. . . . Construction innovations are often invisible to the buyer or tenant of the building. . . . In addition, the certainty and timing of benefits can be problematic when benefits of some building innovations occur over the life span of the building.*

However, innovation is not a clear path to competitive advantage (Rogers, 1995). New technologies might have to be compatible with several organizations (the general contractor, several subcontractors, the lender, and the insurer), might be difficult to introduce on a trial basis; and might be difficult for the end user to observe (Koebel, 1999). Construction innovations are often invisible to the buyer or tenant of the building, who is forced to treat the building as a “black box.” In addition, the certainty and timing of benefits can be problematic when benefits of some building innovations occur over the life span of the building, but the cost of the innovation is typically included in the building price and amortized over the term of the mortgage. Life-cycle costing has been promoted as a way to account for the value of the full benefits of such building innovations, but the consumer is likely to have a steep discount rate for benefits received beyond the period of probable occupancy.

The complexity of the competitive benefits associated with innovation help explain the seeming “paradox” of very gradual diffusion of supposedly cost-effective energy-conservation technologies (Jaffee and Stavins, 1995). Maximum profit reflects the “the discount or premium applied by the market to the value of energy savings”; the quantity of energy consumed with and without the technology; the cost of energy; the characteristics of the home; engineering estimate of purchase and installation cost of the technology; hidden costs of installation; local regulations requiring use of the technology, penalties for noncompliance, enforcement probability, and stigma associated with noncompliance; and the value of any subsidies for adopting the technology. Adoption is thus increased by high energy costs, a low discount or a premium applied to energy savings, more effective technology, and government subsidies. Higher adoption costs and higher interest rates discourage adoption.

Potential explanations for the paradox of low adoption rates of energy-conservation technologies include market and nonmarket failures. Market failures include lack of information, principal/agent slippage (where the technology purchaser does not receive its benefits or cannot recover the cost of adoption), and incomplete pricing of energy. Nonmarket failures (which Jaffee and Stavins argue are not justifications for government action) include hidden costs of installation; private transaction costs (e.g., information acquisition and absorption); high discount rates; the risk of gaining less than the average profit; and, in the case of retrofit, declining costs or risks of deployment.

Factors influencing competitive advantage and performance are not uniform across the construction industry, and seemingly successful construction innovations might not migrate easily between the commercial and residential sectors. The failure to transfer several commercial construction innovations to residential construction has generated significant public controversy about the introduction of new materials in housing.

♦ ***Migration of Innovation from Commercial to Residential Construction***

Exterior insulated finishing systems (EIFSs) and engineered wood I-joists were successfully deployed in commercial structures before being introduced in residential construction. Both technologies encountered significant problems with the transition (NAHB Research Center, 2001), and interviews with practitioners identified the following problems:

- Problems with compatibility with the housing system.
- Inadequacy of skills in the residential labor force.
- Lack of monitoring the products by practitioners and manufacturers.
- Poor communication between practitioners and manufacturers.
- Risk and liability.
- Negative publicity and public perception.

The residential building process lacks a “systems integrator” responsible for managing the implementation of new technologies—a role played by the contractor and architect in commercial construction. For example, an EIFS requires nontraditional sealants on the building envelope, but residential builders left caulking to the painting subcontractor without adequate

The failure to transfer several commercial construction innovations to residential construction has generated significant public controversy about the introduction of new materials in housing. . . . The residential building process lacks a “systems integrator” responsible for managing the implementation of new technologies—a role played by the contractor and architect in commercial construction.

performance specifications, training in the new process, or monitoring. The builder's architect or the building inspector would have caught the problem in commercial construction, but the problem went undetected until homeowners discovered rot and mold problems resulting from water penetration.

Other problems face migration of products from commercial to residential construction. Energy-efficient lighting gained a significant foothold in the commercial building sector, but this did not lead to success in the residential sector (Menanteau and Lefebvre, 2000). Manufacturers were slow to modify the product for residential use, and residential builders (and consumers) were reluctant to shift from a proven technology to the new technology. Owners and occupants of commercial buildings might be more aware of and sensitive to the cost of lighting. In contrast, residential occupants are probably influenced more by the appearance of and familiarity with the incandescent lighting product.

- ***Organizational and Social Factors Influencing Innovation Adoption by Builders***

The social influence model emphasizes the importance of the social system in adoption by individuals or organizations (Fulk, 1993; Dillon and Morris, n.d.; Witherspoon, 1997). Firms are not automatons maximizing objective functions but social systems. Koebel (1999) and Ball (1999) have stressed the importance of the social system of building firms in technology adoption. Criticisms of the residential building industry as technology adverse and "backward" have ignored the social system characteristics that contribute to business success. Technology is but one means of adapting to a complex environment and the contribution of technology to a building firm's profit has been unexplored. If the control of land might be the primary determinant of profit, as Koebel (1999) and Ball (1999) suggest, technological innovation might be an unnecessary expense. Additionally, the opaqueness of most building technology to the consumer might focus the impact of consumer demand on cosmetic innovations (e.g., kitchen styles) rather than building innovations.

> *Criticisms of the residential building industry as technology adverse and "backward" have ignored the social system characteristics that contribute to business success. Technology is but one means of adapting to a complex environment, and the contribution of technology to a building firm's profit has been unexplored.*

A methodologically sophisticated analysis of innovation in home building found that firm size, type of construction, regional characteristics, and the builder's age influenced diffusion, whereas fragmentation and unionization had no effect (Blackley and Shepard, 1996). An earlier study found that the chief building official's education, professional background and contacts, and the size of building firms positively affected adoption of cost-reducing code changes by local code officials, whereas the extent of unionization and affluence of the jurisdiction negatively affected adoption (Oster and Quigley, 1977). Although the latter result appears anomalous since higher education and affluence are typically associated with innovation by consumers, another study also suggests that the homebuyer's income negatively affects adoption of residential construction innovations (Duke, 1989), in stark contrast to the general diffusion literature. Higher-income homebuyers, who prefer custom-built homes, might perceive traditional building practices as superior to innovative practices. Additionally, upper-income communities might impose more exclusionary regulatory requirements.

Unfortunately, little is known about the communications and social networks builders use to learn about innovations or influence their adoption practices. Similarly, questions abound about how builders assess relative advantage; how they estimate the consumer's reaction; information gaps of builders and consumers; information brokers for each; the importance of industry sources and of independent sources of information; and the importance of word-of-mouth among builders. Our survey was designed to comprehensively address these gaps in our knowledge about the diffusion mechanisms and organizational characteristics that influence the adoption of innovations in the residential construction industry.

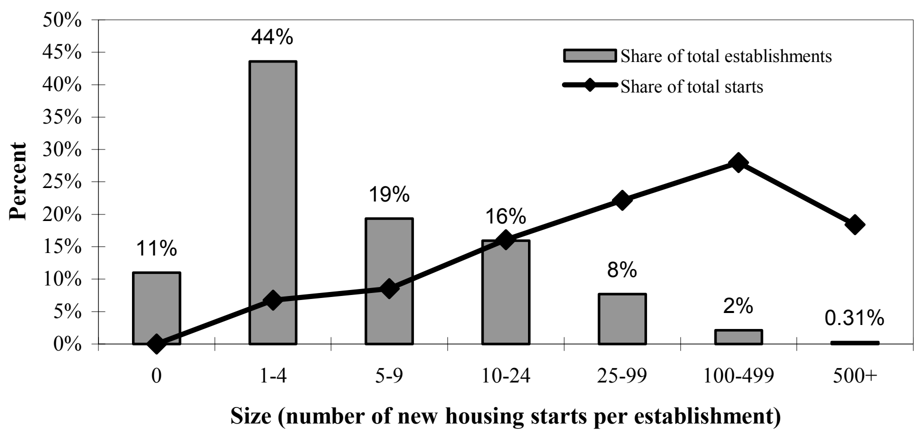
> *Our survey was designed to comprehensively address these gaps in our knowledge about the diffusion mechanisms and organizational characteristics that influence the adoption of innovations in the residential construction industry.*

Housing Industry Profile and Recommendations for Future Research

> *Although innovation is likely to be concentrated among a relatively small number of builders, these could range from an innovative proprietor with only a few employees to complex organizations.*

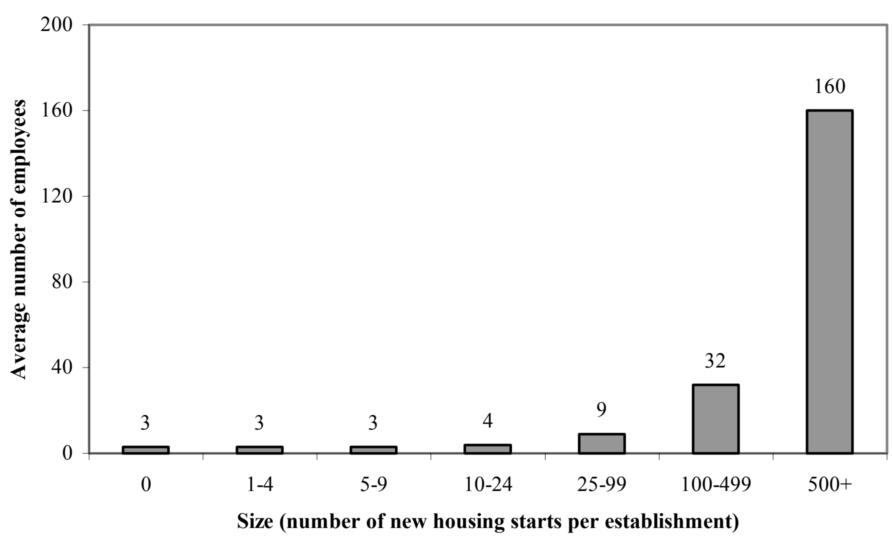
The residential home building industry presents challenges for synthesizing theory and research on innovation diffusion because of the considerable variation in size and level of activity within the industry. As illustrated in Figures 4 and 5, a small fraction of the industry actually accounts for most housing starts, and average employment ranges from 3 to 160 employees. Indeed, the largest firms—those that build 25 or more single-family homes per year—represent only 10% of all establishments but generate two-thirds of all new home starts per year (Figure 6).

Fig. 4 – Contribution of U.S. Homebuilders to US Housing Starts by Size of Establishment, 1997



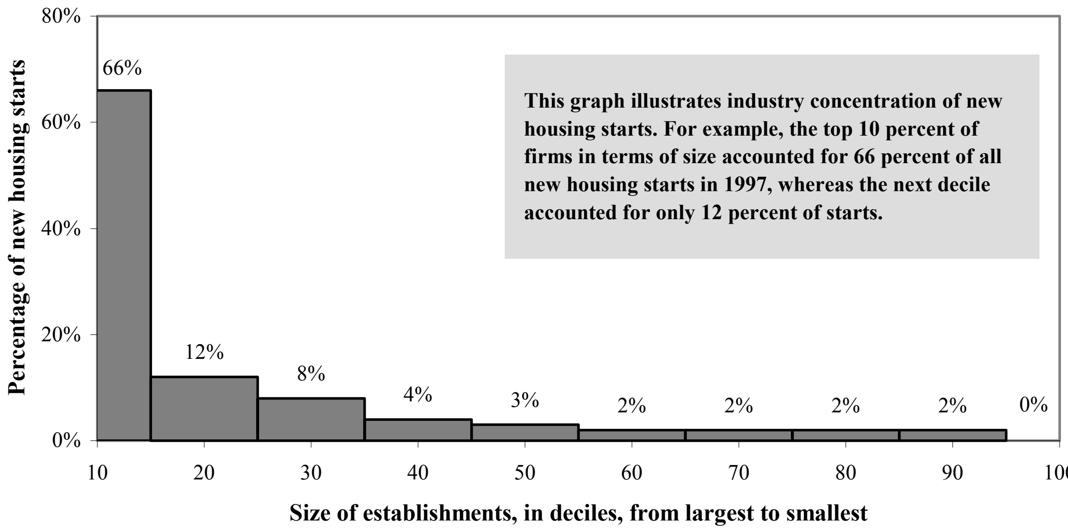
Source: U.S. Census Bureau, 1997 Economic Census--Construction Sector Special Study, Housing Start Statistics (January 2000).

Fig. 5 – Average Number of Employees per Establishment, by Size of Establishment, 1997



Source: U.S. Census Bureau, 1997 Economic Census--Construction Sector Special Study, Housing Start Statistics (January 2000).

Fig. 6 – Concentration of New Housing Starts in the Single-Family Residential Construction Industry, 1997



Source: Calculated from U.S. Census Bureau, 1997 Economic Census--Construction Sector Special Study, Housing Start Statistics (January 2000).

By manufacturing industry standards, residential building has a low level of concentration. Nonetheless, diffusion of new technology is still expected to be heavily reliant on larger firms. According to Eastin et al. (2000), small builders are increasingly reliant on the repair/remodeling market rather than new construction. Additionally, smaller builders in the custom home market might be resistant to innovation due to the attitudes of their customers. The innovations reported in the literature among smaller builders were heavily oriented to modifications of materials and technologies to fit to the housing system. Larger firms apparently introduce the more substantial innovations.

Although innovation is likely to be concentrated among a relatively small number of builders, these could range from an innovative proprietor with only a few employees to complex organizations (an average of 160 employees). The literature strongly suggests that these differences in size and locus of decision within the organization matter in terms of innovation diffusion. Consequently, future research on diffusion in the residential building industry should be designed as follows:

- Disproportionately target the top 10% of residential builders, which collectively account for 66% of all new housing starts. This portion represents approximately 3400 establishments nationally.
- Target the first three types of innovators in the Rogers model: innovators, early adopters, and early majority. This scope would reflect innovations that have a market penetration rate of roughly 1–50%.
- Address specific characteristics of the adopting firm, industry, information channels and social networks, technical attributes of the innovation, economic attributes of the innovation and supplier/vendor characteristics that have been established in the literature as important to diffusion.

HOME BUILDER DIFFUSION SURVEY

To capture the diffusion mechanisms important to home builders, we developed a questionnaire to measure the variables that were identified in the literature review as influencing technology adoption. In addition, the questionnaire measured the use of several building technologies at different stages of market penetration. The questionnaire was divided into four parts:

1. Characteristics of the firm (human resources, organizational structure, market context, organizational culture and decision process).

2. Activities regarding new building and construction products, materials and practices (information channels and social networks, supplier/vendor characteristics).

3. The firm's adoption of specific new building and construction products, materials and practices (perceived benefits, costs, impediments).

4. The firm's market and competitive strategies.

Part 1 contained 12 questions covering the firm's type of home building (single-family production, single-family custom, etc.); number of years in business; production volume (number of units produced); staffing (types of positions in the firm and number of employees); market area; approach toward selecting new building and construction products, materials, and practices; growth plan; use of union labor; business strategies potentially related to technology; and adoption of eight technologies at different stages of diffusion. The eight technologies (see Appendix C for detailed description) by stage of diffusion at the time of the survey were as follows:

To capture the diffusion mechanisms important to home builders, we developed a questionnaire to measure the variables that were identified in the literature review as influencing technology adoption. In addition, the questionnaire measured the use of several building technologies at different stages of market penetration.

1. Pre-cast concrete foundation walls (early stage).
2. Wood/plastic composite exterior trim/molding (late stage).
3. Fiber cement exterior trim material (middle stage).
4. Heatpumps with integral water heating (e.g. desuperheater) (early stage).
5. Laminate flooring (middle stage).
6. Wood I-joists as roof rafters (middle stage).
7. Fiber cement flooring underlayment (middle stage).
8. Wood I-joist structural floors (late stage).

Based on surveys conducted by the NAHB Research Center, we anticipated that two of these technologies (precast concrete foundation walls and heat pumps with integral water heating) would be in the early stage of diffusion with 10% or less market penetration; four would be in a middle stage of diffusion with 11–30% market penetration (fiber cement exterior trim material; laminate flooring; wood I-joists as roof rafters; and fiber cement flooring underlayment); and, two would be in a late stage of diffusion with more than 30% market share (wood/plastic composite exterior trim/moldings and wood I-joist structural floors).

Part 2 included seven questions about attitudes and practices that could influence adoption of technology to identify the following:

- Professional positions in the firm with significant influence over a decision to use a new type of siding.
- The position making the final decision.
- Whether anyone would be considered a strong advocate of innovation.
- The location of the majority of decisions on switching building material brands, new building materials, changes in home design and construction processes.

- The level of influence (from not influential to highly influential) of these information sources.
  - Consultants.
  - Trade shows.
  - Homebuyers.
  - Internet/World Wide Web.
  - Mail or FAX advertisements.
  - Sales and supplier representatives.
  - Manufacturers' toll-free numbers.
  - NAHB seminars.
  - Observing other builders.
  - Seminars.
  - Subcontractor advice.
  - Technology transfer programs like PATH.
  - Trade publications.
  - Universities.
- The degree of agreement that the following factors are impediments to using new building and construction products and materials.
  - Building codes.
  - Higher cost than the products and materials currently used.
  - Customer preference for "tried and true" products or features.
  - Resistance from bankers and insurance companies.
  - Lack of support from manufacturers and suppliers for new products.
  - The company's business strategy for gaining competitive advantage.
  - Risk of call-backs.
  - Subcontractor resistance.
  - Difficulty for construction workers to learn new ways of building.
  - Reliance on established companies that stand behind their products.
- The main benefits to the firm for adopting new building and construction products, materials, and practices.
  - Helping to comply with codes and regulations.
  - Decreasing costs.
  - Creating an image as an innovative builder.
  - Increasing productivity.
  - Increasing profit.
  - Increasing quality.
  - Maintaining or improving market competitiveness.
  - Meeting customers' expectations.
  - Reducing build time.
  - Reducing call-backs.
- The importance of cooperation from the following.
  - Suppliers.
  - Manufacturers.
  - Subcontractors.
  - Architects or engineers.
  - Project or construction managers.

Part 2 reflected general patterns of influence over the adoption decision. To obtain information specific to the adoption of a particular product, material, or practice during the preceding five years, Part 3 first identified the most innovative technology recently adopted by the firm. To do this, nine separate products or materials were listed by their stage of diffusion, starting with those with the least market penetration (see Appendix C for detailed description). Respondents were asked to identify whether each of these products was never tried, was tried but discontinued, or was currently being used by their firm:

- Structural insulated panels (SIPs).
- Light-gauge steel exterior walls.
- Insulated concrete forms (ICFs).
- Panelized walls.
- Ultra-high-efficiency HVAC*.
- Fiber cement siding.
- Wood/plastic composite decking lumber (e.g. Trex™ or ChoiceDek™).
- Fiberglass doors.
- OSB subflooring.

Based on data from NAHB surveys, the first three technologies in the early stage of diffusion were classified with less than 15% market share; the next four in a middle stage of diffusion with 30–70% market share; and the final two in a late stage of diffusion with greater than 80% market share. The respondent identified the *first* item they checked as currently being used and answered the next questions about the firm's decision to use that product. The respondents were asked to again rate the influence of the previously listed information sources, but specific only to the product. Similarly, they rated the importance (on a five-point scale from "not important" to "highly important") of these benefits in their decision to use the product or material they identified:

- Impact on profitability.
- Labor savings.
- Materials savings.
- Ability to recover cost of the product/material.
- Reduction in build time.
- Compatibility with preferred construction practices.
- Quality compared with alternatives.
- Consumer's preference for the product/material.
- Manufacturer's technical support.
- Subcontractors' familiarity with the product/material.
- Suppliers' technical support.
- Reduction in call-backs.

Counterbalancing the benefits that influenced the decision to use the product or material, the respondents rated (on the same five-point scale) the importance of various problems potentially associated with new products:

- Uncertainty/risk.
- Initial cost.
- Continuing cost.
- Difficulty in first use.
- Difficulty of continuing use.
- Acceptance by building inspectors.
- Acceptance by lenders.
- Uncertainty in zoning regulations and building codes.

The respondent also rated the influence of various positions in and outside the firm in making the decision to adopt the most innovative specific product or material identified by the respondent as currently being used. The

* Air conditioning with a SEER (season energy efficiency rating) of 14 or greater (or a geothermal heat pump) or a furnace/boiler with an efficiency rating of 95% or greater.

ratings were on a three-point scale of "not influential," "somewhat influential," and "very influential" for the following:

- General manager or president.
- Purchasing manager.
- Designer or architect.
- Engineer.
- Project or construction manager.
- Installing subcontractor.
- Homebuyer.
- Sales or marketing manager.

The final part of the questionnaire addressed the firm's market and competition strategies. Four questions were asked, covering the following:

- The firm's approach toward achieving success in home building (checking the *one* that fits best) by the following:
  - Offering a lower cost per square foot home than market competitors.
  - Building homes and developments with more desirable features than competitors' homes.
  - Having a reputation for high quality/durable homes and quickly addressing problems in homes.
  - Developing land into more desirable neighborhoods with better locations than competitors.
- How the firm monitors its competitors by the following.
  - Attending trade or association meetings.
  - Monitoring industry data.
  - Touring competitors' houses.
  - Visiting competitors' developments or building sites.
  - Not trying to monitor its competition.
- The amount the firm knows about the building practices of its competitors (nothing, some, a lot).
- The amount of time spent tracking changes and trends in the marketplace.
  - Lengthy.
  - Minimal.
  - Average.
  - Sporadic.

Two samples of home builders were selected. As recommended by the literature review, the sample focused more heavily on early and middle stage adopters than on late adopters. The primary sample was from the NAHB membership list and the smaller, supplemental sample was drawn from previous respondents to NAHB's Annual Builder Practices Survey. The primary sample was drawn randomly (every n^{th} record) by region and was conducted via the mail using procedures described in the methodology section (see Appendix A). The supplemental sample was designed to increase the number of respondents who were likely to be more innovative, based on responses to prior surveys.

As recommended by the literature review, the sample focused more heavily on early and middle stage adopters than on late adopters. . . . Previous research was inconclusive about the relationship between size and innovation in residential construction; consequently it was best to include a broad sample of builders.

The sample was not stratified by firm size. Previous research was inconclusive about the relationship between size and innovation in residential construction; consequently it was best to include a broad sample of builders.

There were 196 respondents in the primary sample and 51 respondents in the supplemental sample, for a total of 247 respondents. The firms in both samples were very similar except for their level of innovation and for a few other characteristics. In general, discussion is focused on the total sample (N=247) that combines the primary and supplemental samples (tables report only on the total sample). Important differences between the samples are noted in the discussion below.

Survey Results

The majority of respondents (58%) built single-family, custom-homes (Table 1). Single-family production builders were the next largest group (25%). Multifamily builders and home improvement contractors were 7% each. The percentages of single-family production builders and home improvement contractors were the main differences between the two samples. In the primary sample, 29% were custom builders, compared to only 6% in the supplement; whereas the percentages of home improvement contractors were 4% in the primary sample and 18% in the supplement. The only modular builder was in the supplemental sample. There were no HUD-code manufacturers in either sample. The remaining eight firms combined single-family construction with another type of construction or represented a construction specialty (e.g. concrete subcontractor).

The majority of respondents (58%) built single-family, custom-homes. Single-family production builders were the next largest group (25%). Multifamily builders and home improvement contractors were 7% each.

Table 1. Home Builders by Type of Firm

Firm Description	Percent
Single-family production	25%
Single-family custom	58%
Multifamily builder or developer	7%
Home improvement contractor/remodeler	7%
Modular home manufacturer	1%
Other	2%
N=245	

See Appendix B, Q1 for complete wording of question.

About half of the firms that responded (49%) had been in business between 10 and 25 years (Table 2). Some were fairly new firms in business for less than 10 years (14%); however, this was the case for 11% of the primary sample and 24% of the supplement. Only a few (5%) had been in business for over 50 years. The mean years established was 23.3 (firms in the supplement were on average 4 years younger).

Table 2. Home Builders by Number of Years Since Firm Established

Years Established	Percent
<10 years	14%
10–25 years	49%
26–50 years	32%
>50 years	5%
N=243	

See Appendix B, Q2 for complete wording of question.

Most of the firms were very small businesses in terms of number of employees. Over half had five or fewer employees and about three-fourths had 10 or fewer employees (Table 3). The rest were mostly in the category of 11–50 employees (22%). Only 13 firms had more than 50 employees and only five had 100 or more employees.

Most of the firms were very small businesses. . . . Eighty-five percent produced fewer than 100 units, and only 8% produced more than 200 units.

Table 3. Home Builders by Number of Employees

Employees	Percent
1–2	28%
3–5	26%
6–10	19%
11–50	22%
51–100	3%
>100	2%
N=244	

See Appendix B, Q10 for complete wording of question.

Since home builders often rely heavily on subcontractors and keep their own firm size small, the firm's production can be much larger than suggested by its number of employees. The median total production in 2001 (the year prior to the survey) was 12 housing units, but the mean was substantially higher at 53 units. Eighty-five percent of the firms produced fewer than 100 units, and only 8% produced more than 200 units (Table 4). Two firms were significantly larger than the others, producing more than 750 units in 2001. Nearly all of the firms (95%) built some single-family detached units, with a median of 10 units and mean of 38 units. In contrast, only one-in-five firms built townhouses or duplexes in 2001, and only 23 firms (10%) built apartments or condominiums.

Table 4. Home Builders by Number of Units Built in 2001 by Building Type

Number of Units	Single-family detached	Townhouse or duplex	Apartment or condo	Total units
0	5%	81%	90%	-----
1–24	67%	10%	6%	64%
25–49	10%	3%	2%	12%
50–99	7%	4%	1%	9%
100–199	5%	1%	1%	7%
≥200	7%	1%	1%	8%
N=235				

See Appendix B, Q3 for complete wording of question.

The majority of firms had a project or construction manager. Far fewer had a marketing or sales manager, a finance director, a purchasing manager, or a designer or architect. … Ten percent were part of a home building company that serves multiple market areas in the same region of the country and only 3% were part of a national home building company.

Previous research has indicated that the number of professional personnel in the firm influences innovation adoption. Respondents were asked to identify which of nine positions are staffed permanently with a least one full-time or part-time employee. Virtually all of the firms had a general manager, president, owner, or partner (Table 5). (The 14 firms without such a position could have been branches or subsidiaries of larger firms. Respondents were instructed to respond for the office or market area where they work, if they were part of a larger company that serves multiple market areas.) The majority of firms had a project or construction manager (57%). Far fewer had a marketing or sales manager (27%), a finance director (24%), a purchasing manager (20%), or a designer or architect (17%). Very few had an information technology manager, urban planner or engineer.

Table 5. Home Builders with Professional Positions*

Position	Percent
General manager/president/owner/partner	94%
Purchasing manager	20%
Designer or architect	17%
Marketing or sales manager	28%
Engineer	3%
Urban planner	4%
Project or construction manager	57%
Information technology manager	7%
Finance director	24%
N=243	

*Have at least one permanent/full-time position in firm.
See Appendix B, Q5 for complete wording of question.

Most of the firms served only their local market area (87%). Ten percent were part of a home building company that serves multiple market areas in the same region of the country, and only 3% were part of a national home building company (Table 6).

Table 6. Home Builders by Market Area

Market Area	Percent
Firm serves only local market area	86%
Firm is part of home building company that serves multiple market areas in this region	10%
Firm is part of home building company that serves multiple market areas across the nation	3%
N=245	

See Appendix B, Q6 for complete wording of question.

About 70% of the firms never use union labor in their construction, including their subcontractors, while very few firms (3%) always use union labor for some trades.

The largest group (35%) had moderate plans for annual growth in profits of 5–10% (Table 7). Slightly more firms planned either slow or negative growth (23%) than planned very aggressive growth in profits of more than 10% a year (19%), and 23% had no specific plan regarding growth in profits.

Table 7. Home Builders by Growth Plan

Growth Plan	Percent
Plan to increase net profits over the next 5 years:	
Expect reduction in net profits due to downsizing	7%
Net profits less than 5% a year	16%
Net profits 5–10% a year	35%
Net profits more than 10% a year	19%
No specific plan for growth in profits	23%
N=244	

See Appendix B, Q8 for complete wording of question.

Three questions were designed to detect "conservative" and "supportive" approaches towards selecting new building and construction products, materials, and practices (Table 8). About one-third of the respondents described their firms as innovative and creative, while 18% described their firms as followers and encouraging use of "tried and true" materials and products. The respondents in the supplement were somewhat more supportive of innovation than the larger sample (as anticipated). Less than 10% of the firms were conservative about meeting but not exceeding current code minimums and market expectations, whereas over half preferred to exceed code minimums and market expectations.

About one-third of the respondents described their firms as innovative and creative, while 18% described their firms as followers and encouraging use of "tried and true" materials and products.

Table 8. Home Builders by Approach to Selecting New Building and Construction Products, Materials, and Practices

Approach	Percent
We like to wait until other builders have successfully offered building and construction products, materials, and practices before we use them.	18%
We are often the first in our area to offer a new and innovative building product or system.	35%
We encourage homebuyers to stick with "tried and true" materials and products.	18%
Our goal is to set ourselves apart, to be creative, and we seek materials and products that are distinctive and unique.	35%
We prefer to use materials that meet, but not exceed, current code minimums and market expectations.	7%
We prefer to use materials that exceed current code minimums and market expectations.	57%
N=244	

See Appendix B, Q7 for complete wording of question.

Similarly, the respondents were asked to rate how likely the firm is to invest time or money to meet several business objectives in the next 5 years (Table 9). Except for offering the best mortgage financing to homebuyers, most firms were positively oriented to investing in all of the objectives listed. The most popular business objectives were improving style and attractiveness of homes, implementing total quality practices, improving subcontractor dependability, improving marketability, and reducing construction defects/call-backs. Fewer firms were as likely to invest time or money in reducing costs by using new products, materials, or practices; reducing legal liabilities related to product and building system failures; or reducing either material costs or overhead costs. Firms in the primary sample compared with the supplement were more likely to invest in improving style (78 vs. 60%), marketability (74 vs. 56%), and their ability to purchase and develop the best land (57 vs. 38%), but were less likely to invest in new products or materials (43 vs. 59%), reducing build time (52 vs. 67%), reducing overhead costs (56 vs. 72%), research new products (48 vs. 69%), or educating buyers about new technologies (44 vs. 61%).

The most popular business objectives were improving style and attractiveness of homes, implementing total quality practices, improving subcontractor dependability, improving marketability, and reducing construction defects/call-backs. Fewer firms were as likely to invest time or money in reducing costs by using new products, materials or practices; reducing legal liabilities related to product and building system failures; or reducing either material costs or overhead costs.

Table 9. Home Builders Likely to Invest in Business Objectives

Objectives	Percent
Likely or very likely to invest time and money over the next 5 years:	
Improving style and attractiveness of our homes	74%
Implementing total quality practices	74%
Improving subcontractor dependability	73%
Reducing costs through use of new building and construction products, materials, and practices	57%
Improving marketability of new homes	68%
Improving our ability to purchase and develop the best land	53%
Protecting or improving market share through use of new building and construction products, materials, and practices	46%
Reducing build time	55%
Reducing construction defects/call-backs	85%
Reducing legal liability related to product and building system failures	65%
Reducing material costs	62%
Reducing overhead costs	59%
Offering the best mortgage financing to homebuyers	29%
Researching new products, materials, and practices	53%
Educating buyers about new technologies	43%
N=230 to 243 depending on question.	

See Appendix B, Q11 for complete wording of question.

Seventy percent of the respondents were most likely to attribute their firms' business success to their reputation for high quality and durable homes and quickly addressing problems in new homes (Table 10), although the primary sample did so less than the supplement (66 vs. 82%). Only 10% attributed their firm's success to offering a lower cost per square foot than competitors, but even fewer of the supplemental sample did so (2%).

Table 10. Home Builders by Approach Attributed to Success

Approach	Percent
Offering a lower cost per square foot home than market competitors	10%
Offering more desirable features than our competitors	13%
Having a reputation for high-quality and durable homes and quickly addressing problems in new homes	70%
Developing land into more desirable neighborhoods with better locations than our competitors	5%
Two or more of the above approaches	2%
N=242	

See Appendix B, Q26 for complete wording of question.

Visiting competitors' developments or building sites (57%) and touring competitors' houses (53%) were the two most frequently cited activities for monitoring competitors followed by attending trade meetings (41%) to get a sense of competitors' activities (Table 11). The primary sample was less likely to attend trade shows than the supplement (38 vs. 51%). Only about one-fourth of the firms monitor industry data, and about the same proportion did not try to monitor their competition. However, only 5% felt they know nothing about the building practices of their competitors and over a third knew a lot of competitors (Table 12). Only a few firms are continuously monitoring the marketplace (18%) or, at the other extreme, spend a minimal amount of time doing so (20%).

Table 11. Home Builders' Practices for Monitoring Competitors

Monitoring Practices	Percent
Attends trade or association meetings to get a sense for competitors' activities	41%
Monitors industry data such as building permits, sales records, etc.	27%
Tours competitors' houses	53%
Visits competitors' developments or building sites	57%
Does not try to monitor competitors	23%
N=244 to 245 depending on question.	

See Appendix B, Q27 for complete wording of question.

Table 12. Home Builders' Knowledge of Competitors

Knowledge	Percent
Nothing	5%
Some	59%
A lot	37%
N=241	

See Appendix B, Q28 for complete wording of question.

♦ Attitudes Towards New Building and Construction Products, Materials, and Practices

Technology advocates within firms have been found to be important in innovation adoption. In two-thirds of the firms in this study someone (mainly the owner or CEO) was considered a strong advocate of new building and construction products, materials, and practices.

The number of positions influencing technology adoption and their placement in the firm has been previously identified as important to technology adoption and diffusion. Given the limited number of professional positions in home building firms, influence within the firm is obviously restricted. Consequently, it is not surprising that the general manager, president, owner, or partner (treated as a single category in the questionnaire) was most likely to have significant influence over a decision to use a new type of siding (84%) and was overwhelmingly the most likely to make the final decision (90%, see Table 13.) The project or construction manager was the only other position frequently identified as having significant influence (41%), followed by the designer or architect (22%), the sales or marketing manager (21%), and the purchasing manager (17%). Rarely does anyone other than the CEO make the final decision to use a new siding. In addition, the majority of the decisions made on switching building material brands, adopting new building materials, and changing home design and construction processes are made at the local office (96%) rather than at a regional (3%) or national (2%) office.

Table 13. Home Builders by Position with Significant Influence over Decision to Use New Type of Siding

Position	Percent with Significant Influence	Percent Making Final Decision
General manager/president/owner/partner	84%	90%
Purchasing manager	17%	2%
Designer or architect	22%	1%
Engineer	5%	1%
Project or construction manager	41%	5%
Sales or marketing manager	21%	0%
	N=245	N=230

See Appendix B, Q13 for complete wording of question.

Technology advocates within firms have been found to be important in innovation adoption. In two-thirds of the firms in this study someone (mainly the owner or CEO) was considered a strong advocate of new building and construction products, materials and practices.

Home builders use a variety of information sources in keeping up to date on new building and construction products, materials, and practices (Table 14). Sales and supplier representatives, subcontractors, other builders, and trade publications were the most influential, followed by trade shows, homebuyers, NAHB seminars, and other seminars. Universities, technology transfer programs, and consultants were considered the least influential. There were very few notable differences between the two samples in rating the influence of these information sources. However, the supplemental sample more so than the primary sample rated trade shows, the Internet, seminars, and trade publications as somewhat more influential.

Home builders use a variety of information sources in keeping up to date on new building and construction products, materials, and practices. Sales and supplier representatives, subcontractors, other builders, and trade publications were the most influential, followed by trade shows, homebuyers, NAHB seminars, and other seminars. Universities, technology transfer programs, and consultants were the least influential.

Table 14. Home Builders' Information Sources for Keeping Up to Date on New Building and Construction Products, Materials, and Practices

Sources	Not Influential (1)	(2)	(3)	(4)	Highly Influential (5)
Consultants	46%	18%	23%	10%	4%
Trade shows	14%	11%	32%	29%	13%
Homebuyers	9%	12%	35%	30%	14%
Internet/World Wide Web	21%	23%	34%	17%	5%
Mail or FAX advertisements	24%	31%	32%	12%	1%
Sales and supplier representatives	4%	9%	28%	42%	18%
Manufacturers' toll-free numbers	34%	34%	24%	8%	8%
NAHB seminars	24%	17%	28%	24%	7%
Observing other builders	5%	13%	41%	31%	11%
Seminars	21%	17%	29%	26%	7%
Subcontractor advice	4%	7%	36%	39%	15%
Technology transfer programs like PATH	54%	22%	18%	6%	1%
Trade publications	7%	8%	40%	32%	14%
Universities	57%	19%	17%	7%	1%

N=235 to 247 depending on question.

See Appendix B, Q16 for complete wording of question.

Respondents most often agreed that new products, materials and practices cost more than those currently used, and that subcontractors do not usually want to adapt to new products and materials. In addition, the respondents overwhelmingly agreed that they rely on established companies that stand behind their products.

Among the various impediments and obstacles to adopting new building and construction products, materials, and practices that were presented to the respondents, they most often agreed that new products, materials, and practices cost more than those currently used and that subcontractors do not usually want to adapt to new products and materials (Table 15). In addition, the respondents overwhelmingly agreed that they rely on established companies that stand behind their products. New products, materials, and practices from smaller, unknown firms are likely to face more resistance among home builders. The respondents were more likely to disagree than to agree that building codes are a barrier to technology diffusion, that it is dangerous to be among the first firms who try new things, that banks and insurance companies are hesitant to underwrite projects with new products and materials, and that gaining competitive advantage by using new products and materials is not an important part of the company's business strategy. The supplemental sample differed from the primary sample only in being more likely to *disagree* that using new building products *was not* an important part of the company's business strategy and being more likely to agree that subcontractors do not usually want to adapt to new products and materials.

Table 15. Home Builders by Impediments for Considering New Building and Construction Products, Materials, and Practices

Impediments	Strongly Disagree (1)	(2)	(3)	(4)	Strongly Agree (5)
Building codes make it difficult to use new building and construction products and materials	13%	23%	38%	18%	9%
New building and construction products and materials generally cost more than ones we currently use	3%	12%	36%	35%	14%
Our customers prefer the "tried and true" and don't like nontraditional products or features	6%	26%	44%	22%	4%
It is dangerous to be among the first firms who try new things in our market	15%	24%	32%	22%	6%
Our bankers and insurance companies are hesitant to underwrite projects with new products and materials	27%	36%	29%	6%	2%
Manufacturers and suppliers generally do not provide enough support for new products	7%	27%	41%	20%	6%
Gaining competitive advantage by using new building and construction products and materials is not an important part of our company's business strategy	19%	29%	27%	19%	7%
Using new building and construction products and materials increases our risk of call-backs	9%	25%	41%	21%	4%
Subcontractors in our market do not usually want to adapt to new building and construction products and materials	3%	21%	33%	31%	11%
Our construction workers find it difficult to learn a new way of building	8%	24%	36%	26%	6%
Our firm only uses new building and construction products and materials from established companies that stand behind their products	1%	3%	19%	49%	28%

N=242 to 246 depending on question.

See Appendix B, Q17 for complete wording of question.

Builders most frequently identified increased quality (74%) as a main benefit to their firms for adopting new building and construction products, materials, and practices over the last 5 years (Table 16). No other potential benefit of innovation was identified by a majority of the respondents for adopting new products, materials and practices. The next most frequently cited benefits were creating an image as an innovative builder (41%), meeting customer expectations (38%), and reducing call-backs (32%). The supplemental sample was more likely to identify creating an image as innovative, increasing profit,

Builders most frequently identified increased quality as a main benefit to their firms for adopting new building and construction products, materials and practices over the last five years. . . . The next most frequently cited benefits were creating an image as an innovative builder, meeting customer expectations, and reducing call-backs.

and reducing build time as benefits of adopting new products, materials, and practices and was less likely to mention decreasing costs and reducing call-backs.

Table 16. Home Builders by Benefits for Adopting New Building and Construction Products, Materials, and Practices

Benefits	Percent
Benefits over the last 5 years:	
Helping to comply with codes and regulations	25%
Decreasing costs	20%
Creating an image of our firm as an innovative builder	41%
Increasing productivity	24%
Increasing profit	16%
Increasing quality	74%
Maintaining or improving market competitiveness	22%
Meeting our customers' expectations	38%
Reducing building time	14%
Reducing call-backs	32%
N=247	

See Appendix B, Q18 for complete wording of question.

Adoption of new materials, products, or practices in home building requires the cooperation of several participants in housing construction. The respondents rated the importance of five different groups (Table 17). Suppliers were rated most often as important, and over half of the respondents rated suppliers as highly important. Subcontractors and manufacturers were next in importance, followed by project or construction managers. Architects or engineers were the least important of the five and were as likely to be rated as not important as often as highly important.

Table 17. Home Builders by Cooperation of Sources in Adopting New Building and Construction Products, Materials, and Practices

	Not Important	→	→	→	Highly Important
Sources	(1)	(2)	(3)	(4)	(5)
Suppliers	2%	1%	13%	36%	48%
Manufacturers	3%	8%	24%	35%	30%
Subcontractors	2%	4%	21%	38%	35%
Architects or engineers	18%	17%	29%	20%	16%
Project or construction managers	15%	11%	19%	29%	26%
N=242 to 246 depending on question.					

See Appendix B, Q19 for complete wording of question.

♦ **Use of New Building and Construction Products, Materials and Practices**

Respondents were asked if they had never tried, tried but discontinued, or were currently using several different products at different stages of diffusion. The first list included eight technologies at three different stages of diffusion:

1. Precast concrete foundation walls (early stage).
2. Wood/plastic composite exterior trim/molding (late stage).
3. Fiber cement exterior trim material (middle stage).
4. Heat pumps with integral water heating (e.g. desuperheater) (early stage).
5. Laminate flooring (middle stage).
6. Wood I-joists as roof rafters (middle stage).
7. Fiber cement flooring underlayment (middle stage).
8. Wood I-joist structural floors (late stage).

Based on previous NAHB surveys, we identified early-stage technologies as less than 10% market share, middle stage as 10–30%, and late stage as over 30%. In general, the level of adoption of these technologies was greater than expected (Table 18). Only 18% had tried precast concrete foundation walls, placing this near the cusp of the early and middle stages of diffusion. Heat pumps with integral water heating were also expected to have limited market penetration. However, 32% of the respondents reported they had tried this technology (split evenly between those who discontinued use and those who were currently using it), much higher than anticipated and beyond the "early stage" of diffusion. Either the respondents to this survey are ahead of the market in adopting desuperheater heat pumps, or some respondents were not familiar with the distinction.

Table 18. Home Builders by Adoption of New Building Products (Group 1)

Products	Never tried	Tried, but discontinued	Currently using
Precast concrete foundation walls	83%	6%	12%
Wood/plastic composite exterior trim/moldings	23%	13%	64%
Fiber cement exterior trim material	48%	7%	45%
Heat pumps with integral water heating (e.g., desuperheater)	68%	15%	17%
Laminate flooring	21%	22%	57%
Wood I-joists as roof rafters	47%	12%	41%
Fiber cement flooring underlayment	49%	7%	43%
Wood I-joist structural floors	13%	10%	77%

N=239 to 245 depending on question.

See Appendix B, Q12 for complete wording of question.

Among the preclassified middle-stage technologies, 52% of the respondents had used fiber cement exterior trim material, 79% used laminate flooring, 53% used wood I-joists as roof rafters, and, 50% used fiber cement flooring. Of the two late-stage technologies, 77% used wood/plastic composite exterior trim or moldings, and 87% used wood I-joist structural floors.

The adoption rates for the primary sample were higher than anticipated, probably reflecting two factors. First, the NAHB survey data were for previous years. The time lags between the surveys would account for some of the difference in market penetration. Second, it is very probable that the respondents to the current survey (which focused on the use of new products, materials, and processes) are disproportionately from firms having adopted some of these technologies. Firms with little interest in new technology or with no experience with any of the technologies covered in the survey were probably the least likely to respond. As anticipated (and intended), the supplemental sample showed higher rates of adoption of the early- and middle-stage technologies, but the differences were not substantial, lending support to the conclusion that the primary sample is skewed toward builders with more experience with and interest in technology. However, since we are studying the factors that relate to adoption and are not estimating diffusion rates or market penetration, this response bias is likely to have little impact on our analysis. It bears stressing, nonetheless, that the diffusion rates found here most likely overstate the diffusion of the covered technologies among all home builders.

The same question about whether the firm has never tried, tried but discontinued, or is currently using specific technologies was asked in Part 3 of the survey. Nine additional technologies were specified (Table 19). SIPS and light gauge steel were used by less than 13% of the respondents, and ICFs were used by 25% (each of these had a high proportion of discontinuation by users). Use of panelized walls, ultra-high-efficiency HVAC, fiber cement siding, and composite decking lumber ranged from 32% to 67%, with only the latter having a majority of current users. The two most widely used products on this list were fiberglass doors and OSB subflooring, which were used by 83% of the firms. The supplemental sample (as intended) was much more likely to have tried or currently use SIPS (21%), light gauge steel (25%), and particularly ICFs (63%).

Table 19. Home Builders by Adoption of New Building Products (Group 2)

Products	Never tried	Tried, but discontinued	Currently using
Structural insulated panels (SIPs)	89%	6%	5%
Light-gauge steel exterior walls	88%	7%	5%
Insulated concrete forms (ICFs)	76%	8%	17%
Panelized walls	68%	17%	15%
Ultra-high-efficiency HVAC*	40%	12%	48%
Fiber cement siding	49%	8%	43%
Wood/plastic composite decking lumber (e.g. Trex® or ChoiceDek®)	33%	14%	53%
Fiberglass doors	17%	13%	69%
OSB subflooring	17%	12%	71%
N=240 to 245 depending on question.			

See Appendix B, Q20 for complete wording of question.

Based on the first item each identified as currently in use, the respondents rated the influence of the same information sources discussed earlier, but based on the adoption of the specific product identified. The ratings of influence of information sources were very similar to those presented earlier. However, every item was more likely to be rated as not influential when evaluated relative to a specific technology than when evaluated in general. In addition, sales and supplier representatives and subcontractors were more often rated as highly influential when evaluated in terms of a specific technology.

As before, the most important sources of information were sales and supplier representatives, other builders, subcontractors, and trade publications (Table 20). The least important were consultants, manufacturers' toll-free numbers, technology transfer programs, and universities. More than half of the respondents rated each of these as not influential.

Table 20. Home Builders by Information Sources for Keeping Up to Date on a Specific Building Product that is Currently Used

	Not Influential	→			Highly Influential
Sources	(1)	(2)	(3)	(4)	(5)
Consultants	54%	15%	16%	13%	3%
Trade shows	32%	14%	23%	22%	9%
Homebuyers	25%	16%	24%	25%	11%
Internet/World Wide Web	43%	19%	25%	10%	3%
Mail or FAX advertisements	41%	24%	21%	13%	1%
Sales and supplier representatives	10%	6%	20%	38%	26%
Manufacturers' toll-free numbers	50%	22%	17%	9%	3%
NAHB seminars	40%	17%	24%	12%	7%
Observing other builders	25%	16%	29%	22%	8%
Seminars	41%	18%	21%	14%	7%
Subcontractor advice	18%	7%	23%	32%	20%
Technology transfer programs like PATH	63%	20%	10%	6%	1%
Trade publications	22%	11%	27%	29%	11%
Universities	69%	15%	12%	5%	0%

N=225 to 233 depending on question.

See Appendix B, Q22 for complete wording of question.

In general, early adopters appear to be much more sensitive to a variety of information sources. As a technology becomes more proven and established, subsequent adopters can rely on fewer sources of information.

There were several notable differences in the importance of various information sources to builders depending on whether they were currently using an early-, mid- or late-stage technology. Table 21 provides the percentage of builders rating each information source as not influential (1 on the 5-point scale) or as highly influential (4 and 5 on the scale). The builders are classified by the stage of the technology they were referencing. Since the builders identified the most innovative technology they were currently using, these categories also reflect whether the builder is an early, middle or late adopter of technology. Builders adopting early, middle, and late technologies were equal in rating sales and supplier representatives as the most important information source. Some information sources, however, were much more important for early adopters, followed by middle adopters and then late adopters. In general, early adopters appear to be much more sensitive to a variety of information sources. As a technology becomes more proven and established, subsequent adopters can rely on fewer sources of information. Late adopters are thus much more likely to classify most information sources as not influential.

For example, nearly half (48%) of the early adopters rated trade shows as highly influential, compared to 28% of the middle adopters and 16% of the late adopters. Consultants were much more important to early adopters (26%), compared to either middle (15%) or late (3%) adopters. Although subcontractors' advice was of relatively high importance to all adopters, middle adopters were the most likely to be influenced by subcontractors in their decision to use a technology. Middle adopters were also more likely to be influenced by trade publications and other builders than early or late adopters were. Although they are of little importance at other stages, technology transfer programs and universities influence a much higher percentage of early adopters.

Table 21. Information Sources by Stage of Diffusion

Sources	Early: Not Influential	Early: Highly Influential	Middle: Not Influential	Middle: Highly Influential	Late: Not Influential	Late: Highly Influential
Consultants*	52%	26%	51%	15%	66%	3%
Trade shows**	22%	48%	30%	28%	45%	16%
Homebuyers	22%	36%	22%	35%	37%	27%
Internet/World Wide Web*	28%	24%	44%	9%	53%	21%
Mail or FAX advertisements*	36%	24%	39%	12%	53%	5%
Sales and supplier representatives	8%	62%	10%	62%	8%	69%
Manufacturers' toll-free numbers*	44%	28%	49%	8%	61%	8%
NAHB seminars*	34%	20%	35%	23%	53%	8%
Observing other builders	28%	24%	24%	34%	26%	18%
Seminars**	34%	30%	39%	20%	55%	5%
Subcontractor advice	20%	44%	12%	45%	37%	32%
Technology transfer programs like PATH**	11%	14%	38%	5%	13%	3%
Trade publications*	14%	46%	20%	33%	32%	29%
Universities**	65%	14%	68%	2%	83%	0%

N=200 to 219 depending on question.

Diffusion stage is based on the first chosen currently used product in question 20 (see Appendix B). Products are grouped by stage. Stage is "Early" if the product is considered innovative, "Middle" if the product is moderately innovative, "Late" if the product is considered not particularly innovative. Diffusion stage is crossed with influence of information sources (see Appendix B, Q22).
*Significance level <=.05
**Significance level <=.01

Nonetheless, there was substantial agreement on the most important sources of information. For early adopters the five most important sources in descending order of importance were sales and supplier representatives, trade shows, trade publications, subcontractors, and seminars. For middle adopters the five most important sources were sales and supplier representatives, subcontractors, homebuyers, other builders, and trade publications. For late adopters, the five most important sources were sales and supplier representatives, subcontractors, trade publications, homebuyers, and other builders.

The most highly rated benefits of adopting these products were their quality compared with alternatives, reduction in call-backs, compatibility with preferred construction practices, and consumers' preference for the product or material.

The most highly rated benefits of adopting these products were their quality compared with alternatives, reduction in call-backs, compatibility with preferred construction practices, and consumers' preference for the product or material (Table 22). The lowest rated benefits were labor savings, material savings, reduced build time, and manufacturers' technical support.

Table 22. Home Builders by Importance of Benefits from Currently Using a Specific Building Product

Benefits	Not Important (1)	(2)	(3)	(4)	Highly Important (5)
Impact of product on profitability	10%	13%	27%	31%	19%
Labor savings derived from the product	18%	15%	23%	26%	19%
Materials savings derived from product	20%	17%	28%	20%	16%
Ability to recover cost of product	13%	13%	30%	24%	20%
Reduction in build time	22%	20%	19%	22%	18%
Compatibility with preferred construction practices	7%	4%	21%	40%	27%
Quality compared with alternatives	2%	2%	12%	38%	46%
Consumer's preference for the product	12%	8%	17%	33%	30%
Manufacturer's technical support	16%	18%	24%	29%	14%
Subcontractor's familiarity with product	9%	11%	32%	26%	22%
Supplier's technical support	14%	13%	27%	27%	19%
Reduction in call-backs	8%	7%	13%	32%	41%

N=226 to 229 depending on question.

See Appendix B, Q23 for complete wording of question.

The potential benefits gained through innovation are offset by potential problems. The problems rated as having greater importance were initial cost, continuing cost, acceptance by building inspectors, and uncertainty/risk (Table 23). The least important problems were acceptance by lenders and uncertainty in zoning regulations and building codes. The low rating for the latter coupled with the high rating for acceptance by building inspectors suggests that home builders perceive a greater problem with the administration of codes rather than with their content.

Table 23. Home Builders by Importance of Problems Associated with Using a Specific Building Product

Problems	Not Important (1)	(2)	(3)	(4)	Highly Important (5)
Uncertainty/risk of product	14%	10%	29%	27%	20%
Initial cost of product	6%	8%	19%	42%	25%
Continuing cost of product	6%	9%	25%	37%	24%
Difficulty in first use of product	11%	17%	31%	25%	16%
Difficulty of continuing use of product	16%	17%	32%	22%	13%
Acceptance by building inspectors	18%	15%	18%	25%	23%
Acceptance by lenders	35%	18%	21%	12%	15%
Uncertainty in zoning regulations and building codes	37%	16%	21%	15%	11%

N=222 to 228 depending on question.

See Appendix B, Q24 for complete wording of question.

The general manager or president was identified most often as very influential in the decision to use the product specified (83%), followed by the project or construction manager (43%), homebuyer (42%), and installing subcontractor (37%). Purchasing managers, designers or architects, engineers, and sales or marketing managers were more likely to be rated as not influential than as very influential (Table 24).

Table 24. Positions with Significant Influence over Decision to Use a Specific Building Product

Position	Not Influential	Somewhat Influential	Very Influential	NA
General manager/president/owner/partner	6%	7%	83%	4%
Purchasing manager	30%	9%	20%	41%
Designer or architect	31%	19%	21%	29%
Engineer	36%	14%	15%	35%
Project or construction manager	20%	16%	42%	23%
Installing subcontractor	18%	29%	37%	16%
Homebuyer	20%	23%	42%	14%
Sales or marketing manager	28%	19%	21%	33%

N=213 to 227 depending on question.

See Appendix B, Q25 for complete wording of question.

There was substantial agreement across early, middle and late adopters on the benefits and problems associated with new technology, as well as on who had influence over the decision to use the technology. However, early adopters rated labor savings, reduced build time, and technical support as more important than either middle or late adopters did. Late and middle adopters rated profit, cost recovery, quality, and reduced call-backs higher than did early adopters. In regard to the problems associated with new technology, early adopters assigned more importance to uncertainty and risk, first-use, lender acceptance, and codes as more important than did middle or late adopters. Many of these problems logically become less important as the technology becomes more widespread.

♦ Factors Influencing Early Adoption of New Technologies by Builders

To assess the influence of a variety of factors on early adoption, we calculated an innovation score for each builder based on the technologies it was using. Four points were counted for each of the four early-stage technologies, one point was given for each of the eight middle-stage technologies, and no points were given for a late-stage technology. The score for a builder using all four early-stage technologies and all eight middle-stage technologies would be 24 (the maximum possible). The score for a builder using no early-stage technologies but all eight middle-stage technologies would be 8. The score for a builder who was only using late-stage technologies would be 0. Table 25 provides the distribution of the innovation scores. Only 10 builders (4%) received 0 points. The mean score was 6.4. As planned, the supplemental sample had higher than average innovation scores, with a mean of 9.5.

To assess the influence of a variety of factors on early adoption, we calculated an innovation score for each builder based on the technologies it was using. . . . Only 10 builders received 0 points. The mean score was 6.4 [out of a maximum 24].

Table 25. Innovation Scores by Sample Type

Sample	N	Score Range	Score Median	Score Mean	Standard Deviation
Total	247	0–23	6.0	6.44	4.426
Primary	196	0–19	5.0	5.64	3.911
Supplemental	51	0–23	10.00	9.51	4.957

Innovation score sums innovative responses on Q12 and Q20 (See Appendix B).

Several questions on the survey asked the respondents to rate a list of related statements. For example, we asked builders to rate how likely their firm is to invest time or money to meet 15 objectives over the next 5 years. The objectives were mostly related to cost, quality, style, construction time, and new technologies. The builders also rated the influence of 14 sources of information and their agreement with 11 statements about problems possibly associated with using new technologies.

To evaluate the association of a range of characteristics with innovation in residential construction, it is necessary to use a statistical technique that measures the association of any one characteristic with innovation while holding constant ("controlling") the effects of other characteristics. The analytical technique used here (multivariate regression) mathematically equates the innovation score to the sum of the characteristics potentially related to innovation. Each characteristic is multiplied by a coefficient that measures the relationship between that characteristic and innovation. Characteristics with little or no relationship are given coefficients close to zero. Characteristics with stronger relationships have larger coefficients that are statistically significant given our sample size.

For multivariate analysis, several of our measures from the questionnaire had to be reduced to a more manageable set of factors that grouped related items together. This step was done through a data reduction technique called "principal components factor analysis" (for technical details of the multivariate analysis, see Appendix D.)

Fifteen business objectives measured in the survey were reduced to four factors (Table 26) related to reducing costs and liabilities, business objectives related to new technology, business objectives related to improving quality and style, and business objectives related to marketability. For convenience, these factors are referred to as REDUCE_COSTS, NEW_TECH, QUALITY_STYLE, and MARKETABILITY.

Table 26. Business Objective Factors

Factor Name	Component Variables
REDUCE_COSTS	Using new products and materials to reduce costs Reducing build time Reducing defects and call-backs Reducing legal liability related to building failures Reducing materials costs Reducing overhead costs
NEW_TECH	Improving market share by construction innovation Researching new products, materials, practices Educating buyers about new technologies
QUALITY_STYLE	Improving style and attractiveness of our homes Implementing total quality practices Improving subcontractor dependability Reducing defects and call-backs
MARKETABILITY	Improving marketability of our homes Improving ability to purchase and develop best land Offering the best mortgage financing

See Appendix B, Q11.

The influence ratings for 14 information sources were also reduced by factor analysis to five factors (Table 27) related to technology transfer (TECH_TRANSFER); trade shows, NAHB seminars, and other seminars (SEMINARS); production networks; and homebuyers.

Table 27. Information Sources Factors

Factor Name	Component Variables
TECH_TRANSFER	Internet/World Wide Web Manufacturers' toll-free numbers Technology transfer programs Universities
SEMINARS	Trade shows NAHB seminars Other seminars
PRODUCTION_NETWORK	Sales or suppliers' representatives Observing other builders Subcontractors' advice
HOME_BUYERS	Homebuyers

See Appendix B, Q16.

The 11 barriers to innovation were reduced to three factors (Table 28). The first factor (TRIED AND TRUE) combines five variables that reflect concern over the risks involved with innovation. The second factor (WORKERS) mainly reflects concerns about the ability of construction workers to handle new technologies. The last factor (ESTAB_MFG) reflects reliance on established manufacturers that stand behind their construction products and materials.

Table 28. Innovation Barriers Factors

Factor Name	Component Variables
TRIED AND TRUE	Customers don't like nontraditional products Dangerous to be among first to try new things Banks and insurance companies hesitant to underwrite projects with new products and materials Using new products and materials not important part of our business strategy Using new products and materials increases risk of call-backs
WORKERS	Subcontractors do not want to adapt to new products and materials Construction workers find it difficult to learn a new of way of building
ESTB_MFG	We use only products and materials from established companies

See Appendix B, Q17.

Several characteristics of home building firms were not associated with innovation, in contrast to research on innovation in other business sectors. . . . the age of the firm, total units produced, the number of professional positions in the firm, or the number of employees.

Even with this reduced number of variables, the survey included many more variables than could be analyzed simultaneously through multivariate regression. To reduce the number of variables further, variables that are statistically associated with innovation were identified through three separate sets of regression equations that separately evaluated similar characteristics. Those characteristics not sufficiently associated with the innovation scale were dropped from further analysis. Those associated with the innovation scale were analyzed in a final regression equation.

Several characteristics of home building firms were not associated with innovation, in contrast to research on innovation in other business sectors. For example, none of the following were statistically associated with the builder's innovation score: the age of the firm, total units produced, the number of professional positions in the firm, or the number of employees. The company characteristics initially associated with innovation were the type of builder (single-family production, single-family custom, etc.), whether the firm was strictly local or was part of a regional or national firm, and whether the firm used union labor. Although firms whose primary consumer market was move-up homes had lower innovation scores, the variable was included in the final regression equation to more clearly establish if there is any relationship between market type and innovation.

Among the benefits associated with innovation identified by these home builders, "increasing productivity" was positively associated with innovation, whereas "increasing profit" was negatively associated with innovation, suggesting that innovators in residential construction are less likely than other builders to be concerned about the impact of the innovation on profits, although increased productivity could be expected to lead to higher profits. This difference is a matter of emphasis. All home builders are concerned about profits. Those who are more highly concerned about profits related to new technology are less likely to be among early adopters. Instead, they are middle- or late-stage adopters waiting for the risks of innovation to be reduced and the impact on profits to be more certain.

Innovators in residential construction are less likely than other builders to be concerned about the impact of the innovation on profits.

Among the other benefits that builders identified as important reasons for adopting new products or materials, none were statistically associated with innovation, including helping to comply with codes and regulations, improving market competitiveness, meeting customers' expectations, reducing build time, reducing call-backs, or decreasing costs and increasing quality.

Among the factors reflecting the firms' business strategies, MARKETABILITY was negatively related to innovation scores, and NEW_TECH was positively related but was not statistically significant. REDUCE_COSTS and QUALITY_ STYLE were unrelated to innovation.

Among the information source factors, TECH_TRANSFER and HOME_BUYERS positively affected innovation. SEMINARS and PROD_NETWORK were unrelated to innovation.

Each of the four factors reflecting "barriers" to innovation was statistically significant. Builders who agreed with TRIED AND TRUE statements had lower innovation scores. However, builders who stressed that subcontractors and construction workers are barriers to adopting new materials had higher innovation scores than those who felt less strongly about this factor (WORKERS). Innovative builders have more opportunities to experience innovation-related problems with subcontractors and workers. Builders had higher innovation scores if they agreed more strongly that they use only new products and materials from established companies that stand behind their products. This finding suggests that builders are less likely to adopt new products and materials introduced by less established companies.

Additionally, the following variables were positively associated with the innovation score at statistically significant levels: having a business strategy that emphasizes innovation (wanting to be the first in the area to offer new and innovative building products or systems, striving to be seen as creative, and preferring to use materials that exceed current code minimums and market expectations); having a technology advocate in the firm; stressing the importance of cooperation from project or construction managers; stressing the firm's reputation for high quality and durable homes and quickly addressing problems in new homes; monitoring competition by attending trade shows; and not knowing much about the building practices of competitors. Attributing the firm's success to its ability to develop land in better locations than competitors is negatively associated with innovation, as suggested previously by Koebel (1999) and Ball (1999). In addition, monitoring industry data is negatively associated with the innovation scale, but at a lower significance level to warrant including this

Innovative builders are more concerned about being a leader in the industry than about monitoring other builders.

variable in the combined regression. Apparently, innovative builders are more concerned about being a leader in the industry than about monitoring other builders.

The following variables were not statistically related to innovation: the number of positions with influence over a new product decision; the firm's planned growth in net profits; the centralization of decision-making on new products and materials (local, regional, national); stressing the importance of cooperation of suppliers, manufacturers, subcontractors, architects or engineers in adopting new products and materials; attributing success to lower costs; building houses with land acquisition; monitoring competitors by touring homes or visiting building sites; or by the amount of time spent monitoring the marketplace.

Multifamily or modular builders have significantly higher innovation scores than custom builders, which in turn have higher scores than single-family production builders. . . . Size was not directly related to innovation.

The elimination of these variables resulted in a significantly reduced set of variables to analyze in a combined equation. The overall equation is associated with approximately 30% of the variation in innovation scores. Multifamily or modular builders have significantly higher innovation scores than custom builders, which in turn have higher scores than single-family production builders. The innovation scores of home improvement firms are statistically indistinguishable from custom builders. Market type (move-up vs. others) has no influence when more variables are controlled.

These findings provide mixed support for the conclusion suggested in the literature review that size and type of construction influence the introduction of new products and materials into residential construction. Size (measured by either number of employees or units produced) was not directly related to innovation, although modular and multifamily builders would be among the larger firms in the industry. Given the small number of very large firms in our sample, the effect of size could have been indistinguishable from the type of building. Additionally, our findings suggest that single-family custom builders are not discouraged to innovate because of their target market. This behavior could be due to a focus by innovating builders on educating homebuyers about new technologies and perhaps to a higher demand for innovation among these homebuyers. In any event, this research identifies custom builders as more innovative than single-family production builders.

National firms and firms serving multiple market areas have higher innovation scores than those serving only a local market area. Regional and national firms are more likely to have the capital and talent to pursue technology innovation than purely local firms. The other variables associated positively and significantly with innovation scores are the use of union labor, technology transfer programs and universities (TECH_TRANSFER), homebuyers, established companies standing behind their building and construction products, wanting to be creative and the first to use new products, and having a technology advocate inside the company. Emphasizing marketability and profit is associated with lower innovation scores, as is attributing the firm's success to the ability to develop land with better locations than competitors.

Regional and national firms are more likely to have the capital and talent to pursue technology innovation than purely local firms.

Emphasizing marketability and profit is associated with lower innovation scores, as is attributing the firm's success to the ability to develop land with better locations than competitors.

Use of union labor and subcontractors (sometimes if not always) is associated with higher innovation scores. This finding could reflect more training opportunities and higher skill levels, as well as a possibly higher likelihood for union trades to be used by national and regional builders and on larger-scale construction projects. Consistent with the previous discussion, builders stressing marketability have lower innovation scores. This equation shows an even weaker relationship between firms emphasizing the use of new products and innovation scores.

Higher influence ratings by builders for technology transfer (including programs like PATH and universities) and homebuyers are positively associated with higher innovation scores. SEMINARS and PRODUCTION_NETWORK are not associated with higher innovation scores. Emphasizing traditional materials and practices along with the risks of innovation (TRIED AND TRUE) decreases innovation scores, but at a relatively weak level. Emphasizing the resistance of subcontractors and construction workers (WORKERS) to new products and materials is associated with higher innovation scores, but also at a weak level. Again, innovators would have more opportunity to experience resistance by subcontractors and construction workers and therefore might be more sensitive to such resistance. Stressing reliance on established companies that stand behind their products remains positively associated with innovation scores.

Higher influence ratings by builders for technology transfer (including programs like PATH and universities) and homebuyers are positively associated with higher innovation scores. Emphasizing traditional materials and practices along with the risks of innovation decreases innovation scores.

Discussion of Survey Findings

The following are associated with *higher* levels of adoption of new products, materials and practices in home building:

- Modular builders and multifamily builders.
- Single-family custom home builders.
- National and regional builders.
- A technology advocate within the building firm.
- Union labor.
- Technology transfer programs like PATH and universities.
- Homebuyers who are aware of and want new products and materials.
- Reliance on established manufacturers standing behind their building and construction products.
- Wanting to be creative and the first to use new products.

The following are associated with *lower* levels of adoption of new products, materials and practices in home building:

- Local firms.
- Single-family production builders.
- Emphasizing marketability and profit.
- Associating the firm's success with land development.
- Emphasizing the "tried and true" and the risks of new materials and products (marginal statistical significance).

This study suggests the following are not associated with earlier adoption of new products, materials and practices in home building:

- Whether the builder focuses on starter homes, luxury homes, move-up homes or a market mix.
- The number of units produced.
- The number of professional positions in the firm.
- The number of employees.
- Whether final decisions on new products/materials are made at the local, regional or national level.
- Seminars and trade shows.
- Monitoring industry data.
- Knowing about the building practices of competitors.
- Perceived benefits of adopting new products, materials and practices.
- Production networks as an information source about new products and materials (other builders, subcontractors, sales and supplier representatives).

The diffusion of residential building technologies is highly complex, and diffusion mechanisms likely vary across stages of diffusion. This study focused on analyzing the differences in use of new technologies between home builders. Two-thirds of these differences relate to unidentified or unmeasured variables and to randomness. One-third, not an insubstantial portion, relate to the characteristics identified above. The roles of technology transfer programs and universities illustrate this complexity. Builders rate both technology transfer programs and universities as the least influential information sources among those included in this study. Sales and supplier representatives, subcontractors, and other builders are rated as substantially more influential. A possible, but erroneous, interpretation is that technology transfer programs and universities are irrelevant to the diffusion of residential building technologies. Quite to the contrary, universities and technology transfer programs are one of the significant distinguishing factors between early and late adopters. The more innovative builder relies on these sources among others to learn about and decide to use a new technology. When technologies are introduced, transfer programs and universities are important in disseminating information. As they gain more widespread acceptance, other information sources become more important.

When technologies are introduced, transfer programs and universities are important in disseminating information. As they gain more widespread acceptance, other information sources become more important.

Although small, less established manufacturers often are the first to introduce new products, residential building construction relies heavily on established manufacturers, likely reflecting the substantial financial and market risks associated with innovation in residential building.

At the early stage of diffusion, national and regional firms, multifamily and modular builders, and (less so) custom builders are more likely to adopt than are single-family production builders. Although sales and supplier representatives, subcontractors, and trade shows are important sources of information about new products and materials for all builders, early adopters rely on technology transfer programs and universities more than later adopters do. But they also rely on established manufacturers who stand behind their products. Although small, less established manufacturers often are the first to introduce new products, residential building construction relies heavily on established manufacturers, likely reflecting the substantial financial and market risks associated with innovation in residential building. Product failures can cost builders dearly, both in direct losses and in damage to the firm's reputation. Establishing a reputation for high quality and durable homes and for quickly addressing problems in new homes was a key business strategy for over two-thirds of the builders in this survey.

In surveys about innovation among home builders, the homebuyer is often identified as an impediment to innovation in residential construction. Homebuyers supposedly are risk adverse and want the "tried and true." Consequently, builders have no choice other than to avoid innovation. Although we did not collect any data on homebuyers, our findings suggest that this perception among home builders plays an important role in the diffusion of residential construction technology. Builders are less likely to be innovative if they emphasize that their customers prefer the "tried and true" and don't like nontraditional products or features, and if they stress marketability and profit. They are also less likely to be innovative if their business strategy emphasizes acquiring and developing land with better locations than their competitors. Innovative builders, by contrast, emphasize educating their customers about new technologies.

Innovative builders . . . emphasize educating their customers about new technologies. . . . Innovation among home builders is associated with firms that establish innovation and creativity as part of their corporate culture.

Technology diffusion and adoption research often identifies the importance of technology advocates within firms. Technology advocates are also important in the diffusion of residential building technologies. Fortunately, two-thirds of the respondents in this study identified a technology advocate—usually the owner—within the firm. Additionally, innovation among home builders is associated with firms that establish innovation and creativity as part of their corporate culture.

Additional research on the data collected in this survey will undoubtedly reveal more about important diffusion mechanisms for residential construction technology. Improved knowledge about diffusion in this sector will help improve the design of technology transfer programs and ultimately further the improvement of housing.

ANALYSIS OF DIFFUSION TRENDS

Each year, the NAHB Research Center collects housing information from home builders throughout the United States through its Annual Builder Practices Survey (ABPS). The questionnaire is very detailed—containing 21 pages of questions about the homes built and materials and methods used to construct them. The Research Center has maintained a database of ABPS responses since 1995.

Construction Technologies

To help better understand the relationship between firm size, house characteristics, and diffusion, the project team analyzed market penetration for several construction technologies between 1995 and 2001. Ten innovative materials were selected, ranging from materials in the introductory phase through those that had reached maturity during this period (Table 29). Some characteristics evaluated were number of completions per builder; size of home; price per square foot; the price-points of starter, move-up, or luxury home; and single- and multifamily housing types.

Table 29. U.S. Construction Technology Shares, New Single-Family Detached Homes, Annual Builder Practices Survey Data, 1995 and 2001

	1995	2001
OSB subflooring	43%	59%
Vinyl windows	21%	44%
Structured wiring	NA	38%
Fiber cement siding	2%	11%
Fiberglass entry doors	6%	16%
Panelized-frame walls	5%	9%
Very-high-efficiency AC (SEER of 13 or greater)	3.5%	7%
Insulated concrete forms – Basement/crawlspace	0.2%	0.9%
Insulated concrete forms – Above grade	0.03%	0.3%
Wood/plastic composite lumber decking	3%	12%
Structural insulated panel walls	0.13%	0.15%
Light-gauge steel exterior walls	0.3%	0.7%

This comparison allows us to examine how new technology usage varies by company size and home characteristics. Further, since the comparisons were made of annual data, from 1995 through 2001, the diffusion of these technologies can be tracked over time. A similar comparison was made for year 2000 structured wiring usage for each of the nine U.S. Census divisions to understand regional influences in new technology diffusion.

Some clear differences emerge in the size of the company, types of homes built, and the average home price in homes using various building materials. Not surprisingly, most of the innovative technologies reviewed were used in homes that were more expensive than average, although some only slightly so (Table 30). Conventional thought holds that many new technologies are more costly than the products they substitute for, especially in the early stages of introduction. The higher price is largely due to lack of economies of scale in production and distribution, which leads to higher material prices. Builders and subcontractors often charge a premium for installing nonstandard materials to compensate for increased efforts. Many new materials also provide increased functionality over existing materials, for which a price premium is expected.

Most of the innovative technologies reviewed were used in homes that were more expensive than average. . . . Builders and subcontractors often charge a premium for installing nonstandard materials to compensate for increased efforts. Many new materials also provide increased functionality over existing materials, for which a price premium is expected.

The only significant exception to the "higher price" of homes using these technologies was OSB subflooring. OSB itself is substantially lower in cost than the plywood for which it substitutes. OSB, however, had reached maturity by 2001 with 59% market share. Two other technologies finishing at the lower end—vinyl windows and structured wiring—also had high penetration rates of about 44% and 38%, respectively, in 2001. (Structured wiring was first included in the survey in 2000.) Six years earlier the penetration rate for vinyl windows was 21%.

Table 30. Average Prices of Single-Family Detached Homes Using Various Materials Annual Builder Practices Survey, 2001

Material Used	Average Price/Sq. Ft.
OSB subflooring	$102
Vinyl windows	$107
Average of All Homes in Sample	**$108**
Structured wiring	$109
Fiber cement siding	$110
Fiberglass entry doors	$111
Panelized walls	$112
Very-high-efficiency AC	$114
Insulated concrete forms	$122
Wood/plastic composite lumber	$124
Structural insulated panels	$131
Light-gauge steel exterior walls	$135

Three of the four highest average prices were for homes using innovative structural wall technologies. These materials were in houses with average prices per square foot ranging from 13 to 25% above the average for all homes. This finding may reflect the adaptations needed to implement these materials into new homes. It may also reflect their relatively low market share and not having reached economies of scale. The materials in the low-cost range, however, tend to be "drop-in" replacements for traditional materials.

The relationship between firm size and innovation appears to be influenced by the type of material adopted, but in highly complex ways. . . . Some materials are first adopted by smaller builders and migrate upward. Others reverse the process. The complexity associated with the adoption patterns of these technologies can be best reviewed on a case-by-case basis.

The analysis of Annual Builder Practices Survey data also revealed that size of home builder varies significantly depending on which housing technologies it uses (Table 31). While new technologies appear to be associated with increased home prices, no such general association is apparent between new technologies and size of builder. The relationship between firm size and innovation appears to be influenced by the type of material adopted, but in highly complex ways. For example, the more substantial changes in building process required by innovative structural wall technologies might be resisted by larger builders until these technologies more clearly justify the changes required. Smaller builders might be more flexible in adopting such technologies, at least initially. Additionally the cost benefits of some materials might be enhanced by volume, thus attracting larger builders.

Table 31. Size of Single-Family Detached Builders Using Various Materials Annual Builder Practices Survey, 2001

	Average Annual Completions
Insulated concrete forms	7
Structural insulated panels	9
Wood/plastic composite lumber	10
Very-high-efficiency AC	12
Light-gauge steel exterior walls	15
Average of all SFD homes in sample	**16**
Fiber cement siding	17
Fiberglass entry doors	18
OSB subflooring	19
Vinyl windows	19
Structured wiring	22
Panelized walls	50

Some materials are first adopted by smaller builders and migrate upward. Others reverse the process. The complexity associated with the adoption patterns of these technologies can be best reviewed on a case-by-case basis. The following discussion briefly describes each material and suggests characteristics of both the material and adopting firms, as well as location, that could influence its adoption pattern.

- **Fiber Cement Siding**

Fiber cement siding consists of cement and cellulose fiber fashioned into planks and panels. Based on ABPS data, it has primarily substituted for natural and engineered wood (hardboard, OSB, and plywood) siding. In 1995, fiber cement had about 2% of the U.S. single- family detached (SFD) home market for exterior finish materials in new home construction. Substitution has taken place primarily in areas where painted, wood-based siding is popular. The market share for fiber cement siding had grown to about 11% by 2001, and it had begun replacing materials other than wood-based siding, such as vinyl.

In 1995, fiber cement was most common in SFD starter and multifamily homes, and least common in luxury homes. That year, homes with fiber cement siding cost less than average. By 2001, the average home using fiber cement siding was more expensive than average, and luxury homes had the greatest concentration of fiber cement homes.

In 1995, builders using fiber cement siding were significantly larger than the average. Over time, however, this size difference vanished as market penetration increased. In 2001, small builders (<10 completions), medium builders (10 to 49), and large builders (50+) were about equally likely to have installed fiber cement siding on their homes.

Fiber cement siding's initial acceptance was probably due to its enhanced durability.

Based on ABPS data, fiber cement siding began first to substitute for hardboard, plywood, and OSB siding—all of which had a strong presence in low- to moderately-priced homes. In later years, however, it had begun taking share from natural wood (cedar, redwood, etc.)—a more costly siding found on more expensive homes. While the installed cost of fiber cement siding is comparable to that of hardboard, plywood, and OSB, it is typically less expensive than natural wood siding. Aesthetically, however, fiber cement is considered less appealing than engineered and natural wood.

Evidence from proprietary industry studies by the NAHB Research Center suggests that fiber cement siding's initial acceptance was probably due to its enhanced durability. Its recent growth in the high-end market provides some evidence that, in addition to durability, its competitive cost compared to natural wood may be driving the current phase of its acceptance. Further analysis of ABPS data reveals that fiber cement siding's next new growth area is likely to be the eastern United States, substituting for vinyl siding.

- **Fiberglass Entry Doors**

Based on ABPS data, fiberglass entry doors have substituted primarily for insulated steel doors, which still maintain the dominant market share. Unlike steel doors, fiberglass doors can be finished with a realistic wood-tone and do not easily suffer permanent dents. Fiberglass doors have also increased in market share at the expense of lower-cost wood doors, though to a lesser degree. Fiberglass doors can be made to appear similar to natural wood with some improvement in durability.

Because fiberglass doors have taken more share from the lower-cost but similarly durable steel door, it is likely that its aesthetic advantage over steel doors has been the primary driver of its acceptance.

New homes with fiberglass doors are substantially larger and higher in cost than the average new home. In 1995, move-up and luxury builders were significantly more likely to use fiberglass doors than were builders of starter homes. Townhouses and multifamily homes were even less likely to have fiberglass doors than starter homes. Also in 1995, large builders were found more likely to use fiberglass doors than others. In 2001, use of fiberglass doors among move-up and luxury builders still exceeded that among starter home builders, but as fiberglass doors have become mainstream, the size of builder is less associated with their usage.

The evidence gathered from ABPS data indicates that, because fiberglass doors have taken more share from the lower-cost but similarly durable steel door, it is likely that its aesthetic advantage over steel doors has been the primary driver of its acceptance. However, since some share has been captured from wood doors, durability has probably played an important role also, especially in the market for the most expensive homes that favors natural wood.

- **Vinyl Windows**

Builders in the sample using vinyl windows were slightly larger than average, and their homes were slightly smaller. Early in the comparison period, vinyl windows had about equal penetration among builders of starter and move-up homes. By 2001, they had their greatest penetration among move-up builders—which stands to reason, as the price of vinyl windows presently falls between clad wood on the high end, and aluminum on the low end. Over the study period, medium-sized builders began to emerge as the most likely to install them.

Window industry experts typically cite superior thermal performance, reliability in operation, and durability as the primary reasons that vinyl windows have gained dominant market presence.

In 1995, vinyl windows had about 20% market share of new construction windows—less common than either wood or aluminum windows. By 2001, its share had grown to 46%, surpassing both wood and aluminum. Their substitution has primarily been for aluminum windows, which tend to be lower in cost than vinyl windows. Secondarily, vinyl windows have replaced "unclad" wood windows due to their ease of installation (no painting required) and durability (vinyl does not rot like wood). In a year 2000 study by the NAHB Research Center (2000), home builders reported vinyl windows to be more reliable than aluminum and unclad wood windows. Window industry experts typically cite superior thermal performance, reliability in operation, and durability as the primary reasons that vinyl windows have gained dominant market presence.

♦ **Wood/Plastic Composite Lumber**

The wood/plastic composite decking industry has grown immensely since its introduction in the 1980s, and the number of manufacturers of wood/plastic composites for decking materials is increasing annually. In 1995, wood/plastic composite decking had 3% of the new home decking materials market. By 2001, its share had grown to 9%, increasing primarily at the expense of wood decking material despite wood/plastic composite materials' typically costing more than double preservative-treated lumber.

Wood/plastic decking has penetrated the repair and remodeling market much faster than it has new construction. Combined with its primary usage by smaller builders, this fact may signal that consumers are the primary drivers for the adoption of this material.

Based on ABPS data, luxury builders were more likely to specify wood/plastic composite decking (21% in 2001) than builders of any other housing type. Second to SFD luxury homes were townhouses (18% in 2001). Only about 7% of SFD starter and 6% of multifamily builders specified it. Small and medium-sized builders are much more likely to install wood/plastic composite decking than large builders (22% and 19% for small and medium companies, compared to 6% for large companies). The wood/plastic composite decking industry largely believes that its appearance and longevity are two major factors influencing the adoption of this material.

Past NAHB Research Center studies suggest that consumers play a large role in purchase decisions for repair and remodeling expenditures and in homes built by smaller builders. According to NAHB Research Center's *Consumer Practices Survey*, wood/plastic decking has penetrated the repair and remodeling market much faster than it has new construction. Combined with its primary usage by smaller builders, this fact may signal that consumers are the primary drivers for the adoption of this material.

♦ **Insulated Concrete Forms**

In 2001, the average number of home completions per year for SFD builders using ICF wall systems was 7, compared to 16 for the entire sample. Five percent of small, 3% of medium, but only 1% of large builders used ICFs in 2001. This relationship held true throughout the study period. Like wood/plastic composite decking, acceptance of ICFs may be linked to their popularity among consumers, indicated by smaller builders' favoring this technology.

The average cost of an ICF home was substantially higher than an average new home—$122 compared to $108 per square foot. This suggests that ICFs are most popular in the luxury home market. The penetration rate for ICFs among builders of starter, move-up, and luxury homes, however, is not significantly different. In 2001, 2.2% of starter-home builders from the sample reported using ICFs, 2.1% of the move-up builders, and 2.5% of luxury builders. These figures compare to 0.3%, 1.3%, and 1.1% of builders in 1995.

ICFs have claimed greater market share in foundations than as an above-grade wall material. In 2001, ICFs had about 0.9% share of all foundation walls and only about 0.3% in above-grade walls. One possible explanation is that two disadvantages of ICFs—higher cost than traditional materials and integration of utilities and finish systems—are minimized when using ICFs for foundations. The cost difference between ICF walls and traditional materials is smaller in foundations (poured concrete, concrete block) than in above-grade construction (frame lumber and sheathing). Further, builders using ICF walls in foundations are likely to leave the basement unfinished, reducing the need to integrate utilities and finish materials into the wall system.

♦ **Structural Insulated Panels**

Like ICFs, structural insulated panels (SIPs) were more popular with small builders than with large builders. The average number of single-family homes completed per builder using SIPs was 9 compared to 16 for the entire sample. About 2% each of small and medium builders and 0.3% of large builders reported using them in 2001. These figures compare to about 1% each of small and medium builders and a negligible fraction of large builders in 1995.

The difference between the average builder and builders using SIPs with respect to price-level of home (starter, move-up, and luxury homes) was smaller in degree than the size difference. In 1995, about 0.5% each of all three price-level categories of homes used SIPs. In 2001, about 1% each of starter and move-up home builders reported using SIPs, while about 1.7% of luxury home builders reported using them. Overall, the average cost per square foot for the SIPs home was $131 per square foot in 2001, compared to $108 for the average home in the sample. Unlike the other technologies in this analysis, SIPs do not show any significant growth in popularity as a structural wall material in new home construction.

♦ **Panelized Walls**

Wall panels were used in about 9% of the homes constructed in the U.S. in 2001—up from about 5% in 1995. They have substituted primarily for site-built wood walls. While wall panels do not necessarily improve the functionality of a home (some quality differences are noted, but not universally), the construction process is altered, shifting some site labor to a factory.

About 130 home builders of the 2,650 builders surveyed in 2001 reported using wall panels in their homes. The average builder in the sample using wall panels completed about 50 units per year, substantially higher than the sample average of 16. Nearly one-fourth of the builders in the ABPS sample building more than 50 homes per year reported using wall panels, compared to about 5% who built fewer than 10 homes per year. Larger builders favored wall panels each year from 1995 through 2001.

Townhouse and apartment builders were most likely to report panel usage in 2001—36% and 23% of the sample, respectively. Among single-family builders, however, builders of starter homes were only slightly more likely to use wall panels than move-up and luxury home builders.

The size of builders that use panelized walls continues to become larger relative to the average builder. . . . This general trend counters the traditional wisdom that as technologies become mainstream, the characteristics of their users become more like the "average."

The average size of homes built with wall panels is minimally smaller than the average SFD home, but the price per square foot is slightly higher, signaling they are not used necessarily on low-cost homes.

The size of builders that use panelized walls continues to become larger relative to the average builder in the ABPS sample. This general trend counters the traditional wisdom that as technologies become mainstream, the characteristics of their users become more like the "average." This rule is true for most of the technologies reviewed here with this one significant exception.

♦ **OSB Subflooring**

Presently, OSB as a subflooring material is a mature technology. Only in recent years, however, has it surpassed plywood as a subflooring material. OSB gained maturity as a wall and roof sheathing much earlier than as subflooring. This delay in acceptance relates to performance issues that are less easily resolved in the floor assembly than in roof and wall sheathing applications (edge swell is more acute and is less acceptable in floors). However, recent product improvements in OSB subflooring and increases in the price of plywood have fueled its rate of acceptance.

In general, builders using OSB subflooring were somewhat larger than average. Homes built using OSB subflooring were slightly smaller than average (2,172 sq. ft. vs. 2,242) and were built for less than average ($102 per sq. ft. vs. $108). Users were about equally as likely to be starter, move-up, townhouse, and apartment builders, but slightly less likely to be luxury home builders. This pattern has remained true throughout the years from 1995 to 2001.

Further, large builders have been more likely to use OSB than medium or small builders. One plausible explanation is that the reward for purchasing lower-cost materials increases as purchasing volumes increase.

- **Very-High-Efficiency Air Conditioning**

As defined in the survey, very-high-efficiency air conditioning systems are those having a SEER (seasonal energy efficiency ratio) of greater than 13. Despite its higher cost, adding very-high-efficiency AC introduces almost no change to a builder's process, no increased exposure to liability, and little or no additional effort in coordinating its installation. Homebuyers, however, reap the primary benefits of low energy bills.

Builders reporting usage of very-high-efficiency systems tend to be smaller than average—12 completions per year vs. the 16 per year average for the entire year 2001 sample. In 2001, about 16% of small builders, 13% of medium-sized firms, and 9% of large builders reported installing them. Smaller builders were more likely to report installing very-high-efficiency systems throughout the entire study period. Like wood/plastic composites, small builder acceptance of this technology may signal that this market is driven by homebuyer demand.

Among single-family detached homes, the likelihood of installing a very-high-efficiency system increased as the price level of the home increased. About 10% of starter and move-up home builders installed these systems, while 16% of luxury home builders installed them. This relationship remains true for all years from 1995 through 2001.

While an efficient AC system increases the price of the home, many people believe that savings in energy bills over the life of the system more than offset its higher initial cost. It is ironic, however, that energy-efficient air conditioning is least accepted in the housing markets that most need low operating costs. Assuming a rational and informed homebuyer, the low usage rates for high-SEER air conditioning indicates that lower initial cost of housing is generally more valuable to homebuyers than low operating or life-cycle costs. This finding is consistent with previous research identifying high discount rates for consumers and low energy costs as critical factors in discouraging adoption of energy-saving residential technologies.

The low usage rates for high-SEER air conditioning indicates that lower initial cost of housing is generally more valuable to homebuyers than low operating or life-cycle costs.

- **Steel Exterior Wall Framing**

Few consistent patterns emerge with builders using light-gauge steel framing for exterior walls. This indistinct pattern was probably due to variability from small sample sizes (57 builders in 2001) and increases in steel prices that would have affected larger builders and builders of lower-cost homes. In years prior to 2000, the average number of completions per builder using steel exterior walls was significantly higher than average, and homes were smaller than average. After 2000, however, smaller builders became more likely to use steel exterior walls, and the homes involved became substantially larger and more costly.

- **Structured Wiring**

Structured wiring is unique among the materials reviewed that it does not replace a material, but only adds functionality to a home.

Structured wiring enables the home to handle data (computer networking), telephone, cable TV, security, and other bandwidth requirements. The NAHB Research Center began tracking structured wiring in new homes in 2000. In that year, 1,175 builders responded as having installed structured wiring in at least one home. Structured wiring is unique among the materials reviewed in that it does not replace a material, but only adds functionality to a home.

In general, multifamily homes were more likely to have structured wiring than single-family homes. This finding seems counterintuitive, as many multifamily homes are often “affordable” and tend to be offered with basic rather than extra features. Generally speaking, it appears that the luxury home market is first to adopt new technologies whose primary benefit is to add functionality. At second glance, new multifamily homes are generally built in urban areas—where there is a high concentration of Internet- and computer-savvy professionals. Only in these densely populated regions in the country—New England, Mid-Atlantic, South Atlantic, and East North Central Census Divisions—did the multifamily structured wiring penetration exceed single-family penetration.

Predictably, single-family luxury homes were far more likely to have structured wiring than move-up or starter homes (45% compared to 29% and 19%, respectively). New Mid-Atlantic Census Division homes were *least* likely to have structured wiring—only 16% of new SFD homes. New SFD homes in West South Central and Pacific states—areas with notable concentrations of the high-tech industries—were *most* likely to have structured wiring, with 41% and 40% penetration rates, respectively.

Single-family detached builders installing structured wiring were larger than the average builder (21 homes/year vs. 16) in the 2001 sample. The average SFD home with structured wiring is about 2,500 sq. ft. compared to 2,258 square feet for the entire sample.

Discussion of Diffusion Trends Findings

No single path exists for housing industry adoption of new technologies. Diffusion of some of the technologies reviewed began among smaller builders, while others began with larger builders. Some saw first acceptance in more expensive homes and others in low-cost homes. Acceptance of new technologies and materials ultimately depends on whether they meet the needs of the consumer and the builder better than existing technologies and materials. The needs for high- and low-end markets, or for large and small builders are not always the same. Additionally, geographic differences also help shape the needs of both builder and buyer.

Some generalizations, however, have emerged from this review of diffusion trends from 1995 to 2001 that warrant further research. Large builders seem to be first to adopt new materials that offer a cost savings, improvement in production process, reduction in call-backs or exposure to liability. Smaller builders are often first to adopt technologies where high consumer awareness of a material exists, the price of the new technology is significantly higher than what it replaces, or if the home construction process must be substantially altered. Homes in geographic areas where homebuyers and builders have an increased awareness of a new technology or find a technology most useful are likely to be first to adopt.

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INTEGRATION OF SURVEY AND DIFFUSION TRENDS FINDINGS

Our analysis of diffusion of 11 separate technologies from 1995 to 2001 illustrates the complexities suggested in our survey results. Among the reasons why the relationships among firm size, housing type, and adoption are so complex are variations in the market segments served by the technology. Additionally, technologies differ in the basis of their competitive advantage, be that aesthetics, performance, durability, price, or consumer preference.

Most new technologies in housing are substitutes for existing technologies; consequently, diffusion depends on the market segment of the product being replaced. Fiber cement siding had its initial market penetration due to enhanced durability in the low- to moderately priced housing segment where hardboard, plywood, and OSB siding were heavily used. Superior performance, reliability, and durability have given vinyl windows a competitive edge against aluminum and unclad wood windows. Their price advantage, however, is currently against unclad wood windows, making them more attractive to builders of move-up rather than starter homes. The advantages of wall panels are largely related to factory production, a fact that might favor larger builders.

Consumer preference and the tendency of innovative builders to be less concerned about competitive advantage related to factors other than price might explain the somewhat greater acceptance by small builders of ICFs, which cost more than alternatives. The overall slow pace of acceptance of ICFs and high-SEER air conditioning might be due to high discount rates among consumers and low energy costs.

Product-specific characteristics help explain some of the variations in diffusion patterns. Clearly these patterns are dynamic, and competitive advantage changes as products are modified, as prices of both the new and older technologies change, and as builders learn more about the benefits of new technologies. The analyses of diffusion processes and trends presented here provide significant insights into the diffusion of new technologies in residential construction, while at the same time identifying important directions for new research. Additional analysis of both the current survey and the Annual Builder Practice Survey can provide additional insights into the diffusion of residential construction technologies.

APPENDIX A. RESEARCH METHODOLOGY

Research Methodology

Following a review of the literature on diffusion, we designed a questionnaire to send to a national sample of residential home builders to find out how they make decisions to use new building materials. The project team (Ted Koebel, Maria Papadakis, Ed Hudson of the National Association of Home Builders Research Center [NAHB Research Center], Marilyn Cavell, and Elizabeth Matthews) met on several occasions to discuss the content of the questionnaire and the procedures for execution. Survey questions were created based on the project goals, the literature review, and the expertise of the researchers. After numerous iterations, we printed a draft questionnaire that we sent to five representatives from the home building industry for pretesting. Based on comments following pretesting and a review by Carlos Martin (the HUD Government Technical Representative), we completed a final version of the questionnaire.

♦ Literature Review

We reviewed current literature on technology diffusion (particularly in the construction industry) to identify the current general state of diffusion for technologies and to consider the topics and themes that were not addressed in current surveys, including such things as professional affiliations, attendance at builders' shows, communications with peers, communications within a large building firm, communications with participants, etc. The questionnaire was developed to explicitly reflect the variables and measures identified in the literature review. For example, based on the literature review, we developed a basic model incorporating general factors influencing diffusion as well as factors specific to residential construction that resulted in the diffusion mechanisms component of the survey. Additionally, we designed the sample and the technology questions to allow future analysis of differences in diffusion mechanisms between early-, mid-, and late-stage technology adopters (based on market penetration calculations by Ed Hudson of the NAHBRC and approved by Carlos Martin). We further developed the literature review into report form.

♦ Questionnaire

We designed a questionnaire that would provide information about how home builders make decisions about new building materials. The questionnaire was divided into four parts: Part 1. The Nature of Your Firm (asks for basic information about the local firm); Part 2. New Building and Construction Practices (asks about the firm's attitudes towards activities regarding new building and construction products, materials, and practices); Part 3. Use of New Building and Construction Products, Materials, and Practices (asks for information about the firm's adoption of specific new building and construction products, materials, and practices); and Part 4. Business Strategy (asks for information about the firm's market and competition strategies).

We formatted the questionnaire into a 5½ × 8½ inch booklet (four sheets of 8½ × 11 inch paper printed front and back, folded and stapled in the middle). The questionnaire had a total of 29 questions. For the most part, respondents were asked to check a box or circle a number to indicate their response. Many of the questions consisted of a series of statements requiring the respondent to circle a number indicating the degree to which he or she felt a statement was important, influential, etc. We gave the respondents an opportunity to write comments at the end of the questionnaire.

♦ Pretest

We contacted six representatives known to us from the home building industry and asked them to pretest our questionnaire. One of the six failed to get back in touch with us. The other five agreed to participate and were mailed questionnaires. The pretesters were asked to complete the questionnaire, keep track of the time it took to complete the questionnaire, and give us comments and suggestions for improvements. All pretesters said the questionnaire was clear and took about 20 minutes to complete. We received hard copies of the questionnaire from three pretesters, but only one was mailed back (one hand-delivered; one faxed). We received verbal comments from the fourth pretester since, although the pretester attempted to mail the completed questionnaire back to us, we never received it. This one failed mail attempt along with lack of feedback on success of the mailing process, prompted us to rethink the mail-back process. Rather than asking respondents to mail back the questionnaire with a business reply addresses on the back and requesting that the questionnaire be taped closed, we chose to provide a 6 × 9 inch business reply envelope for each of the respondents. We made this adjustment with the anticipation of reducing the number of mail-back problems.

- **Sample**

The National Association of Home Builders Research Center provided us with an electronic mailing list in spreadsheet form that it had drawn from a sample of its membership. The national sample of 1,200 took into consideration a cross-section of residential home builders from the various regions of the United States (New England, Mid Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, and Pacific), controlling for the number of homes built based on 1–10, 11–25, 26–100, 101–500, and >500 homes built. Using the electronic file provided by NAHB Research Center, we created a master address data file in Microsoft Word and used mail merge to produce personalized letters and mailing labels.

- **Data Collection Procedure**

To promote a good response rate, we used Dillman's Total Design Method to conduct a mailed survey. Questionnaires were mailed to owners of building firms in the United States. We asked specifically that someone in the local firm in a position to make decisions on new building products answer the questionnaire. If the respondent represented a firm that was part of a larger company, we explained that we wanted responses to reflect the office and market area where the respondent worked. We asked respondents that were not home builders in the United States to check a box on the front of the questionnaire and return the questionnaire without completing it.

As an option, we designed a Web version of the questionnaire and gave the respondents the opportunity to go to a Web site to answer on-line rather than complete and mail back a hard copy. In the cover letter that accompanied the questionnaire, we provided a Web site address and, for security, a password. In addition, we translated the questionnaire into Spanish and provided a post card with a message in both English and Spanish that asked respondents to return the post card if they preferred for us to send them a copy of the questionnaire in Spanish.

The packet mailed to respondents contained a number of items that had to be carefully matched by respondent name and address. Along with the questionnaire, we included a cover letter explaining the purpose of the study, stressing the importance of participation, and assuring confidentiality of information. We printed each of the 1,200 letters on Virginia Tech letterhead with personalized addresses. Each letter was personally signed by Dr. Koebel. We included a request-for-results post card that the respondent could either include with the completed survey or mail to us separately. We also included the request-for-Spanish-questionnaire post card. On one side of both types of post cards, we printed our Virginia Tech address. Below the printed message on the other side, we affixed a mailing label with the respondent's address so that when receiving back the post card, we would be able to clearly identify the requestor. Finally, we included a 9 × 6 inch brown business reply envelope with our Virginia Tech return address so that a respondent could easily return the completed questionnaire at no expense. We put all of the above components into a 9 ½ × 6 ½ inch brown envelope to which we affixed the respondent's personalized mailing label and sent them by first-class U.S. mail.

From the electronic file, we printed a hard copy master list with the names and addresses of all the respondents in the sample. Each was assigned a control number that was printed on the business reply envelope included in the respondent's packet. As completed questionnaires were returned, we recorded this number on the master list so that no additional mailings would be sent to those who had already responded. We also recorded on the master list packets returned as undeliverable to ensured that no additional mailings would be sent to faulty addresses. We took the respondents who never actually received a questionnaire into account in calculating our response rate. For any questionnaire that was returned with forwarding information, the address was updated on the master list and on the electronic master address data file, and the respondent was sent a new questionnaire. We created a subset of the original master address file representing the respondents with updated addresses and provided it to NAHB Research Center so they could update their membership mailing list.

Approximately one week following the initial mailing, we mailed a reminder post card reminding the recipient of the importance of participating and thanking the respondent if a completed questionnaire had already been returned. Approximately four weeks following the initial mailing, we sent out a second mailing (while ordinarily the Dillman method suggests three weeks between the first and second mailing, our returns were coming in slowly, so we opted to wait longer). This mailing included another questionnaire in case the recipient had misplaced the original, a personalized letter reemphasizing the importance of responding, and a business reply return envelope. We did not send a second mailing to respondents who had already returned a completed questionnaire or to those whose first mailing had been returned for insufficient address or had been returned saying the respondent was not a home builder in the United States.

- **NAHB Research Center Supplementary Respondents**

To increase the number of completed questionnaires, we produced additional copies of the questionnaire and sent them to NAHB Research Center for distribution to supplementary respondents. NAHB Research Center called innovative home builders not included in the mail survey and asked for their participation. NAHB Research Center secured the cooperation of 70 builders by telephone and sent out questionnaires for them to complete and return. The questionnaires were mailed directly to NAHB Research Center and then forwarded to Virginia Tech for processing.

- **Responses**

Of the 1,200 questionnaires mailed to U.S. home builders from Virginia Tech, we had a response rate of 17.4% based on 196 completed questionnaires. In calculating this response rate, we took into consideration that 72 of the original 1,200 respondents never received the questionnaire due to an insufficient address or were not a U.S. home builder and thus not qualifying as a valid respondent. Thirteen of the 196 completed questionnaires were electronic responses from builders who chose to complete the questionnaire via the Web site.

NAHB Research Center secured additional completed questionnaires by contacting 70 innovative builders by telephone, securing an agreement to participate, and sending them surveys to complete. Of those 70 builders, 51 returned completed questionnaires for a response rate of 56.7%.

Forty-six respondents returned the post card requesting a summary of results. We created a subset of the original master address file representing these respondents and will use it to create mailing labels once the summary of results is complete. Although we translated the questionnaire into Spanish and informed respondents that if they preferred we would promptly send them a Spanish questionnaire, no such request was made. Two respondents sent back the request for Spanish questionnaire post card with a note protesting our attempt to accommodate Spanish-speaking builders.

- **Analysis**

We created a master codebook for the questionnaire and used it as a guideline for entering data into an SPSS database. We designed the questionnaire to facilitate coding of the data, so most questions were "precoded," meaning a number was provided as an answer. For questions that did not have a number answer, we assigned a number for coding purposes. We entered data into the SPSS database directly from each questionnaire and thoroughly checked for errors.

Once the data from all returned questionnaires had been entered, using SPSS PC, we ran frequencies on all the variables obtained from the mailed survey from Virginia Tech and also ran cross-tabulations (two-way tables comparing variables) on selected variables. Separately, we ran frequencies and cross-tabulations on the variables obtained from the supplementary NAHB Research Center questionnaires. On both, we ran descriptive statistics (mean, median, etc.) on interval level variables such as number of years the establishment had been in business. We created new variables from existing variables to provide better measures of interest. The most notable "created" variable was an innovation score that was based on responding with specific answers on a series of questions.

Once we established there were few differences between the primary (Virginia Tech) sample and the supplement (NAHB Research Center) sample, we combined the two samples into a total sample (N=247) and reran the frequencies, cross-tabulations, and descriptives. In addition, we used factor analysis (principal component with varimax rotation) as a data-reduction procedure for eliminating redundant variables and making the analysis more reasonable. Finally, we performed multivariate linear regression with three sets of independent variables to identify the variables having the best association with our created innovation score.

APPENDIX B. QUESTIONNAIRE

VirginiaTech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Survey on the Use of New Building and Construction Products, Materials, and Practices

Please return by Friday, June28, 2002

This survey asks questions on how home builders make decisions about new building materials. The information will be used to help government and trade associations improve the use of new building and construction products, materials, and practices in the home building industry. If you are a home builder in the U.S., we would appreciate 20 minutes of your time to complete this questionnaire. Your responses will be completely confidential and will not be released or published in any form that could identify you or your firm.

We want to know how decisions are made within your local firm. If you are part of a larger company that serves multiple market areas, please respond for the office and market area where you work.

If you have questions about this survey, please contact:

Dr. Ted Koebel, Director
Virginia Tech Center for Housing Research
Mail Code 0451, Virginia Tech, Blacksburg, Virginia 24061
Phone: 540 231-3993Email: tkoebel@vt.edu

If you are not a home builder in the U.S., you do not need to complete this survey. Please check the box below. Then using the pre-addressed envelope provided, return this survey through the U.S. mail (no postage necessary). Thank you.

☐ No, we are not a home builder.

Part 1. The Nature of Your Firm

Part 1 asks for basic information about your firm (please answer for your local establishment if you are part of a larger company).

Q1. Which of the following best describes your firm? (Please check the one that fits best.)

- ❑ Single-family production home builder
- ❑ Single-family custom home builder
- ❑ Multifamily builder or developer
- ❑ Home improvement contractor/ remodeler
- ❑ Modular home manufacturer
- ❑ HUD-code manufacturer
- ❑ Other (please specify): ____

Q2. Approximately how many years has your establishment been in business as a home builder?

____________________________ (write in # years)

Q3. How many of the following types of homes did your firm build in 2001? (If your firm builds homes in multiple metropolitan market areas, please write in totals for the office/division that operates in your market area.):

Single-family detached dwellings ____________ (write in)
Townhouses or duplexes ____________ (write in)
Apartments or condos ____________ (write in)

Q4. Does your firm build primarily: (Please check the one that fits best.)

- ❑ Starter homes
- ❑ Move-up homes
- ❑ Luxury homes
- ❑ Fairly even mix

Q5. In your firm, which of the following positions are staffed permanently with at least one full- or part-time employee? If one person serves in multiple functions or positions, select only their primary role. (Please check all that apply.)

- ❑ General manager/president/owner/partner
- ❑ Designer or architect
- ❑ Engineer
- ❑ Project or construction manager
- ❑ Finance director
- ❑ Purchasing manager
- ❑ Marketing or sales manager
- ❑ Urban planner
- ❑ Information technology manager

Q6. Which of the following best describes your firm? (Please check the one that fits best.)

- ❑ My firm serves only our local market area
- ❑ My firm is part of a home building company that serves multiple market areas in this region of the country
- ❑ My firm is part of a home building company that serves multiple market areas across the nation

Q7. Please indicate which of the following statements describe your firm's approaches towards selecting new building and construction products, materials, and practices. (Please check all that apply.)

- ❑ We like to wait until other builders have successfully offered building and construction products, materials, and practices before we use them.
- ❑ We are often the first in our area to offer a new and innovative building product or system.
- ❑ We encourage homebuyers to stick with "tried and true" materials and products.
- ❑ Our goal is to set ourselves apart, to be creative, and we seek materials and products that are distinctive and unique.
- ❑ We prefer to use materials that meet, but not exceed, current code minimums and market expectations.
- ❑ We prefer to use materials that exceed current code minimums and market expectations.

Q8. By how much does your firm plan to increase its net profits over the next 5 years? (Please check one only.)

- ❑ We expect a reduction in net profits due to planned downsizing of our firm
- ❑ Less than 5% a year
- ❑ 5–10% a year
- ❑ More than 10% a year
- ❑ No specific plan for growth in profits

Q9. To what extent do you use union labor in your construction (including subcontractors)?

❑ Always for all trades ❑ Always for some trades ❑ Sometimes ❑ Never

Q10. About how many full-time employees did you have on your firm's payroll in calendar year 2001? (If you're self- employed, be sure to include yourself and any partners.)

❑ 1–2	❑ 11–50
❑ 3–5	❑ 51–100
❑ 6–10	❑ 100+

Q11. How likely is your firm to invest time or money to meet the following objectives in the next 5 years? (Please circle one number for each objective.)

	Not likely				Very likely
Improving style and attractiveness of our homes	1	2	3	4	5
Implementing total quality practices	1	2	3	4	5
Improving subcontractor dependability	1	2	3	4	5
Reducing costs through use of new building and construction products, materials, and practices	1	2	3	4	5
Improving marketability of new homes	1	2	3	4	5
Improving our ability to purchase and develop the best land	1	2	3	4	5
Protecting or improving market share through use of new building and construction products, materials, and practices	1	2	3	4	5
Reducing build time	1	2	3	4	5
Reducing construction defects/call-backs	1	2	3	4	5
Reducing legal liability related to product and building system failures	1	2	3	4	5
Reducing material costs	1	2	3	4	5
Reducing overhead costs	1	2	3	4	5
Offering the best mortgage financing to homebuyers	1	2	3	4	5
Researching new products, materials, and practices	1	2	3	4	5
Educating buyers about new technologies	1	2	3	4	5

Q12. During the past 5 years, please tell us whether your firm has never tried, tried but discontinued, or is currently using <u>each</u> of the following building products.

	Never tried	Tried, but discontinued	Currently using
Precast concrete foundation walls	❑	❑	❑
Wood/plastic composite exterior trim/moldings	❑	❑	❑
Fiber cement exterior trim material	❑	❑	❑
Heat pumps with integral water heating (e.g., desuperheater)	❑	❑	❑
Laminate flooring	❑	❑	❑
Wood I-joists as roof rafters	❑	❑	❑
Fiber cement flooring underlayment	❑	❑	❑
Wood I-joist structural floors	❑	❑	❑

Part 2. New Building and Construction Products

Part 2 is about your firm's attitudes towards activities regarding new building and construction products, materials, and practices.

Q13. Who in your firm would have significant influence over a decision to use a new type of siding?

	Has significant influence (Please check <u>all</u> that apply.)	Makes final decision Please (Check <u>one</u> only.)
General manager/president/ owner/partner	❑	❑
Purchasing manager	❑	❑
Designer or architect	❑	❑
Engineer	❑	❑
Project or construction manager	❑	❑
Sales or marketing manager	❑	❑
Other (please specify): ____________	❑	❑

Q14. Is anyone in your firm considered a strong advocate of new building and construction products, materials, and practices?

❑ Yes ❑ No

If yes, who?
(Owner, purchasing manager, etc.): ____________________

Q15. Where in your firm are the majority of decisions made on switching building material brands, new building materials, changes in home design and construction processes?

	Made at an office located in our market area	Made by the regional office (if available)	Made by the national office (if available)
Switch brands	❑	❑	❑
New building material decisions	❑	❑	❑
Home design decisions	❑	❑	❑
Construction process decisions	❑	❑	❑

Q16. How influential are each of the following information sources in keeping you up to date on new building and construction products, materials, and practices? (Please circle one number for each source.)

	Not influential				Highly influential
Consultants	1	2	3	4	5
Trade shows	1	2	3	4	5
Homebuyers	1	2	3	4	5
Internet/World Wide Web	1	2	3	4	5
Mail or FAX advertisements	1	2	3	4	5
Sales and supplier representatives	1	2	3	4	5
Manufacturers' toll-free numbers	1	2	3	4	5
NAHB seminars	1	2	3	4	5
Observing other builders	1	2	3	4	5
Seminars	1	2	3	4	5
Subcontractor advice	1	2	3	4	5
Technology transfer programs like PATH	1	2	3	4	5
Trade publications	1	2	3	4	5
Universities	1	2	3	4	5
Other (please specify: ____________________	1	2	3	4	5

Q17. Several statements about your firm's consideration of new building and construction products, materials, and practices are presented below. (Please indicate how strongly you agree or disagree by circling one number for each statement.)

	Strongly disagree				Strongly agree
Building codes make it difficult to use new building and construction products and materials.	1	2	3	4	5
New building and construction products and materials generally cost more than ones we currently use.	1	2	3	4	5
Our customers prefer the "tried and true" and don't like nontraditional products or features.	1	2	3	4	5
It is dangerous to be among the first firms who try new things in our market.	1	2	3	4	5
Our bankers and insurance companies are hesitant to underwrite projects with new products and materials.	1	2	3	4	5
Manufacturers and suppliers generally do not provide enough support for new products.	1	2	3	4	5
Gaining competitive advantage by using new building and construction products and materials is not an important part of our company's business strategy.	1	2	3	4	5
Using new building and construction products and materials increases our risk of call-backs.	1	2	3	4	5
Subcontractors in our market do not usually want to adapt to new building and construction products and materials.	1	2	3	4	5
Our construction workers find it difficult to learn a new way of building.	1	2	3	4	5
Our firm uses only new building and construction products and materials from established companies that stand behind their products.	1	2	3	4	5

Q18. What were the main **benefits** to your firm over the last 5 years for adopting new building and construction products, materials, and practices? (Please check the **3** most important reasons.)

Check 3 only

- ❑ Helping to comply with codes and regulations
- ❑ Decreasing costs
- ❑ Creating an image of our firm as an innovative builder
- ❑ Increasing productivity
- ❑ Increasing profit
- ❑ Increasing quality
- ❑ Maintaining or improving market competitiveness
- ❑ Meeting our customers' expectations
- ❑ Reducing build time
- ❑ Reducing call- backs

Q19. In adopting new building and construction products, materials, and practices for your firm over the past 5 years, how important was cooperation from the following? (Please circle one number for each.)

	Not important				Highly important
Suppliers	1	2	3	4	5
Manufacturers	1	2	3	4	5
Subcontractors	1	2	3	4	5
Architects or engineers	1	2	3	4	5
Project or construction managers	1	2	3	4	5

Part 3. Use of New Building and Construction Products, Materials, and Practices

Part 3 asks you for information about your firm's adoption of specific new building and construction products, materials, and practices.

Q20. During the past 5 years, please tell us whether your firm has never tried, tried but discontinued, or is currently using each of the following building products.

	Never Tried	Tried, but discontinued	Currently using
Structural insulated panels (SIPS)	❑	❑	❑
Light-gauge steel exterior walls	❑	❑	❑
Insulated concrete forms (ICFs)	❑	❑	❑
Panelized walls	❑	❑	❑
Ultra-high-efficiency HVAC*	❑	❑	❑
Fiber cement siding	❑	❑	❑
Wood/plastic composite decking lumber (e.g. Trex® or ChoiceDek®)	❑	❑	❑
Fiberglass doors	❑	❑	❑
OSB subflooring	❑	❑	❑

* Air conditioning with a SEER (season energy efficiency rating) of 14 or greater (or a geothermal heat pump), or a furnace/boiler with an efficiency rating of 95% or greater.

Q21. Please write below the **first** item checked above that you currently use and refer to it in answering the following questions (Q22 – Q25). If none are currently used, please skip to Part 4, Question 26.

Product/material referred to: ______________________________

Q22. How influential are each of the following information sources in keeping your firm up to date on the product/material you've specified in question 21? (Please circle one number for each source.)

	Not influential				Highly influential
Consultants	1	2	3	4	5
Trade shows	1	2	3	4	5
Homebuyers	1	2	3	4	5
Internet/World Wide Web	1	2	3	4	5
Mail or FAX advertisements	1	2	3	4	5
Sales and supplier representatives	1	2	3	4	5
Manufacturers' toll-free numbers	1	2	3	4	5
NAHB seminars	1	2	3	4	5
Observing other builders	1	2	3	4	5
Seminars	1	2	3	4	5
Subcontractor advice	1	2	3	4	5
Technology transfer programs like PATH	1	2	3	4	5
Trade publications	1	2	3	4	5
Universities	1	2	3	4	5
Other (please specify): ______________________	1	2	3	4	5

Q23. Please rate the importance of the following benefits in your decision to currently use the product/material you've specified in question 21. (Please circle one number for each.)

	Not important				Highly important
Impact of product/material on profitability	1	2	3	4	5
Labor savings derived from the product/material	1	2	3	4	5
Materials savings derived from the product/material	1	2	3	4	5
Ability to recover cost of the product/material	1	2	3	4	5
Reduction in build time	1	2	3	4	5
Compatibility with your preferred construction practices	1	2	3	4	5
Quality compared with alternatives	1	2	3	4	5
Consumers' preference for the product/material	1	2	3	4	5
Manufacturers' technical support	1	2	3	4	5
Subcontractors' familiarity with the product/material	1	2	3	4	5
Suppliers' technical support	1	2	3	4	5
Reduction in call-backs	1	2	3	4	5

Q24. Please rate the importance of the following problems in your decision to currently use the product/material you've specified in question 21. (Please circle one number for each.)

	Not important				Highly Important
Uncertainty/risk of product/material	1	2	3	4	5
Initial cost of the product/material	1	2	3	4	5
Continuing cost of the product/material	1	2	3	4	5
Difficulty in first use of the product/material	1	2	3	4	5
Difficulty of continuing use of the product/material	1	2	3	4	5
Acceptance by building inspectors	1	2	3	4	5
Acceptance by lenders	1	2	3	4	5
Uncertainty in zoning regulations and building codes	1	2	3	4	5

Q25. How influential was each of the following in making the decision to use the product/material you've specified in question 21? (Please circle one number for each.)

	Not influential	Somewhat influential	Very influential	NA
General manager or president	1	2	3	4
Purchasing manager	1	2	3	4
Designer or architect	1	2	3	4
Engineer	1	2	3	4
Project or construction manager	1	2	3	4
Installing subcontractor	1	2	3	4
Homebuyer	1	2	3	4
Sales or marketing manager	1	2	3	4
Other (please specify): ____________	1	2	3	4

Part 4. Business Strategy

Part 4 asks you for information about your firm's market and competition strategies.

Q26. Please indicate which of the following statements best describes your firm's approach towards home building. (Please check the <u>one</u> that fits best.)

- ❑ We are successful through offering a lower cost per square foot home than our market competitors
- ❑ We are successful in this market because our homes and developments have more desirable features than our competitors.
- ❑ We are successful in this market because we have a reputation for high-quality and durable homes and quickly addressing problems in new homes.
- ❑ We are successful in this market largely from our ability to develop land into more desirable neighborhoods with better locations than our competitors.

Q27. How does your firm monitor its competitors? (Please check all that apply.)

- ❑ Attends trade or association meetings to get a sense for competitors' activities.
- ❑ Monitors industry data such as building permits, sales records, etc.
- ❑ Tours competitors' houses.
- ❑ Visits competitors' developments or building sites.
- ❑ We don't try to monitor our competition.
- ❑ Other (please specify): ______________________________

Q28. How much do you know about the building practices of your competitors?

❑ Nothing ❑ Some ❑ A lot

Q29. Which of the following <u>**best**</u> describes the amount of time your firm spends on tracking changes and trends in the marketplace? (Please check <u>one</u> only.)

- ❑ Lengthy: We are continuously monitoring the marketplace.
- ❑ Minimal: We really don't spend much time tracking market changes and trends.
- ❑ Average: We spend a reasonable amount of time monitoring the marketplace.
- ❑ Sporadic: We sometimes spend a great deal of time tracking the marketplace while at other times very little.

THANK YOU! Please take a minute to make sure you've answered each question. Then using the preaddressed envelope provided, return this survey through the U.S. mail. **No stamp is necessary**.

Comments (If you have any comments about this survey, please feel free to mention them here.)

APPENDIX C. DESCRIPTION OF TECHNOLOGIES/BUILDING PRODUCTS

Description of Technologies/Building Products

- **Technologies Referenced in Table 18 (Question 12 of the Survey)**

Precast concrete foundation walls: Basement or crawlspace walls consisting of factory-cast, concrete wall elements with steel-reinforced wall studs, top beam, and integral footing that are delivered to job site and set into place to form permanent foundation walls.

Wood/plastic composite exterior trim/moldings: Exterior trim and molding materials that are made from a mixture of recycled or virgin plastic and waste wood fiber.

Fiber cement exterior trim material: Planks made of cement and cellulose fiber that are formed to imitate wood exterior trim materials.

Heat pumps with integral water heating (or desuperheater): Systems that allow domestic water heating from either waste heat from the air conditioning function or incorporate both domestic hot water and household heating year-round from a single heat pump unit.

Laminate flooring: Flooring typically consisting of a medium- or high-density fiberboard base that incorporates a transparent wear layer, a decorative layer, and a moisture-resistant backing. Laminate flooring is generally installed as a "floating" floor—not attached with nails or glue to the floor.

Wood I-joists: Sometimes called "wood I-beams," this engineered wood structural member consists of a thin, oriented strand board (OSB) web material with natural lumber or laminated veneer lumber (LVL) top and bottom flanges. The wood I-joist is most often used in place of 2 × 10 and 2 × 12 lumber joists.

Wood I-joists as roof rafters: Though more common as floor joists, wood I-joists may also be used as roof rafters.

Fiber cement flooring underlayment: Panels formed of cement and cellulose fiber used as a water-resistant substrate for tile flooring.

- **Technologies Referenced in Table 19 (Question 20 of the Survey)**

Structural insulated panels (SIPS): Structural panels consisting typically of a rigid foam core sandwiched by two structural wood panels, such as oriented strand board or plywood. SIPS may constitute the load-bearing floors, walls, and roofs of homes.

Light-gauge steel wall framing: Roll-formed galvanized steel studs, usually C-shaped structural members, with support headers that constitute structural a load-bearing wall, used as a substitute for wood-frame construction.

Insulated concrete forms (ICFs): Rigid plastic foam forms set in a wall configuration, reinforced with steel reinforcing bar, and filled with concrete. The concrete hardens to form a structural wall, and the forms remain in place afterwards to serve as thermal insulation.

Panelized walls: Light-frame walls, usually of 2 ×4 or 2 × 6 construction with sheathing attached, that are assembled in a factory and delivered to construction site. The wall panels are set in place with the aid of a light crane.

Ultra-high-efficiency HVAC: Defined in the study as (1) a geothermal heat pump, (2) an air conditioning or heat pump with a SEER (seasonal energy efficiency ratio) of 14 or greater, or (3) a furnace or boiler that is 95% or more efficient.

Very-high-efficiency HVAC: Defined for the analysis of ABPS data as a heat pump or air conditioning unit with a SEER (seasonal energy efficiency ratio) of 13 or greater.

Fiber cement siding: Planks and panels, formed typically 5/16–inch thick, made of cement and cellulose fiber. Fiber cement siding generally imitates wood clapboard or vertical board siding.

Wood/plastic composite decking material (e.g., Trex® or ChoiceDek®): Decking materials made from a mixture of recycled or virgin plastic and waste wood fiber that are formed into planks. Wood/plastic composite decking often substitutes for preservative-treated lumber on porches and deck.

Fiberglass doors: Exterior entry doors with fiberglass-reinforced plastic facings, often imprinted with a wood grain texture, with a foam-insulated core reinforced with wood stiles and rails.

OSB subflooring: Structural floor panels made of oriented strand board (OSB) that provide support and serve as a base for flooring, such as carpeting, tile, and hardwood.

- **Technologies Referenced in Table 29**

OSB subflooring: Structural floor panels made of oriented strand board (OSB) that provide support and serve as a base for flooring, such as carpeting, tile, and hardwood.

Vinyl windows: Windows with frame and sash material composed of hollow polyvinyl chloride (PVC) extrusions.

Structured wiring: Also known as "home networks," which consists typically of a central distribution panel that connects cable for audio/video signals and wiring for data/voice to multiple outlets throughout the house.

Fiber cement siding: Planks and panels, formed typically 5/16–inch thick, made of cement and cellulose fiber. Fiber cement siding generally imitates wood clapboard or vertical board siding.

Fiberglass entry doors: Exterior entry doors with fiberglass-reinforced plastic facings, often imprinted with a wood grain texture, with a foam-insulated core reinforced with wood stiles and rails.

Panelized frame walls: Light-frame walls, usually of 2 x 4 or 2 x 6 construction with sheathing attached, that are assembled in a factory and delivered to construction site. The wall panels are set in place with the aid of a light crane.

Very-high-efficiency HVAC: Defined for the analysis of ABPS data as a heat pump or air conditioning unit with a SEER (seasonal energy efficiency ratio) of 13 or greater.

Insulated concrete forms—basement crawlspace (ICFs): Rigid plastic foam forms set in a wall configuration, reinforced with steel reinforcing bar, and filled with concrete. The concrete hardens to form a structural wall, and the forms remain in place afterwards to serve as thermal insulation.

Insulated concrete forms—above grade (ICFs): Rigid plastic foam forms set in a wall configuration, reinforced with steel reinforcing bar, and filled with concrete. The concrete hardens to form a structural wall, and the forms remain in place afterwards to serve as thermal insulation.

Wood/plastic composite decking material (e.g., Trex® or ChoiceDek®): Decking materials made from a mixture of recycled or virgin plastic and waste wood fiber that are formed into planks. Wood/plastic composite decking often substitutes for preservative-treated lumber on porches and deck.

Structural insulated panel walls (SIPS): Structural wall panels consisting typically of a rigid foam core sandwiched by two structural wood panels, such as oriented strand board or plywood.

Light-gauge steel exterior walls: Roll-formed galvanized steel studs, usually C-shaped structural members, with support headers that constitute structural a load-bearing wall, used as a substitute for wood-frame construction.

APPENDIX D. MULTIVARIATE ANALYSIS TABLES

Multivariate Analysis Tables

A principal components factor analysis with varimax rotation was conducted for three sets of measures covering business objectives, information sources, and barriers to innovation. Loadings of 0.5 and greater were used to calculate each builder's scores for the building objective factors. The factor scores used to calculate the indexes included in the analysis are given in Table D-1.

Table D-1. Business Objective Factors with Weights

Factor Name	Component Variables	Weight
REDUCE_COSTS	Using new products and materials to reduce costs	0.547
	Reducing build time	0.686
	Reducing defects and call-backs	0.581
	Reducing legal liability related to building failures	0.573
	Reducing materials costs	0.825
	Reducing overhead costs	0.826
NEW_TECH	Improving market share by construction innovation	0.673
	Researching new products, materials, practices	0.888
	Educating buyers about new technologies	0.881
QUALITY_STYLE	Improving style and attractiveness of our homes	0.688
	Implementing total quality practices	0.745
	Improving subcontractor dependability	0.671
	Reducing defects and call-backs	0.539
MARKETABILITY	Improving marketability of our homes	0.696
	Improving ability to purchase and develop best land	0.835
	Offering the best mortgage financing	0.688

See Appendix B, Q11.

The influence ratings for 14 information sources were reduced by factor analysis to five factors that captured 64% of the variance in the original 14 variables. The information source factor loadings are reported in Table D-2.

Table D-2. Information Sources Factors with Weights

Factor Name	Component Variables	Weight
TECH_TRANSFER	Internet/World Wide Web	0.589
	Manufacturers' toll-free numbers	0.691
	Technology transfer programs	0.760
	Universities	0.785
SEMINARS	Trade shows	0.808
	NAHB seminars	0.754
	Other seminars	0.707
PRODUCTION_NETWORK	Sales or suppliers' representatives	0.604
	Observing other builders	0.573
	Subcontractors' advice	0.806
HOME_BUYERS	Homebuyers	0.858

See Appendix B, Q16.

The 11 barriers to innovation were reduced to three factors capturing 50% of the total variance among the 11 variables (Table D-3).

Table D-3. Innovation Barriers Factors with Weights

Factor Name	Component Variables	Weight
TRIED AND TRUE	Customers don't like nontraditional products	0.719
	Dangerous to be among first to try new things	0.723
	Banks and insurance companies hesitant to underwrite projects with new products and materials	0.535
	Using new products and materials not important part of our business strategy	0.615
	Using new products and materials increases risk of call-backs	0.612
WORKERS	Subcontractors do not want to adapt to new products and materials	0.785
	Construction workers find it difficult to learn a new of way of building	0.841
ESTB_MFG	We use only products and materials from established companies	0.853

See Appendix B, Q17.

The final regression equation (Table D-4) is statistically significant with an R^2 of .357. After adjusting for the number of variables, the overall equation is associated with approximately 30% of the variation in innovation scores.

Table D-4. Innovation Score Analysis

Coefficients	B	t	Sig.
Constant	.163	.071	.944
Single-family custom home builder (suppressed)	NA	NA	NA
Single-family production builder	-1.144	-1.608	.109
Multifamily builder or modular manufacturer	1.667	1.680	.094
Home improvement, other	-0.0028	-.003	.998
Move-up market	-.330	-.621	.535
Part of regional company	1.574	1.797	.074
Part of national company	2.754	1.682	.094
Uses union labor	1.023	1.767	.079
NEW_TECH factor	.155	1.008	.315
MARKETABILITY factor	-.468	-3.575	.000
TECH_TRANS factor	.305	2.251	.025
HOME_BUYER factor	.514	2.232	.027
TRIED AND TRUE factor	-.144	-1.029	.305
WORKERS factor	.148	1.000	.318
ESTAB_MFGS factor	.577	1.800	.073
Increased productivity	.759	1.227	.221
Increased profit	-1.217	-1.650	.101
Business strategy, innovative and creative	.820	2.215	.028
Advocate	1.277	1.999	.047
Cooperation of project managers	.202	.957	.339
Success based on quality and durability	.492	.805	.422
Success based on land	-1.790	-1.491	.138
Attends trade shows to monitor competition	0.0079	.014	.989
Monitors industry data	-.470	-.737	.462
Knows nothing about competitor's practices	1.212	.948	.344

N=226

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