Characteristics of Innovative Production Home Builders

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Characteristics of Innovative Production Home Builders

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Prepared by:
Center for Housing Research
Virginia Tech
Blacksburg, Virginia

Authors

C. Theodore Koebel
Marilyn Cavell

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SUMMARY

Purpose and Significance of this Study

Industry, government and universities in the United States and across the world have demonstrated a heightened interest in innovation as a driver of economic growth. That innovation—broadly understood as the application of discoveries and inventions—might be critically important to the vitality of the economy is not a new notion. Joseph Schumpeter identified the centrality of innovation to economic growth in *Theory of Economic Development*, published in 1911, and Adam Smith's *The Wealth of Nations* in 1776 reflected the fundamental changes spurred by the first industrial revolution. But even a small sampling of business and economics books published in the last 20 years shows a continued interest in the role of innovation in both broad economic terms and more finite industrial analysis. Such interest has permeated national culture, too, as recent biomedical and information technologies have dramatically shaped and been shaped by changing popular perceptions and needs.

The innovation process, though pervasive, is not formulaic. Every industry—and, for that matter, every technology within an industry—can displace established practices and companies through an idiosyncratic process of "creative destruction" when innovations are successfully commercialized.[1] Cycles of creative destruction vary across industries, partly due to the different relationships between science and engineering and the technologies associated with specific industries (Nelson 1998). Industries with closer ties to science and engineering are likely to experience more frequent cycles of creative destruction, while industries less dependent on science and technology have longer periods between disruptive innovations and instead rely on refinements of existing technologies.

Housing is clearly in the latter category. For the most part, innovation in this sector has refined established technologies and materials or incrementally replaced existing materials and equipment. As a result, homebuilding is sometimes criticized as a laggard industry that is resistant to change. Technologies and practices persist for long periods in homebuilding for various reasons, many still unknown.

In 2003, PATH commissioned a pioneering study on the diffusion of innovations in the homebuilding industry. The report from that study (Koebel et al. 2003) reviewed the research on the diffusion of innovation in construction as well as other industries. It reported the results of a national survey of home builders on their decisions to adopt new products, processes, and technologies and presented an analysis of the correlation of company size and geographic region to company innovativeness, measured through the use of several innovative products in the National Association of Home Builders Research Center's Annual Builder Practices Survey (ABPS).

Though not fully representative of the full homebuilding population, the 2003 study resulted in the following key findings:

[1] Schumpeter's theory of economic growth identified innovation as a central force for long-term growth. In this view, innovation is inherently disruptive in the sense that it creates opportunities for change (Schumpeter 1911, 1942). This "creative destruction" forces existing firms to adapt to new technologies or perish.

- At the early stage of diffusion, national and regional firms, multifamily and modular builders, and single-family custom builders are more likely to adopt innovations than are local 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.

- Although small, less established manufacturers often are the first to introduce new products, residential building construction adopters rely heavily on established manufacturers who stand behind their products.

- A key business strategy for over two-thirds of the builders in the survey was establishing a reputation for high quality and durable homes and quickly addressing any problems buyers reported in those homes.

- A higher level of adoption of new products, materials, and practices by home builders was generally associated with: having a technology advocate within the firm (most often the owner); a company emphasis on being creative and being the first to use new products and technology transfer programs; the use of union labor (at least some of the time); and explicit demand from informed homebuyers.

- In contrast, a lower level of adoption was generally associated with local production builders and builders who emphasize marketability and profit, who associate the firm's success with land development, and who emphasize the "tried and true" rather than risking new materials and products.

The 2003 report's analysis of annual diffusion rates for specific technologies from 1995 to 2001 in the ABPS demonstrated even further complexity. Diffusion of some technologies began with larger builders, while small builders spearheaded the adoption of others. Similarly, some technologies entered the market in more expensive homes and others in low cost homes. These differences reflected the relative advantages of these products within regions, differences in supply and demand between market segments, variances in distribution and access to technologies, and different business philosophies and strategies. As an example of the last potential cause for innovation variances, large builders appeared to stress cost savings, improvements in production, reduced call-backs, or reduced exposure to liability, whereas smaller builders stressed high consumer awareness (demand pull) and were less concerned about price or impact on production processes.

Most of the responding homebuilders to the 2003 study were small firms. Nearly two-thirds of them built fewer than 25 houses in 2001 and three-fourths built fewer than 50 houses. Only 15 percent of the respondents built 100 or more houses in 2001. Although the findings helped identify differences in innovation between larger and smaller builders, the survey predominately reflected the experiences of smaller builders.

In order to understand innovation among larger builders, specifically large production builders, PATH commissioned a national survey of production builders building 200 or more homes a year. This universe includes several national (and international) homebuilding firms, of which a few have become publicly traded Fortune 500 companies, as well as regional and local housing production companies.

Synopsis of Findings

The findings of this study advance our understanding of building technology innovation among production builders in particular and conceptually for the homebuilding industry at large. The key findings are that:

- Size matters. Larger national production home builders are more innovative than smaller production builders.

- Organization matters. Decentralization contributes to innovation at regional and local operational levels, where decisions on innovative products and materials are often made—assisted by technology support from national offices. Influence over innovation spans across purchasing, marketing, and construction. The opportunities for building technology innovation, then, are negotiated throughout these companies.

- Purchasing matters. While numerous departments within a production builder's organization can influence technology adoption, purchasing departments across the company play a large role in influencing and making decisions on new products and materials for production builders. The corporate head of purchasing was identified by 93% of the corporate respondents and 54% of the operations respondents as having significant influence over decisions to adopt a new building product, material, or process; regional and local purchasing directors were also identified as having significant influence.

- Vision matters. Most production builders believe building technology innovation involves serious risks but also that innovation can contribute to higher quality and performance. Large production builders agreed with smaller builders that innovative products and materials cost more than those they replace and subcontractors are resistant to using new products. Production builders with aggressive growth plans included building technology innovation as one element in their plans to increase market share and profitability.

- Information sources matter. To keep up-to-date on building and construction products, materials, and practices, production builders rely on local offices within the company, subcontractors, manufacturers, and wholesalers and suppliers. They also appear to use technology transfer programs to a greater extent than small builders, though both sectors mostly rely on established manufacturers and suppliers that stand behind their products.

- Focus matters. Production builders were most likely to invest in innovations that reduce construction defects and call-backs, improving subcontractor dependability, and improving the style and attractiveness of the homes they build, followed by investment in cost reduction and reduced cycle times. Less than half of the production respondents rated investments in building technology as a means to improve market share as very likely, and a slightly smaller group rated creation of formal R&D as very likely to affect share. However, one-fifth to one-half of the respondents included core aspects of building technology as part of their business strategies, and three-fourths of the companies identified research and technology development as part of their corporate strategy. So, technology can be an important part of production builders' business models—but only one of many.

- Barriers matter. Production builders are more prone than small builders to think that building codes impede innovation, that new building products increase risks of call-backs, and that their own construction workers are resistant to innovation.

- Opportunities matter. Beyond the reasons for initially investing in technology, builders see many opportunities for reaping benefits once the technologies have been implemented. Production builders rated increased quality as the highest benefit from building technology innovation, followed by meeting customers' expectations, increased competitiveness, creating an image as an innovative builder, and reducing call-backs. The opportunities for building technology innovation could increase significantly in the coming years, as the survey respondents identified trends in energy costs, land costs and availability, labor, and competition from large national builders as likely to influence building technology innovation over the next 10 to 20 years.

Elaboration of each these findings, as well as survey results and further research recommendations, is provided in the following discussions.

PREVIOUS RESEARCH ON INNOVATION IN RESIDENTIAL CONSTRUCTION

Attention to innovation in construction, particularly residential construction, has increased with the recent publication of several scholarly books on construction innovation (for example, Gann 2000; Manseau and Seaden 2001; Manseau and Shields 2005) and the introduction of a journal (*Construction Innovation*) devoted exclusively to the topic. Further, three major public programs devoted to residential construction innovation in some form were created: Building America; EnergyStar®; and PATH. Significant industry and consumer attention has also been paid to residential construction concerns. Although construction is still very much underrepresented in the research literature on innovation, more research has occurred on innovation in construction in the past decade than in multiple previous decades.

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The focus of this review of literature is to identify the issues that affect the adoption decision and the adoption process of innovative technologies by large production builders. (For earlier reviews of research on residential construction innovation, see Toole 1998; Slaughter 1993a, 2000; Koebel et al. 2003; Hassell et al. 2003.) Although firm size is often taken into consideration in studies of innovation, in searching the literature revealed no prior studies that specifically targeted large organizations within the residential construction industry. Previous studies related to innovative adoption practices of home builders were either based on samples dominated by small firms or targeted small to medium sized builders.

In 2003, two significant contributions to the understanding of diffusion of innovative technologies in the residential construction industry were published: *The Diffusion of Innovation in the Residential Building Industry* (Koebel et al. 2003) and *Building Better Homes* (Hassell et al. 2003). The former was summarized in the previous section. Hassel et al. (2003) reviewed the state of innovation in the building industry and provided strategies for the government to promote innovation in the homebuilding industry. They pointed to three major categories that motivate builders, manufacturers, or other homebuilding stakeholders to innovate: "seeking competitive advantage" (when decisionmakers believe adopting an innovation may differentiate their product or reduce costs and increase profits); "improving technological efficiency" (when the decision to innovate is not based on need but on a desire to have a better quality product or production); and "meeting external requirements" (when the decisionmaker is forced to innovate due to a change in building codes or existing consumer demand). They also pointed out that decisionmakers' past experience, context, environment, and professional training contribute to their decision of whether or not to adopt an innovation. The implications are that "enabling and influencing agents" may act to expand a decisionmaker's frame of reference, allowing broader acceptance of new ideas.

"Enabling and influencing agents" may act to expand a decisionmaker's frame of reference, allowing broader acceptance of new ideas.

Hassell et al. (2003) identified the size of builders as an important factor relating to the adoption of innovations, although there is disagreement on this issue in the literature. Other factors affecting adoption of innovations in the homebuilding industry, as discussed by Hassell et al. (2003), were competition (as in the impacts of reputation,

differentiation, and profits) and business fragmentation. Fragmentation includes several dimensions: geography (manifesting in different regulations and codes and/or information sharing), horizontal organization (resulting in possible problems in communications between builders and in turnover rates), and vertical organization (from independence rather than interdependence within the process, information sharing, and the protection of intellectual property associated with a new product). In addition, they pointed out that homebuilding is a complex process that includes multiple participants with different but often interrelated motives that impact innovation.

The broad categories that Koebel et al. (2003) identified as possible determinants of adoption and diffusion serve as a useful organization of the literature pertinent to residential production builders. The categories are Organizational Structure, Organizational Culture and Decision Process, Human Resources, Market Context, Industry Characteristics (including communication channels and social networks, particularly between suppliers and venders), Technical Attributes of the Innovation, and Economic Attributes of the Innovation. These categories also serve as operationalizing guides for this study.

Organizational Structure

The impact of firm size probably has been discussed more than any single organizational attribute influencing adoption and diffusion. Yet, size does not appear to have a uniform relationship to innovation.

The impact of firm size probably has been discussed more than any single organizational attribute influencing adoption and diffusion. Yet, size does not appear to have a uniform relationship to innovation. The capital, talent, and market advantages of large firms could enable them to be more innovative, as suggested by Hassell et al. (2003), but this is not always the case. Large builders are constrained by their responsibilities to shareholders or other investors to not risk losing quality, safety, and profitability—all of which may be an outcome of adopting an innovative technology. Since they produce a significant number of units quickly, large builders are especially vulnerable to compounding the effect of defective innovations.

Slaughter (1993a) demonstrated that small firms are a significant source of innovation in homebuilding. Koebel et al. (2003) found that national builders were more innovative than builders operating in a single market area but otherwise found that size was not statistically significant. The sample for that study, however, was dominated by small firms. In their analysis of the NAHB Annual Builder Practices Survey, they also found that the impact of firm size on innovation was mediated by the characteristics of the innovation. Hudson and Cantrell (2004) found that larger builders are more likely to be the first to adopt innovative materials if they result in cost savings, improvement in production process, or a reduction in call-backs or other liabilities. Eastin et al. (2000) argued that small builders tend to adopt modifications of materials and technologies to fit the existing housing system, while larger firms are more likely to introduce more substantial or radical innovations. Furthermore, small builders might be more sensitive to the opinions of their customers, making them more responsive to “demand-pull.” Several studies of commercial construction point to higher innovation levels for medium and large firms than for small firms (Seaden et al. 2003; Kangari and Miyatake 1997; Nam and Tatum 1992) and associate this phenomenon with their greater access to capital and talent.

Koebel and McCoy (2006) argue that larger firms might be more path-dependent (that is, reliant on extant practices) and resistant to change than some small homebuilding firms, where the owner has more direct control and can champion innovation more effectively. According to several prominent analysts of innovation (Christensen 1997), disruptive innovations (those that change industry practices significantly) are most likely to come from—and, similarly, be adopted by—new companies (either start-ups or companies entering the industry from some other sector) that develop completely new business models for the industry. In short, the verdict is still out as to the effect of firm size on innovativeness.

Further complicating this picture are the definitions and parameters for size. Although measuring firm size would appear to be a simple task, it is complicated when data are collected at the level of operational offices (most studies have been done on an establishment, or local office, basis). Large homebuilding companies decentralize their operations to metropolitan and regional levels, in part due to the importance of site variability in construction (Koebel and McCoy 2006). Measuring the size of the "company" can thus confuse the size of the local establishment and the size of the larger corporation. Research to date has not adequately addressed this complexity.

A less studied subtopic in the field of organizational effects on construction innovation has been the organizational structure of a firm. Since larger firms are likely to have more formal and more complex organizational structures, this intervening variable could be a significant causal factor for adoption rates. Certainly, the centralization of decisionmaking, organizational complexity, and formalization could be possible impediments to innovation. Since most studies of residential construction have involved small companies, the relationship among these organizational characteristics of larger, more complex firms has not been studied. Among smaller home builders, the owner is often both the technology champion and the decisionmaker (Koebel et al. 2003). When the owner of a small firm is a technology champion, the firm is more likely to be innovative, and purchasing, design, and marketing departments have less frequent influence on innovation in these firms. There is no evidence in the literature regarding how this plays out in larger firms.

Organizational Culture

Organizational culture, as opposed to size and structure, reflects the firm's business strategy, approach to innovation, support for innovation champions and R&D, and emphasis on internal and external cooperation or competition. Past research has found that business strategies emphasizing innovation and the presence of technology champions contribute to innovation. Though intuitively obvious, home builders who portray themselves as innovative and that have in-house technology champions are indeed more innovative. Yet, few firms in the construction industry, with the possible exception of production builders, have the necessary resources to maintain a formal R&D program. In addition, Koebel and McCoy (2006) argue that a combination of risk factors and difficulties in exacting first-mover advantage associated with homebuilding make a second-mover business strategy more rational than a first-mover strategy in the industry.

Business strategies emphasizing innovation and the presence of technology champions contribute to innovation.

The construction industry is often criticized as resistant to change and depicted as a "laggard" relative to innovation (Koebel 1999; Hassell 2003; Toole 2001). Much of this literature was based on studies of small firms with limited resources for innovative strategies or investment—the industry's cultural norm. Although it seems reasonable to assume that organizational culture partially reflects the industry within which the organization operates, this has not been addressed in the research literature; the link between size and culture must still be explored. It also seems reasonable, further, that the recent shift toward greater industrial concentration by national production builders is also transforming the industrial culture, though this also remains to be explored.

Other studies of business strategy and organizational culture issues that have been found to influence innovation in residential construction are summarized below.

- Blackley and Shepard (1996) argue that firms that operate in multiple markets reduce risks and increase opportunities for regulatory acceptance.

- Slaughter (2000) claims that small firms are risk-averse.

- Toole (1998) makes many conclusions relating to organizational culture, including the observation that those firms who inadequately manage knowledge and scan for technology have reduced innovation and, as a corollary, those that seek wider involvement in vetting innovation rates and make better use of diffuse, tacit knowledge reduce uncertainties and consequently increase innovation rates.

- Koebel (2003) discerns correlations in innovativeness among those organizations that have no explicit plans for growth or change from those who do (a positive relationship), as well as those that do but emphasize "land development" or "increased profits" over "increased productivity" within those plans (a negative relationship).

Again, it is evident that there are a variety of studies in the field, and there are numerous gaps in our understanding of innovation in home building.

Human Resources

The breadth and depth of internal talent available to a company can promote greater innovation through leadership and technological competence as well as increased sources for innovative ideas within the company (Ling 2003; Tatum 1984; Tatum 1989; Gann 2000; Nam and Tatum 1997). The human resources available to a company can also increase its ability to assess or reduce the uncertainties associated with innovation (Toole 1998).

Human resources within the residential construction firms are limited by firm size. Many companies have only a handful of direct employees and professional specialization is rare within firms. The emergence of larger firms provides more opportunities for depth and breadth in human resources, ranging from corporate and regional executives and managers to onsite managers, construction supervisors, and laborers. This diversity and depth of talent can create opportunities for identifying and assessing innovations, but only if companies develop the knowledge management tools to identify, capture, analyze and use this information. The

relationships between knowledge management, organizational learning, and innovation are receiving increased attention (Park and Kim 2006) but have yet to be addressed with any depth in the construction industry (Demaid and Quintas 2006).

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Market Context

Market context is said to play a significant role in the adoption of innovation among the community of homebuilders. Of greatest interest among the market context factors are: the agency of clients and buyers; the restrictiveness of building codes and regulations; and the pricing effects of non-construction costs (such as land).

The role of clients in promoting construction innovation is one of the most striking themes running through the literature. The theme is an echo of findings in many other industries (Winch 1998). Nam and Tatum (1992) and Gann (2000) argue that clients play a key role in requiring more innovative construction in large commercial projects. However, Koebel and McCoy (2006) argue that client involvement in homebuilding only occurs in high end, custom building, and demand-pull is less likely to be significant in other segments of the industry.

Codes and regulations that increase costs and uncertainty are associated with innovation rates (Ventre 1973; Blackley and Shepard 1996; Slaughter 2000; Toole 1998). Gann and Salter (2000) address the relationship between governments and builders and argue that government regulatory policies exert a strong influence on demand and play an important part in shaping the direction of technological change. Regulations that guarantee markets might spur innovation (Miozzo and Dewick 2002), but government regulations have generally been seen as hampering innovation (Dubois and Gadde 2002). However, in Koebel et al. (2003), more builders disagreed than agreed that codes and regulations were a barrier to technology diffusion.

An increasing contribution of land costs relative to construction costs also appears to reduce the value of building technology innovation (Slaughter 2000), and as a result land acquisition might be a primary determinant of profit (Koebel 1999; Ball 1999) over productivity or changes (like technology) therein.

An increasing contribution of land costs relative to construction costs also appears to reduce the value of building technology innovation … and as a result land acquisition might be a primary determinant of profit.

Numerous other market characteristics have been identified as negatively influencing innovation in residential construction, including variability and complexity of residential structures (Toole, 1998); site variability (Toole 1998); demand and price volatility (Slaughter 2000); and time frames required for production (Toole 1998). Because these factors are inherently part of homebuilding as an industry and homes as its products, further studies in these areas are of a less operational interest. Rather, the preceding three issues are of direct relevance to differences in perceptions among homebuilders.

Industry Characteristics

Koebel (1999), as well as Hassell (2003) and Toole (2001), stated that complexities within the construction industry make introducing innovation technologies difficult, because the technology may have to be compatible with numerous parties (the general contractor, subcontractors, the lender, and the insurer). The social (organizational) networks involved in construction are complex and are frequently cited as impediments to innovation adoption, but their role has not been clearly established in the research literature. Diffusion theory attributes the spread of innovations to the social and communications networks that link people and organizations. The rate and overall magnitude of diffusion is based on the density of these networks between the sources of innovations (for example, manufacturers and suppliers) and early or later adopters.

Complexities within the construction industry make introducing innovation technologies difficult, because the technology may have to be compatible with numerous parties.

Although the internal social networks associated with larger builders are likely to involve more nodes and layers, the impact of this complexity on technological adoption is uncertain. Similarly, the difference between that and the complexity arising from the smaller, but more external, network of smaller builders is not clear. Social networks could play a significant role in adoption behavior for large builders due to the intricacies of the building process and number of parties involved in that process. Production builders rely on standardized construction processes and relationships with subcontractors, which shorten cycle times (the length of time required to complete a housing unit) and assure uniform quality, in order to improve efficiency and profitability. Production builders are likely to be resistant to changes that interfere with their production process, unless the changes are highly likely to contribute to efficiency and profitability. These relationships are managed at multiple levels with site supervisors managing scheduling and quality control, while regional managers handle contractual relations. No general research has been conducted on whether or how companies manage these relationships, let alone research relative to innovation.

Production builders are likely to be resistant to changes that interfere with their production process, unless the changes are highly likely to contribute to efficiency and profitability.

Very little is actually known about how social networks in construction operate. Toole (1998) and Slaughter (2000) point to a wealth of tacit knowledge, the ability to provide field testing, and involvement in integrating products within the housing system as advantages that builders have within the industry in deploying innovation but did not investigate whether relationships between manufacturers, suppliers, and builders impede or facilitate innovation. Harkola (1995) observed that firms that attempt to formalize that tacit knowledge increase innovation adoption within international infrastructure construction firms.

Within residential construction, the multi-firm production of housing and industry fragmentation (dominance of the industry by small firms) has often been cited as an impediment to innovation, but Blackley and Shepard (1996) did not find any impact attributable to industry fragmentation. In Koebel et al. (2003) sales and supplier representatives, subcontractors, other builders, and trade publications were the most influential sources of information on innovation, while universities and technology transfer programs were the least influential (Koebel 2003). Suppliers

were rated the most important for cooperation in innovation, followed by subcontractors, manufacturers, and project managers. In addition, innovators relied on established companies that stand behind their products. If coordinated, following this logic, innovation channels could conceivably overcome purported fragmentation barriers.

The quality and quantity of use of these social network and communication channels, of course, are just as important as their existence. Toole (1998) found that a greater number of information sources reduced uncertainty associated with innovation. Builders who process and gather more information about innovations are more likely to be early adopters, obviously. Adoption of high risk innovations requires more sources of information and greater quality of information as well as knowledge of multiple sectors of the environment. Slaughter (2000) argues that inadequate opportunity for field testing reduces innovation in construction. Builders have an advantage over manufacturers in being able to demonstrate the efficacy of an innovation through field testing but do not necessarily obtain the market benefits from that field testing.

Builders have an advantage over manufacturers in being able to demonstrate the efficacy of an innovation through field testing but do not necessarily have difficulty obtaining the market benefits from that field testing.

One particular set of relationships in this network is particularly worthy of mention and elaboration: the supply chain. The 2003 survey results (Koebel et al. 2003) pointed to the possible influence of supply-chain relationships on innovation among homebuilders, although there was very little data collected on this topic. Innovative homebuilders emphasized both the roles of manufacturers and suppliers as important sources of information about new products, and their reliance on manufacturers that they trust to stand behind their products. Other, albeit largely anecdotal, evidence also suggests the importance of supply-chain relationships to builders' decisions about innovation.

Given the strategic placement of manufacturers and suppliers, it is surprising that their role in innovation in the homebuilding industry has been overlooked until very recently. Slaughter (1993a, 1993b) found that manufacturers largely ignored the opportunities to commercialize innovations originated by homebuilders. As noted already, field testing is critical for reducing uncertainties surrounding new building products but Slaughter finds that manufacturers leave this to builders who are willing to absorb first-mover risks. Koebel and McCoy (2006) argue that these risks contribute to the reluctance of home builders to adopt innovations that have yet to be proven in the field. This area deserves additional scholarly attention.

Technical Attributes of the Innovation

The magnitude of change required for implementing an innovation is part of its complexity and is assumed to be positively associated with risk and, in turn, negatively associated with adoption. Slaughter's (1998) classification of innovations might similarly reflect risk, but she does not address the relationship among these categories to risk: "incremental" (small, based on existing experience and knowledge), "radical" (a breakthrough in science or technology),

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"modular" (a change in concept within a component only), "architectural" (a change in links to other components or systems), or "system" (multiple, integrated innovations). She does report that integrative innovations are seen as prohibitively risky. Similarly, Toole (1998) reports that builders are reluctant to adopt architectural or system innovations due to uncertainties surrounding costs and benefits and assumptions that innovations are too risky without ample field testing and demonstration of results. Comparisons of qualitatively different technologies' adoption rates are needed, while being conscious of the effect of different technologies among respondents' biases.

Economic Attributes of the Innovation

Nam and Tatum (1992) explored the role of potential economic causes for innovation (that is, supply-push versus demand-pull) as well as the processes involved in converting those causes to internal innovation decision-making. Yet very little work explores the microeconomic patterns (or macroeconomic ones, for that matter) of construction innovation.

Rather, more work explores non-financial economic causes. Competitive advantage is one of the major motivations for builders, manufacturers, or other homebuilding stakeholders to innovate (Hassell 2003; Mitropoulos and Tatum 1999). Mitropoulos and Tatum (1999) also demonstrate that the factors influencing adoption of innovations among construction companies change over time as the innovation matures and gains market share. When innovations are first introduced, it can be very complex and difficult to clearly establish their relative advantage. In addition, consumers prefer visible benefits (aesthetics) and discount invisible building improvements that do not have demonstrable short-term payoffs. All of these factors contribute to a fairly widespread perception among builders that innovation always costs more than current products and practices without providing equitable returns or benefits (Koebel et al. 2003).

When innovations are first introduced, it can be very complex and difficult to clearly establish their relative advantage. In addition, consumers prefer visible benefits (aesthetics) and discount invisible building improvements that do not have demonstrable short-term payoffs. All of these factors contribute to a fairly widespread perception among builders that innovation always costs more than current products and practices without providing equitable returns or benefits.

Recent Advances in Innovation Theory

Some recent work sheds additional light on atypical innovation processes—such as that found in residential construction. For example, traditional theories of innovation assume that the profit incentive to innovate is primarily captured by manufacturers through patents and other protections. Recent history challenges that assumption and demonstrates that a "distributed innovation process" can exist (von Hippel 1988) and that innovation profits can be captured outside of manufacturing. This democratizing of innovation (von Hippel 2005) promotes user-centered innovation as an alternative to manufacturer-initiated innovation. There is, however, still little evidence of this playing out in the residential construction sector. Experience in high-tech industries demonstrates that companies can successfully search for innovative ideas to commercialize without having to be the originator of those ideas through their own R&D programs (Chesbrough 2003). Approaches to open innovation involve technology scanning, knowledge management, and data mining to capture ideas from others and to promote learning

internally. Advances in information technology, for example, are enabling companies in other industries to overcome the inertia of path dependency and to become adaptive learners. The implications of these approaches for residential construction, if any, have yet to be explored. But they do suggest that there are emerging opportunities to look at innovation in residential construction in new ways, and in finding innovation throughout the supply chain and beyond traditional sources.

Summary of Previous Research

The themes identified in previous studies of construction innovation are summarized in Figure 1, through the seven major categories already identified.

Figure 1. Factors Influencing Adoption and Diffusion of Innovation in Residential Construction

<table>
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<tr><th>Organizational Structure</th><th>Organizational Culture</th><th colspan="2">Human Resources</th></tr>
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▪ Profitability
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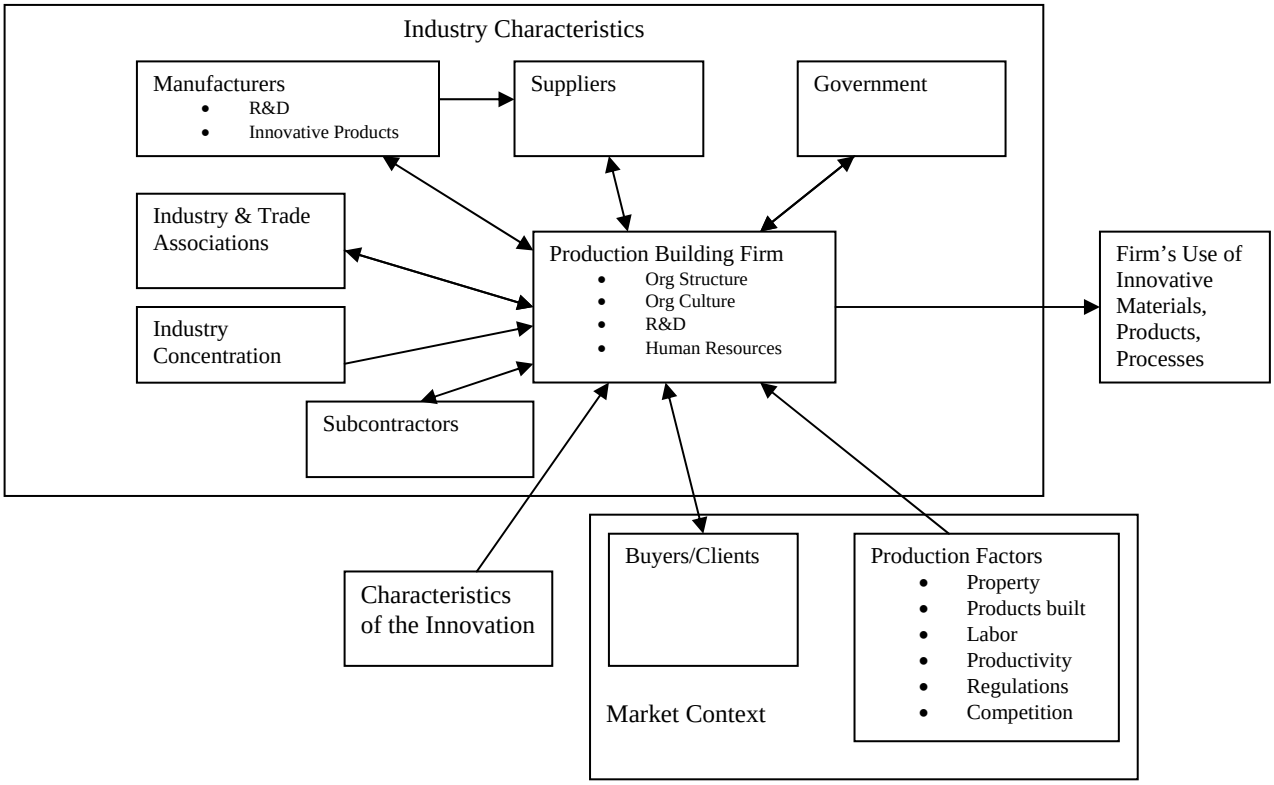
▪ Labor saving or materials saving
▪ Improved productivity</td></tr>
</table>

Figure 2 places these categories into a conceptual model of a company's use of innovative building materials, products, and processes. The building firm is at the center of the model, reflecting its role in decisions to adopt building technology innovations though this certainly does not imply that builders are the only actors in innovation. Double-headed arrows indicate the organizational and social networks that influence the building firm's decision to adopt and use building technology innovations. The model captures the complexity of innovation diffusion in residential construction.

Figure 2. Factors Influencing Firm's Use of Innovative Materials, Products, and Processes



Note that the survey was designed to investigate as many of these themes as possible and to help illuminate the numerous potential paths of influencing technology diffusion among homebuilders. As such, measures covering each of these categories were included in the survey and are further discussed in the next section.

STUDY DESCRIPTION

General Description

PATH commissioned the authors to conduct a national survey of large production home builders in order to define characteristics of innovative residential builders, including how and where they make the decisions to use new technologies and materials. In this study, large production home builders are defined as companies building 200 or more single-family residential units per year from stock plans rather than custom designs.

The authors designed a survey instrument based on a review of literature relating to innovation in the construction industry and pre-survey interviews with industry contacts. Questions that would address the seven factors influencing innovation shown in Figure 1 were developed.

Since respondents would be representatives of large national or regional builders, information obtained from corporate headquarters could be different from information obtained from an operations office serving only some market areas. This relationship between corporate and field or operations offices became an additional area of interest falling under numerous categories. The survey then became a potential vehicle for exploring this relationship. Two versions of the survey instrument were produced: one targeted for respondents working in the corporate headquarters and one for respondents working in field operations or market area offices.

Questionnaires (either a corporate version or an operations version) were sent to approximately 1,700 NAHB individual members affiliated with the 400 largest builders in the United States. To increase the response rate, telephone interviews were conducted based on a shortened version of the questionnaire. In addition, an online version of the questionnaire was offered. The results are based on 84 responses, 42 corporate and 42 operations level.

To bring a qualitative perspective to the information collected through the mailed surveys, telephone interviews, and online responses, three concentrated personal interviews were conducted. Questions based on the results of the quantitative survey were asked of representatives whose quantitative responses indicated a high level of interest in innovation.

Survey Instrument

To determine the characteristics of innovative production builders in the United States, a questionnaire was developed to measure the variables that were identified in the literature review as influencing technology adoption, as well as those obtained from pre-survey interviews with production builder staff.

Two versions of the questionnaire were developed, one for respondents working in corporate headquarters and one for respondents working in field or operations offices. The two versions had slightly different wording in the introduction, which explained the purpose of the survey. Questionnaires for both respondent groups explained that additional questionnaires were being sent to both operations level and corporate offices for their respective firms. For the most part, the same questions were asked of both the corporate respondents and the operations respondents,

though the operations questionnaire had an additional series of questions asking for basic information about the operations level office.

The questionnaire contained three major parts, plus the one additional part for operations level respondents only. These included:

1. *New Building and Construction Products* asked about influences generally affecting the use of new building and construction products, materials, and practices (decision factors, information sources, perceived benefits, costs, and impediments) and covered both the company's activities and the respondent's personal opinions regarding new building and construction products, materials, and practices.

2. *Use of New Building and Construction Products, Materials, and Practices* sought information about adoption of specific new building and construction products, materials, and practices. Corporate level respondents were asked to answer for their company and the operations level respondents to answer for their office. First, a list of technologies was provided and respondents were asked about their use of each of those technologies. Respondents were asked to write down one specific technology (the first technology the respondent indicated they currently use). Three questions followed, which asked the respondents to refer to the one specific technology in answering those questions.

3. *Corporate Characteristics* asked for information about the company as a whole related to human resources, organizational structure, market context, and organizational culture. Both operations level and corporate level respondents were asked to respond for the company as a whole. Questions posed to the corporate respondents but omitted on the operations questionnaire were: departments at the corporate level, corporate profit projections, and number of full time employees.

4. *Characteristics of the Office Where you Work* (asked of operations level respondents only) asked for information about the operations level office regarding human resources, organizational structure, market context, and organizational culture.

The questions on the survey instrument were purposely organized to flow methodically for respondent convenience rather than by the factors identified in Figure 1. For the purposes of this discussion, however, questions are categorized according to their related typology factor in Figure 1. A brief description of each question is provided followed by the corresponding question number on the corporate questionnaire and the corresponding question number on the operations questionnaire. For the actual questions and possible responses, see Appendix B (corporate) and Appendix C (operations).

- **Organizational Structure**
  - The number of homes built in the United States in 2004 (Q16; Q1 and Q25).
  - The market areas your company serves (Q15; Q24).
  - Proportion of single-family units that are a specific type (Q17; Q2 and Q26).

- Departments your company has at the corporate level (Q21; Q3).

- Ways your company supports research and development for new building products and processes (Q19 and Q20; Q28 and Q29).

- **Organizational Culture: Influence and Locus of Decisionmaking**
  - Level of the company that identifies and approves use of a new type of siding (Q1; Q10).

  - Whether anyone would be considered an advocate of innovation (Q3; Q12).

  - Professional positions with significant influence over decision to use a new building material and professional position making final decision (the respondents rated the influence of various positions in deciding to use a new building material and identified the positions participating in the final decision to use the material) (Q4 and Q12; Q13 and Q21).

  - Where in the company (national, regional, local) decisions are made (Q18; Q27).

- **Organizational Culture: Corporate Philosophy and Business Strategy**
  - Increase in net profits over the next 5 years (Q22; Q4).

  - Degree of likelihood (not likely to very likely) your company will invest money to meet the following objectives in the next 5 years (Q24; Q8 and Q30).

  - Degree of contribution (low, average, high) of business practices to your company's success relative to your competitors (Q25; Q9 and Q31).

  - Company approach toward selecting new building and construction products, materials, and practices (Q2; Q11).

  - Involvement in Master Planned Communities (operations only Q7).

- **Human Resources**
  - The number of employees (Q23 and Q6).
  - Use of union labor (operations only Q5).

- **Market Context**
  - The perceived level of influence of factors in the use of new materials and building techniques in your work over the next 10-20 years (Q9; Q18)

- **Industry Characteristics**
  - The level of influence (no influence to high influence) of information sources (Q5 and Q13; Q14 and Q22).

- Importance of cooperation from sources in adopting new building and construction products, materials, and practices (Q8; Q17).

- **Technical and Economic Attributes of Specific Innovations**
  - The degree of agreement with statements in your individual consideration of new building products, materials, and practices (Q6; Q15).
  - The main perceived benefits from adopting new building and construction products, materials, and practices (Q7; Q16).
  - The impact of decision factors in deciding to use new building and construction products, materials, and practices (Q14; Q23).

Population and Sample

The questionnaires were mailed to over 1,700 large production builders (342 to representatives of corporate offices and the remaining to representatives of field or operations offices) using procedures described in the methodology section (see Appendix A for a detailed discussion of methodology). The sample of large production builders was drawn from the NAHB membership list and was stratified by company size (all individual members associated with one of the 400 largest U.S. builders, otherwise referred to as a top 400 builder). It was assumed that the top 400 builders would include all builders within the definition for the study (a large production builder was defined as a company that builds 200 or more single-family residential units in a year). As a precaution, respondents whose company did not meet our definition were asked to return the questionnaire to us incomplete.

Methods and Response Rate

Our results are based on a total of 84 responses. Using Dillman's Total Design Method for mailed surveys (which involved sending the questionnaire accompanied by a personalized letter, sending a reminder postcard, and sending a second questionnaire and personalized letter), 58 completed mail surveys were received. In response to slow returns after the first mailing and reminder postcard, online versions of both questionnaires were developed and the second mailing offered instructions for electronic completion as an option. Four online completions were received. To further increase the response rate, telephone interviews with selected respondents who did not return a completed mail survey or respond online were conducted, specifically targeting corporate respondents from the top 100 companies. They were called and asked to complete a shortened version of the mailed questionnaire via telephone. The phone interviews resulted in 15 completed phone interviews, and an additional seven online completions also resulted from of the phone contacts.

Through the combined methods of the mailed survey, online option, and telephone interviews, responses were obtained from representatives of 42 corporate offices and 42 operations level offices (that the sample sizes are equal is coincidental).

Following the general description of the survey responses in the next section on Survey Results, a descriptive analysis of building technology innovation is introduced.

Key Definitions and Variables

To set the stage for the discussion of survey responses, certain ideas and variables need to be clarified and defined.

- **Innovative Technologies**

As part of the survey, the respondents were asked about their use of 11 technologies (products and processes). These are listed here and are more fully described in technical detail in Appendix D.

1. Structural Insulated Panels (SIPs).
2. Laminate flooring.
3. Spray-in foam insulation (Icynene).
4. Pre-cast concrete foundation walls.
5. Enterprise Resource Planning software.
6. Factory built wall or floor panels.
7. Wood/plastic composite or cellular PVC exterior trim.
8. GPS land tracking.
9. Web-based scheduling.
10. Wood I-joist structural floors.
11. Handheld PCs or PDAs for project scheduling & management.

"Innovative" technologies and products with a broad range of market penetration were purposely chosen (some technologies were known to be widely used, and some were known to be used by relatively few builders). Based on studies conducted by the NAHBRC (a January 2005 survey and a 2002 study of data technologies), four of these technologies or products (structural insulated panels, laminate flooring, spray-in foam insulation, and pre-cast concrete foundation walls) were in the early stage of diffusion with 2% or less market penetration; three (Enterprise Resource Planning software, factory built wall or floor panels, and wood/plastic composite or cellular PVC exterior trim) were in a middle stage of diffusion with 5 to 9% market penetration; and four (GPS land tracking, Web-based scheduling, wood I-joist structural floors, and handheld PCs or PDAs for project scheduling & management) were in a late stage of diffusion with more than 26% market share.

In analyzing the results, however, the definition of an innovative product or technology could include anything as long as it was "new" to the adopter. This definition does not distinguish between mature products that have already achieved a high level of market penetration (and might be subject to replacement by newer products) and those that are new to the market and have low levels of market penetration. The "newness" of a product can also be difficult to measure accurately since some products go through a longer process of refinement before they can be fully commercialized. For example, structural insulated panels (SIPs) have been available for more than two decades, but they have not reached full market penetration. So while the list of 11 technologies (see Appendixes B and C, Part on Use of New Building and Construction Products, Materials, and Practices) was developed based on prior studies and knowledge of market penetration, the operational definition of innovation in this study is based on the degree of market penetration among the respondents of this study.

- **Innovation Measures**

Rather than utilize the pre-selection criteria for product innovativeness, the overall percent of respondents who were currently using or had tried but discontinued using a product was used in order to classify the innovativeness of the products. Determined by the product's degree of market penetration, three new categories resulted: early-stage, middle-stage, and late-stage innovations. Four products were classified as early-stage innovations (SIPs, pre-cast concrete foundation walls, Enterprise Resource Planning software, and GPS land tracking) based on a market penetration of approximately 25% or lower. Five products were classified as middle-stage innovations (spray-in foam insulation, factory built wall or floor panels, wood/plastic composite or cellular PVC exterior trim, Web-based scheduling, and handheld PCs or PDAs) based on a broad middle range of market penetration (from 30%-75%), and two products above 75% market penetration were classified as late-stage innovations (laminate flooring and wood I-joist structural floors).

Two related measures of innovation were created for each respondent. The first innovation measure has three categories identifying (1) those respondents who never tried any of the four early-stage technologies (*N*=47 or 56%); (2) those respondents who had used only one of the four early-stage technologies (*N*=22 or 26%); and (3) those respondents who had used two to four of the early-stage technologies (*N*=15 or 18%).[2] Cross-tabulations and chi-square tests of this innovation measure with other measures in the survey were prepared to help identify statistically significant associations between these measures and innovation. Only statistically significant associations (at the .10 or lower level) are reported in the following analysis of the results of the survey.

The second innovation measure is a weighted index of the degree to which the respondents used any of the products. Early-stage innovations have the most weight (4) in the index; middle-stage innovations have a weight of 1; and the two late-stage innovations have a weight of 0. The maximum score for this innovation index is 21 (16 points for the four early-stage innovations and 5 points for the five middle-stage innovations). A similar weighting scheme was used to calculate the innovation index used in the 2003 study report (Koebel et al. 2003).

The highest score for the innovation index was one company with 19 (using all four early-stage innovations and three middle-stage innovations). Three companies used three of the early-stage innovations and had index scores from 15 to 17. Eleven companies used two of the early-stage innovations and had index scores from 9 to 13. Twenty-two companies used one of the early-stage innovations and had index scores from 5 to 9. The remaining 47 companies did not use any of the early-stage innovations and had index scores from 0 to 4. The innovation index is used in a multivariate analysis of innovation reported in the Survey Results section.

Comparison with 2003 Study of Small to Midsize Builders

To put the results of this study in perspective, a section that compares the responses of large production builders with those of small to midsize builders from an earlier, similar study (Koebel et al. 2003) is included, removing builders that reported building 200 or more residential units in

[2] Since two of the four early-stage innovations involve information technology, they were checked to see if they occurred together and would thus bias the innovation measure. They appear to be independent.

a year from the prior study's database so that only small to midsize builders would be compared to the group of large builder respondents. There were 216 respondents in the 2003 sample after removing the larger builders. For a deeper discussion of that survey, refer to Koebel et al. 2003.

Qualitative Assessment

While the quantitative assessment of diffusion of innovation for large production builders provided valuable information, it also presented issues needing further clarification. Following an initial analysis of the data collected from the survey instrument, questions were formed whose answers could help give a qualitative perspective to some of the results. Considering responses from a number of survey questions, a measure of interest in innovation was derived. A list of corporate respondents with high interest scores was compiled, and personal interviews were subsequently arranged with three high-level corporate respondents and were conducted on-site. These interviews not only helped make sense of the quantitative data but also provided key information beyond that which had been collected from the mailed survey (for further methodological discussion, see Appendix A). This information is presented in the section on Qualitative Results.

Summary

Both survey instruments as well as an expanded methodology are presented in appendixes to this report: an extensive methodological discussion is included in Appendix A; Appendix B provides the corporate office questionnaire; and Appendix C provides the operations-level office questionnaire.

SURVEY RESULTS

The survey results are presented in five sections covering the products and technologies included in the survey: a description of survey responses including significant relationships between the variables identified in the typology and model presented in Figures 1[3] and 2; a descriptive analysis of building technology innovation by production builders including significant relationships between the variables identified in the typology and model presented in Figures 1 and 2; a multivariate analysis of building technology innovation by production builders; and a comparison of the 2003 survey results for small builders with the results from the current survey of larger production builders including significant relationships between the variables identified in the typology and model presented in Figures 1 and 2.

Depending on the question, results are presented below combining the corporate and operations level responses except where noted, either because of strong variances between the two or because the analysis requires a distinction. It should be noted that there was little difference between the answers of corporate and operations respondents on most questions. Any important differences are reported in the discussion. On some questions, missing data resulted in a reduced number of responses.

[3] The factors presented in Figure 1 are discussed in a different order in the Survey Results section of this report to demonstrate that these issues work from the industrial level, to the firm level, to the level of the innovation in question.

Products and Technologies Included in the Survey

The primary objective of the survey was to learn about the diffusion of innovation among production home builders. The survey covered 11 products and process technologies with various levels of market penetration (Table 1) among production home builders. The first tier of products or process technologies (SIPs, pre-cast concrete foundation walls, Enterprise Resource Planning software, and GPS land tracking), with market penetration (previously tried or currently using) of 25% or less, represents the most innovative or early-stage innovations based on the combined responses for currently using and tried but discontinued. The second tier of products or process technologies (spray-in foam insulation, factory built wall or floor panels, wood/plastic composite or cellular PVC exterior trim, Web-based scheduling, and handheld PCs or PDAs), with approximately 30% to 75% market penetration, represents middle-stage innovations. The third tier of products or process technologies (laminate flooring and wood I-joist structural floors) represents late-stage innovations.

Table 1. Production Home Builders by Adoption of New Building Products

Products	Never Tried	Tried but Discontinued	Currently Using
Structural Insulated Panels (SIPS)	93%	4%	4%
Pre-cast concrete foundation walls	83%	2%	14%
Enterprise Resource Planning software	82%	1%	17%
GPS land tracking	74%	-----	27%
Spray-in foam insulation (Icynene)	67%	15%	18%
Handheld PCs or PDAs for project scheduling & management	42%	6%	52%
Web-based scheduling	41%	2%	57%
Factory built wall or floor panels	38%	12%	50%
Wood/plastic composite or cellular PVC exterior trim	37%	7%	55%
Laminate flooring	23%	21%	57%
Wood I-joist structural floors	9%	11%	80%

Corp and operations combined. Operations asked to answer for their market area office.
Depending on the question, *N*=82 to 84

See Appendix B, Q10 and Appendix C, Q19 for complete wording of questions.

General Survey Responses

- **Organizational Structure**

About a third of the total respondents built between 1,000 and 10,000 units, and 5% were among the very largest builders in the nation.

As intended, the respondents represent relatively large firms who mainly build single-family detached houses and townhouses. Fewer than 1 in 5 respondents had annual production below 250 units (Table 2). Since operations level respondents were asked to answer for their market area office, the size of the corporations is understated. Whereas 35% of corporate respondents reported production of 2,500 or more units,

only 6% of the operations respondents reported production of this magnitude. Nonetheless, about a third of the total respondents built between 1,000 and 10,000 units, and 5% were among the very largest builders in the nation. Nearly all of the respondents built single-family detached units and nearly 60% built townhouses, but only a quarter built apartments or condo units.

Table 2. Number of Units Built by Building Type

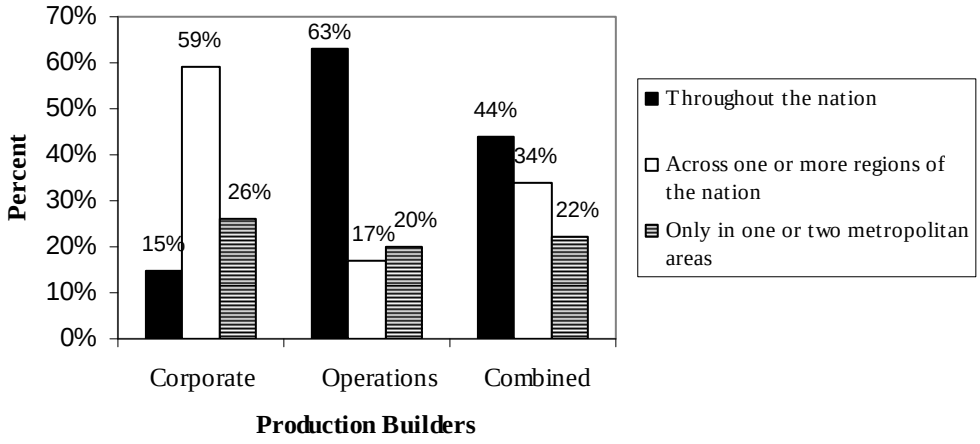
Number of units	Single-family detached	Townhouse or duplex	Apartment or condo	Total units
0	6%	41%	75%	-----
1-249	22%	34%	12%	18%
250-999	37%	18%	6%	39%
1,000-2,499	22%	3%	3%	26%
2,500-9,999	9%	4%	4%	12%
10,000+	4%	0%	0%	5%

Corp and operations combined. Operations asked to answer for their market area office.
N=68

See Appendix B, Q16 and Appendix C, Q1 for complete wording of questions.

Nearly half of the respondents were from companies operating throughout the nation (Figure 3). Although there are not many national home builders (at the corporate level this category only accounted for 15% of respondents), the extensiveness of their operations resulted in national companies having nearly two-thirds of the operations level respondents. Between one-fourth and one-fifth of the respondents operate in only one or two metropolitan areas.

Figure 3. Production Home Builders by Market Area Served

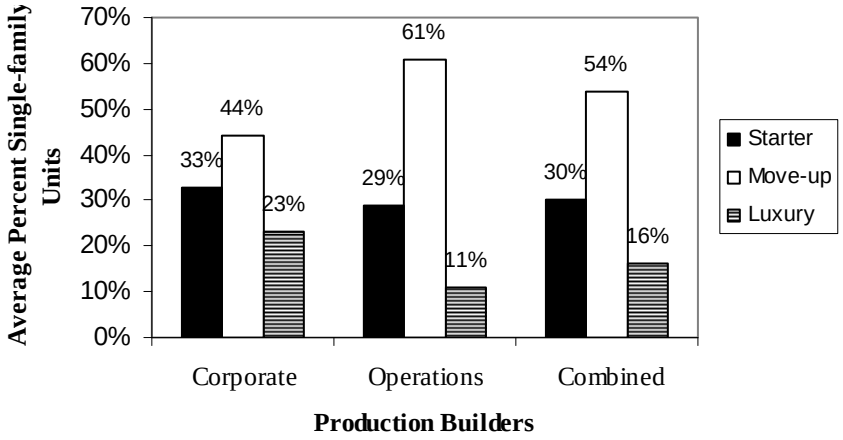


Operations asked to answer for company as a whole.
Corp *N*=26, operations *N*=42, combined *N*=68

See Appendix B, Q15 and Appendix C, Q24 for complete wording of questions.

The respondents serve every market type, from starter to luxury (Figure 4). About half build for the move-up market and one-third build for starter homes, and 16% build luxury homes.

Figure 4. Production Home Builders by Average Percent of Single-family Units Built



Operations asked to answer for their market area office.
Corp *N*=26, operations *N*=40, combined *N*=66

See Appendix B, Q17 and Appendix C, Q2 for complete wording of questions.

Based on corporate and operations respondents, most of the companies responding to the survey had Finance, Marketing, and Purchasing Departments (Table 3). Corporate respondents were more likely to identify an Information Technology Department (81%) than did operations respondents (45%), but corporate IT departments might be less visible at the operations level.

Table 3. Production Home Builders by Departments within Company

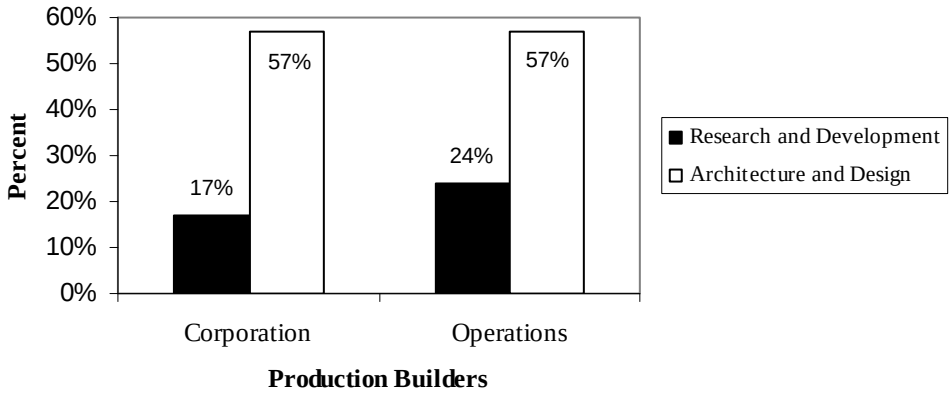
Departments within Company	Corp	Operations
Research and Development	17%	24%
Architecture and Design	57%	57%
Information Technology	81%	45%
Finance	95%	86%
Purchasing	81%	93%
Marketing	88%	98%
Engineering	36%	21%

Operations asked to answer for their market area.
Corp *N*=42, operations *N*=42, small builders *N*=214 (those building under 200 units per year)

See Appendix B, Q21 and Appendix C, Q3 for complete wording of questions.

This organizational structure gives these companies substantial resources in business operations, but they are less likely to have internal departments dealing with the technical aspects of homebuilding. Among departments dealing more directly with building science, the most frequent is Architecture and Design (A&D). This was reported by over half of the corporate and operations level respondents. Engineering and Research and Development (R&D) Departments were reported by about a quarter to a third of the respondents (Figure 5).

Figure 5. Production Home Builders by R&D and A&D Departments



Operations asked to answer for their market area.
Corp *N*=42, operations *N*=42, small builders *N*=214 (those building under 200 units per year)

See Appendix B, Q21 and Appendix C, Q3 for complete wording of questions.

Although formal R&D departments are found infrequently, production companies can support technology development in a variety of other ways. Most of these companies have a technology champion who keeps others abreast of innovative products and processes (Table 4). About half support R&D efforts at the regional or local operational levels and use technology innovation as part of their marketing strategy, which could help push R&D support down to the level where opportunities and needs for new products often originate. Partnerships with manufacturers, which were reported by two-thirds of the respondents, provide another avenue for capturing greater technical capacity in building science; companies also use these partnering arrangements for product branding and advertising.

Table 4. Production Home Builders' Support of R&D for New Building Products or Processes

Support of Research and Development	Corp	Operations	Combined
Has a champion within the company to keep abreast of innovative products and processes	76%	68%	72%
Supports regional or local operations in R&D efforts	43%	53%	48%
Uses innovative products or processes as part of our marketing strategy	50%	60%	55%
Has formed partnerships with manufacturers	62%	70%	66%
Does not support research and development of new building products or processes	12%	18%	15%

Corp and operations asked to answer for the company as a whole.
Corp *N*=42, operations *N*=40, combined *N*=82

See Appendix B, Q20 and Appendix C, Q29 for complete wording of questions.

The lack of a formal R&D department does not mean that the company does not support R&D in more informal ways—indeed, a majority of the respondents indicated that their companies do support R&D in some fashion, despite the lack of a formal R&D department. Very few

A majority of the respondents indicated that their companies do support R&D in some fashion, despite the lack of a formal R&D department…. Perhaps the best description of R&D within the industry is that it is prevalent as an informal activity but is only emerging as an organized effort.

respondents (15%) indicated that their companies do not support R&D. Perhaps the best description of R&D within the industry is that it is prevalent as an informal activity but is only emerging as an organized effort.

- **Organizational Culture: Influence and Locus of Decision-Making**

There are multiple points of influence and dispersed authority to make decisions about innovations in the companies responding to this survey… Although the authority to approve a new technology is more centralized than influence over that decision, in a majority of firms the decision is made at or shared between the local and regional levels.

The current survey demonstrates that there are multiple points of influence and dispersed authority to make decisions about innovations in the companies responding to this survey. Among these production builders, the responsibility for identifying a new type of siding (used as an example of innovation) is shared across the corporation from the corporate level to the local level (Table 5). Although the authority to approve a new technology is more centralized than influence over that decision, in a majority of firms the decision is made at or shared between the local and regional levels (Figure 6).

Table 5. Locus of Decisions on Identifying and Approving a New Type of Siding

	Identifies		Approves	
Locus	Corp	Operations	Corp	Operations
Corporate level	15%	25%	40%	33%
Sub-corporate level				
Regional level	19%	0%	8%	5%
Local level	27%	45%	28%	35%
Shared between headquarters and regional offices	31%	18%	20%	10%
Shared between regional and local offices	8%	13%	4%	18%

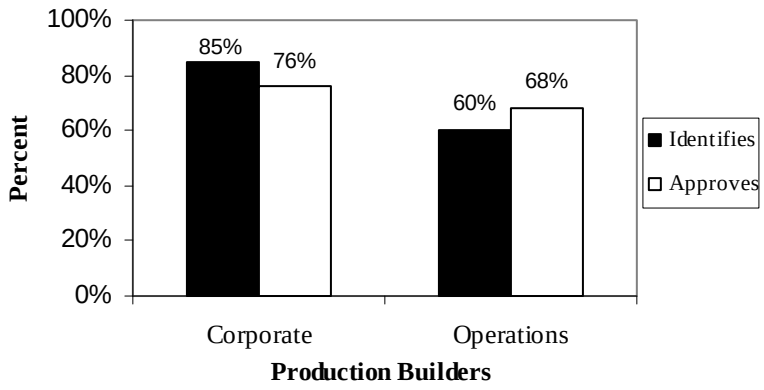
Operations asked to answer for their market area office.
Corp *N*=26 on Identifies and *N*=25 on Approves, operations *N*=40 on both Identifies and Approves

See Appendix B, Q1 and Appendix C, Q10 for complete wording of questions.

Many of the production builders participating in the current survey have a strong technology advocate within the firm.

Many of the production builders participating in the current survey have a strong technology advocate within the firm (Figure 7). Corporate respondents were more likely to identify technology advocates at the corporate level, but a majority also knew of technology advocates at the operations level. Operations respondents were just as likely to identify operations level technology advocates as they were corporate level advocates, perhaps reflecting better knowledge of their own operational level.

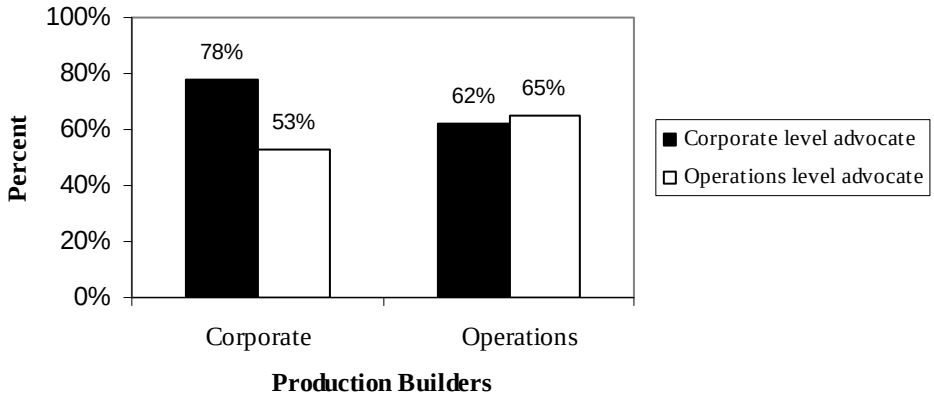
Figure 6. Production Home Builders by Sub-Corporate Locus of Decisions on Identifying and Approving a New Type of Siding



Sub-corporate excludes national or corporate level. Sub-corporate includes regional, local, or any combination of company levels.
Operations asked to answer for their market area office.
Corp *N*=26 on Identifies and *N*=25 on Approves, operations *N*=40 on both Identifies and Approves

See Appendix B, Q1 and Appendix C, Q10 for complete wording of questions.

Figure 7. Production Home Builders with a Strong Advocate of Innovation by Company Level



Corp *N*=41 on corporate level and *N*=40 on operations level, operations *N*=34 on corporate level and *N*=37 on operations level

See Appendix B, Q3 and Appendix C, Q12 for complete wording of questions.

Table 6 shows that influence and decision authority on innovative products among large production builders is not controlled by the CEO or a board member (even though in some companies the founding owner serves as chairman of the board). Obviously, these positions have influence, but the sources of influence and decisions are spread across departments at the corporate and operations levels.

Table 6. Production Home Builders by Position with Significant Influence over Decision to Use a New Type of Siding

Position	Significant Influence		Final Decision	
	Corp	Operations	Corp	Operations
Board Member	19%	5%	4%	0%
Chief Executive Officer	52%	12%	30%	12%
Chief Financial Officer	11%	0%	0%	0%
Head of Research & Development	22%	32%	7%	10%
Head of Purchasing	93%	54%	37%	34%
Chief Designer/Architect	44%	44%	0%	10%
Chief Engineer	4%	7%	0%	2%
Head of Sales/Marketing	41%	27%	4%	0%
Others in corporate offices	22%	5%	15%	5%
Regional Office Dir.	11%	24%	0%	7%
Regional Purchasing Dir.	48%	46%	7%	27%
Regional Senior Project Mgr.	26%	12%	0%	0%
Regional Project Mgr.	15%	15%	0%	0%
Others in regional offices	7%	5%	0%	0%
Local Office Director	7%	44%	4%	27%
Local Purchasing Dir.	48%	76%	7%	24%
Local Senior Project Mgr.	19%	46%	0%	7%
Local Project Mgr.	22%	42%	0%	0%
Others in local offices	11%	37%	0%	15%

Corp *N*=27, operations *N*=41 on Significant Influence, corp *N*=21, operations *N*=22 on Final Decision

See Appendix B, Q4 and Appendix C, Q13 for complete wording of questions.

Table 6 and Figure 8 reveal that while R&D and A&D departments frequently have significant influence over decisions on new products, they seldom make the final decisions on adoption. These departments provide depth in technical aspects of building systems, but decisions are made by others with broader responsibilities for business operations.

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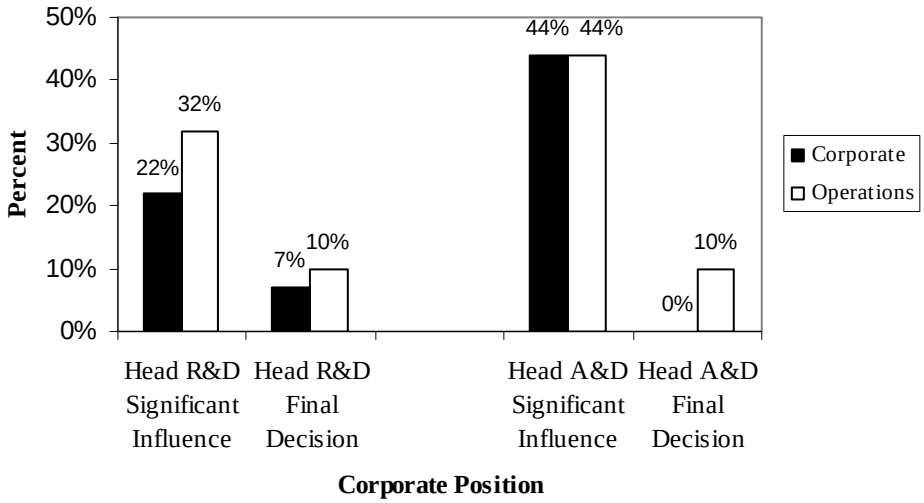
Purchasing departments play a large role in influencing and making decisions on new products and materials among these production builders.

Purchasing departments play a large role in influencing and making decisions on new products and materials among these production builders. The corporate head of purchasing was identified by 93% of the corporate respondents and 54% of the operations respondents as a

Figure 8. Head R&D and A&D with Significant Influence in Choosing a New Type of Siding

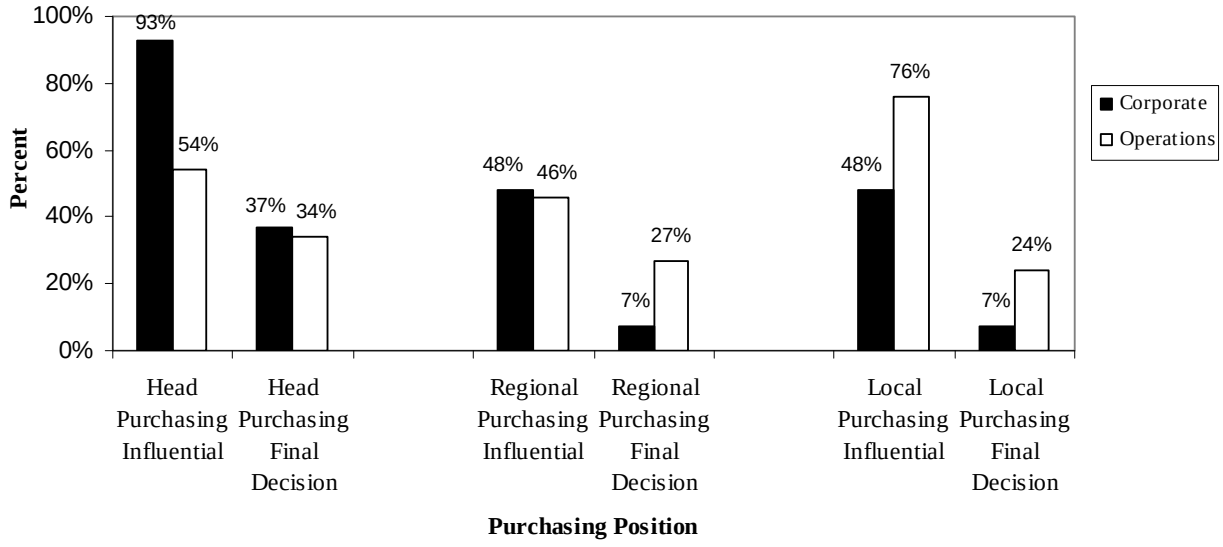


Corp *N*=27, operations *N*=41 on Significant Influence, corp *N*=21, operations *N*=22 on Final Decision

See Appendix B, Q4 and Appendix C, Q13 for complete wording of questions.

significant influence on decisionmaking (Figure 9). In addition, regional purchasing directors were identified as having significant influence by about half of the corporate and operations respondents. Local purchasing directors were just as frequently mentioned by corporate respondents and were identified as having significant influence over new product decisions by 76% of the operations respondents.

Figure 9. Purchasing Position with Significant Influence in Choosing a New Type of Siding



Corp *N*=27, operations *N*=41 on Significant Influence, corp *N*=21, operations *N*=22 on Final Decision

See Appendix B, Q4 and Appendix C, Q13 for complete wording of questions.

- **Organizational Culture: Corporate Philosophy and Business Strategy**

Growth is an important element of a company's business strategy. The corporate respondents among larger production builders reported aggressive plans for growth (Table 7). Although the operations level included more diverse expectations about growth, three-fourths reported plans for similarly aggressive growth in their market areas.

Table 7. Production Home Builders by Growth Plan

Growth Plan	Corp	Operations
Plan to increase net profits over the next 5 years:		
Expect reduction in net profits due to downsizing	0%	2%
Net profits less than 5% a year	0%	10%
Net profits 5-10% a year	68%	29%
Net profits more than 10% a year	32%	57%
No specific plan for growth	-----	2%

Operations asked to answer for their market area office.
Corp *N*=25, operations *N*=42

See Appendix B, Q22 and Appendix C, Q4 for complete wording of questions.

In terms of objectives related directly to construction, the highest ratings (72%-81%) were given to reducing construction defects and call-backs, improving subcontractor dependability, and improving the style and attractiveness of the homes they build.

The production builders in the current survey were asked to rate the likelihood of investing time and money over the next five years toward a variety of management and building technology objectives. In terms of objectives related directly to construction, the highest ratings (72%-81%) were given to reducing construction defects and call-backs, improving subcontractor dependability, and improving the style and attractiveness of the homes they build (Table 8). Again, the themes of quality and marketability come through clearly. Cost reduction and productivity (reduced cycle time) were rated as very likely by 61% or 62% of the respondents. Less than half of the production respondents rated investments in building technology as a means to improve market share as very likely, and a slightly smaller group rated investments in R&D as very likely.

Production builders' business models are revealed somewhat by identifying business strategies that they see as contributing highly to their success (Table 9). Three-fourths of these firms emphasize customer service in terms of quickly addressing problems in new homes. This aspect of customer service rates in importance well above the next two items, providing amenities within the communities they develop and offering high quality architectural design (Figure 10). Structural quality and better mechanical systems, two building technology items, were rated by half of the respondents as contributing highly to the company's success, and fewer than half rated homes with desirable finishing features this way. One-third, a good-size minority of these firms, rated energy-efficient, environmentally sensitive homes as a high contributor to success. Only 19% saw investing in the development of new building technologies as contributing highly

to success, and 22% saw it as having low contribution. The only item of less importance was providing a lower cost per square foot home.

What emerges from this is a dominant business strategy oriented towards customer service, community design and house design. From one-fifth to one-half of the respondents include core aspects of building technology as part of their business strategies.

What emerges from this is a dominant business strategy oriented towards customer service, community design and house design.

Table 8. Production Home Builders Likely to Invest in Business Objectives

Objectives	Not Likely	Somewhat Likely	Very Likely
Likelihood of investing time and money over the next 5 years in:			
Improving style and attractiveness of our homes	5%	23%	72%
Improving subcontractor dependability	5%	19%	76%
Reducing costs through use of new building and construction products, materials, and practices	2%	36%	62%
Reducing cycle times	7%	31%	61%
Improving our ability to purchase and develop the best land	7%	10%	83%
Protecting or improving market share through use of new building and construction products, materials, and practices	6%	45%	49%
Reducing construction defects/ call-backs	4%	16%	81%
Reducing overhead costs	4%	38%	58%
Offering the best mortgage financing to homebuyers	21%	31%	48%
Researching new products, materials, and practices	11%	43%	46%
Educating buyers about new technologies	18%	51%	31%

Corp and operations combined. Operations asked to answer for their market area office.
Depending on the question, *N*=83 to 84 on corp and operations combined

See Appendix B, Q24 and Appendix C, Q8 for complete wording of questions.

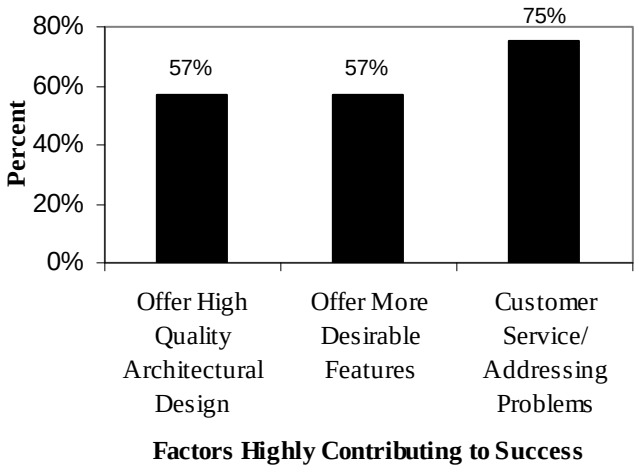
Table 9. Production Home Builders by Factors Contributing to Success

Factors	Low Contribution	Average Contribution	High Contribution
We provide a lower cost per square foot home	34%	46%	19%
Our homes have more desirable features (for example, countertops and trim work)	4%	50%	46%
Our developments have more desirable features like public areas, trails, bike-paths, gated access	7%	35%	57%
We offer energy-efficient, environmentally sensitive homes	13%	52%	35%
Our homes have higher structural quality and better mechanical systems	3%	46%	51%
We have a strong reputation for quickly addressing problems in new homes	2%	24%	75%
Our land acquisition capabilities and ability to gain government approvals for development	6%	50%	44%
We offer high quality architectural design	4%	38%	57%
We invest in the development of new building technologies	22%	59%	19%

Corp and operations combined. Operations asked to answer for their market area office.
Depending on the question, *N*= 27 to 68

See Appendix B, Q25 and Appendix C, Q9 for complete wording of questions.

Figure 10. Top Three Factors Contributing to Success



Corp and operations combined. Operations asked to answer for their market area office.
Depending on the question, *N*= 27 to 68

See Appendix B, Q25 and Appendix C, Q9 for complete wording of questions.

Table 10 provides responses to another question about business strategy more specifically targeting building technology innovation. Two of the responses reflect conservative stances toward innovation: waiting until other builders demonstrate the success of new products and encouraging homebuyers to stick with "tried and true" products and materials. Two other questions represent strategies that embrace innovation: being the first to offer new and innovative building products and distinguishing themselves as creative by offering distinctive and unique materials and products.

Among corporate respondents, about half were clearly in the "second-mover" position relative to innovation in building technology, and between one-third and one-half endorsed innovation and creativity as part of their approach to selecting new building and construction products, materials, and practices.

The answers reveal several interesting patterns. Among corporate respondents, about half were clearly in the "second-mover" position relative to innovation in building technology, and between one-third and one-half endorsed innovation and creativity as part of their approach to selecting new building and construction products, materials, and practices. Both stances were more likely among corporate respondents than operations level respondents, although they express the same level of support for being a first-mover relative to new building products (about one-third).

Table 10. Production Home Builders by Approach to Selecting New Building and Construction Products, Materials, and Practices

Approach	Corp	Operations
We like to wait until other builders have successfully offered new building and construction products, materials, and practices before we use them	48%	22%
We are often the first to offer a new and innovative building product or system	31%	29%
We encourage homebuyers to stick with "tried and true" materials and products	50%	15%
Our goal is to set ourselves apart, to be creative, and to offer materials and products that are distinctive and unique	52%	32%

Operations asked to answer for their market area.
Corp *N*=42, operations *N*=41

See Appendix B, Q2 and Appendix C, Q11 for complete wording of questions.

- **Market Context**

Perspectives about market trends that will influence the use of new materials and techniques over the next ten to twenty years can point to emerging business strategies among these builders (Table 11). Perhaps the single most important trend that could affect future innovation in building technology is the increase in energy costs. Seven of ten respondents rated energy costs as influencing building technology innovation over this time span. In addition, our qualitative interviews with builders confirmed that energy costs will likely play a major role in pushing technology innovations into the market.

Perhaps the single most important trend that could affect future innovation in building technology is the increase in energy costs

Table 11. Factors Influencing the Use of New Building and Construction Products, Materials, and Practices over the Next 10-20 Years

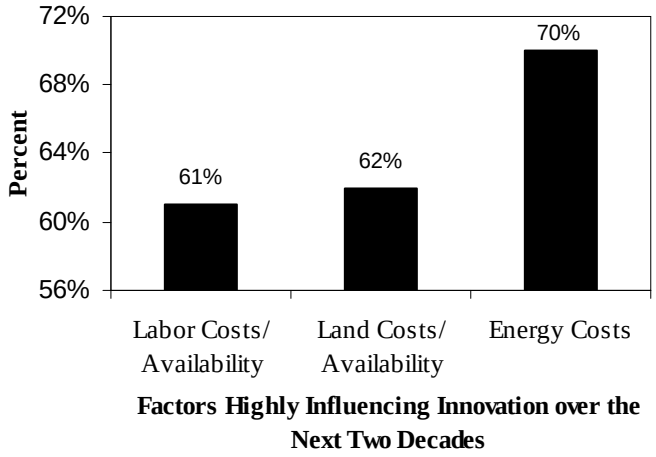
Factors	Low Influence	Average Influence	High Influence
Energy costs	1%	29%	70%
Land costs/availability	10%	29%	62%
Labor costs/availability	2%	37%	61%
Labor quality	5%	40%	56%
Competition from large national builders	6%	41%	54%
Cost savings achieved through technology	8%	46%	45%
Higher quality buildings created through technology advances	8%	49%	43%
Government regulations	8%	54%	38%
More centralized control over production within our company	25%	39%	36%
Consumers becoming more aware of building technologies	7%	63%	30%
Decentralized, local decisions over production	39%	55%	6%
Innovation by smaller builders	42%	51%	7%

Corp and operations combined. Corp and operations asked to answer from an individual perspective.
N=84

See Appendix B, Q9 and Appendix C, Q18 for complete wording of questions.

Also identified as highly influential in building technology innovation over the next two decades were land costs/availability and labor costs/availability with nearly two thirds of the survey respondents rating these trends as having high influence (Figure 11). Labor quality and competition from large national builders were other trends identified by half or more of the survey respondents as highly influential in building technology innovation over the next 10 to 20 years.

Figure 11. Top Three Factors Influencing the Use of New Building and Construction Products, Materials, and Practices over the Next 10-20 Years



Corp and operations combined. Corp and operations asked to answer from an individual perspective. *N*=84

See Appendix B, Q9 and Appendix C, Q18 for complete wording of questions.

As noted earlier, the respondents did not include cost savings as a primary business strategy. They compete more on quality, land, community amenities and customer services than on price. Only a third of the respondents identified government regulations, consumer awareness of building technologies, and centralized control over production as highly influencing building technology innovation over the next twenty years, but over 90% rated government regulations and consumer awareness as having average to high influence. In addition, these larger builders saw innovation by smaller builders as having relatively low influence in their own use of technology innovation.

- **Industry Characteristics**

Technology scanning is a relatively new strategy for companies to keep abreast of innovations that they can exploit to improve operations, increase profits, expand market share, or develop new markets. Since few home builders invent or create new homebuilding products or technologies, they are primarily reliant on internal and external sources of information about technology advances.

Production builders rated the following information sources as having a high level of influence on keeping them up-to-date on building and construction products, materials, and practices: local offices within the company; subcontractors (more so at the operations level than corporate level); and manufacturers (Table 12 and Figure 12). Wholesalers and suppliers also were identified by nearly a third of the survey respondents as having a high level of influence on keeping them up-to date. Production builders' reliance on local offices (as well as subcontractors) as a source of information on new products fits their corporate culture of decentralization, particularly related to construction. They also appear to rely somewhat more on manufacturers than on suppliers, perhaps due to the direct access large builders have to manufacturers. Larger builders are much less reliant on other builders, trade shows, trade publications and technology transfer programs to keep them informed about new products. Universities are the least influential sources of information about new building and construction products, materials, and practices.

Residential construction requires cooperation among multiple parties, none of which controls the entire process. The production home builder manages the assembly of the product—the house—at the final site. Although the degree of site assembly varies based on the number of pre-assembled components, homebuilding relies on a complex network of companies, including manufacturers, suppliers, corporate offices of the production builder, regional and local offices of the production builder, project/construction managers, and subcontractors, among others. Seven of ten production builders rated cooperation by suppliers, manufacturers, and subcontractors of high importance, much more so than cooperation by their internal architects or engineers, regional managers and project/construction managers (Table 13).

Seven of ten production builders rated cooperation by suppliers, manufacturers, and subcontractors of high importance.

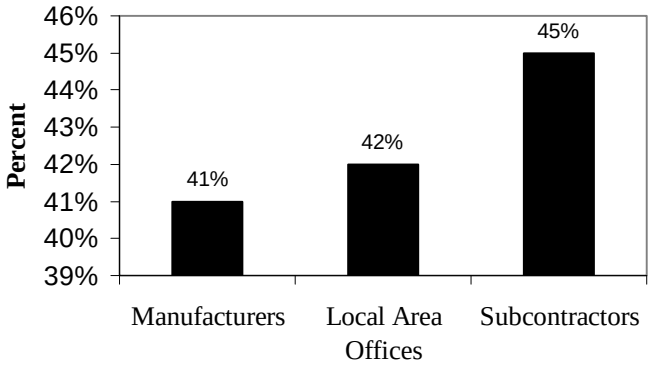
Table 12. Production Home Builders' Information Sources for Keeping Up-to-Date on New Building and Construction Products, Materials, and Practices

Sources	No Influence	Some Influence	High Influence
Company headquarters	15%	59%	27%
Company regional offices	23%	60%	17%
Company local offices	10%	48%	42%
Trade shows	15%	59%	26%
Homebuyers	39%	45%	16%
Internet in general	43%	50%	7%
Internet sites like HousingZone.com or Toolbase.org	58%	37%	5%
Retail Outlets (Home Depot, Lowe's)	70%	30%	-----
Wholesalers and suppliers	12%	55%	33%
Manufacturers	3%	57%	41%
NAHB and other trade associations	19%	65%	16%
Other builders	29%	57%	15%
Subcontractors	7%	48%	45%
Technology transfer programs like PATH, EnergyStar, Building America, or local green building programs	35%	52%	13%
Trade publications	22%	67%	12%
Universities	82%	16%	2%

Corp and operations combined. Both corp and operations asked to answer for the company as a whole.
Depending on the question, *N*=60 to 68 on corp and operations combined

See Appendix B, Q5 and Appendix C, Q14 for complete wording of questions.

Figure 12. Top Three Influential Sources for Keeping Up-to-Date on New Building and Construction Products, Materials, and Practices



Corp and operations combined. Both corp and operations asked to answer for the company as a whole.
Depending on the question, *N*=60 to 68 on corp and operations combined

See Appendix B, Q5 and Appendix C, Q14 for complete wording of questions.

Table 13. Production Home Builders by Cooperation of Parties in Adopting New Building and Construction Products, Materials, and Practices

Parties of Cooperation	Low Importance	Average Importance	High Importance
Suppliers	1%	27%	71%
Manufacturers	5%	24%	71%
Subcontractors	7%	23%	70%
Corporate architects or engineers	20%	50%	30%
Regional managers (if applicable)	8%	40%	52%
Project/construction managers in local offices	18%	42%	41%

Corp and operations combined. Corp and operations asked to answer from an individual perspective.
N=84 on corp and operations combined

See Appendix B, Q8 and Appendix C, Q17 for complete wording of questions.

- **Technical and Economic Attributes of Innovation**

In general, the respondents felt that innovative products and materials cost more than those they replace and that their subcontractors are resistant to using new products

Various factors associated with the characteristics of innovations have been identified as possible impediments to adoption of innovations in residential construction. In general, the respondents felt that innovative products and materials cost more than those they replace and that their subcontractors are resistant to using new products. They agree their companies rely on established manufacturers and suppliers that stand behind their products (Table 14). About one-fourth to one-third think that building codes impede innovation, new building products increase risks of call-backs, and their own construction workers are resistant to innovation. One-fourth reported they identify competitive advantage through innovation as part of their company's business strategy, and few felt that their customers resist innovation. They are evenly split in their impressions about whether manufacturers and suppliers provide inadequate support for new products.

Although many production companies include technology innovation as part of their business strategy, the specific benefits to their companies from innovative building and construction products, materials, and practices are not as clear. Quality of homes built was the only factor identified as highly beneficial by a majority of the survey respondents.

Although many production companies include technology innovation as part of their business strategy, the specific benefits to their companies from innovative building and construction products, materials, and practices are not as clear (Table 15). A majority (64%) of the production builders in the current survey only rated increased quality as being highly beneficial. Given their perceptions about the higher costs associated with new products and materials, decisions to innovate might rely heavily on consumers' willingness to pay the price of higher quality. Between 41% and 45% of production builders rated four other potential benefits from using new building products: meeting customers' expectations, increased competitiveness, creating an image as an innovative builder, and reduced call-backs.

Table 14. Production Home Builders by Impediments for Considering New Building and Construction Products, Materials, and Practices

Impediments	Disagree	Neutral	Agree
Building codes make it difficult to use new building and construction products and materials	16%	45%	39%
New building and construction products and materials generally cost more than ones we currently use	15%	33%	52%
Our customers prefer the "tried and true" and don't like nontraditional products or features	38%	51%	12%
It is dangerous to be among the first firms who try new things in our market	32%	38%	30%
Our bankers and insurance companies are hesitant to underwrite projects with new products and materials	57%	38%	4%
Manufacturers and suppliers generally do not provide enough support for new products	29%	41%	30%
Gaining competitive advantage by using new building and construction products and materials is not an important part of our company's business strategy	59%	29%	12%
Using new building and construction products and materials increases our risk of call-backs	19%	41%	41%
Subcontractors in our market do not usually want to adapt to new building and construction products and materials	13%	46%	41%
Our construction workers find it difficult to learn a new way of building	12%	45%	44%
Our firm only uses new building and construction products and materials from established companies that stand behind their products	4%	18%	78%

Corp and operations combined. Both corp and operations asked to answer from an individual perspective.
Depending on the question, *N*=68 to 69 on corp and operations

See Appendix B, Q6 and Appendix C, Q15 for complete wording of questions.

Table 15. Production Home Builders by Benefit of Adopting New Building and Construction Products, Materials, and Practices

Benefit over Past 5 Years	Low Benefit	Average Benefit	High Benefit
Decreased costs of building	23%	55%	23%
Created image as an innovative builder	17%	43%	41%
Increased productivity	11%	54%	35%
Increased quality of homes built	4%	32%	64%
Helped comply with codes and regulations	20%	55%	25%
Increased profit	25%	52%	23%
Increased competitiveness	17%	38%	45%
Helped meet customers' expectations	6%	48%	46%
Reduced build time	25%	52%	23%
Reduced call-backs	11%	47%	42%

Corp and operations combined. Corp and operations asked to answer from an individual perspective.
N=84

See Appendix B, Q7 and Appendix C, Q16 for complete wording of questions.

The potential for reduced call-backs was also perceived as a high benefit by 42% of the production builders, who were also three times more likely to rate increased productivity as a high benefit (35%) than as a low benefit (11%). Increased quality, the highest rated benefit from innovation, should result in reduced "call-backs." Production builders should be receptive to new building products from manufacturers who can deliver products with these attributes.

Fewer production builders believe that building technology innovation can generate higher than average benefits in terms of decreased costs, increased profits, compliance with building codes, or reduced build times.

Survey Responses Based on Innovativeness

The operational definition of innovation in this study is based on the degree of market penetration of peer-determined technological innovations among the respondents. The overall percent of respondents who were currently using or had tried but discontinued a product was used in order to classify the innovativeness of the products. Based on their degree of market penetration, products were classified as early-stage innovations (25% or lower market penetration), middle-stage innovations (30%-75%), and late-stage innovations (above 75%).

To create a measure of innovation for each respondent, the degree of use of the early-stage products described above was determined. Three categories were used to identify (1) those respondents who never tried any of the four early-stage technologies (*N*=47 or 56%); (2) those respondents who had used only one of the four early-stage technologies (*N*=22 or 26%); and (3) those respondents who had used two to four of the early-stage technologies (*N*=15 or 18%). Cross-tabulations and chi-square tests of this innovation measure (referred to in the following tables as "Number of Innovations Tried or Being Used") were prepared with the other measures in the survey to help identify statistically significant associations between these measures and innovation. Only statistically significant associations (at the .10 or lower level) are reported in the following analysis of the results of the survey.

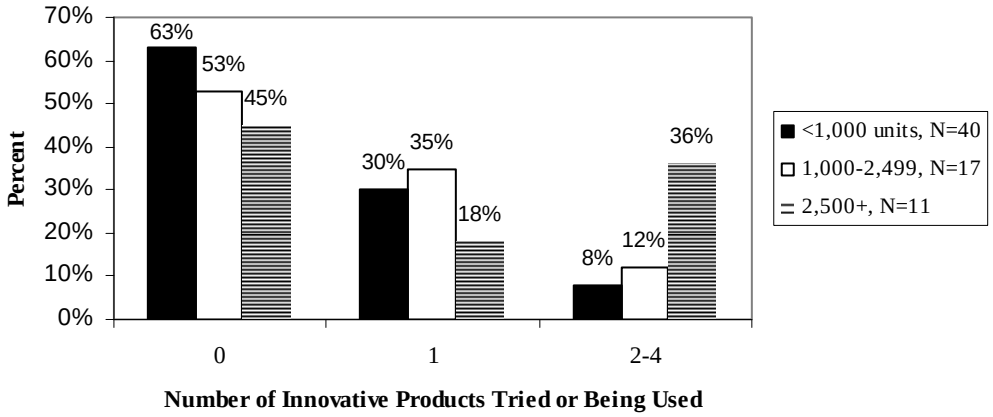
- **Organizational Structure**

Company size, as measured by units built, is associated with the number of innovative products adopted. … [In addition,] production builders operating throughout the nation were much more likely to use the early- stage innovations.

Company size, as measured by units built, is associated with the number of innovative products adopted (Figure 13). Among companies producing fewer than 1,000 housing units, 38% had used one or more of the early stage innovations in the survey and only 8% had used two to four. This increases to 47% and 12% for companies building 1,000-2,499 units and to 54% and 36% for companies building 2,500 or more houses in a year.

Production builders operating throughout the nation were much more likely to use the early-stage innovations measured in the survey (Figure 14). This could be a reflection of their larger size, but these firms might also be more innovative because of their business philosophies. Although national companies are more likely to be innovative in building technology, innovation does occur in some non-national companies.

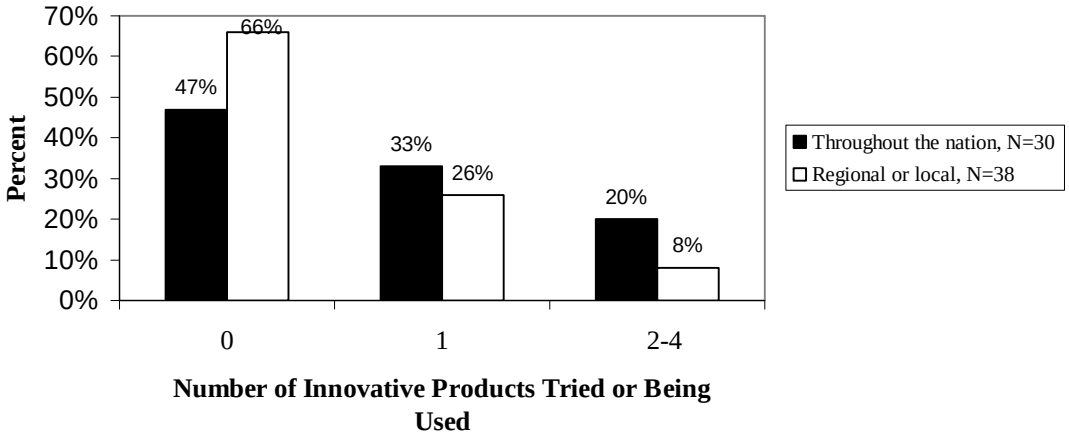
Figure 13. Number of Innovative Products Tried or Being Used by Company Size (Units Built Per Year)



Corp and operations combined. Operations asked to answer for their market area office.

See Appendix B, Q16 and Appendix C, Q1 for complete wording of questions.

Figure 14. Number of Innovative Products Tried or Being Used by Market Area Served



Corp and operations combined. Operations asked to answer for company as a whole.

See Appendix B, Q15 and Appendix C, Q24 for complete wording of questions.

Commentaries on innovation in construction often suggest that the industry's low level of R&D investment impedes innovation. But the relationship between R&D and innovation in construction has never been addressed empirically. The representation of several firms reporting R&D departments in this survey provides an opportunity to examine if the presence of R&D increases innovation. It should be noted that the survey results cannot be interpreted as an estimate of the national frequency of R&D among production builders, since the low response rate could have reduced the randomness of the sample, and the survey left the respondent to define "research and development." Since R&D is thought to be rare in homebuilding firms, it might be overrepresented in this survey.

The survey results do not indicate a clear relationship between an R&D department and innovation. Having an R&D department increased the likelihood of trying or using one of the innovative products measured in the survey, but not two or more (Table 16). Overall, based on a chi-square test, the relationship was statistically insignificant. Having an Engineering Department was statistically associated with an increased likelihood of trying or using two or more of these products. The presence of other departments was not related to the use of these innovations.

The survey results do not indicate a clear relationship between an R&D department and innovation.

Table 16. Innovation When Companies Have R&D or Engineering Departments

	Number of Innovations Tried or Being Used			
Departments within Company	0	1	2-4	*N*
With R&D Dept	47%	35%	18%	17
Without R&D Dept	58%	24%	18%	67
With Engineering Dept	38%	29%	33%	24
Without Engineering Dept	63%	25%	12%	84

Corp and operations combined. Operations asked to answer for their market area office.

See Appendix B, Q21 and Appendix C, Q3 for complete wording of questions.

Since manufacturers typically initiate the commercialization process for new products (and often are the source for invention or creation) and builders have greater ability to field test new products, the lack of partnership between manufacturers and builders noted by Slaughter (2000) could impede technology development and commercialization in residential construction. Large companies can use their size to their advantage with organizations up-stream in the supply chain, and the current survey indicates that many of them are indeed starting to develop closer ties with manufacturers. Two-thirds of the production companies responding to the survey had formed partnerships with manufacturers. Although the nature of these partnerships was not explored, increased development of manufacturer-builder relationships should create additional opportunities to bring innovations to the market. As noted elsewhere (Koebel and McCoy 2006), builders need to develop new approaches in order to exact first-mover advantages in technology innovation by bundling technology innovation, marketing, and customer service.

Large companies can use their size to their advantage with organizations up-stream in the supply chain, and the current survey indicates that many of them are indeed starting to develop closer ties with manufacturers.

Builders need to develop new approaches in order to exact first-mover advantages in technology innovation by bundling technology innovation, marketing, and customer service.

- **Organizational Culture: Influence, Locus of Decisionmaking and Innovation**

The impact on innovation of multiple points of influence and decentralized or participatory decision-making is not transparent. A single decisionmaker who allows relatively few sources of influence might act more quickly and perhaps more rashly when making decisions than multiple

parties. The current survey results indicate that centralization of decision-making for production builders might discourage innovation, although the results are somewhat uncertain (Table 17). When decisions to adopt a major new product were approved at the corporate or regional level, companies had lower levels of adoption of only one of the innovative products included in the survey but equal rates for having adopted two to four of these technologies.

Table 17. Innovation under Central or Local Approval

	Number of Innovations Tried or Being Used			
Locus	0	1	2-4	*N*
Corporate or regional approval	74%	14%	11%	27
Local or shared approval	50%	39%	11%	38

Corp and operations combined. Operations asked to answer for their market area office.

See Appendix B, Q1 and Appendix C, Q10 for complete wording of questions.

Overall, a majority of the respondents reported an inhouse technology advocate at either the corporate or operations levels. This allows us to examine the impact on innovation of champions at both the corporate and operational levels. Companies with corporate or office level technology advocates were somewhat more likely to have used one or more of the innovative technologies measured, but the difference was insufficiently large to be statistically significant.

Although R&D and A&D departments frequently have significant influence over decisions on new products, they seldom make the final decisions on adoption. These departments provide depth in technical aspects of building systems, but decisions are made by others with broader responsibilities for business operations. Companies where R&D had significant influence on new building products were more likely to have adopted two to four of the innovative items in the survey (Table 18) but were not any more likely to adopt one or more of these products.

Although R&D and A&D departments frequently have significant influence over decisions on new products, they seldom make the final decisions on adoption.

Table 18. R&D and A&D Influence and Innovation

	Number of Innovations Tried or Being Used			
Position	0	1	2-4	*N*
R&D influential	58%	16%	26%	19
All others	57%	35%	8%	49
A&D influential	67%	17%	17%	30
All others	50%	40%	11%	38

Corp and operations combined.

See Appendix B, Q4 and Appendix C, Q13 for complete wording of questions.

A&D influence, on the other hand, was associated with companies with somewhat lower levels of innovation—34% of companies with A&D influence used one or more of these products,

A&D influence could be based on design criteria unrelated to technology innovation, whereas R&D influence is likely to concentrate on improving building performance through the use of new products and technologies.

while 51% of other companies did so. A&D influence could be based on design criteria unrelated to technology innovation, whereas R&D influence is likely to concentrate on improving building performance through the use of new products and technologies. The differences are not clear-cut, as A&D departments likely evaluate new technologies in companies without R&D departments.

These findings suggest that R&D influence increases the frequency of innovation, perhaps due to the company's greater ability to identify and evaluate new products and technologies.

These findings suggest that R&D influence increases the frequency of innovation, perhaps due to the company's greater ability to identify and evaluate new products and technologies. The impact of R&D is apparently mediated by other departments and priorities within the company. Although three-fourths of the companies identified research and technology development as part of their corporate strategy, these companies were no more likely than others to use the technologies measured. Having an R&D department at the corporate level does, however, appear to increase the likelihood of innovation.

Influence by purchasing departments has either a positive or neutral association with innovation, but decision-making power by regional or local purchasing departments might negatively impact innovation.

Influence by purchasing departments has either a positive or neutral association with innovation (Table 19), but decision-making power by regional or local purchasing departments might negatively impact innovation (Table 20). Companies where purchasing had significant influence over decisions to use a new building material were more likely to use one or more the innovative products covered, and companies where regional purchasing managers were influential were significantly more likely to use two or more of these products. Companies where the corporate head of purchasing made decisions on new building materials were also more likely to have used two or more of the products measured. But when this authority was exercised by purchasing departments at the regional or local levels, the companies were less likely to have used one or more of these products.

Table 19. Purchasing Influence and Innovation

	Number of Innovations Tried or Being Used			
Position	0	1	2-4	*N*
Corp Purchasing influential	55%	28%	17%	47
All others	62%	33%	5%	21
Regional Purchasing influential	59%	19%	22%	32
All others	56%	39%	6%	36
Local Purchasing influential	55%	32%	14%	44
All others	63%	25%	13%	24

Corp and operations combined.

See Appendix B, Q4 and Appendix C, Q13 for complete wording of questions.

Table 20. Purchasing Makes Final Decision and Innovation

Position	Number of Innovations Tried or Being Used 0	1	2-4	*N*
Corp Purchasing decides	58%	21%	21%	24
All others	57%	34%	9%	44
Regional Purchasing decides	77%	8%	15%	13
All others	53%	35%	13%	55
Local Purchasing decides	75%	25%	0%	12
All others	54%	30%	16%	56

Corp and operations combined.

See Appendix B, Q4 and Appendix C, Q13 for complete wording of questions.

Purchasing departments also can positively impact building technology decisions through their influence at corporate, regional, and local levels. However, if purchasing departments below the corporate level have decision-making authority, the impact becomes negative.

Although these associations are statistically weak (particularly given the relatively small number of companies participating in the survey), they help identify a complex pattern of influence and authority in decisions about new building materials. The technical expertise in building science represented in R&D or possibly in A&D departments can positively influence innovation, but these departments rarely have the authority to make the final decisions. Purchasing departments also can positively impact building technology decisions through their influence at corporate, regional, and local levels. However, if purchasing departments below the corporate level have decision-making authority, the impact becomes negative. Corporate purchasing departments are probably more likely to be influenced by R&D or other technology advocates at the corporate level, whereas regional and local purchasing departments might be more sensitive to incentives associated with reducing costs. Companies emphasizing innovation as part of their business strategy should be cautious in assigning decision authority to purchasing departments except at the corporate level, or they may need to carefully evaluate the incentives provided to purchasing departments at regional and local levels

- **Organizational Culture: Corporate Philosophy, Business Strategy and Innovation**

An aggressive growth plan was also associated with recent building technology innovation… Building technology both benefits from and contributes to growth.

An aggressive growth plan was also associated with recent building technology innovation (Table 21). Based on questions about commitment to research and development and about various aspects of corporate philosophy, building technology both benefits from and contributes to growth. On the one hand, growth generates the corporate revenues that allow a greater commitment to R&D and to building technology innovation. At the same time, companies with aggressive growth plans appear to be including building technology innovation as one

element in their plans to increase market share through increased quality, reduced call-backs, and higher performance.

Table 21. Growth Plan and Innovation

	Number of Innovations Tried or Being Used			
Growth Plan	0	1	2-4	*N*
Annual growth >10%	50%	34%	16%	32
All others	68%	26%	9%	35

Corp and operations combined. Operations asked to answer for their market area office.

See Appendix B, Q22 and Appendix C, Q4 for complete wording of questions.

For the most part, there were no clear associations between business strategies and current or past use of the innovative technologies measured in the survey. However, companies planning to invest in educating buyers about new technologies were much more likely to have adopted one or more of the early-stage innovations measured (Table 22). This pattern confirms other findings stating that building technology innovation by production builders is not pulled by demand and suggests that these innovators focus on their role in (or even the necessity of) educating buyers about the benefits of higher building performance. Given that many building technology improvements are invisible to the consumer, the successful innovator will need to be highly skilled in communicating the benefits of a better quality product.

Building technology innovation by production builders is not pulled by demand… [and] the successful innovator will need to be highly skilled in communicating the benefits of a better quality product.

In addition, the companies who were very likely to invest in their land development capability were less likely to have adopted two to four of these innovations. Surprisingly, the nine companies that were "not likely" to invest in researching new products had higher adoption rates for the innovative technologies than companies who were somewhat or very likely to invest in this strategy.

Table 22. Business Strategies and Innovation

	Number of Innovations Tried or Being Used			
Investment very likely in	0	1	2-4	*N*
Ability to purchase and develop the best land	59%	25%	16%	69
All others	43%	29%	29%	14
Educating buyers about new technologies	39%	35%	27%	26
All others	64%	22%	14%	58

Corp and operations combined. Operations asked to answer for their market area office.

See Appendix B, Q24 and Appendix C, Q8 for complete wording of questions.

Companies that rated providing a lower cost per square foot home as a high benefit were significantly less likely to have adopted one or more of the innovative technologies (Table 23). A business strategy that emphases quality and performance above costs appears to better promote building technology innovation.

Table 23. Factors Contributing to Success and Innovation

	Number of Innovations Tried or Being Used			
Saw high benefit from	0	1	2-4	*N*
Lower cost per sq ft	46%	46%	8%	13
All others	61%	24%	15%	54

Corp and operations combined. Operations asked to answer for their market area office.

See Appendix B, Q25 and Appendix C, Q9 for complete wording of questions.

- **Market Context**

The only significant association between these perceived trends and current building technology innovation was for higher quality buildings created through technology advances (Table 24). This is consistent with the other data from the survey supporting a business model that emphasizes the building quality benefits of innovation.

Table 24. Future Trends and Current Innovation

	Number of Innovations Tried or Being Used			
High Influence from	0	1	2-4	*N*
Higher quality buildings created through technology	47%	25%	28%	36
All others	63%	27%	10%	48

Corp and operations combined. Corp and operations asked to answer from an individual perspective.

See Appendix B, Q9 and Appendix C, Q18 for complete wording of questions.

Fundamental changes in the diffusion of innovative building technologies could result from the confluence of market trends with the recent emergence of large national housing production companies. These companies and some regional housing production companies have the capital, talent, and size to develop business strategies to allow them to exact first-mover advantages from innovation. This outcome will require new approaches that combine builder-manufacturer partnerships, knowledge management, open innovation, marketing, and customer service with building technology innovation to build, sell, and service a higher quality house.

Fundamental changes in the diffusion of innovative building technologies could result from the confluence of market trends with the recent emergence of large national housing production companies. … This outcome will require new approaches that combine builder-manufacturer partnerships, knowledge management, open innovation, marketing, and customer service with building technology innovation to build, sell, and service a higher quality house.

- **Industry Characteristics**

Larger production builders tend to be more innovative than smaller production builders for a variety of reasons, including their access to internal sources of information and to manufacturers.

For the most part, the influence of information sources had no association with the company's use of one or more of the innovative products measured in the survey. The only source of information that had a positive impact on innovation was the company's local offices. Even though the association is weak, this reinforces other evidence in the survey identifying a decentralized approach to innovation among production builders. Two sources had slightly negative impacts on innovation—retail outlets and trade associations. This impact is complicated by the effect of company size: these sources are more important to smaller builders, and company size is positively associated with innovation. Larger production builders tend to be more innovative than smaller production builders for a variety of reasons, including their access to internal sources of information and to manufacturers.

Production builders who rated the importance of cooperation by subcontractors as high were somewhat less likely to have used one or more of the innovative products in the survey (Table 25). This emphasis on cooperation by subcontractors could reflect resistance by those subcontractors to innovation. No other aspects of communication channels and social networks were associated with the level of innovation by production builders.

Table 25. Cooperation by Subcontractors and Innovation

	Number of Innovations Tried or Being Used			
High Cooperation from	0	1	2-4	*N*
Subcontractors	63%	22%	15%	59
All others	40%	36%	24%	25

Corp and operations combined. Corp and operations asked to answer from an individual perspective.

See Appendix B, Q8 and Appendix C, Q17 for complete wording of questions.

- **Technical and Economic Attributes**

Production builders who saw high benefit to their competitiveness from building technology innovation were more likely to have used one or more of the innovative products in the survey (Table 26). In addition, those who saw high benefit in reduced build time (less than one in four production builders) were more likely to have used two to four of these products. No other perceived benefits were associated with the innovation measure.

Table 26. Perceived Benefits and Innovation

	Number of Innovations Tried or Being Used			
High Benefit from	0	1	2-4	*N*
Increased Competitiveness	45%	40%	16%	38
All others	65%	15%	20%	46
Reduced Build Time	37%	26%	37%	19
All others	62%	26%	12%	65

Corp and operations combined. Corp and operations asked to answer from an individual perspective.

See Appendix B, Q7 and Appendix C, Q16 for complete wording of questions.

The impact of perceived impediments is not very clear. Although it is hard to dismiss the potential impact of perceived impediments on innovation, none of the perceived impediments had any association with the company's use of the innovative products covered in the survey. Innovation by production builders appears to rely on their ability to identify the building innovations that they can successfully communicate to consumers, thereby increasing their competitive position. Innovation in building technology does not operate independently of the company's broader business strategies and has to be bundled into those strategies in order to realize their benefit to the company.

Innovation by production builders appears to rely on their ability to identify the building innovations that they can successfully communicate to consumers, thereby increasing their competitive position.

Multivariate Analysis of Building Technology Innovation by Production Builders

In order to examine the joint impacts of several variables on building technology innovation by production builders, a multivariate regression analysis was conducted using a weighted index of the degree to which the respondents used any of the products. Early-stage innovations have the most weight (4) in the index; middle-stage innovations have a weight of 1; and late-stage innovations have a weight of 0. The maximum score for this innovation index is 21 (16 points for the four early-stage innovations and 5 points for the five middle-stage innovations). Koebel et al. (2003) used a similar weighting scheme in calculating their innovation index.

The highest score for the innovation index was one company with 19 (using all four early-stage innovations and three middle-stage innovations). Three companies used three of the early-stage innovations and had index scores from 15 to 17. Eleven companies used two of the early-stage innovations and had index scores from 9 to 13. Twenty-two companies used one of the early-stage innovations and had index scores from 5 to 9. The remaining 47 companies did not use any of the early-stage innovations and had index scores from 0 to 4.

The innovation index was used in a multivariate analysis. Several variables were analyzed, but only a few had statistically significant relationships with building technology innovation. Given the size of the sample and our rather rudimentary knowledge of innovation in residential construction, it is not very surprising that only a few significant relationships in a multivariate analysis would be isolated. Nonetheless, this analysis helps us to understand further the factors that more strongly influence innovation.

The most important of these variables is the size of the company, as measured by the total number of units produced. Larger production builders had higher innovation index scores. In addition, centralization reduced innovation. If decisions about new products were controlled by company headquarters, the company's innovation index was lower. Further reinforcing the negative consequences of centralization, companies with board members or CEOs making these decisions had even lower innovation index scores (although this relationship was of borderline significance in the final equation).

If decisions about new products were controlled by company headquarters, the company's innovation index was lower.

The number of highly perceived benefits from adopting new building and construction products, materials, and practices was also positively associated with the company's innovation index score. As noted earlier, the most frequently perceived benefit was increased quality.

The percent of starter homes in the company's production reduced its innovation index score. This further supports the conclusion that companies pursue building technology innovation to achieve quality and to improve production rather than to decrease costs.

Finally, companies operating at the national level had higher innovation index scores even when the number of units produced was taken into consideration. National companies, perhaps more than others, have the potential to invest in building technology innovation and to exact market rewards from that innovation. Other housing production companies might successfully include building technology innovation in their business strategies, but national companies appear to have an edge in doing so.

National companies, perhaps more than others, have the potential to invest in building technology innovation and to exact market rewards from that innovation.

Comparisons with the 2003 Survey

A study by Koebel et al. (2003) similarly reported on diffusion of innovation in the residential building industry but primarily sampled small to midsize builders. Although the questionnaires were very similar between the two surveys, there were some important differences, particularly in the technologies included in the surveys.

In order to explore differences between large production builders and smaller builders, responses to survey questions that were common to both studies were compared. Respondents from the earlier study that built 200 or more residential units per year (the definition of a large builder for the current study) were eliminated to ensure a valid comparison. There were 216 respondents in the 2003 sample after removing the larger builders. For an indepth discussion of that survey, refer to Koebel et al. 2003.

- **Organizational Structure**

Koebel et al. (2003) found that national home builders were more likely to be innovative than builders with only local or regional operations. Additionally, Blackley and Shepard (1996) found that operating in multiple markets reduced risks and increased opportunities for regulatory acceptance.

The companies responding to the survey of large production builders have much more organizational depth than the smaller builders who participated in the 2003 survey. Few of the latter were organized into different departments. The respondents to the production builders' survey were very likely to have multiple departments, particularly finance, marketing, purchasing, and information technology.

- **Organizational Culture**

The relationship between innovation and corporate philosophy or business strategy is stressed throughout the literature and this report. The 2003 study demonstrated the importance of the owner's vision of the contribution of building technology to the image of the company and its responsiveness to its customers. Large production builders represent much more complex companies with multiple departments and organizations spanning national and sometimes international markets. Innovation does not exist in isolation but as part of the company's overall orientation to growth.

The multiple roles played by owners and general managers in these [small] firms, including the … authority to make the final decision about innovation …could be one reason why small firms are often reported to be more innovative than larger firms.

Whereas influence and decision authority are dispersed in large production building companies, both influence and decision-making were heavily vested in the owner, president, or general manager among the builders responding to the 2003 survey—for 90% of the respondents, the owner-CEO-general manager position made the final decision on new products. This partly reflects the lack of organizational depth in small firms. It also reflects the multiple roles played by owners and general managers in these firms, including the nearly universal authority to make the final decision about innovation. This autonomy could be one reason why small firms are often reported to be more innovative than larger firms. If owners and CEOs champion technology in these companies, they also have the authority to purchase the technology and to take the associated risks.

Toole's research (1998) emphasizes the importance of reducing uncertainty in the decision to adopt innovations. Toole found that decisions about low-risk innovations can be made more easily by a single individual, whereas innovations involving greater complexity and uncertainty were more likely to be adopted if more people participated in the decision.

Consistent with nearly every study of innovation, the 2003 study found that the presence of a technology advocate within the firm—very often the owner—increased the likelihood of using innovative building products and technologies. The current study documented the widespread presence of technology advocates among production builders, but they did not have a discernable association with higher levels of innovation.

The production builders differed from the smaller builders in the 2003 study in terms of their growth plans. One-third of those smaller builders had no specific plan for growth or expected to downsize. Another 16% planned growth in profits of less than 5% per year. In contrast, the production builders surveyed in the current study reported aggressive plans for growth.

Production builders in the current survey were generally very similar to small builders in the 2003 survey when rating the likelihood of investing time and money over the next five years in a variety of management and building technology objectives. The largest difference between large and small builders was the likelihood of investing in their ability to purchase and develop the best land (83% among

The largest difference between large and small builders was the likelihood of investing in their ability to purchase and develop the best land.

production builders and only 51% among small builders).

- **Market Context**

Production builders are more prone than small builders to think that building codes impede innovation, that new building products increase risks of call-backs, and that their own construction workers are resistant to innovation. They are less likely than small builders to agree that their customers resist innovation, and they are more likely to identify competitive advantage through innovation as part of their company's business strategy.

- **Industry Characteristics**

Among the small builders surveyed in 2003, more than 40% identified wholesalers and suppliers, other builders, subcontractors, trade publications, homebuyers, and trade shows as highly influential sources of information. Larger builders are much less reliant on other builders, trade shows, and trade publications to keep them informed about new products. They also appear to use technology transfer programs to a greater extent than small builders but rate these programs as moderately influential rather than highly influential.

The lower reliance on homebuyers as a source of information for large production builders compared to small builders could mean that technology innovation by large production builders is less a matter of demand-pull. Production builders rely on delivering a specific product with a defined set of options. The impact of consumer demand on these builders is probably less direct than on smaller builders, as consumer preferences are mediated through marketing departments.

- **Technical and Economic Attributes**

In general, the large production builders agreed with the smaller builders in the 2003 survey that innovative products and materials cost more than those they replace and that subcontractors are resistant to using new products. Both types of builder agree their companies rely on established manufacturers and suppliers that stand behind their products.

The primary benefit of technology innovation in builders' eyes is its contribution to improving quality, whether expressed directly or more narrowly as reductions in call-backs. About two-thirds of builders, whether small or large, identify increased quality as a "high benefit" of building technology innovation. This is substantially higher than creating an image as an innovative builder (identified by 40% of small and large builders as a high benefit of building technology innovation).

Home builders evaluate other potential benefits of innovations against their exposure to risks. Corporate respondents from large production builders were much more likely to identify high benefit from building technology innovation than either operations respondents or the small builders responding to the 2003 survey in the following areas: decreased costs; increased productivity; increased competitiveness; and reduced call backs.

QUALITATIVE RESULTS

Purpose

Information collected through personal interviews with representatives of large production builders provided added perspective to the survey results. In this section, information resulting from three post-survey onsite personal interviews and the pre-survey interviews that were used to help formulate the survey questions is presented. In addition, information drawn from comments provided by survey respondents is incorporated.

Findings

- **Organizational Structure**

Increased concentration among the top national housing producers became a pronounced trend during the past twenty years. Our qualitative interviews indicated that these large producers expect the trend to continue and that they will increase market share through their competitive advantages in implementing aggressive plans for growth.

The qualitative interviews suggested that large national firms might be able to exploit first-mover advantage through innovation in building technology better than non-national firms, but they are also very reliant on the success of established business models. The risks associated with building innovations are magnified by the volume of units built by a large production builder. Without substantial field-testing to demonstrate the performance and benefits of an innovation, the risks faced by large production builders generally outweigh any advantages associated with being a first-mover.

The risks associated with building innovations are magnified by the volume of units built by a large production builder. Without substantial field-testing to demonstrate the performance and benefits of an innovation, the risks faced by large production builders generally outweigh any advantages associated with being a first-mover.

The successful business models that combine open innovation, knowledge management, technology scanning, incentives tied to successful innovation, marketing, and a variety of other strategies have yet to be clearly established.

Nonetheless, some companies are clearly investing in their capacity to identify, assess, and deploy innovative building technologies where performance is clearly established and the risks are limited and are outweighed by probable rewards. This strategy is still an emergent trend, and the successful business models that combine open innovation, knowledge management, technology scanning, incentives tied to successful innovation, marketing, and a variety of other strategies have yet to be clearly established. And although national companies are more likely to be innovative in building technology, innovation does occur in some non-national companies. Some companies operating within a region or even a few metropolitan areas are also investing in their capability to develop business models that include building technology innovation. It remains to be seen which companies will be able to move more quickly or nimbly in identifying ways to increase market share and profits through building technology innovation.

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- **Organizational Culture**

The corporate cultures of homebuilding companies value local knowledge; this includes tacit and formal information on market conditions, site variability, consumer preferences, supply-chain relationships, and subcontractors that occurs within regions and local market areas.

The corporate cultures of homebuilding companies value local knowledge; this includes tacit and formal information on market conditions, site variability, consumer preferences, supply-chain relationships, and subcontractors that occurs within regions and local market areas. National homebuilding corporations grew out of the success of a local operation and value the contribution of local autonomy to profitability. Growth strategies include purchasing homebuilding companies operating within market areas targeted for expansion. This strategy involves capturing the best features of national management techniques, purchasing power, and access to capital with local autonomy on construction.

Companies interviewed in this study expressed reluctance to force decisions about innovation in building technology onto regional and local operations and prefer to use incentives and communications to promote corporate goals for building technology. Decisions about business operations, however, are made at the corporate level more readily.

Local autonomy also helps manage the risks in homebuilding associated with local markets and with the variability among construction sites. Our qualitative interviews reinforced our survey findings emphasizing decentralized decisions about building materials and products. Companies interviewed in this study expressed reluctance to force decisions about innovation in building technology onto regional and local operations and prefer to use incentives and communications to promote corporate goals for building technology. Decisions about business operations, however, are made at the corporate level more readily.

The importance of purchasing departments in new product decisions was also identified in our qualitative interviews. Given the influence of purchasing departments at all levels, their criteria and incentives in product selection are central to managing technology innovation among production builders. The criteria and the financial incentives motivating purchasing decisions can be antagonistic to new products, particularly if they reward cost savings over potential improvements in performance. Quite logically, incentives encourage purchasing to buy the desired products at the lowest possible price, which might involve discounts negotiated with manufacturers and suppliers based on volume. A new product, even if identified as improving building performance and profits, could be disadvantaged due to higher initial costs and lower volumes.

Companies are looking to integrate (or "sell") building technology innovation throughout their corporations. Strategies include the development of national purchasing agreements, incentives that reward increased profitability on the total house rather than on individual components, incentives for adopting best practices in materials and processes, field testing to confirm performance, monitoring to correct problems quickly, and cross-corporation communications about building technology and performance. Knowledge management remains more ad hoc than structured, but there is increased interest in information technology tools that enable organizational learning.

These companies are looking to integrate (or "sell") building technology innovation throughout their corporations. Strategies include the development of national purchasing agreements, incentives that reward increased profitability on the total house rather than on individual components, incentives for adopting best practices in materials and processes, field testing to confirm performance, monitoring to correct problems quickly, and cross-corporation communications about building technology and performance. Knowledge management remains more ad hoc than structured, but there is increased interest in information technology tools that enable organizational learning.

- **Market Context**

The housing market in recent years has been a "sellers' market," and there has not been much competitive pressure to innovate. Several shifts in market trends could create a better environment for building technology innovation, including a slowdown in the housing market, rising energy costs, and increased materials and supplies costs. Each of the interviews identified the strength of housing demand over the last several years as decreasing the returns to building technology innovation. Shortages in skilled construction labor in terms of both overall availability and the inadequacy of training by small subcontractors is pushing companies to look to solutions that include process and quality control technologies and vertical integration. The impact of rising energy costs was less clear, but there was some indication that energy efficiency could provide an opportunity for differentiating a company from competitors.

Land is also an essential component in housing production and is becoming more scarce and expensive. Our interviews indicated that large production builders are focusing on their land inventories as part of their business strategy. This could prevent smaller builders from obtaining desirable locations for development and could accelerate concentration in the industry.

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The importance of land in the cost of housing and in corporate success diminishes the potential impact of building technology innovations. As "bricks and mortar" contribute proportionately less to final cost, the contribution of building technology innovation to profitability declines.

The importance of land in the cost of housing and in corporate success diminishes the potential impact of building technology innovations. As "bricks and mortar" contribute proportionately less to final cost, the contribution of building technology innovation to profitability declines. For example, opportunities to reduce cycle times through innovation were seen as much less important as process controls that assure the delivery date. This supports the survey results that emphasize the impact of innovation on quality and customer satisfaction rather than costs or profits and reinforces the need to integrate building performance quality into marketing strategies.

This supports the survey results that emphasize the impact of innovation on quality and customer satisfaction rather than costs or profits and reinforces the need to integrate building performance quality into marketing strategies.

Higher land costs could also push development inward within large, high growth metropolitan areas towards opportunities for building more densely.

Our qualitative interviews affirmed this trend to look inward and upward. Some housing production companies have already gone "vertical" in the development of midrise and high rise residential buildings. This will create new opportunities for technology innovation and could facilitate the migration of building technologies from commercial construction to residential construction.

The key to marketing building performance appears to be customer satisfaction rather than engineering details. Some companies believe they can develop brand loyalty and repeat customers through improved building performance, but this has yet to be established and will require several more years of documenting the relationship between building performance and customer satisfaction.

The companies have yet to integrate building performance into marketing, although they are pushing to do so. They agreed that technology innovation was not being pulled by demand and that customers need to be educated about the benefits of improved building performance. The key to marketing building performance appears to be customer satisfaction rather than engineering details. Some companies believe they can develop brand loyalty and repeat customers through improved building performance, but this has yet to be established and will require several more years of documenting the relationship between building performance and customer satisfaction.

- **Industry Characteristics**

Manufacturers and suppliers remain key sources of information about new products. Selling a new product remains the primary communication channel, and there are examples of cross-branding (including the building company's name on the manufactured product). In developing installation requirements for the product to remain within warranty, manufacturers rely on lab testing rather than field testing and review by construction personnel. But there are also indications that a more sophisticated relationship between manufacturers, suppliers, and large production builders is emerging. This includes cooperation in addressing supply-chain problems, field testing, and joint development of products.

Large production builders are also "professionalizing" home building from top to bottom. At corporate levels, corporate culture is increasingly driven by management and finance professionals. Corporate managers are coming from other industries bringing perspectives and approaches that are still new to homebuilding.

Large production builders are also "professionalizing" home building from top to bottom. At corporate levels, corporate culture is increasingly driven by management and finance professionals. Corporate managers are coming from other industries bringing perspectives and approaches that are still new to homebuilding. And the companies are recruiting university graduates in engineering, building construction, and business as construction superintendents. (Staff turnover was cited as an ongoing challenge to the industry.) These changes in human resources are likely to facilitate deployment of best practices in building science, though the effect on the full supply chain has yet to be studied.

- **Technical and Economic Attributes**

National and regional production builders are experimenting with building technology innovations that range from factory produced panels to incremental improvements in existing

processes. The easy opportunities are in identifying improvements in the company's core competency of managing the construction process and improving quality.

The risks and costs of innovation remain as serious impediments. Site variability and subcontractor variability were stressed as ongoing challenges to the deployment of building technology innovations.

R&D efforts are primarily devoted to finding improved products or processes, troubleshooting problems identified by operations, and developing quality control procedures. Even incremental changes frequently are ahead of building codes, and approvals involve increased costs in communication and time. So, increased technical complexity—combined with either increased cost or the inability to predict cost—increases the likelihood of not adopting technologies among the production builders interviewed.

CONCLUSION

Summary of Findings

This study helps to provide a clearer perspective of innovation among large production homebuilders. Among these builders, size matters. Larger companies have greater access to a variety of factors that contribute to successful implementation of building technology innovation as one part of the company's business strategy. Large companies have greater leverage to form partnerships with manufacturers that could increase the benefits and reduce the risks associated with innovation. They have greater organizational depth and are much more likely than small builders to invest in research and development. Operating at a national level further contributes to the company's use of innovative building technologies.

Among these builders, size matters. Larger companies have greater access to a variety of factors that contribute to successful implementation of building technology innovation as one part of the company's business strategy.

Whereas centralized decisions by a technology champion in a small company facilitates innovation, in larger housing production companies innovation is fostered through decentralization.

Whereas centralized decisions by a technology champion in a small company facilitates innovation, in larger housing production companies innovation is fostered through decentralization. Regional and particularly local offices play important roles in providing information on new building technologies, influencing decisions about new products, and making decisions about building technology innovations. The dominant business model in the industry involves a significant commitment to decentralized authority. The innovative production builder has to meet the challenges of providing adequate technology support, incentives, communications, and knowledge management to foster innovation at regional and local operational levels.

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In addition to occasionally providing inhouse R&D expertise, production companies support technology development through technology champions, supporting R&D efforts at the regional or local operational levels, and using innovation as part of their marketing strategy. Having R&D increases the frequency of innovation, somewhat obviously, but the impact of R&D is mediated by other departments and priorities within the company.

One of the key findings of this study is that purchasing departments play a large role in influencing and making decisions on new products and materials among production builders. The influence of purchasing is felt throughout the corporation… As a result, it is important to align the criteria and financial incentives motivating purchasing decisions at the regional and local levels with the company's building technology goals.

One of the key findings of this study is that purchasing departments play a large role in influencing and making decisions on new products and materials among production builders. The influence of purchasing is felt throughout the corporation, from the corporate head of purchasing, regional purchasing directors, and local purchasing directors. As a result, it is important to align the criteria and financial incentives motivating purchasing decisions at the regional and local levels with the company's building technology goals.

Production builders rely more on manufacturers and technology transfer programs and are much less reliant than small builders on other builders, trade shows, and trade publications to keep them informed about new products. Larger production builders tend to be more innovative than smaller production builders for a variety of reasons, including their access to inhouse sources of information and to manufacturers.

These large production builders agreed with the smaller builders surveyed in 2003 that innovative products and materials cost more than those they replace, that subcontractors are resistant to using new products, and that their companies rely on established manufacturers and suppliers who stand behind their products. Production builders are more likely than small builders to think that building codes impede innovation, that new building products increase risks of call-backs, and that their own construction workers are resistant to innovation.

Although many production companies include technology innovation as part of their business strategy, the specific benefits to their companies from building technology innovation are not as clear. Given their perceptions about the higher costs associated with new products and materials, decisions to innovate might rely heavily on consumers' willingness to pay the price of higher quality. Innovation by production builders appears to rely on their ability to identify the benefits of building innovations that they can successfully communicate to consumers, thereby increasing the company's competitive position. Innovation in building technology does not operate independently of the company's broader business strategies and has to be bundled with those strategies in order to realize their benefit to the company. Innovation does not exist in isolation but as part of the company's overall orientation to growth.

Innovation in building technology does not operate independently of the company's broader business strategies and has to be bundled with those strategies in order to realize their benefit to the company. Innovation does not exist in isolation but as part of the company's overall orientation to growth.

Growth itself is an important difference between these larger production builders and the smaller builders covered by the 2003 survey. Whereas nearly half of the smaller builders planned growth in profits of less than 5% per year, many of the corporate respondents among larger production builders reported aggressive plans for growth exceeding 10% per year. Companies with such aggressive growth plans were also more likely to be using building technology innovations. They include building technology innovation as one element in their plans to increase market share through increased quality, reduced call-backs, and higher performance.

In terms of the likelihood of investing time and money over the next five years toward a variety of management and building technology objectives, the highest ratings were given to reducing construction defects and call-backs, improving subcontractor dependability, and improving the style and attractiveness of the homes the companies build. Investing in building technology and R&D are not seen as very likely means to improve market share, reinforcing the theme that building technology innovation has to be integrated into broader business models oriented to customer service, community design, and house design. Given that many building technology improvements are invisible to the consumer, the successful innovator will need to be highly skilled in communicating the benefits of a better quality product. Large production builders can also capture greater benefits from building technology innovation through partnerships with manufacturers, purchasing incentives, marketing strategies that emphasize building quality and performance, and customer service.

Given that many building technology improvements are invisible to the consumer, the successful innovator will need to be highly skilled in communicating the benefits of a better quality product. Large production builders can also capture greater benefits from building technology innovation through partnerships with manufacturers, purchasing incentives, marketing strategies that emphasize building quality and performance, and customer service.

Several emerging trends, particularly increasing energy costs, could significantly affect building technology innovation over the next ten to twenty years. Other trends include land costs and availability; labor costs, availability and quality; and competition from large national builders. Land costs and availability could push development inward within large, high growth metropolitan areas to find opportunities for building more densely. Production builders going "vertical" in the development of midrise and high rise residential buildings could create new opportunities for technology innovation and could facilitate the migration of building technologies from commercial construction to residential construction.

These companies and some regional housing production companies have the capital, talent, and size to develop business strategies that allow them to exact first-mover advantages from innovation. This will require new business models combining building technology innovation with builder-manufacturer partnerships, knowledge management, open innovation, marketing, and customer service in order to build, sell, and service a higher quality house.

Fundamental changes in the diffusion of innovative building technologies could result from the confluence of these trends with the recent emergence of large, national housing production companies. These companies and some regional housing production companies have the capital, talent, and size to develop business strategies that allow them to exact first-mover advantages from innovation. This will require new business models combining building technology innovation with builder-manufacturer

partnerships, knowledge management, open innovation, marketing, and customer service in order to build, sell, and service a higher quality house.

Recommendations

The diffusion of innovative building technologies could be positively impacted if large builders:

- Form partnerships with manufacturers that could increase the benefits and reduce the risks associated with innovation.
- Provide adequate technology support, incentives, communications, and knowledge management to foster innovation at regional and local operational levels.
- Provide inhouse R&D expertise and support R&D efforts at the regional or local operational levels that could more readily track and adapt to emerging trends in all construction sectors.
- Encourage technology champions.
- Use technology innovation as part of a marketing strategy, finding better ways to communicate the benefits of using innovative technologies to consumers.
- Align the criteria and financial incentives motivating purchasing decisions at the regional and local levels with the company's building technology goals. Firms could bundle technology innovation with broader company business strategies such as increasing quality, reducing call-backs, and improving performance.

While these recommendations address industry concerns, there are additional needs in scholarship that this study might also recommend. In the literature review, more detailed lists of research gaps are provided but specific priority areas for study that this work's findings point to include:

- The role of technology champions in large production home building companies.
- The role of R&D and A&D departments in identifying, testing, and vetting innovations.
- The role of purchasing departments in identifying and choosing building technologies and materials.
- The impact of investment markets on technology innovation by large, publicly-traded production home builders.
- The development of knowledge management to identify, evaluate, deploy, and exploit technology innovations.
- The development of partnerships between builders, manufacturers, and suppliers in identifying, testing, deploying, and marketing technology innovations.

- The evolution of business models that bundle technology innovation, building quality, marketing, and customer service.

In pursuing these industrial and intellectual initiatives, a wider understanding and, in turn, opportunity for technological innovation is likely to emerge.

APPENDIX A. RESEARCH METHODOLOGY

Research Methodology

The project team consisted of Ted Koebel and Marilyn Cavell of Virginia Tech, Ed Hudson of the National Association of Home Builders Research Center (NAHBRC), and Candace Mandel of Market Insights. The first course of action in carrying out the project was to conduct a literature review of diffusion in the construction industry. The procedures for execution of a national survey of large production builders were then established. To help prepare for the national study, personal interviews with contacts representing large production builders were conducted. Based on the literature review and the personal interviews, questionnaires were designed to find out how large production builders make decisions to use new building products, materials, and practices. Following pre-testing of the survey instrument, a large national mailing was carried out and the information collected was processed. Based on preliminary results, points needing clarification were established. Additional questions that would give a qualitative perspective to the quantitative data from the survey were formulated and several personal interviews with respondents who showed high interest in innovation were conducted. With a better perspective of the quantitative results, a more indepth analysis of the data from the national survey was completed. The research methodology that was followed is discussed below.

- **Literature Review**

The current literature on technology diffusion in the construction industry was reviewed. The goal was to identify variables that affect the adoption decision and the adoption process of innovative technologies by large production builders. Since the study would be the first related to innovation to focus solely on large production builders, there was particular interest in reviewing the literature that discussed size as a factor. Although size is very often taken into consideration in technology adoption studies, conflicting views as to its impact on the construction industry show the need for further study.

The information gained from the literature review was used to develop the survey instrument. For example, Cantrell and Hudson (2004) reported that two surveys conducted by NAHBRC led to some generalizations about large builders and their propensity to try particular technologies. The information on market penetration from those surveys was used in forming a question on use of specific technologies. In addition to using the literature review to help develop the survey instrument, the review of information for this report was summarized.

- **Pre-survey Interviews**

In order to better understand the target respondents and to formulate questions that would provide information most beneficial to the project goal, personal interviews with a few representatives of large production builders were arranged. The January 2005 NAHB International Trade Show in Orlando was used as a forum. Attendees from the top 400 builders (the sample for this study) were identified and called prior to the Show to attempt to arrange an interview. Eight interviews (Director of Purchasing, VP for Construction, President, Secretary/ Treasurer, Strategic Operations Manager for Construction and Purchasing, Construction Manager, and two Area Managers) were conducted. In addition to asking what position in the company might best be able to answer the survey (VPs for Purchasing and Construction were

most often suggested) and gathering information for developing and refining the survey instrument, the representatives were asked how their company handled innovation technologies and processes.

- **Questionnaire**

A questionnaire was designed that would provide information about how large production builders make decisions about using new technologies and materials. It was determined that large production builders would have a corporate headquarters office and field or operations offices. Not knowing where decisions regarding innovation are made and wanting to explore relationships between the corporate and operations level offices, two versions of the questionnaire, one targeted for corporate level offices and one for operations level offices were created.

The corporate questionnaire was divided into three parts: Part 1. New Building and Construction Products (asked about the company's activities and the respondent's personal opinions regarding new building and construction products, materials, and practices); Part 2. Use of New Building and Construction Products, Materials, and Practices (asked for information about the company's adoption of specific new building and construction products, materials, and practices); and Part 3. Corporate Characteristics (asked for basic information about the corporation as a whole).

The operations questionnaire was divided into four parts beginning with a part unique to operations: Part 1. Characteristics of the Office Where You Work (asked for basic information about the operations level office); Parts 2, 3 and 4 were the same as Parts 1, 2 and 3 on the corporate questionnaire with only a few minor question differences.

The questionnaires were formatted into 4¼ × 5½ inch booklets. The corporate questionnaire was printed on ivory paper, whereas the operations questionnaire was printed on white paper (this was to help the researchers determine easily if a questionnaire was corporate or operations). The corporate questionnaire had a total of 25 questions, and the operations questionnaire had a total of 31 questions. For the most part, the 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, and so forth. The respondents were given the option to write comments at the end of the questionnaire and to provide an e-mail address for receiving a copy of the survey results.

- **Pre-test**

Key industry contacts were asked to provide names of VPs for Purchasing, Operations, or Construction for companies identified as large production builders. The executives identified were called and asked to pre-test the questionnaire. The questionnaires were mailed to four executives who agreed to participate with the understanding they would receive a follow up phone call to discuss any comments or concerns. After repeated attempts to complete the pre-test process, comments were received from one corporate executive. In addition, comments were received from three construction industry colleagues who completed both the corporate and operations questionnaires.

- **Sample**

The target respondents for the survey were large production home builders in the United States. "Large" builders were defined as builders producing over 200 single-family residential units per year from stock plans rather than custom designs. To assure achieving an adequate number of responses, the sample selected included all members from the NAHB membership list associated with the top 400 builders in the United States. The original sample provided by NAHBRC consisted of 1,750 members and multiple names associated with the top 400 builders. NAHBRC was asked to identify the top 100 corporate offices and provide phone numbers. The 100 corporate offices were called to verify the address and get names and titles of key individuals (corporate VP for Purchasing or Construction or other person with knowledge of how decisions are made to use new building products and technologies). This process resulted in some replacement of names on the original sample list and addition of names. In addition, the records (*N*=54) associated with one builder who agreed to coordinate dissemination of the survey were removed. Rather than mailing questionnaires to members associated with that firm, one point of contact was used to secure its responses. After the adjustments to the sample list, the final sample consisted of 1,711 members (371 from corporate offices and 1,340 from operations level offices).

- **Data Collection Procedure**

To promote a satisfactory response rate, Dillman's Total Design Method was used to conduct the mailed survey. Using the electronic file of the sample provided by NAHBRC, a master address data file was created in Microsoft Word and mail merge was used to produce personalized letters and mailing labels. 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, a cover letter explaining the purpose of the study was included which stressed the importance of participation and assured confidentiality of information. Each of the 1,711 letters was printed on Virginia Tech letterhead signed electronically by the project manager. A 9 × 6 inch brown business reply envelope printed with the Virginia Tech return address was included so that a respondent could return the completed questionnaire easily and at no expense. Each respondent was assigned a unique control number that was printed on the questionnaire, on the personalized cover letter, and on the business reply envelope. All of the above components were put into a 9 ½ × 6 ½ inch brown envelope and the respondent's personalized mailing label was affixed. The envelope was then sent to the respondent by first-class U.S. mail.

As completed questionnaires were returned, the control number was recorded so that no additional mailings would be sent to those who had already responded. The control numbers of those packets returned as undeliverable were also recorded to ensure that no additional mailings would be sent to faulty addresses. For any packet that was returned with forwarding information (*N*=49), the address was updated on the master address data file and the respondent was sent a new questionnaire.

Two weeks following the first mailing, a reminder postcard was mailed to those who had not yet responded. Two to three weeks following the postcard, a second copy of the questionnaire (in case the recipient had misplaced the original or never received it) was mailed to those who had not yet responded along with a personalized letter and a business reply envelope. In the cover

letter included in the second mailing, the respondent was offered a choice to either complete the questionnaire and return by mail or access an online version and complete the questionnaire electronically (an electronic version of the questionnaire was created in hopes of improving the response rate).

Reacting to slow mail returns, an online version of both the corporate questionnaire and the operations questionnaire was developed as an alternative and faster method of responding. Corporate and operations respondents each had their own Web site containing their version of the questionnaire. In the cover letter of the second mailing, a URL address to access the online questionnaire along with a unique ID for the respondent to enter once at the site was provided. The online versions were nearly identical to the hard copy questionnaires and required the respondent simply to click on the appropriate answer and submit. The Web site was periodically checked for returns and the information was downloaded into a data spreadsheet (Excel).

Approximately six weeks into the data collection process, respondents were called and asked to complete the survey by phone interview. No operations respondents were contacted for phone interviews. Corporate respondents in the top 100 companies were targeted since a correct phone number and contact name for this group had already been determined. If a top 100 company had more than one contact name, one name was chosen to contact. Also, any company that had already responded was removed from the list. The initial call list included 76 respondents. A detailed phone protocol was produced so that the telephone interviewer would be ready for any situation. The caller first asked the contact to complete the survey over the phone. If the contact did not have the time, the caller asked for an e-mail address so that instructions for responding online could be sent. The survey (excluding some questions) was streamlined for the telephone interviews to keep the phone interview time commitment to a minimum (approximately 20 minutes). To increase the likelihood of the contact agreeing to a phone interview, an incentive of $25 was offered. The call list was later expanded to include corporate contacts from smaller companies.

- **Post-survey Personal Interviews**

To augment the quantitative data collected through the mail survey, online survey, and phone interviews, personal interviews were conducted with respondents identified as having high interest in innovation. Using variables from the mailed survey that indicated an interest in innovation, an index was created and an innovation score was calculated for each respondent. A subset of respondents with scores indicating high interest in innovation was created and those respondents identified were contacted in an attempt to set up personal interviews. Three respondents agreed (one from the mid-Atlantic region, one from the Northeast, and one from the Midwest). Two represented companies that were top 10 builders, and one represented a company that was closer to a top 100 builder. After establishing questions about issues needing clarification, those questions were shared with the respondents prior to visiting their company. The indepth interviews resulted in qualitative information that provided valuable perspective to the survey data.

- **Responses**

The total number of responses was 84, 42 corporate and 42 operations (the equal *N*'s was only coincidental). Of the 1,711 questionnaires mailed to large production builders, 47 completed questionnaires were received through the mail and four were completed online for a total of 51 responses. However, three had to be eliminated because the company did not fit the definition of a large production builder, resulting in 48 useable responses. In addition, 14 completed questionnaires were received from the firm who agreed to coordinate dissemination internally (13 from operations and one from corporate). An additional 22 completions (a shortened version) were obtained from the phone survey: 15 responses resulted directly from the phone interviews, and an additional seven responses resulted from online completions by respondents who provided an e-mail address through the phone contact and were subsequently sent information necessary for completing the questionnaire online.

The response rate for the survey was 6% (70/1,205). In calculating the response rate, the fact that 38 questionnaires were returned not completed with the respondent saying their company was not a large production builder was taken into consideration. Also taken into consideration were the 468 questionnaires that were returned as undeliverable. There were 1,205 potential returns after subtracting 506 from the original sample of 1,711. There were 70 completed returns after subtracting the 14 completions from the firm who agreed to coordinate dissemination internally from the 84 total responses.

Electronic files were prepared containing the names and addresses of returned surveys and were sent to NAHBRC for updating the NAHB member list. The rate of undeliverable surveys (27%) was unexpected and unexplained. Ordinarily about 10% would be expected to be returned as undeliverable. A file containing the names and addresses for surveys that were returned by respondents indicating that their company was not a large production builder (*N*=38) was prepared and forwarded to NAHBRC. A file containing the names and addresses for surveys that were returned as undeliverable (*N*=468) was prepared and forwarded to NAHBRC. A file containing the names and addresses for surveys that were returned by the U.S. Post Office with a forwarding address (*N*=49) was also prepared. The file prepared included both the original address and the updated address and was forwarded to NAHBRC.

- **Analysis**

A master codebook for both the corporate and operations questionnaires was created and used as a guideline for entering data into a data spreadsheet (Excel). The questionnaires were designed 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, a number was assigned for coding purposes. The data were entered into a spreadsheet directly from each questionnaire. The data from each questionnaire were entered a second time and compared for errors. After a thorough check, the data from the spreadsheet were imported into a format for statistical analysis (SPSS PC).

A slight modification to the online data was implemented make it consistent with data from the hard copy returns for both corporate and operations. The online data were incorporated into the corporate and operations database containing data from the mailed-back questionnaires. The

information obtained from the phone interviews was recorded on a shortened hard copy questionnaire. The responses from the telephone interviews were coded into a form consistent with the data from the original corporate questionnaire. The phone data were then incorporated into the corporate database containing data from the mailed-back questionnaires.

Once the data from all sources had been entered, statistical software was used to run frequencies on all the variables. Frequencies were run separately for the corporate responses, the operations responses, and combined corporate and operations responses. For all three sets, cross-tabulations (two-way tables comparing variables) were preformed on selected variables.

New variables from existing variables were created to provide measures of innovation. A key variable created was based on the number of innovative specific products respondents reported having tried or were currently using. Early-stage innovation products were defined as those having low market share penetration (approximately 25% or lower) as determined by the overall percent of respondents who had tried or were currently using the products. Four products met the criteria for early-stage innovation (Structural Insulated Panels or SIPs, Pre-cast concrete foundation walls, Enterprise Resource Planning Software, and GPS land tracking). Respondents were categorized into three levels of innovation, ranging from those who had never tried nor were currently using any of the four early-stage products, those who reported having tried or were currently using one early-stage product, and those who reported having tried or were currently using two to four early-stage products. Cross-tabulations were run for the categorical variable representing use of early-stage products with other measures in the study, calculating the chi-square statistic as a measure of association.

Multivariate linear regression was performed with several sets of independent variables to identify the variables having the best association with a weighted index of innovation. A weighted index was created based on the adoption penetration of specific products reported by respondents as having tried or currently using and the number of those products the respondents had tried or were currently using. As reported earlier, early-stage innovations were defined as those having low market share penetration (25% or lower) as determined by the overall percent of respondents who had tried or were currently using the products. Respondents were assigned a weight of 4 for using an early-stage product. Middle-stage innovations were defined as those products having market penetration of 33% to 68% and respondents were assigned a weight of 1 for using a middle-stage product, of which there were five. Finally, late-stage innovations were defined as those products having market penetration greater than 68% and respondents were assigned a weight of 0 for using a late-adoption product, of which there were two. If a respondent had never used a product, the product was assigned a weight of 0. The innovation index was created by adding the weighted values for the eleven specific products, resulting in a maximum score of 21.

To bring perspective to this study, responses were compared to those of a similar earlier study targeting small to midsize builders (Koebel et al. 2003). The data set from the 2003 study had an N=216 after removing respondents that met the definition of large builder for the current study (building 200 or more residential units per year). This ensured that the comparison would be between small and large builders. Frequencies and cross-tabulations were run to explore differences.

APPENDIX B. CORPORATE QUESTIONNAIRE

VirginiaTech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Virginia Tech is conducting a major national study of Innovation and Production Home Builders in conjunction with the Department of Housing and Urban Development and the National Association of Home Builders Research Center. We want to know how decisions are made about using new technologies and materials at both the corporate and operations levels among companies producing 200+ single-family units per year from stock plans rather than custom designs. We believe our results will help your company and others in the industry to improve the use of new building and construction products, materials, and practices (we will send you the results of the survey and our recommendations if you provide us your email address on the last page of the survey).

You were selected as someone who could answer questions about how decisions are made at the corporate level, and we would appreciate your taking 20 minutes of your time to complete this survey. Your responses will be completely confidential and will not be released or published in any form that could identify you or your company. We also identified one or more key staff in your operations level offices and sent them surveys with similar questions. If you do not work at the headquarters or regional level, please contact me, and I will send you a survey designed for decisions at the operational level. Also contact me if you have questions about this survey or if you believe you are not the best person to answer from your office.

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

Please return by Friday, September 23, 2005

If the company you work for is not a large, production home builder (defined above), you do not need to complete this survey. Please check the box below and return the survey through the U.S. mail in the pre-addressed envelope provided (no postage necessary). Thank you.

❑ My company is not a large, production home builder.

Part 1. New Building and Construction Products

Part 1 is about your company's activities and your personal opinions regarding new building and construction products, materials, and practices (PLEASE READ QUESTIONS CAREFULLY TO ANSWER FROM THE INTENDED PERSPECTIVE).

Q1. If **your company** considers using a new type of siding, which of the following best describes who is most likely to identify a new siding product and who would make the decision to use the product?

	Identifies	Approves
Corporate level	❑	❑
Regional level	❑	❑
Local level	❑	❑
Shared between headquarters and regional offices	❑	❑
Shared between regional and local offices	❑	❑

Q2. Please indicate which of the following statements describe **your company's** approaches towards selecting new building and construction products, materials, and practices. (Please check all that apply.)

	Corporate-wide	Only some markets
We like to wait until other builders have successfully offered new building and construction products, materials, and practices before we use them.	❑	❑
We are often the first to offer a new and innovative building product or system.	❑	❑
We encourage home buyers to stick with "tried and true" materials and products.	❑	❑
Our goal is to set ourselves apart, to be creative, and to offer materials and products that are distinctive and unique.	❑	❑

Q3. Is anyone in **your company** considered a strong advocate of new building and construction products, materials, and practices?

Corporate ❑ Yes ↓ ❑ No

If yes, please write their job title

_____

Local production offices ❑ Yes ↓ ❑ No

If yes, please write their job title

_____

Q4. Who in **your company** would have significant influence over a decision to use a new building material (e.g. siding)?

	Has Significant Influence (Check all that apply.)	Makes final decision (Check one only.)
Board Member	❑	❑
Chief Executive Officer	❑	❑
Chief Financial Officer	❑	❑
Head of Research & Development	❑	❑
Head of Purchasing	❑	❑
Chief Designer or Architect	❑	❑
Chief Engineer	❑	❑
Head of Sales or Marketing	❑	❑
Others in corporate offices (please specify):_____	❑	❑
Regional Office Director	❑	❑
Regional Purchasing Manager	❑	❑
Regional Senior Project Manager	❑	❑
Regional Project Manager	❑	❑
Others in regional offices (please specify):_____	❑	❑
Local Office Director	❑	❑
Local Purchasing Manager	❑	❑
Local Senior Project Manager	❑	❑
Local Project Manager	❑	❑
Others in local offices (please specify):_____	❑	❑

Q5. How influential are each of the following information sources in keeping **you individually** up to date on new building and construction products, materials, and practices? (Please circle one number for each source.)

	No Influence	Some influence	High influence
Company headquarters	1	3	5
Company regional offices	1	3	5
Company local offices	1	3	5
Trade shows, conventions/meetings	1	3	5
Home buyers	1	3	5
Internet in general	1	3	5
Internet sites like HousingZone.com or Toolbase.org	1	3	5
Retail Outlets (Home Depot, Lowes, etc.)	1	3	5
Wholesalers and suppliers	1	3	5
Manufacturers	1	3	5
NAHB and other trade associations	1	3	5
Other builders	1	3	5
Subcontractors	1	3	5
Technology transfer programs like PATH, EnergyStar, Building America, or local green building programs	1	3	5
Trade publications	1	3	5
Universities	1	3	5
Other (please specify: _____	1	3	5

Q6. Several statements about **your individual consideration** of new building and construction products, materials, and practices are presented below. (Please indicate how you agree or disagree by circling one number for each statement.)

	Disagree	Neutral	Agree
Building codes make it difficult to use new building and construction products and materials.	1	3	5
New building and construction products and materials generally cost more than ones we currently use.	1	3	5
Our customers prefer the "tried and true" and don't like non-traditional products or features.	1	3	5
It is dangerous to be among the first firms who try new things in our market.	1	3	5
Our bankers and insurance companies are hesitant to underwrite projects with new products and materials.	1	3	5
Manufacturers and suppliers generally do not provide enough support for new products.	1	3	5
There is no competitive advantage gained from using new building and construction products and materials.	1	3	5
Using new building and construction products and materials increases our risk of call-backs.	1	3	5
Subcontractors in our markets do not usually want to adapt to new building and construction products and materials.	1	3	5
Our construction workers find it difficult to learn a new way of building.	1	3	5
Our company only uses new building and construction products and materials from established companies that stand behind their products.	1	3	5

Q7. Rate the following potential benefits, **in your opinion**, from adopting new building and construction products, materials, and practices over the past 5-years?

	Level of benefit in adopting new building products, materials, practices		
	Low	Average	High
Decreased costs of building	1	3	5
Created image as an innovative builder	1	3	5
Increased productivity	1	3	5
Increased quality of homes built	1	3	5
Helped comply with codes and regulations	1	3	5
Increased profit	1	3	5
Increased competitiveness	1	3	5
Helped meet customers' expectations	1	3	5
Reduced build time	1	3	5
Reduced call-backs	1	3	5

Q8. In **your personal experience** with adopting new building and construction products, materials, and practices over the past 5 years, how important was cooperation from the following? (Please circle one number for each.)

	Low	Average	High
Suppliers	1	3	5
Manufacturers	1	3	5
Subcontractors	1	3	5
Corporate architects or engineers	1	3	5
Regional managers (if applicable)	1	3	5
Project/construction managers in local offices	1	3	5

Q9. What factors do you think will influence the use of new materials and building techniques in your work over the next 10-20 years? (Please circle one number for each.)

	No influence	Some influence	High influence
Competition from large national builders	1	3	5
Energy costs	1	3	5
Land costs/availability	1	3	5
Labor costs/availability	1	3	5
Labor quality	1	3	5
Innovation by smaller builders	1	3	5
Consumers becoming more aware of building technologies	1	3	5
Government regulations	1	3	5
Higher quality buildings created through technology advances	1	3	5
Cost savings achieved through technology	1	3	5
More centralized control over production within our company	1	3	5
Decentralized, local decisions over production within our company	1	3	5

Part 2. Use of New Building and Construction Products, Materials, and Practices

Part 2 asks you for information about your company's adoption of specific new building and construction products, materials, and practices.

Q10. During the past 5 years, please tell us whether your company has never tried, tried but discontinued, or is currently using each of the following.

	Never Tried	Tried, but discontinued	Currently using
Structural Insulated Panels (SIPS)	❑	❑	❑
Laminate flooring	❑	❑	❑
Spray-in foam insulation (Icynene)	❑	❑	❑
Pre-cast concrete foundation walls	❑	❑	❑
Enterprise Resource Planning software	❑	❑	❑
Factory built wall or floor panels	❑	❑	❑
Wood/plastic composite or cellular PVC exterior trim	❑	❑	❑
GPS land tracking	❑	❑	❑
Web-based scheduling	❑	❑	❑
Wood I-joist structural floors	❑	❑	❑
Handheld PC's or PDA's for project scheduling & management	❑	❑	❑

Q11. Please write below the first item checked under Question 10 that you currently use and refer to it in answering the remaining questions in Part 2 (Q12 – Q14). If none are currently used, please skip to Part 3.

Process/Product/material referred to:

_____

Q12. Who in your company significantly influenced the decision to use the product or material you've specified in Question 11?

	Had Significant Influence (Check all that apply.)	Participated in the final decision (Check one only.)
Board member	❑	❑
Chief Executive Officer	❑	❑
Chief Financial Officer	❑	❑
Head of Research & Development	❑	❑
Head of Purchasing	❑	❑
Chief Designer or Architect	❑	❑
Chief Engineer	❑	❑
Head of Sales or Marketing	❑	❑
Others in corporate offices (please specify): _____	❑	❑
Regional Office Director	❑	❑
Regional Purchasing Manager	❑	❑
Regional Senior Project Manager	❑	❑
Regional Project Manager	❑	❑
Others in regional offices (please specify): _____	❑	❑
Local Office Director	❑	❑
Local Purchasing Manager	❑	❑
Local Senior Project Manager	❑	❑
Local Project Manager	❑	❑
Others in local offices (please specify): _____	❑	❑

Q13. How influential are each of the following information sources in keeping your company up to date on the process/product/material you've specified in Question 11? (Please circle one number for each source.)

	No Influence	Some influence	High influence
Company headquarters	1	3	5
Company regional offices	1	3	5
Company local offices	1	3	5
Trade shows, conventions/meetings	1	3	5
Home buyers	1	3	5
Internet in general	1	3	5
Internet sites like HousingZone.com or Toolbase.org	1	3	5
Retail Outlets (Home Depot, Lowes, etc.)	1	3	5
Wholesalers and suppliers	1	3	5
Manufacturers	1	3	5
NAHB and other trade associations	1	3	5
Other builders	1	3	5
Subcontractors	1	3	5
Technology transfer programs like PATH, EnergyStar, Building America, or local green building programs	1	3	5
Trade publications	1	3	5
Universities	1	3	5
Other (please specify): _____	1	3	5

Q14. Please rate the impact of the following decision factors in your company's decision to currently use the product/material you've specified in Question 11.

	No impact	Positive impact	Negative impact
Impact of product/material on profitability	1	3	5
Labor savings derived from the product/material	1	3	5
Materials savings derived from the product/material	1	3	5
Ability to recover cost of the product/material	1	3	5
Streamlining the production process	1	3	5
Reduction in build-time	1	3	5
Compatibility with your construction practices	1	3	5
Quality compared with currently used product/material	1	3	5
Consumer's preference for the product/material	1	3	5
Reduction in cycle-time	1	3	5
Manufacturer's technical support	1	3	5
Subcontractors' familiarity with the product/material	1	3	5
Suppliers' technical support	1	3	5
Reduction in call-backs	1	3	5
Uncertainty/risk of product/material	1	3	5
Initial cost of the product/material	1	3	5
Continuing cost of the product/material	1	3	5
Difficulty in first use of the product/material	1	3	5
Difficulty of continuing use of the product/material	1	3	5
Acceptance by building inspectors/building codes	1	3	5
Acceptance by insurers	1	3	5
Acceptance by lenders	1	3	5
Acceptance by our local production offices	1	3	5

Part 3. Corporate Characteristics

Part 3 asks for basic information about the corporation (i.e. the company as a whole) where you work. If someone else is better able to answer questions about the company characteristics below, please skip to the last page and provide their name and contact information so we can collect the information from that person. Otherwise, please continue answering.

Q15. Does your company build houses:

- ❑ Throughout the US
- ❑ Across one or more regions of the US (check those that apply)
  - ❑ Northeast
  - ❑ Midwest
  - ❑ Southeast
  - ❑ Southwest
  - ❑ West
- ❑ Only in one or two metropolitan market areas

Q16. How many of the following types of homes did the company as a whole build in the U.S. in 2004?

Single-family detached dwellings #____
Townhouses or duplexes #____
Apartments or condos #____

Q17. Of single-family homes built by your company, what proportion (percent) of units are:

Starter homes_____ Move-up homes_____ Luxury homes_____

Please check to make sure the total sums to 100%

Q18. Where in your company are the majority of decisions made on switching building material brands, new building materials, changes in home design and construction processes?

	National Office	Regional Office	Market Area Office
Switch brands	❑	❑	❑
New building material decisions	❑	❑	❑
Home design decisions	❑	❑	❑
Construction process decisions	❑	❑	❑

Q19. Are research and technology development part of your company's corporate strategy?

❑ Yes ❑ No ❑ Don't know

Q20. In what ways does your company as a whole support research and development for new building products or processes? (Check all that apply.)

- ❑ Has an in-house research and development program.
- ❑ Has formed partnerships with manufacturers.
- ❑ Has a champion within the company to keep abreast of innovative products and processes.
- ❑ Use innovative products or processes as part of our marketing strategy
- ❑ Supports regional or local operations in R&D efforts.
- ❑ Does not support research and development of new building products or processes.
- ❑ Other (please specify): _____

Q21. Which of the following departments does your company have at the corporate level? (Please check all that apply.)

- ❑ Research and development
- ❑ Architecture and design
- ❑ Information technology
- ❑ Finance
- ❑ Purchasing
- ❑ Marketing
- ❑ Engineering

Q22. By how much does your company plan to increase its net profits over the next 5 years? (Please check <u>one</u> only.)

- ❑ We expect a reduction in net profits due to planned downsizing
- ❑ Less than 5% a year
- ❑ 5-10% a year
- ❑ More than 10% a year

Q23. About how many full-time employees did you have on your company's payroll in calendar year 2004?

❑ <25	❑ 100-249	❑ 500-749
❑ 25-49	❑ 250-299	❑ 750-999
❑ 50-99	❑ 300-499	❑ 1,000+

Q24. How likely is your company to invest time or money to meet the following objectives in the next 5 years? (Please circle <u>one</u> number for each objective.)

	Not likely	Somewhat likely	Very likely
Improving style and attractiveness of our homes	1	3	5
Improving subcontractor dependability	1	3	5
Reducing costs through use of new building and construction products, materials, and practices	1	3	5
Reducing cycle-times	1	3	5
Improving our ability to purchase and develop the best land	1	3	5
Protecting or improving market share through use of new building and construction products, materials, and practices	1	3	5
Reducing construction defects/callbacks	1	3	5
Reducing overhead costs	1	3	5
Offering the best mortgage financing to home buyers	1	3	5
Researching new products, materials, and practices	1	3	5
Educating buyers about new technologies	1	3	5

Q25. Please rate each of the following in terms of their contribution to your company's success relative to your competitors. (Please circle one number for each.)

	Low	Average	High
We provide a lower cost per square foot home	1	3	5
Our homes have more desirable features (e.g., countertops and trim work)	1	3	5
Our developments have more desirable features like public areas, trails, bike-paths, gated access	1	3	5
We offer energy efficient, environmentally sensitive homes	1	3	5
Our homes have higher structural quality and better mechanical systems	1	3	5
We have a strong reputation for quickly addressing problems in new homes	1	3	5
Our land acquisition capabilities and ability to gain government approvals for development.	1	3	5
We offer high quality architectural design	1	3	5
We invest in the development of new building technologies	1	3	5

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

Your Comments and/or Additional Contact Information:

To receive the survey results, please provide us your email address below:

_____

APPENDIX C. OPERATIONS QUESTIONNAIRE

VirginiaTech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Virginia Tech is conducting a major national study of Innovation and Production Home Builders in conjunction with the Department of Housing and Urban Development and the National Association of Home Builders Research Center. We want to know how decisions are made about using new technologies and materials at both the corporate and operations levels among companies producing 200+ single-family units per year from stock plans rather than custom designs. We believe our results will help your company and others in the industry to improve the use of new building and construction products, materials, and practices (we will send you the results of the survey and our recommendations if you provide us your email address on the last page of the survey).

You were selected as someone who could answer questions about how decisions are made at the operations level (for our purpose, the operations level includes offices directly involved in producing homes in one or more market areas). We would appreciate your taking 20 minutes of your time to complete this survey. Your responses will be completely confidential and will not be released or published in any form that could identify you or your company. For companies with national or regional headquarters, we are also sending a key person at the corporate level a survey with similar questions. Please contact me if you have questions about this survey, if you work at the headquarters or in a regional office rather than at an operations level, or believe you are not the best person to answer from your office.

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

Please return by Friday, September 23, 2005

If the company you work for is not a large, production home builder (defined above), you do not need to complete this survey. Please check the box below and return the survey through the U.S. mail in the pre-addressed envelope provided (no postage necessary). Thank you.

❑ My company is not a large, production home builder.

Please note that different parts of this survey ask you to respond from different perspectives. Parts 1 and 3 of this survey ask that you answer questions about your office (where you work). Part 2 asks that you answer questions about your office or about both your office and your company as a whole. In addition, a few questions ask for your personal opinion. Part 4 asks that you answer questions about your corporation or company as a whole. Please be attentive to how a question is worded so that you answer from the intended perspective. Thank you!

Part 1. Characteristics of the Office Where You Work

Part 1 asks for basic information that should be answered from the perspective of the office where you work.

Q1. How many of the following types of homes did **your office** build in the U.S. in 2004?

Single-family detached dwellings #____
Townhouses or duplexes #____
Apartments or condos #____

Q2. Of single-family homes built by **your office**, what proportion (percent) of units are:

Starter homes _____ Move-up homes _____ Luxury homes _____
Please check to make sure the total sums to 100%

Q3. In **your office**, 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.)

❑ Research and Development manager
❑ Designer or architect
❑ Information technology manager
❑ Project or construction manager
❑ Purchasing manager
❑ Marketing or sales manager
❑ Engineer
❑ Finance Manager

Q4. By how much does **your office** 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
❑ Less than 5% a year
❑ 5-10% a year
❑ More than 10% a year
❑ No specific plan for growth in profits

Q5. To what extent does **your office** use union labor in your construction (including sub-contractors)?

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

Q6. About how many full-time employees did you have on **your office's** payroll in calendar year 2004?

❑ <25	❑ 100-249
❑ 25-49	❑ 250-299
❑ 50-99	❑ 300+

Q7. How important are Master Planned Communities (MPCs) in **your office's** housing production?

❑ We primarily build in MPCs that we also develop
❑ We primarily build in MPCs that are developed by others
❑ We seldom build in MPCs

Q8. How likely is **your office** to invest time or money to meet the following objectives in the next 5 years? (Please circle one number for each objective.)

	Not likely	Somewhat likely	Very likely
Improving style and attractiveness of our homes	1	3	5
Improving subcontractor dependability	1	3	5
Reducing costs through use of new building and construction products, materials, and practices	1	3	5
Reducing cycle-times	1	3	5
Improving our ability to purchase and develop the best land	1	3	5
Protecting or improving market share through use of new building and construction products, materials, and practices	1	3	5
Reducing construction defects/callbacks	1	3	5
Reducing overhead costs	1	3	5
Offering the best mortgage financing to home buyers	1	3	5
Researching new products, materials, and practices	1	3	5
Educating buyers about new technologies	1	3	5

Q9. Please rate each of the following in terms of their contribution to **your office's** success relative to your competitors. (Please circle one number for each.)

	Contribution to success:		
	Low	Average	High
We provide a lower cost per square foot home	1	3	5
Our homes have more desirable features (e.g., countertops and trim work)	1	3	5
Our developments have more desirable features like public areas, trails, bike-paths, gated access	1	3	5
We offer energy efficient, environmentally sensitive homes	1	3	5
Our homes have higher structural quality and better mechanical systems	1	3	5
We have a strong reputation for quickly addressing problems in new homes	1	3	5
Our land acquisition capabilities and ability to gain government approvals for development.	1	3	5
We offer high quality architectural design	1	3	5

Part 2. New Building and Construction Products

Part 2 is about your office's or your company's activities and your personal opinions regarding new building and construction products, materials, and practices (PLEASE READ QUESTIONS CAREFULLY TO ANSWER FROM THE INTENDED PERSPECTIVE).

Q10. If **your office** considers using a new type of siding, which of the following best describes who is most likely to identify a new siding product and who would make the decision to use the product?

	Identifies	Approves
Corporate level	❑	❑
Regional level	❑	❑
Local level	❑	❑
Shared between headquarters and regional offices	❑	❑
Shared between regional and local offices	❑	❑

Q11. Please indicate which of the following statements describe **your company's** and **your office's** approaches towards selecting new building and construction products, materials, and practices. (Please check all that apply.)

	Corporate-wide	Your office
We like to wait until other builders have successfully offered new building and construction products, materials, and practices before we use them.	❑	❑
We are often the first to offer a new and innovative building product or system.	❑	❑
We encourage home buyers to stick with "tried and true" materials and products.	❑	❑
Our goal is to set ourselves apart, to be creative, and to offer materials and products that are distinctive and unique.	❑	❑

Q12. Is anyone in **your company and/or office** considered a strong advocate of new building and construction products, materials, and practices?

Corporate ❑ Yes ↓ ❑ No
If yes, please write their job title _____

Your Office ❑ Yes ↓ ❑ No
If yes, please write their job title _____

Q13. Who in **your company** would have significant influence over a decision to use a new building material (e.g. siding)?

	Has significant influence (Check all that apply.)	Makes the final decision (Check one only.)
Your Office Director	❑	❑
Your Office Purchasing Manager	❑	❑
Your Office Senior Project Manager	❑	❑
Your Office Project Manager	❑	❑
Others in your office (please specify): _____	❑	❑
Regional:		
Regional Office Director	❑	❑
Regional Purchasing Manager	❑	❑
Regional Senior Project Manager	❑	❑
Regional Project Manager	❑	❑
Others in regional offices (please specify): _____	❑	❑
Corporate:		
Board member	❑	❑
Chief Executive Officer	❑	❑
Chief Financial Officer	❑	❑
Head of Research & Development	❑	❑
Head of Purchasing	❑	❑
Chief Designer or Architect	❑	❑
Chief Engineer	❑	❑
Head of Sales or Marketing	❑	❑
Others in corporate (please specify): _____	❑	❑

Q14. How influential are each of the following information sources in keeping you individually up to date on new building and construction products, materials, and practices? (Please circle one number for each source.)

	No influence	Some influence	High influence
Company headquarters	1	3	5
Company regional offices	1	3	5
Company local offices	1	3	5
Trade shows, conventions/meetings	1	3	5
Home buyers	1	3	5
Internet in general	1	3	5
Internet sites like HousingZone.com or Toolbase.org	1	3	5
Retail Outlets (Home Depot, Lowes, etc.)	1	3	5
Wholesalers and suppliers	1	3	5
Manufacturers	1	3	5
NAHB and other trade associations	1	3	5
Other builders	1	3	5
Subcontractors	1	3	5
Technology transfer programs like PATH, EnergyStar, Building America, or local green building programs	1	3	5
Trade publications	1	3	5
Universities	1	3	5
Other (please specify: _____	1	3	5

Q15. Several statements about your individual consideration of new building and construction products, materials, and practices are presented below. (Please indicate how you agree or disagree by circling one number for each statement.)

	Disagree	Neutral	Agree
Building codes make it difficult to use new building and construction products and materials.	1	3	5
New building and construction products and materials generally cost more than ones we currently use.	1	3	5
Our customers prefer the "tried and true" and don't like non-traditional products or features.	1	3	5
It is dangerous to be among the first firms who try new things in our market.	1	3	5
Our bankers and insurance companies are hesitant to underwrite projects with new products and materials.	1	3	5
Manufacturers and suppliers generally do not provide enough support for new products.	1	3	5
There is no competitive advantage gained from using new building and construction products and materials.	1	3	5
Using new building and construction products and materials increases our risk of call-backs.	1	3	5
Subcontractors in our market do not usually want to adapt to new building and construction products and materials.	1	3	5
Our construction workers find it difficult to learn a new way of building.	1	3	5
Our office only uses new building and construction products and materials from established companies that stand behind their products.	1	3	5

Q16. Rate the following potential benefits, **in your opinion**, from adopting new building and construction products, materials, and practices over the past 5-years?

	Level of benefit in adopting new building products, materials, practices		
	Low	Average	High
Decreased costs of building	1	3	5
Created image as an innovative builder	1	3	5
Increased productivity	1	3	5
Increased quality of homes built	1	3	5
Helped comply with codes and regulations	1	3	5
Increased profit	1	3	5
Increased competitiveness	1	3	5
Helped meet customers' expectations	1	3	5
Reduced build time	1	3	5
Reduced call-backs	1	3	5

Q17. In **your personal experience** with adopting new building and construction products, materials, and practices over the past 5 years, how important was cooperation from the following? (Please circle one number for each.)

	Low	Average	High
Suppliers	1	3	5
Manufacturers	1	3	5
Subcontractors	1	3	5
Architects or engineers in your office	1	3	5
Project/construction managers in your office	1	3	5
Regional Offices (if applicable)	1	3	5
Headquarters	1	3	5

Q18. What factors do **you** think will influence the use of new materials and building techniques in residential construction over the next 10-20 years? (Please circle one number for each.)

	No influence	Some influence	High influence
Competition from large national builders	1	3	5
Energy costs	1	3	5
Land costs/availability	1	3	5
Labor costs/availability	1	3	5
Labor quality	1	3	5
Innovation by smaller builders	1	3	5
Consumers becoming more aware of building technologies	1	3	5
Government regulations	1	3	5
Higher quality buildings created through technology advances	1	3	5
Cost savings achieved through technology	1	3	5
More centralized control over production within our company	1	3	5
Decentralized, local decisions over production with our company	1	3	5

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

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

Q19. During the past 5 years, please tell us whether **your office** has never tried, tried but discontinued, or is currently using each of the following.

	Never tried	Tried, but discon-tinued	Currently using
Structural Insulated Panels (SIPS)	❑	❑	❑
Laminate flooring	❑	❑	❑
Spray-in foam insulation (Icynene)	❑	❑	❑
Pre-cast concrete foundation walls	❑	❑	❑
Enterprise Resource Planning software	❑	❑	❑
Factory built wall or floor panels	❑	❑	❑
Wood/plastic composite or cellular PVC exterior trim	❑	❑	❑
GPS land tracking	❑	❑	❑
Web-based scheduling	❑	❑	❑
Wood I-joist structural floors	❑	❑	❑
Handheld PC's or PDA's for project scheduling & management	❑	❑	❑

Q20. Please write below the first item checked under Question 19 that you currently use and refer to it in answering the remaining questions in Part 3 (Q21 – Q23). If none are currently used, please skip to Part 4.

Process/Product/material referred to:

_____

Q21. Who significantly influenced the decision for **your office** to use the product or material you've specified in Question 20?

	Had significant influence (Check all that apply.)	Participated in the final decision (Check one only.)
Your Office Director	❑	❑
Your Office Purchasing Manager	❑	❑
Your Office Senior Project Manager	❑	❑
Your Office Project Manager	❑	❑
Others in your office (please specify): _____	❑	❑
Regional:		
Regional Office Director	❑	❑
Regional Purchasing Manager	❑	❑
Regional Senior Project Manager	❑	❑
Regional Project Manager	❑	❑
Others in regional offices (please specify): _____	❑	❑
Corporate:		
Board member	❑	❑
Chief Executive Officer	❑	❑
Chief Financial Officer	❑	❑
Head of Research & Development	❑	❑
Head of Purchasing	❑	❑
Chief Designer or Architect	❑	❑
Chief Engineer	❑	❑
Head of Sales or Marketing	❑	❑
Others in corporate (please specify): _____	❑	❑

Q22. How influential was each of the following information sources in keeping **your office** up to date on the process/product/material you've specified in question 20? (Please circle one number for each source.)

	No Influence	Some influence	High influence
Company headquarters	1	3	5
Company regional offices	1	3	5
Company local offices	1	3	5
Trade shows, conventions/meetings	1	3	5
Home buyers	1	3	5
Internet in general	1	3	5
Internet sites like HousingZone.com or Toolbase.org	1	3	5
Retail Outlets (Home Depot, Lowes, etc.)	1	3	5
Wholesalers and suppliers	1	3	5
Manufacturers	1	3	5
NAHB and other trade associations	1	3	5
Other builders	1	3	5
Subcontractors	1	3	5
Technology transfer programs like PATH, EnergyStar, Building America, or local green building programs	1	3	5
Trade publications	1	3	5
Universities	1	3	5
Other (please specify: _____	1	3	5

Q23. Please rate the impact of the following decision factors in **your office**'s decision to currently use the product/material you've specified in question 20.

	Negative impact	No impact	Positive impact
Impact of product/material on profitability	1	3	5
Labor savings derived from the product/material	1	3	5
Materials savings derived from the product/material	1	3	5
Ability to recover cost of the product/material	1	3	5
Streamlining the production process	1	3	5
Reduction in build-time	1	3	5
Compatibility with your construction practices	1	3	5
Quality compared with currently use product/material`	1	3	5
Consumer's preference for the product/material	1	3	5
Reduction in cycle-time	1	3	5
Manufacturer's technical support	1	3	5
Subcontractors' familiarity with the product/material	1	3	5
Suppliers' technical support	1	3	5
Reduction in call-backs	1	3	5
Uncertainty/risk of product/material	1	3	5
Initial cost of the product/material	1	3	5
Continuing cost of the product/material	1	3	5
Difficulty in first use of the product/material	1	3	5
Difficulty of continuing use of the product/material	1	3	5
Acceptance by building inspectors / building codes	1	3	5
Acceptance by insurers	1	3	5
Acceptance by lenders	1	3	5
Compliance with company headquarters	1	3	5

Part 4. Corporate Characteristics

Part 4 asks for basic information about the corporation (i.e. the company as a whole) where you work. If someone else is better able to answer questions about the company characteristics below, please skip to the last page and provide their name and contact information so we can collect the information from that person. Otherwise, please continue answering.

Q24. Does your **company as a whole** build houses:

- ❑ Throughout the US
- ❑ Across one or more regions of the US (check those that apply)
  - ❑ Northeast
  - ❑ Midwest
  - ❑ Southeast
  - ❑ Southwest
  - ❑ West
- ❑ Only in one or two metropolitan market areas

Q25. How many of the following types of homes did **the company as a whole** build in the U.S. in 2004?

Single-family detached dwellings #____
Townhouses or duplexes #____
Apartments or condos #____

Q26. Of single-family homes built by **your company as a whole**, what proportion (percent) of units are:

Starter homes_____ Move-up homes_____ Luxury homes _____
Please check to make sure the total sums to 100%

Q27. Where in your **company as a whole** are the majority of decisions made on switching building material brands, new building materials, changes in home design and construction processes?

	Market Area Office	Regional Office	National Office
Switch brands	❑	❑	❑
New building material decisions	❑	❑	❑
Home design decisions	❑	❑	❑
Construction process decisions	❑	❑	❑

Q28. Are research and technology development part of **your company's** corporate strategy?

❑ Yes ❑ No ❑ Don't know

Q29. In what ways does **your company as a whole** support research and development for new building products or processes? (Check all that apply.)

- ❑ Has an in-house research and development program.
- ❑ Has formed partnerships with manufacturers.
- ❑ Has a champion within the company to keep abreast of innovative products and processes.
- ❑ Use innovative products or processes as part of our marketing strategy
- ❑ Supports regional or local operations in R&D efforts.
- ❑ Does not support research and development of new building products or processes.
- ❑ Other (please specify): _____

Q30. How likely is **your company as a whole** to invest time or money to meet the following objectives in the next 5 years? (Please circle <u>one</u> number for each objective.)

	Not Likely	Somewhat likely	Very likely
Improving style and attractiveness of our homes	1	3	5
Improving subcontractor dependability	1	3	5
Reducing costs through use of new building and construction products, materials, and practices	1	3	5
Reducing cycle-times	1	3	5
Improving our ability to purchase and develop the best land	1	3	5
Protecting or improving market share through use of new building and construction products, materials, and practices	1	3	5
Reducing construction defects/callbacks	1	3	5
Reducing overhead costs	1	3	5
Offering the best mortgage financing to home buyers	1	3	5
Researching new products, materials, and practices	1	3	5
Educating buyers about new technologies	1	3	5

Q31. Please rate each of the following in terms of their contribution to **your company's** success relative to your competitors. (Please circle <u>one</u> number for each.)

	Contribution to success:		
	Low	Average	High
We provide a lower cost per square foot home	1	3	5
Our homes have more desirable features (e.g., countertops and trim work)	1	3	5
Our developments have more desirable features like public areas, trails, bike-paths, gated access	1	3	5
We offer energy efficient, environmentally sensitive homes	1	3	5
Our homes have higher structural quality and better mechanical systems	1	3	5
We have a strong reputation for quickly addressing problems in new homes	1	3	5
Our land acquisition capabilities and ability to gain government approvals for development.	1	3	5
We offer high quality architectural design	1	3	5

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

Your Comments and/or Additional Contact Information:

To receive the survey results, please provide us your email address below:

APPENDIX D. DESCRIPTION OF TECHNOLOGIES/BUILDING PRODUCTS

Technologies Referenced in Table 1 (Corp Q10, Operations Q19)

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.

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

Spray Foam Insulation: Using special equipment, a liquid polymer is sprayed into open cavities of walls, ceilings, or floors to provide the primary insulation for a home. The liquid quickly expands into foam to fill voids and provide an insulated, air-tight building assembly.

Pre-cast 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 the job site and set into place to form permanent foundation walls.

Enterprise Resource Planning software: An information technology tool that integrates all facets of business—planning, manufacturing, sales, and marketing—into a single platform. ERPs typically incorporate the functions of inventory control, customer service, financing, and human resources.

Factory-built wall or floor panels: Wall or floor assemblies using light-frame building materials; the panels consist of framing with attached sheathing and are assembled in a factory and delivered to the construction site. The panels are set in place with the aid of a light crane.

Wood/plastic Composite Exterior Trim: Exterior trim and molding materials that are made from a mixture of recycled or virgin plastic and waste wood fiber extruded into solid lineals that resemble wood.

Cellular PVC exterior trim: Exterior trim and molding materials that consist of foamed or cellular PVC and are either molded or extruded into solid shapes or boards.

GPS land tracking: A Global Positioning System uses a satellite triangular to find a global position or a particular location point. GPS is often used in conjunction with Geographic Information Systems for mapping purposes.

Web-based scheduling: Software system that uses a Web site as the communications hub for managing the scheduling of the construction project, including home builder and subcontractor activities.

Wood I-joist structural floors: 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.

Handheld PCs or PDAs for project scheduling & management: Use of handheld PCs or PDAs, which are linked (typically) via wireless communications to a central computer database, by construction project staff to access real-time project status updates and communications.

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