U.S. Department of Housing and Urban Development
Office of Policy Development and Research

PATH
Partnership for Advancing Technology in Housing

Commercialization of Innovations: Lessons Learned

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Commercialization of Innovation: Lessons Learned

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by
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Foreword

The housing industry must learn from its own experiences with innovation if it is to avoid repeating the mistakes of the past. In looking at two innovation experiences—exterior insulated finishing systems and engineered wood I-joists—this study suggests several important recommendations for improving the diffusion of innovation in the residential construction industry.

This report recommends that individual innovations should be viewed parting the context of a larger housing system and that members of the housing delivery system should monitor problems and collaborate earlier in the commercialization process. It is important that both the public and private sectors share the risk of innovation if we are to avoid the dampening effects of litigation. The challenge is to provide the environment for collaboration while preserving the competitive nature of the industry.

We expect that this report will stimulate public discussion and be useful for initiatives in innovation.

Executive Summary

If the housing industry is to appropriate the benefits of new technology and innovation, it needs to understand its own experiences with innovations and learn from them. In this report, PATH asked practitioners associated with two innovations, exterior insulated finishing systems (EIFS) and wood I-joists to reflect on their experiences and relate what they thought worked well and what they would do differently. Both innovations experienced difficulties during commercialization; on the basis of those difficulties PATH derived general advice that could be applied to the introduction of new technology by other private parties and public officials concerned with innovation in the housing industry.

Too often, innovators focus on the technology of construction at the expense of understanding the factors that influence commercialization. To provide a more balanced perspective, the project staff also looked at previous studies on the diffusion of innovation to provide a framework for understanding earlier experiences with commercialization as well as the advantages and disadvantages of the subject technologies. The literature discussed the context in which innovation takes place as well as the factors that determine the rate and degree of substitution of innovation in the market. The context consisted of changes in the national economy and environment external to the building industry, as well as changes in the home building industry itself. The factors influencing the rate and degree of substitution of an innovation take the form of five physical attributes of any given innovation. The project staff's independent evaluation of the two innovations found that, despite differences relative to the physical attributes, the attributes offset one another to contribute to the same moderate impact. Accordingly, the staff to examined the way decision makers processed the innovation during its introduction, diffusion, and commercialization.

Based on practitioners' experiences as well as on the literature on innovation, PATH arrived at findings from both the EIFS and I-joist experiences. Some of the key findings are summarized as follows:

- Both innovations experienced difficulties in making the transition from commercial to residential markets.
- Both innovations had to address problems dealing with the compatibility of the product with the housing system.
- Both innovations came up against limitations associated with the inadequacy of skills in the construction labor force.
- Both innovations differed in the extent to which practitioners monitored the products and dealt with early problems.
- Both innovations generated negative perceptions during the commercialization process; practitioners responded to the problems in a variety of ways.

These findings led to the following major recommendations:

- Innovators need to understand how an innovation fits into the overall housing product.
- Innovators need to gain an understanding of how the housing industry functions.

- Innovators need to take into account the possible benefits of shifting certain activities, such as design and fabrication, off site under controlled conditions.
- A forum needs to be established to allow affected parties to come together on neutral ground to discuss various problems.
- Training and education workshops need to be provided, particularly if an innovation requires significant changes in current practices.
- The innovator needs to inquire as to whether adequate testing and performance standards are in place to assess the innovative product.
- The innovator needs to evaluate the perceptions of its product or process and take appropriate action.
- A monitoring system is needed for the collection and evaluation of information about the use of the innovative product.
- Research is needed on major "root causes" of generic industry issues.
- A clearinghouse of readily available information needs to be established.
- Consideration needs to given to how risks are allocated to the various parties involved with innovative products.
- The industry needs to develop an effective means of achieving collaboration among participants in the housing industry.
- The regulatory environment needs to respond to the needs of the innovator.
- An "Innovator's Handbook" would be a useful tool.
- The feasibility of using "super contractors" needs to be subjected to further study.
- The risks of litigation need to be limited in a fair way.
- The industry should develop a heightened sense of product stewardship when innovation products are used.

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1.0 Purpose

Under the sponsorship of the U.S. Department of Housing and Urban Development's (HUD) Partnership for Advancing Technology in Housing (PATH), the NAHB Research Center (Research Center) conducted two case studies. The objective of the case studies was to gain insight into the commercialization of innovations in the housing industry and to make preliminary recommendations for possibly broad-based public and private actions that can expedite the commercialization of innovation. Project staff sought to base the recommendations on an analysis of experiences with innovations, identifying the factors that contribute to success or difficulties in bringing innovations to market. The examination is not intended to be exhaustive or to draw conclusions about the products' performance or suitability; rather, it attempts to determine whether innovation-specific discussions with decision makers are appropriate in providing a framework for gaining insight into future decision making related to advancing housing innovations in the commercial marketplace. A subsidiary objective was to update knowledge of the diffusion of innovation. Since the Research Center undertook studies into the diffusion of innovation from 1989 to 1991, no significant study has added to the store of knowledge of innovation in the housing industry.[1]

2.0 Approach

Two case studies were central to PATH's approach to understanding the intricacies of decision making involved in the commercialization of innovation. One case study deals with a relatively successful innovation and another with an innovation that encountered difficulties. The methodology for conducting the two case studies involved development and circulation of "white papers" to key stakeholders in the industry and holding discussion workshops with these stakeholders (see Appendix A). Based on experiences with the innovations and a review of published articles and papers, project staff drafted a summary of each innovation's technology and the circumstances surrounding its introduction, deployment, and implementation. Staff also attempted to discover how future difficulties in commercialization might be avoided. Similarly, staff sought to find out what actions and strategies accounted for commercialization of a successful housing innovation. This report summarizes and synthesizes the results of these investigations.

[1] NAHB Research Center, *Diffusion of Innovation in the Housing Industry*, for the U.S. Department of Energy, November 1989.
NAHB Research Center, *Advanced Housing Technology Program, Phase I*, for the Oak Ridge National Laboratories, September 1991.

3.0 Lessons Learned: Recommendations and Considerations for Private Action and Public Policy

Analysis of the innovation experiences of the two building technologies led to the following lessons for private and public policy consideration:

- Innovators need to understand how an innovation fits into the overall housing product. Workshop participants emphasized the importance of tracing the interrelationships between their products and the rest of the housing product so as to identify potential problems. An early warning system would identify interfaces that create performance problems associated with either the innovative product or other housing components affected by the new product. Such systems are fairly new to the housing industry.
- Innovators need to evaluate how the housing industry functions. An innovative product or process often alters established relationships and shifts responsibilities. The innovator must become aware of the impact of the innovation on the various participants in the housing production chain including manufacturers, distributors, installers, retailers, builders, subcontractors, and regulators. Changed relationships may require other actions be taken if the innovations are to be implemented. This evaluation should be conducted early in the innovation process.
- Innovators need to take into account the possible benefits of shifting certain activities, such as design and fabrication, off site under controlled conditions. Off-site may reduce many of the problems associated with complex installations involving a wide range of installers.
- A forum needs to be established to allow affected parties to come together on neutral ground to discuss various problems. As early as possible in the innovation process, parties affected by a proposed innovation should have the opportunity to meet, discuss, and brainstorm various approaches to innovation and commercialization. They should discuss both short- and long-term considerations and identify points of possible failure.
- Training and education workshops need to be provided, particularly if an innovation requires significant changes in current practices. Care must be taken to match the type of knowledge required with the appropriate mechanism for delivering such knowledge. The mix and nature of technical supporting activities will likely vary depending on the innovation and its impact on the way work is conducted.
- The innovator needs to inquire as to whether adequate testing and performance standards are in place to assess the innovative product. Standards apply not only to the innovation itself but also to the product as an integral component of the housing system. The inquiry should include the identification of well-respected "authoritative" entities whose testing or evaluation will carry weight as to the acceptability of the innovation.
- The innovator needs to evaluate the perceptions of its product or process and take appropriate action. The innovator should investigate both positive and negative perceptions in order to be prepared to counteract or build on those perceptions.

The investigation will probably require research on the costs and benefits of the innovation so that the innovator can influence the perceptions of adopters.

- <u>A monitoring system is needed for the collection and evaluation of information about the use of the innovative product.</u> The case studies vividly illustrate the importance of an early warning system to "flag" issues that need to be addressed. Monitoring incorporates quality control procedures not only at the manufacturer level, but also at the distributor, installer, and user levels. Monitoring might be an area where the public sector can exert some leadership. An innovator should consider whether it can create the needed information flow. The monitoring system should be designed to pick up early indications of problems.
- <u>Research is needed on major "root causes" of generic industry issues.</u> Gaps in basic research need to be identified. In some cases where there is basic research on generic problems, research needs to be focused and applied to practical problems in the field. In the case of EIFS, well-established research on moisture intrusion into homes and its remediation could have been critical. Such research might take into account externalities such as regional variations.
- <u>A clearinghouse of readily available information needs to be established.</u> Such a clearinghouse would contain information on market trends, the evolving regulatory environment, government policies, technical studies, and so forth. It would also be used to disseminate research.
- <u>Consideration needs to be given to how risks are allocated to the various parties involved with innovative products.</u> It is essential to explore opportunities for a more efficient allocation of risks for innovative products, particularly when the value of an innovation is relatively small relative to the potential cost exposure due to failure. Insurance companies play a powerful role in whether innovative products are used. The inquiry should involve the insurance industry in exploring whether its practices help or hinder the diffusion of innovations and what actions might be appropriate to strengthen the positive effects. Government likewise should be brought into the discussion to consider whether it should assume part of the risk for innovative products and processes. Possible public actions may include no-fault insurance or the use of special mortgage insurance when innovative products are used in a dwelling.
- <u>The industry needs to develop an effective means of achieving collaboration among participants in the housing industry.</u> The housing industry is highly competitive. However, occasions arise when collaboration is in the best interest of all parties. Actions should be pursued that encourage collaboration. The following questions need to be asked and answered: What should be the role of associations, the government, universities, and others in fostering collaboration? Is there a role for public/private partnerships, consortiums, and coalitions? What skills might participants develop to be more collaborative? What activities might participants undertake to increase trust between parties?
- <u>The regulatory environment needs to respond to the needs of the innovator.</u> Regulators have an impact on the innovation process. Despite research into the role of regulation, some questions remain. What further actions might be taken to strengthen the positive role of regulation and diminish its negative effects? Might

these actions play a role in the authoritative testing and evaluation of innovations and the dissemination of information?

- An "Innovator's Handbook" would be a useful tool. Case studies demonstrate that the complexity of the innovation process gives rise to numerous questions. Firms currently deal with the innovation process in an ad hoc manner. A generic handbook, the "A,B,Cs of Successful Innovation" should be available to innovators before they make sizeable investments in research and development.
- The feasibility of using the "super subcontractor" needs to be subjected to further study. Super-contractors consolidate a variety of trades under one umbrella, thereby offering the potential for more efficiently diagnosing and handling system problems that occur during installation. The arrangement also provides a more efficient method of facilitating communication among specialized trades.
- The risks of litigation need to be limited in a fair way. Workshop participants did not take the opportunity to address this issue in any significant way because of the current status of litigation involving EIFS. However, they did indicate that the threat of litigation does have a dampening impact on innovation. They recommend the continued study of litigation exposure.
- The industry should develop a heightened sense of product stewardship when innovative products are used. Stewardship may involve a systems approach to quality control. Not only is there quality control in the manufacturer's plant, the system extends down to those who install the product and maintain it. Stewards would also look at the various incentives that operate on participants in the production-distribution-installation system to anticipate and overcome adverse effects.

4.0 Case Studies: Product Descriptions and Commercialization

4.1 Exterior Insulation and Finish Systems

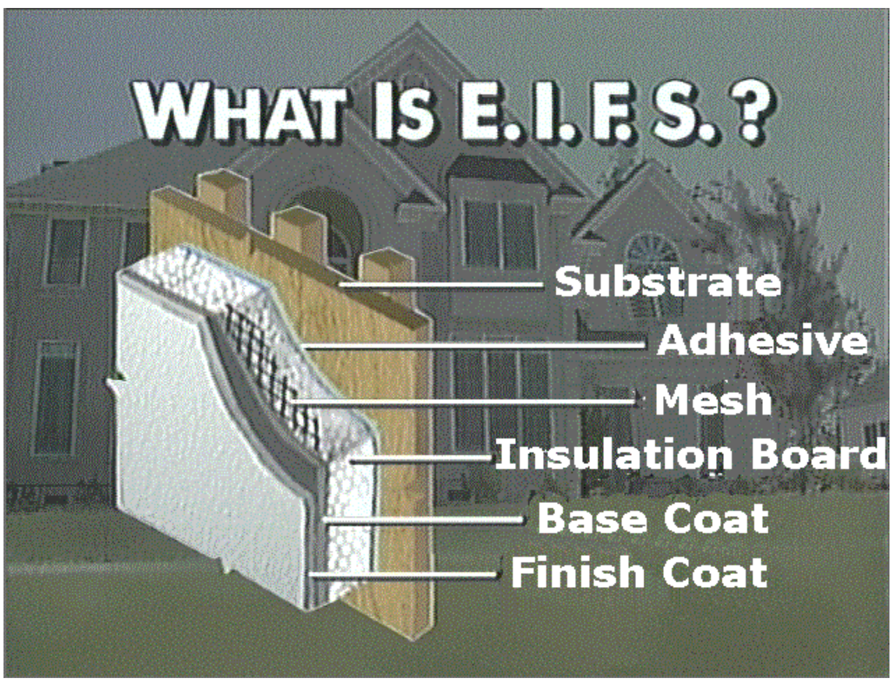
4.1.1 Product Description

EIFS is a cladding/siding system that provides an exterior surface and insulation in an integrated composite system. EIFS has the appearance of traditional stucco but differs from stucco in its components, methods of construction, performance and physical attributes, and so forth. The most common EIFSs consist of an expanded polystyrene insulation board (EPS) that is adhesively or mechanically attached to sheathing, a cementitious base coat troweled onto the EPS board that embeds fiberglass reinforcing mesh, and a colored and textured acrylic finish coat that is troweled over the base coat. Each component has a functional purpose such as mechanical support, insulation, resistance to crack initiation, resistance to water transmission, and surface appearance.

Most EIFSs used previously in residential applications were barrier-type claddings that relied on the EIFS lamina to prevent water penetration and moisture intrusion beyond the EIFS system and into the building envelope elements. Figure 1 illustrates the barrier system. The systems were designed as a face-sealed barrier that provided a weatherproof membrane and required watertight sealing around penetrations such as windows, doors, electrical outlets, vents, roofing, decks, hose bibs, and so forth, to maintain the integrity of the building envelope. Within the past few years, a drainable water–managed form of EIFS has seen increased use in the residential market in response to the issues related to barrier systems and the associated changes in building codes that were intended to strengthen the provisions covering barrier EIFS.

Damage from moisture intrusion is a significant complaint with all cladding systems. Barrier EIFSs were intended to resist water penetration at their outer surface; however, they were not designed to drain water that infiltrated below the surface. Thus, if significant water intrusion occurred through building components or as sealants cracked or broke down, and the components/sealants then remained in a state of disrepair, water could enter behind the cladding and wet the substrate and, in some cases, the wood structural members. Depending on the climate and overall makeup of the wall assembly, the wall may not have readily dried out. Sustained elevated moisture without adequate drying causes wood to decay. Decay may not have been easy to detect because the visible exterior surfaces might not have shown damage that occurred behind EIFS surfaces.

FIGURE 1
EIFS Illustration



4.1.2 Commercialization

In general, commercialization by a firm emphasizes the active use of knowledge in facilitating the actual application of an innovative technology to potential customers in the market. Underlying commercialization is the need to receive a high enough rate of return to recoup the firm's cost of the investment relatively quickly, even though negative rates of return may be acceptable for a short time so that a firm can achieve first-mover advantage.

EIFSs were developed in Europe after World War II for repair of damaged buildings. In the European context, EIFS was primarily used over masonry, which is moisture-tolerant. In the United States, however, conventional practice called for wood-frame construction, which is less moisture-tolerant than masonry. With wood-frame construction not common in Europe, the experience with early uses of EIFS did not directly reflect what would happen when EIFS was used with wood.

In 1969, Dryvit Systems introduced EIFS to the United States. Initial applications were limited to commercial buildings. The industry reports extensive testing of EIFS products for commercial application and evaluation for code compliance by the various U.S. Building Code Evaluation through the 1970s and 1980s.

During the oil crisis of the 1970s, Dryvit subsequently expanded its markets to the high-end residential segment where it rapidly became an attractive cladding among energy conscious builders and buyers. To some degree, the energy crisis and new energy regulations drove the market for the use of EIFS during this period. Other manufacturers often representing European manufacturers also entered the market (e.g., Sto and Parex). EIFSs' several desirable properties—expected low maintenance, superior insulation, and ease of architectural detailing—made the cladding system popular. It became a building material of choice in the Southeast and started to penetrate other American markets in the Midwest, Pacific Northwest, and Southwest—areas that were experiencing a building boom and shortage of qualified labor. These same areas, however, are also noted for their wet climates. By the 1990s, an estimated 250,000 homes were clad with EIFS, although precise numbers are difficult to determine. These homes were invariably custom built and in the higher price ranges. Manufacturers historically sold their product to distributors and did not trace the sale of their product through to the installer-contractor. Today, EIFS finds application in both residential and commercial construction.

To the extent that a new product such as EIFS should be analyzed and tested with respect to existing methods of construction, it appears that the cladding technology was transferred from the European setting with limited consideration for its application in concert with the different materials and construction processes used for residential building in the United States. The absence of testing for residential use might be attributable to the initial use and acceptance of the product for commercial applications and/or to the absence of test standards and specific code criteria for residential applications. In the commercial sector, architects play a prominent role in the design and supervision of the construction process. Their job is to see that the special requirements associated with EIFS are followed. It seemed to be a good marketing strategy and easy step to expand EIFS sales into the residential sector. Furthermore, the residential builder did not employ the same technical staff, such as architects, as commercial contractors. Therefore, there was no appropriately trained staff to pay attention to the installation specifications critical to successful EIFS installation.

The capital costs of entry for EIFS manufacturers are relatively low, thereby allowing easy entry for firms. Several manufacturers have entered the market with no one firm dominating. Each firm varies the components used in its cladding system. Over time, the manufacturers have joined together to form the EIFS Industry Members Association (EIMA). The association has established minimum industry performance standards and developed industry technical representation for various model building code organizations. In addition, EIMA's technical committees developed generic performance standards and installation requirements for the various classes of EIFS product design. Also represented in EIMA are installer-contractors and product distribution companies.

Manufacturers of EIFS do not make a cladding per se or control the construction process. Rather, they manufacture the EIFS compounds, recommend adhesives and other materials for use, and provide instructions for installer-contractors. Many EIFS manufacturers provide training for installers while others depend on distributor-suppliers and the plaster trade associations to provide the needed training. Typically, EIFS are sold to distributors, who in turn sell the components to installer-contractors hired by builder-contractors.

The buyer and/or builder, not the manufacturer, make the decision to use EIFS on a home. The contractual relationship exists between the builder-contractor and the installer-contractor. Builders, by and large, have not been trained in the installation of EIFS. They report that they depend on the training the installer-contractors received from the manufacturers or distributors. For whatever reasons, it was not unusual for the manufacturers to be unaware of the practices of installers. One consequence has been that a home often contained EIFS components from more than one manufacturer, a result of which nullified manufacturers' warrantees. Another issue arose with the application of sealants, a required component of the EIFS. Painters traditionally did caulking as part of their job. Thus, the builder relied on the painter to caulk areas of the building envelope, such as the interface between windows and EIFS, where water could intrude. Painters are typically not trained in EIFS installation requirements and therefor relied on traditional caulking materials and methods instead of using low-modulus sealants as specified by EIFS manufacturers.

Another technical issue arose with the window and EIFS industries. Neither industry fully understood the performance issues associated with the the other's products. The window industry's performance standards permitted a "wet zone" in the jamb-to-sill joint—where the joint is to the outside of the mounting flange. To the extent that the EIFS industry expected windows to be watertight, the sealant joint details for windows to EIFS provided by the EIFS manufacturers were inadequate.

With an almost limitless number of combinations and permutations associated with building products and configurations, the traditional function of incorporating various building elements in the final structure and accounting for the element's compatibility can be the responsibility of the builder or his/her architect. In the case of EIFS, the proper installation requires that subcontractors experienced in installing windows, flashing, sealants, and cladding work together to maintain the quality integrity of the cladding product. In fact, it should be noted that design-build firms do not typically rely on professional architects to detail and specify various cladding systems; instead, they charge the subcontractor with responsibility for figuring out the process. To be sure, the complex mix of decision-makers blurs the lines of responsibility.

The early years of EIFS's use in the United States were largely without incident. The first indications of EIFS-related problems began to surface in the late 1980s and early 1990s. The gypsum industry started to distance itself from EIFS in cases involving delamination of paper facing from the EIFS gypsum core where water had penetrated joints. In the early 1990s, the U.S. Department of Housing and Urban Development undertook investigations in Dade County, Florida, with respect to damage to HUD-financed projects in the wake of Hurricane Andrew. Massachusetts initiated a study to evaluate state buildings that specified EIFS. The U.S. Army Corps of Engineers Construction and Engineering Research Laboratory studied the use of EIFS in various military buildings (in the Midwest and East). All of these studies, however, focused mainly on commercial and mid-rise residential buildings, not on wood-frame one- and two-family structures. In any event, the studies addressed concerns raised by the various agencies and the gypsum industry.

The first major signs of large-scale problems involving single-family houses began to emerge in the mid-1990s. In November 1994, the New Hanover County (North Carolina) Inspections Department received its initial complaint about moisture accumulation and damage in EIFS-clad homes. Investigations began in the spring of 1994, and a report issued in the summer stated that many of the EIFS-clad homes had high levels of moisture within the building wall structural system as well as in cavities and showed the potential for damage. Later, that year, various stakeholders with potential liability met with representatives of the Consumer Protection Section of the North Carolina Office of the Attorney General to seek an out-of-court settlement. That effort failed. Later a task force consisting of New Hanover County, the National Association of Home Builders, EIFS manufacturers, and installers issued special alerts and notices about the potential of damage from moisture intrusion associated with EIFS. The notices concentrated on the use of appropriate flashings and sealants as well as on proper use of secondary weather barriers.

The publicity associated with moisture damage focused on homes with extensive damage. Television footage of inspectors opening up an exterior wall in a high-priced EIFS home to show extensive rot dominated the images. A more detailed survey of damaged homes in New Hanover County, where EIFS was totally removed showed that most damage to EIFS homes, as of the time of the documentation, was minor and localized to windows, doors, decks, roof-wall intersections, and penetrations through the system, only a few homes experienced extensive damage. Because damage obviously increases with the passage of time, it is likely that the recorded damage would have been more severe if more time had elapsed.

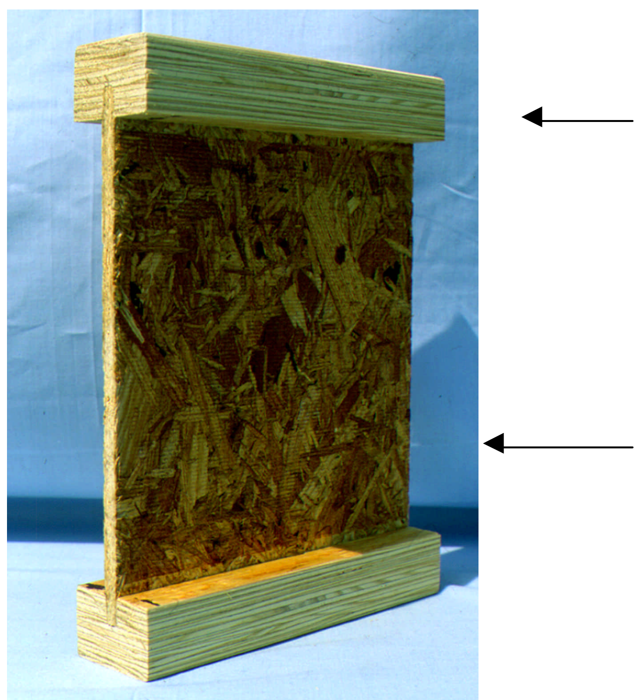
Shortly thereafter, a series of state and federal class action lawsuits were litigated, many of which were ultimately settled.

4.2 I-Joists

4.2.1 Product Description

I-joists involve relatively simple construction that consists of just three components: top and bottom flanges or cords, a web, and adhesive to hold the webs to the flanges. Despite I-joists' relative simplicity, several configurations and combinations of materials are possible. The wide variety of raw materials and processes used in making I-joists as well the lack of standardization are a function of the industry's youth and the process of "settling in" that occurred during the industry's initial years.[2] In satisfying the high-volume demand for I-joist applications in residential buildings, many different firms offer products that appear interchangeable but are in reality unique. Each has different performance attributes in regard to load, fire- and sound-transmission ratings, warranties, or other proprietary characteristics that meet the various load, fire separation, and other, criteria specified in building codes throughout the United States. Figure 2 illustrates an I-joist.

FIGURE 2
I-Joist Illustration



The flanges are the top and bottom members of the "I" that support the bending stresses in the beam. They also give the beam stiffness, and provide an element to accept connection with other building elements (e.g., subflooring, and so forth.). The flanges are typically made of single or laminated pieces of visually graded or machine stress

[2] Op. cit., Nelson, p. 4-95.

rated (MSR) lumber[3] or laminated veneer lumber (LVL).[4] In the case of longer lengths, high-grade lumber is sometimes finger-jointed. LVL flanges are stronger and narrower and exhibit less variation than those fabricated of MSR lumber. An engineer calculates the required flange size based on a home designs load requirements. Flanges' cross-sections typically range from 1 1/2 inches by 1 1/2 inches to 4 5/8 inches by 2 5/8 inches.

The webs serve as the primary structural member and consist of either plywood or oriented strand board (OSB), typically 3/8 inches to 5/8 inches thick. At least two producers use sawn dimension lumber for webs. The web panels are glued together at each end and may be connected by a butt joint, v-groove, tongue and groove, or serrated connection. Most I-joists have a single web, but one producer makes an insulated double-webbed I-joist header that encloses rigid foam board between the webs. The depths of the I-joists or the heights of the "I" range from 9 ¼ inches to 38 inches and are available in lengths up to 80 feet.

Exterior, water-resistant adhesives are used exclusively to bond webs and flanges and, pursuant to industry standards and building codes, must conform to ASTM D2559, "Standard Specification for Adhesives for Structural Laminated Wood Products for Use Under Exterior (Wet Use) Conditions" or "CSA 012-M Standards for Wood Adhesives." Use of other adhesives not included in the standards is permitted if it can be shown through testing that their performance is equivalent. Phenol resorcinol glue is generally used for the joint and requires 24 hours to reach full strength. The configuration of the web-to-flange connection, a groove in the flange into which webs are inserted, varies among manufacturers, as do the web-to-web connections used to make the webs continuous. The ideal joints provide maximum surface area for gluing while holding the web and flange in place without pressure. The joint, which is a proprietary product, is a critical factor in determining the joist shear properties.

In mass production of I-joists, sawn lumber or LVL is ripped to width for flanges and fed into a continuous roller press that cuts a rout into the flange. In an earlier operation, a mating tongue is routed onto the edges and ends of webs cut to width. The web panels are then bonded to the flange to make the finished I-joist. The process occurs in a fully automated continuous production line with operating speeds up to 350 feet per minute or more, accepting webs and flanges at one end and producing the finished product on the fly at the other end.

I-joists are mainly used as floor joists and not as structural beams; they are sometimes used in cathedral ceilings. According to the American Plywood Association (APA), over 80 percent of I-joists produced in 1998 were used in new-home floors, followed by 10 percent in nonresidential buildings, 8 percent in remodeling applications, and 3 percent in walls and roofs. In 1999, according to the NAHB Research Center's Annual Builder's

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[3] In MSR, each piece is flexed and measured so that a known modulus of elasticity can be measured. The modulus of elasticity is the ratio of the amount that the lumber will deflect in proportion to an applied load. The higher the number, the stiffer the wood.

[4] LVL is made from veneer and glue. Veneer is peeled from logs, clipped into sheets, dried, and graded in a process similar to that followed in a plywood plant. The sheets are then coated with a phenolic resin and layed up into a continuous billet of LVL, which is then pressed and sawn into lumber.

Practices Survey (ABPS), I-joists were used in 22 percent of all floors in both new single-family and low-rise multifamily dwellings. They were used on 17 percent of all first floors and 32 percent of all second floors.[5] First-floor use of I-joists is less common because some sections of the nation tend to build structures on concrete slab-on-grade, which provides support for the first floor. Excluding multifamily dwellings, I-joists were used in the floors of about one-third of all new single-family homes, and 50 percent of builders are said to have used wood I-joists.[6] In 1995, the largest proportion of all LVL production, about 45 percent, was devoted to residential wood I-joists compared with 37 percent devoted to residential beams and headers. In addition, the availability of evaluation reports from U. S. evaluation services facilitates confirmation of compliance with the U.S. building codes.

In summary, as will be shown below, builders rely on much more diversified channels of distribution for I-joists than for framing lumber and are much more dependent on manufacturers and their distributors for a supply of I-joists. The system of customized technical support under the auspices of specialized or manufacturer-owned distribution not only supports branded products but also helps speed the commercialization of I-joists by ensuring product quality, thereby relieving builders and architects of liability from failure.

Specific characteristics that contribute to I-joist ***advantages*** follow:

- Longer and continuous spans provide enhanced structural capability and flexibility, allowing clear spans with greater on-center spacing, longer ceiling lines, and fewer pieces for more rapid installation. Continuous spans that can be supported by more than two bearing points eliminate lap joints, extra material, and labor. Ends of continuous beams are not allowed to rotate, permitting a 20 to 30 percent improvement in deflection.
- Consistent product performance leads to improved dimensional stability. Controlled moisture results from close tolerances in controlled manufacturing processes as well as the use of engineered woods, which are also manufactured to specification. Consequently, it is easier to predict product performance.
- With more efficient routing of HVAC, plumbing, and wiring, webs provide a convenient location for conduits with minimal impact on performance when holes are properly placed. The result is better coordination with relevant subcontractor trades and improved construction cycle time.
- With improved support for subfloors, wide dry flanges provide additional support; an excellent gluing surface for subfloors results in increased floor performance and reduction of floor squeaks at minimal cost.
- By incorporating more wood where it is needed, more efficient structural use of wood fiber overcomes the main bending stresses in floor joists, which are most severe at the middle of the span and at the outer edges at the top and bottom of the

[5] A cross-sectional mail survey to 1,500 builders with a response rate of 12 percent found that 23 percent of builders used I-joists in floor systems and only 7 percent used them in ceiling systems, defined as the upper floors of a home. Ivan L. Eastin et al., "Softwood Lumber Substitution in the U.S. Residential Construction Industry in 1994," *Forest Products Journal*, May 1999, Vol. 49, No. 5, p. 24.
[6] Lee McGinley, "Engineered Lumber Update," *Journal of Light Construction*, 1998.

beam. Since an 11 ¼-inch I-joist uses high-strength engineered or other woods in which the tensile strength exceeds the bending strength of conventional woods, the joist's structural capacity is equal to a 2 by 12 while using only 62 percent of the 2 by 12's wood fiber.

- More efficient use of wood fiber resources translates into the ability to produce a great variety of larger, more structurally sound lumber products out of smaller, younger-growth trees, eliminating resource constraints imposed by the scarcity of larger, older trees.

A number of the advantages of I-joists are in part offset by some ***disadvantages*** associated with design, economics, and installation as follows:

- The numerous proprietary designs of I-joists can add to their expense and confuse both builders in specifying products and code officials in reviewing and approving them. APA standards (see discussion below) and code evaluation reports temper these concerns. Each product uses different materials, production processes, and quality control methods, resulting in different capacities and the added expense of requiring the evaluation and verification of I-joists for each intended use.
- Although most I-joists use less linear footage than conventional lumber and permit faster installation and better performance, the cost per linear foot exceeds that of conventional lumber.
- The longer lengths of I-joists result in poor lateral stability and thus require extra care in handling while offloading product and during installation.
- The 1 by 4 blocks attached to the side of the web, so-called web stiffeners, are required to increase the bearing and shear capacities of I-joists and to prevent web buckling of deeper joists in certain applications.
- Squash blocks, cripples, or struts in the form of 2 by 4 vertical blocks are required under bearing walls to transfer loads around the joist into supports below. In addition, short pieces of joists or blocking panels are often placed perpendicular to a framing joist to transfer bearing loads from above and to provide lateral support.
- Plywood may be required at cantilevers to support concentrated loads from roof structures.
- The increased structural capabilities and longer spans of I-joists compared with conventional materials may require special care in design. Code minimums are not always adequate for longer spans. As a result, most manufacturers provide tables with recommended spans that are more stringent than the code minimums. I-joists of 60-foot lengths present the opportunity for severe misapplications and overstress conditions.

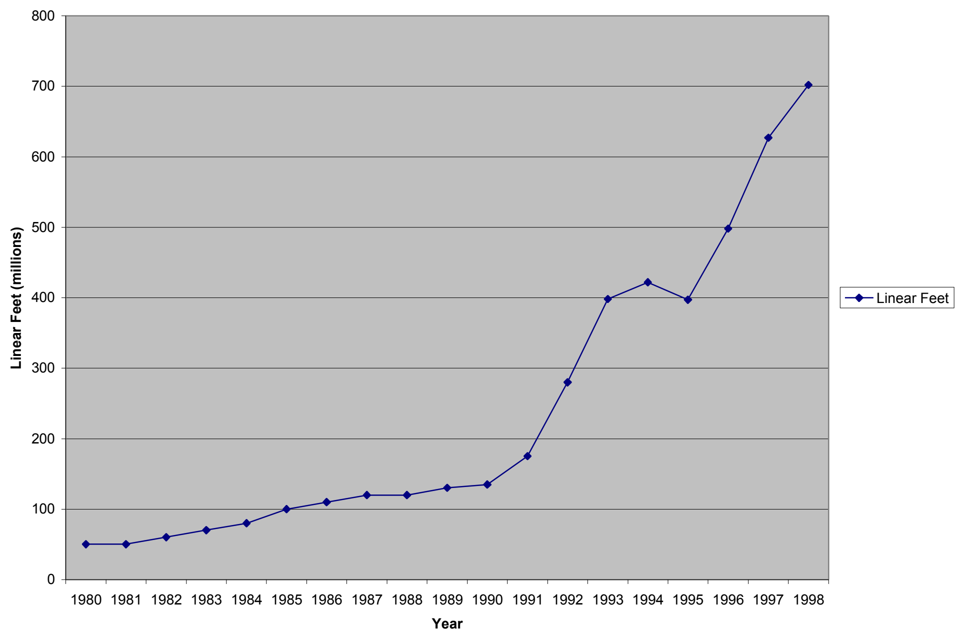
4.2.2 Commercialization

I-joists began to find application in the residential market in 1980 just as the APA began recording data on wood I-joist production in North America. Given that I-joist production data are readily available and reflect market demand, I-joist production is considered a reasonable proxy for market demand. From 1980 to 1998, I-joist production experienced annual growth in every year except for a slight dip in 1995, paralleling a downturn in the housing market, and in two periods of stability between 1980 and 1981 and 1987 and 1988. Production increased thirteen-fold during the period, from 50 million linear feet in 1980 to over 700 million linear feet in 1998 (see Figure 3).

Innovation research has shown that diffusion of many innovations follows a bell-shaped curve—that is slow or almost level at first, rising slowly, tracing a steeper rise, and then decelerating. Between 1980 and 1990, the earliest and most entrepreneurial builders, so-called *innovators*, first began to adopt the use of I-joists. As a result, I-joist production grew modestly at an average of 8.5 million linear feet per year, or a 10 percent average annual growth rate, forming a lead-in to the normal curve.

FIGURE 3

North American I-Joist Production (million linear feet)



Source: "Regional Production & Market Outlook for Structural Panels and Engineered Wood Products 2001-2006," American Plywood Association, March 2001, p.51, and the NAHB Research Center.

Growth began to accelerate and take off between 1990 and 1993, when a larger group of *early adopters*, accepted members and leaders of the builder community, adopted I-joists ahead of other builders. In this period, I-joist production jumped to an average of 87.7 million linear feet per year, or an average annual growth rate of 44 percent. The early adopters account for the sharp ascent of the bell-shaped curve, representing about 13.5 percent of potential adopters.

As the base of builders using I-joists increased, it became more difficult to sustain the high rate of growth in the period from 1994 to 1998. The average 60.8 million linear feet of I-joists produced per year was substantial, but the level moderated somewhat as *early* *majority* builders began to adopt I-joists. The early majority builders are followers who adopt innovations, such as I-joists, more slowly. They eventually accounted for an additional 34 percent of all potential adopters, who, combined with previous innovators and early adopters, represent a majority or 50 percent of all potential adopters of I-joists and the peak of the normal curve.

A number of contextual factors were responsible for the increased adoption and successful commercialization of wood I-joists.

- *The decline in the supply of old-growth, high-quality lumber*

Old-growth trees that used to be the basis for visually grading conventional lumber still exist, but they are no longer available owing to institutional factors. At one point, public forests provided a quarter or more of domestic lumber production and a similar percentage of softwood plywood.[7] The closing of federal forests by fiat and litigation resulted in a decline in the availability of high-quality lumber despite imports of lumber from Canada and an increase in private timber harvesting from small holdings throughout the Pacific Northwest. "Almost all structural lumber is now derived from second (or third) growth, as well as from species (e.g., aspen) that were not considered commercial four decades ago. We can no longer trust a piece of wood graded visually to do all that it is supposed to do."[8] Consequently, the strength of conventional lumber varies widely, and values for strength have been recalculated and downgraded compared with values assigned in the past. In practice, either more wood is required to span the same distance or bear the same load, or loads have to be reduced for the same sizes of lumber. The decline in the quality of dimensional lumber accentuated the functional advantages of engineered wood I-joists in terms of consistency and reliability.

- *Past high prices for conventional lumber and price uncertainty*

"Over the longer term, higher prices and price uncertainty will stimulate efforts to build with alternative materials, and even a modest shift toward substitution and conservation could have a big effect on prices."[9] Builders are extremely price-sensitive. Therefore, it is no surprise that increasing consumption of I-joists by early adopters from 1990 to 1993 and by some of the early majority builders in 1994 coincided with a steady 60 percent rise in the producer price index (PPI) of softwood lumber from 1990 to 1994. The price spike from 1992 to 1994 was unusual in that it was supply-driven rather than demand-driven. By 1993, harvests in northwestern forests had decreased by 90 percent over 1980 levels.

Prices of lumber, however, have always fluctuated with the booms and busts of the housing market as well as with "changes in expectations about future supply due to federal court actions and other changes in government policies."[10] For example, the softwood lumber PPI declined in 1995 only to increase again to a higher peak in 1997

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[7] Leonard M. Guss, "Engineered Wood Products: The Future is Bright," *Forest Products Journal*, Vol. 45, No. 7/8, July/August, 1995, p. 17.
[8] Ibid., p. 18.
[9] Michael Carliner, "What's Driving Lumber Prices?" *Housing Forecast*, National Association of Home Builders, January 1994, p. 6.
[10] Ibid.

and decline again in 1998.[11] As the cost of lumber increased in 1993 and 1994, builders began to find that the use of I-joists was cost-competitive. Given that I-joists are precut and that all pieces are usable, they do not involve the additional labor and high capital costs associated with the production of other engineered woods. Consequently, in the environment of 1993 and 1994, they were more price-competitive with dimensional lumber than other engineered woods. In fact, builders often doubled I-joists for use as beams to avoid use of the more expensive LVL beams, even though I-joists are often manufactured with LVL.

I-joist production continued to increase despite declines in the softwood lumber PPI, indicating that once builders use I-joists they seldom abandon them.[12] Apparently, the superior functionality or quality of I-joists compared with dimensional lumber has been an important factor even amid increasing price competition from conventional lumber. In addition, it is claimed that price declines of dimensional lumber were attributable not only to slackening demand but also to the fact that the very substitution of I-joists for long and wide dimensional lumber has put a cap on potential increases of dimensional lumber.[13]

- *The increasing size and complexity of single-family homes*

Single-family homes are the largest users of I-joists. In addition, new construction of single-family homes has become increasingly more complex in response to the changing tastes and demands of more affluent homebuyers and the availability of an expanding array of new products. Cathedral ceilings, cantilevered supports, and complex roof shapes often require larger spans and greater structural support than can be can economically accomplished with conventional wood products. Larger open spaces require longer floor spans that can be more economical achieved with wood I-Joists.

- *Extensive product distribution networks and engineering design and technical support for wood I-joists*

A variety of channels is available for the distribution of structural lumber. Dimensional lumber has typically been sold in a two-step distribution system. Harvested wood or timbers are sent to mills for cutting, planing, and dressing to form finished board products. Mills, in turn, typically sell the finished lumber to distributors or brokers who are responsible for securing transportation and processing orders from retailers. In contrast to office wholesalers or brokers who consign shipments via telephone without storing or transporting the product, other distributors stock, ship, and sell lumber directly to retailers. These distributors either can be part of an independent chain or are owned by vertically integrated manufacturers. In 1996, about 22 percent of retailers purchased lumber through independent distributors.[14]

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[11] Dean Crist, "The Cost for Building Materials and Components," *Housing Economics*, March 1999, p. 15.
[12] Op. cit., Guss, p. 19.
[13] Ibid., p. 20.
[14] "Survey Reveals Dealers' Buying Habits," *Random Lengths*, August 2, 1996, pp. 1-2; "Dealers List Pros and Cons of Buying Direct," *Random Lengths*, August 6, 1996, pp. 1-2.

Retailers can consist of

- specialty dealers or contract yards that sell one or two specialized products to subcontractors or other retailers;
- lumberyards that primarily sell lumber and other wood products to builders; and
- building supply dealers that sell a variety of building products to builders in addition to lumber.

In 1999, most builders, about 88 percent, purchased lumber directly from lumberyards while manufacturers' distribution centers and factories each supplied only 2 percent of builders' I-joists.[15]

The I-joist is a custom product that is approved by an engineer or designer for a builder's specific home design. Manufacturers of I-joists purchase material components from mills (some of which they own) and ship the finished products to their own distributors whose engineers and technicians can design and certify I-joists for specific builder designs. Many independent lumber distributors and some retail lumberyards do not have the expertise to perform the I-joist design function. Builders are therefore more likely to obtain their I-joists either from manufacturer-owned distributors or directly from the factory. Nonetheless, some retailers such as lumberyards and specialty contractor yards employ personnel sufficiently familiar with the parameters and associated software to design and certify I-joists for their customers. They order I-joists directly from manufacturers or their distributors and tend to deal with only one manufacturer's product.

In summary, builders use much more diversified channels of distribution for I-joists than for framing lumber and are much more dependent on manufacturers and their distributors for a supply of I-joists. The system of customized technical support under the auspices of specialized or manufacturer-owned distribution not only supports branded products but also helps speed the commercialization of I-joists by ensuring product quality, thereby relieving builders and architects of product liability.

- *Early establishment of performance standards for I-joists*

Competing manufacturers' early development of performance standards was influential in facilitating the commercialization of I-joists. Given that the I-joist is less complex in its production requirements than other engineered wood products, a manufacturer's entry into the industry proved relatively easy. Consequently, the industry soon grew from a single innovative manufacturer to several manufacturers. With the formation of the Wood I-Joist Manufacturers Association (WIJMA) in 1984, manufacturers joined with the larger wood products industry and regulatory agencies to develop industry performance standards for their products. Each company had the flexibility to develop proprietary products as long as it met performance standards. With proprietary products, however, each I-joist manufacturer had to gain individual building code acceptance for the use of its products. Although some jurisdictions may have specific requirements for I-joists, state, county, and local building code jurisdictions generally grant approval to proprietary I–joist products that can be shown to meet the design conditions applicable to a building

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[15] Ashok Chaluvadi, "Channels of Distribution for Building Materials," *Housing Economics*, October 1999, p. 8.

as provided in adopted building codes. The building codes, in turn, usually reference the performance standards developed by WIJMA.

The initial I-joist wood performance standard, AC14 "Acceptance Criteria for Prefabricated Wood I-Joists," was accepted by the International Conference of Building Officials (ICBO) in 1987 and remains in force today.[16] WIJMA also assisted in the creation of ASTM D5055, "Standard Specification for Establishing and Monitoring Structural Capacities of Prefabricated Wood I-Joists," in 1990. The latter standard was sponsored by the D07 Committee on Wood and is periodically updated according to ASTM procedures. The U.S. model building codes reference ASTM D5055 and its Canadian counterpart.

As noted earlier, the products of competing I-joist manufacturers vary only slightly in their details. Nonetheless, differences in regard to flange widths, installation details, hole placement, and materials usage force potential customers to wade through a variety of installation manuals and specifications before choosing an I-joist for a specific application. Accordingly, customers must obtain an engineer's approval for each application. Consequently, in 1997, the APA—The Engineered Wood Association (APA-EWA) developed a new performance standard that all products must meet in order to qualify as an APA Performance Rated I-Joist. The common load/span tables, installation instructions, and engineering design values in the standard make certain that APA-performance-rated I-joists meet standards regardless of manufacturer. Thus, under a performance-rated standard, it will be easier for any manufacturer to produce acceptable I-joists. It will also be easier and less expensive for customers to order an APA I-joist since they will not have to obtain individual engineering approval and deal with varying specifications. The I-joist, in effect, may become a commodity product.[17]

5.0 Diffusion of Innovation: A Framework for Study

To understand EIFSs' and I-joists' implications for technology innovation in general, it is useful to synthesize and compare the experiences of both products in terms of the normative models of innovation described in the literature. The several models presented below provide the project staff with a framework and language for understanding and comparing the EIFS and I-joist experiences as well as with an opportunity to generalize to other housing technologies. The models' conceptual basis is grounded in Rogers's study of the diffusion of innovation and two previous studies of housing innovations performed by the NAHB Research Center.[18] The evaluations were based on subjective judgments by the project staff rather than on group discussions with practitioners.

[16] The other model building codes (BOCA National and SBCCI Standard as well as the ICC international) also have provisions covering this product and means to confirm compliance through their evaluation services (BOCA ES, SBCCI ESI, and NES).

[17] There are two different views on the impact of the APA performance-rated I-joists. Some think that the I-joists may become a commodity product. On the other hand, it is reported that Trus Joist, Boise-Cascade, and LP, representing 80 percent of production, do not subscribe to this view.

[18] See Rogers, Everett M., *Diffusion of Innovations*, New York, Free Press, 1983 and *Ibid.,* NAHB Research Center, *Diffusion of Innovation,* and NAHB Research Center*, Advanced Housing Technology Program.*

5.1 The Nature of Innovation

Innovation occurs when one product or material replaces another in the performance of a particular set of processes or functions for a buyer. Products are successful substitutes for the "best" or most popular current practice if they offer value to the buyer by providing "engineering efficiency," which consists of one or two components as follows:

- Functionality, i.e., adding to or extending functions; such as appearance, or energy efficiency; and/or
- Productivity, i.e., reducing costs of inputs, such as labor, materials, equipment, as they relate to the final output, the housing product.

The buyer is not necessarily the homebuyer. When the innovation is an intermediate product, the buyer is often a home builder, wholesaler, retailer, or intermediate producer located somewhere along the housing production chain.

Costs often determine both the rate and degree of substitution of an innovation in the market. New products, however, often emerge first in those more technologically complex commercial, industrial, and institutional segments of the construction industry where margins or product performance specifications are sufficiently high that there is tendency to adopt better products and materials despite initial costs. In this manner, advanced materials and products such as EIFS and I-joists have found their way into the housing industry via commercial and other segments of the construction industry.

5.2 The Context for Innovation

Changes external to the home building industry in the national economy or the natural environment have been the "mother of invention" for the home building industry. Many of these changes have had an effect on the increased adoption of EIFS and I-joists. Such changes include the following:

- increases in labor or material costs;
- scarcity of inputs such as old-growth timber or skilled craftspersons;
- volatility in prices such as might occur in lumber or other materials;
- decline in the quality of inputs such as timber due to dependence on younger-growth trees;
- technological advances in competing products such as engineered wood and stucco-like finishes;
- changes in building, environmental, or energy regulations such as those requiring higher levels of insulation; and
- shifting tastes of more demanding and affluent homebuyers toward larger, higher-quality homes.

The home building industry, as a contextual matter, is also distinguished by characteristics and trends that have affected the adoption of innovations, in particular EIFS and I-joists. Key characteristics of the industry follow:

- a particularly long and complex production chain that complicates communication from producer to buyer;

- final product assembly on site, close to the customer;
- sharp economic and seasonal fluctuations in demand;
- online construction and procurement functions performed by subcontractors; and
- two distinct segments of the industry that produce custom and tract housing.

Certain trends occurring within the housing industry are changing some of the industry's characteristics and affecting the commercialization of both EIFS and I-Joists. The trends include the following:

- increasing share of the value of housing created off site;
- housing components increasingly fabricated- and integrated off site;
- the merger of custom and production industries as customization occurs on a production basis (mass customization);
- builder-owners increasingly coming from business backgrounds rather than from the construction trades and thereby functioning as packagers, general contractors, and coordinators; and
- separate ownership of online and procurement functions increasing with the greater use of subcontracting.

5.3 Physical Attributes Contributing to Innovation

The five attributes of an innovation identified in the literature as significantly influencing an innovation's rate of adoption also apply to housing innovations. They are compatibility, trialability, observability, simplicity, and relative advantage. The following is a rating of EIFS and I-joists according to the above attributes:

- ***Compatibility*** of the innovation with the previously held values of adopters such as homebuyers or with builders' building systems or manufacturers' production processes is an important factor influencing the adoption of innovations if the adopters are firms.
  - *EIFS:* Although not immediately apparent to builders, EIFS's ***compatibility*** with residential wood framing systems has turned out to be low. In its original application, the system resulted in the retention of moisture within the wood frame of the house. The moisture ultimately contributed to rot.
  - *I-joists:* Made of wood, I-joists are in the family of wood products produced by wood product manufacturers and are compatible with wood-frame construction. Their ***compatibility***, however, is only moderate because they add to depth compared with conventional floor joists, disrupting some of the modularity of the house and requiring extra support in certain situations.

- ***Trialability*** or the capacity or relative ease with which an innovation allows for experimentation, evaluation, or reinvention to adapt to particular circumstances facilitates the adoption of innovation.
  - *EIFS:* Given that careful modification of construction practice and installation associated with the original product in the field could have helped minimize the EIFS moisture problem, EIFS's ***trialability*** is rated moderate. Overlapping responsibilities between the producer, who must educate installers or promulgate clear instructions, and the builder and installer, who

must strictly adhere to good construction practice in regard to details such as flashing, complicate trials and make them difficult. Although some of the moisture issues could be avoided by the manufacturer's redesign of the product, the resulting installation can become more complicated.
    - *I-joists:* Given that I-joists are predesigned to the specific structural requirements of a house by manufacturers or wholesalers, their ***trialability*** in the field is limited or low.

- ***Observability*** or visibility of an innovation to potential adopters—either the homebuyer or a member of the housing production chain such as a builder or supplier—can accelerate innovation.
    - *EIFS:* EIFSs' exterior finish was readily ***observable*** and pleasing to the homebuyer and contributed to its successful adoption by the purchaser, but the significant moisture issues resulting from the innovation's inherent complexity were latent and not immediately apparent to builder or buyer. Consequently, the rating of EIFS in regard to observability is somewhere between low and moderate.
    - *I-joists:* I-joists' strength is not immediately apparent from visual inspection, even though the joists as physical entities are readily observable to the builder. Moreover, the joists are not ***observable*** to the homebuyer, presenting some problems in marketing through the end user. Consequently, I-joists rate only moderate in regard to visibility.

- ***Simplicity*** or the relative complexity of the innovation that may contribute to or detract from a potential adopter's (either builder's or homebuyer's) understanding of how the innovation works or of the scientific or engineering principles upon which it is based increases the adoption of innovation.
    - *EIFS:* The ***simplification*** of the construction process resulting from EIFSs' application belies the underlying high physical complexity of the EIFS product. EIFS is an amalgamation of three products produced by firms not within the family of the wood products industry. These firms may not have been familiar with wood-frame construction practice, thus leaving themselves vulnerable to unanticipated problems. EIFSs' successful and relatively problem-free performance in the commercial segment of the construction industry served as a basis for its introduction into the residential segment.
    - *I-joists:* I-joists are relatively **simple** in construction but are moderately complex in design. Their design requires experienced engineering and knowledge of engineering principles.

- ***Relative advantage*** of the innovation over its predecessor or the "best" current practice in terms of engineering efficiency, such as functionality and productivity (see above), is a factor that significantly contributes to the adoption of innovation. In addition, a factor such as "systems efficiency" contributes to relative advantage. For example, a "systemic" reduction in construction cycle time can reduce set-up time of on-site house assembly. Such efficiencies allow the builder to concentrate on essential activities that contribute to construction of the basic form of the house. Efficiencies can be achieved through any one or a number of the following systemic improvements:

- *Increase connectivity* by increasing the ease with which connections are made among different housing components or subsystems.
- *Prefabricate components or subsystems* by converting internal construction activities to external activities and completing such external activities before set-up.
- *Eliminate and simplify tasks* by combining previously separate functions into one product, thereby eliminating the necessity of employing and coordinating the separate trades that formerly performed the needed functions.
- *Reduce waste* by moving on-site support activities such as design, measurement, and inspections off site as part of producing the product before delivery or through precertification.

  - *EIFS:* Builders originally viewed EIFS as offering a high ***relative advantage*** because the system significantly reduced costs by contributing to systems efficiency of construction in reducing cycle time. It integrated the functions of insulation, sheathing, and exterior finish into one product, simplifying the construction process by reducing the set-up time of house assembly and eliminating some of the separate trades otherwise involved. Significant issues with moisture, however, reduced the system's intrinsic advantage to only moderate. With some modification, the inherent systemic advantage of EIFS was still evident, and the product remains in use.
  - *I-joists:* Owing to prefabrication, increased connectivity, and off-site support activities such as design and measurement, I- joists offer ***relative advantages*** in reducing set-up and cycle-time. Their functional advantages over their predecessors in providing strength, increasing spans, decreasing the number of framing members, and reducing needed wood quantities are significant. Despite these advantages, some of which reduce cost, I-joists still cost more than conventional joists. Their overall comparative advantage is therefore only moderate.

These attributes, as they apply to EIFS and I-joists, are summarized in Table 1 below.

TABLE 1
Summary of Attributes

Basic Attributes	I-Joists	EIFS
Compatibility	XX	X
Trialability	X	XX
Observability	XX	X-XX
Simplicity	XX	X
Relative Advantage	XX	XX
System Efficiency		
Connectivity	XX	X
Prefabrication	XXX	XX
Simplification	XX	XXX
Reduction of Waste	XXX	XXX
Key X=low, XX=medium, and XXX=high		

5.3.1 Summary

Overall, the attributes of both EIFS and I-joists and contribute moderately to innovation, although EIFSs' rating may be a little lower due to a slightly lower evaluation in regard to observability.

- EIFS and I-joists are both moderate in regard to compatibility and relative advantage, but EIFS is more flexible in relation to trials in the field. EIFS received a moderate rating compared with I-joists' low rating in field trials. (see Table 1).
- On the other hand, I-joists' are moderately simple while the relatively high complexity of EIFS contributes to a low rating in this regard.

I-joists' primary advantages are related to cycle time in the construction process, such as

- converting internal construction activities to external activities through prefabrication; and
- reducing waste by moving support activities such as design and measurement off site.

Increasing connectivity with other housing components and subsystems is, however, only moderate. I-joist depths have proved incompatible with the dimensions of some traditional framing members.

EIFSs' advantages in regard to cycle time in the construction process are less pervasive and more focused.

- EIFSs' principal advantage lies in eliminating and simplifying tasks by combining into one product the previous separate tasks related to insulation, sheathing, and external finishing. EIFS installation requirements are, however, more rigorous than for other cladding. The work in progress must be protected from extreme climatic conditions, and conditions of freeze and rain and excessive heat can limit application time.
- Prefabrication is only moderate because conversion of previously separate on-site functions into one product produced off site is incomplete. Much of the activity facilitating the combination of functions still occurs on site as part of the installation process.
- EIFS has limited ability to reduce waste by moving support activities, such as design, off site. EIFS has a low rating in providing increased connectivity with other components or subsystems in the house.

5.4 The Innovation Decision-Making Process

Significant differences exist in the individual physical attributes of EIFS and I-joists, but the differences net out to the same moderate impact. In other words, the varying reaction of users or adopters to the two technologies and the resulting differential in the innovations' relative success are attributable as much or more to the way relevant decision makers process the innovation during its introduction, diffusion, and commercialization.

The classic model of decision making proceeds in the following stages:

- Acquisition of *knowledge*, which may involve an <u>awareness</u> that the innovation exists and an understanding of <u>how</u> it works or of the underlying <u>principles</u>. Recognition of a need may precede knowledge, or knowledge may generate a need.
- *Persuasion* of a potential adopter to develop a favorable or unfavorable attitude toward an innovation either by directly making a <u>trial</u> or indirectly using <u>interpersonal</u> channels of communication with <u>peers</u> or <u>opinion leaders</u> who have already tried the innovation.
- Making a *decision* to <u>adopt</u> or reject an innovation.
- Through *implementation* in which the decision maker uses the innovation, often through <u>reinvention</u> by making minor or major modifications to the innovation to suit his or her needs and circumstances.

The complexity of an innovation determines the degree to which the adopter needs to consider the types of interaction, communication, and nature and sequence of trials that take place.

5.4.1 EIFS

EIFS, for example, is a relatively complex innovation and its learning requirements are therefore high. Under such circumstances, the following actions make sense:

- Adopters would ordinarily rely not only on the mass media and indirect knowledge from peers and opinion leaders to become aware that EIFS exists but would also require more specialized or interpersonal communication about how EIFS works, often through experimental demonstrations or research.
- An added, intensive phase devoted to attitude formation would take place before undertaking a trial of EIFS and reaching a decision on adoption.
- To encourage adoption, high levels of personal influence and training are necessary on the part of the manufacturer, engaging all segments of the housing production chain.

A disconnect apparently exists within the housing production chain among the manufacturers, builders, installers, and other trades associated with the installation of EIFS. Builders who purchase EIFS are not trained in its installation but rather rely on the manufacturers and their distributors to train their subcontractor installers. The installers, in turn, may not precisely follow the manufacturers' instructions and recommendations. Other trades concerned with flashing and construction details of the roof, wall openings, and other penetrations are not necessarily familiar with or may question EIFS requirements in regard to their trade. Codes may not have properly covered the product, and increased need for building inspections to ensure a quality installation may not have been apparent early on. The consequence is the possibility of failure in use of the product, which is precisely what occurred.

5.4.2 I-joists

Manufacturers of I-joists are members of the family of wood products and responded to problems as they arose. In contrast to the EIFS experience, I-joist manufacturers kept "their ear to the ground" and, through trial and error, worked toward continued improvement of their product.

- The manufacturers recognized that "number one problem was educating the housing production chain all the way to the end-user".
- The manufacturers identified a tendency for misuse of the product in the field.
- In making the transition from the commercial to residential market, the manufacturers were aware of and responded to the different characteristics and needs of the markets.
- Manufacturers acted on what they learned and created an expanded, specialized distribution and sales force devoted to the residential market.
- Although originally devoted to promotion and sales, the manufacturers' technical sales personnel eventually devoted more of their time to training.

5.5 Rate of Diffusion of Innovation

It is difficult to establish a timeline for the beginning of an innovation. Definitions are vague, criteria are absent, and the critical points are often subjective. *Invention* occurs when a practice or product is created or objectively documented as in a patent. An *innovation* is a product or practice embodying a technology that is perceived as new to an individual or other unit of adoption.

Innovation is a relative term. What one group perceives as new may be "old hat" to another group. Nor are the terms invention and innovation synonymous. The European inventors of EIFS no longer perceive the product as new or as an innovation, but with the product's introduction in the United States during the last 15 to 20 years, the U.S. market still perceives EIFS as new and therefore an innovation. Although the idea of an I-joist was first advanced in the 1920s, the joists were first patented in 1938. Practitioners in the I-joist workshop had little idea of the product's early history but were generally aware that the Trus Joist Corporation introduced the first commercial product in 1968.

The rate of diffusion describes the cumulative effects of several decisions among a number of adopters over time. In mature industries such as steel, diffusion of innovations took as long as 30 years. The diffusion of some housing innovations has taken as long as 45 to 50 years. Overall, it has been estimated that the innovation process in home building from awareness/knowledge to adoption takes an average of nine years.

The diffusion process for both EIFS and I-joists in the commercial and residential markets took a total of about 32 years while their diffusion in the residential market took about 24 years. Nonetheless, distinct differences are apparent between the two products' rates of diffusion. A cumulative percent increase and rate of adoption of I-joists follows an S-shaped curve (see Figure 3). The slow growth rate evolved into a progressively steeper rate of increase, which paralleled the level of attention that manufacturers devoted to education and training. EIFS, on the other hand, appeared to experience a sharp spike of exponential growth in the late 1980s and early 1990s due in great measure to the attractiveness of the product to the end consumer. EIFS homes sold to the high end of the market and gained ready acceptance. When such growth occurs, adopters are more focused on marketing than on conducting experiments and trials of the product to learn about its potential problems. Awareness is based on trials of peers and opinion leaders, instead of on careful demonstration and education, and leads to multiplier effects.

6.0 Major Findings: EIFS and I-joists

6.1 EIFS

Participants at the EIFS workshop raised the following issues:

- ***Lack of standards for analyzing the performance of EIFS as a component of the housing system***

When EIFS was introduced into the United States, there were no standards for testing the performance of the product within the residential building system. It was not until 1996 that significant changes were made to the requirements for EIFS and then largely in response to new information on field performance. Accordingly, the ICBO-Evaluation Service changed its acceptance criteria, and BOCA changed the language in its building code. SBCCI required EIFS systems with drainage and banned the "barrier" face-sealed systems from wood-frame construction. There was no opportunity to test against accepted standards and to identify problems that would arise at interfaces between housing components. Development of such standards is costly, and no existing party had sufficient interest to fund the effort. Consequently, early applications may have gone somewhat under underregulated. More recent initiatives recognized the difficulty of developing performance criteria or standards on which to base code compliance and instead focused on prescribing specific provisions.

- ***Lack of systems integrator***

It was assumed that the builder would play the role of systems integrator just as the contractor, through his or her architect, would control the commercial construction process. This untested assumption proved to be mistaken. Although both residential and commercial construction depend on subcontractors, they differ significantly in the extent to which they employ on-site staff professionals to oversee design and construction work. Residential construction is simple compared with most commercial construction, with less attention to specification. There is a cost, however, associated with the role of systems integrator. The point is that a product manufacturer needs to recognize the builder's standard operating procedures and accommodate conventional practices regardless of experiences with other sectors (commercial building).

- ***Less control over subcontractors***

In commercial construction, the general contractor usually exercises the coordination and quality control function. In residential construction, an integrated level of supervision and oversight is lacking.

- ***Lack of adequate enforcement***

Some participants made the point that proper enforcement by regulatory authorities could have averted many problems, assuming that the applicable residential codes provided an adequate foundation for EIFS evaluation and approval. It appears that manufacturers assumed the same level of regulatory oversight in the residential sector as in the more heavily regulated commercial sector. The relative complexity of EIFS has caused some jurisdictions to require special third-party inspections to remove the burden from the building inspector.

- ***Slow adjustment to innovative approaches***

Subcontractors and their labor force are slow to adjust to new construction approaches. Most residential construction firms are small and command only limited resources; they do not traditionally involve themselves in conducting education programs. Many subcontractors experience high labor turnover and, in recent years, have seen a shift to lower-skilled labor. Thus, there is no readily available educational foundation for delivering training in the new skills required for proper use of an innovative product.

- ***An adversarial relationship hinders problem solving***

Once serious problems developed with the use of EIFS, an adversarial relationship quickly developed among the various parties that needed to cooperate for successful commercialization. Each participant thought it was in the "right" and that the other party was in the "wrong. No one stepped forward to solve the problem. As a result, the problem quickly spiraled out of control.

- ***Ambiguity over the nature of the issue***

The parties to the EIFS issue could not agree as to the nature of the issue. Was it a design flaw or an installation issue? Workshop participants thought that such thinking resulted from a limited technical understanding of the product and its interactive effects with other parts of the housing system. Estimates to fix the problem and make necessary modifications ran to hundreds of millions of dollars. Absent agreement on the nature of the issue and the allocation of cost exposure, no one was prepared to step forward to accept responsibility.

- ***Tendency to look for simple, uniform solutions when flexibility of design would be more appropriate***

Workshop participants suggested that some parties look for simple use of an innovative product—one size fits all irrespective of geographic or design variations. In the case of EIFS, however, complicated interactions with various components of the housing system require a more detailed analysis of how the product would function under different design and environmental conditions. In hindsight, participants thought that users should have recognized and prepared for the product's complexity. Some participants raised concerns that flexible innovations would be more expensive and difficult to enforce.

- ***Allocation of risk and role of insurance***

Insurance and warranties secure liability protection for EIFS failures. Manufacturer warranties typically are limited to the performance of the EIFS itself and provide that the installer must follow installation instructions without variation. Furthermore, the warranty is void if the installer uses components not specified by the manufacturer. Installers and builders generally carry their own liability insurance. At first, these policies covered EIFS. With the rise of claims for EIFS-related damage, however, several major insurance companies incorporated provisions to exclude EIFS damage as an insurable event.

Limitations on insurance coverage for participants (manufacturers, installers, builders) can have a harmful effect on the commercialization of an innovative product. Insurance companies often provide coverage for new products even though, they are concerned about their unknown financial exposure. When claims are filed, a problem often arises in determining whether insurance covers the claims. Coverage issues can be vexing, particularly where technical causes are ambiguous as to who is at fault. No mechanism exists for a rapid, early-on assessment of product experience that would help insurance companies evaluate and adjust their policies.

Manufacturers, in turn, indicated that insurance arrangements discourage them from taking early action to fix problems. To be reimbursed for expenses incurred, there must be a claim. Manufacturers therefore may not make immediate corrections but sometimes wait to act until a claim has been filed and processed. Claims, moreover, often entail additional administrative and legal costs. In the absence of a claim, the manufacturer or builder has no insurance vehicle in cases where maintenance and repair are the most effective means of solving problems.

Participants noted that insurance plays a major role in the introduction of new technologies; however, they did not have the opportunity to discuss intricate matters of insurance in detail. Their conclusion is, however, that insurance is an area that must be addressed and that insurance companies need to be part of the discussion.

- ***Root causes of the problem not addressed***

EIFS manufacturers feel that they have been singled out for an issue that is generic to housing, namely, the infiltration of water into the house. If progress is to be made in using innovative technologies such as EIFS, a determination of root causes is in order. The culture in this country generally does not devote sufficient time and research dollars to understanding the nature of root causes until a substantial problem arises. As a result, root causes are frequently evaluated only after the problem arises. More consideration should be given to failure mode analyses before product finalization and implementation.

- ***Changing composition and competence of the workforce***

EIFS requires demanding attention to detail in its installation and at the interfaces with other housing components. Innovations originally designed for one type of labor force can be undermined by unforeseen changes in the composition and skills of the workforce, thereby adding substantial risks to the diffusion of innovation. Constant labor force turnover also contributes to problems of proper installation.

- ***Absence of an effective monitoring system***

Manufacturers had no effective means of monitoring the use of EIFS. The nature of the product, moreover, presented some problems with early detection. As a result, problems were not identified at a time when parties would have been more willing to work together and the costs of correction would have been potentially much lower. To the extent that it might have been feasible, an early detection system would have given the participants the opportunity to find remedial solutions before the situation "blew" out of control as a consequence of adverse publicity and lawsuits.

- ***Managing the perception of product failure***

Adverse publicity so colored user confidence in the product that many homeowners tended to look for the most expensive remediation measure—the complete removal and replacement of the EIFS cladding. Lawyers contributed to adverse publicity by bringing class action lawsuits. Removal of the product was a rational response to the lack of certainty about types of remediation that would leave EIFS in place.

- ***Information is not readily shared within the industry***

Some participants thought that information is available but is not easily accessible to those with a need to know. There are no mechanisms for timely dissemination of technical and other data.

- ***Absence of a functional technology acceptance model***

One participant mentioned the absence of a useful workbook, a roadmap that would assist decision makers in managing the technology innovation process. A manual on how to manage the process would raise all the right questions and issues that an innovator or early adopter should ask and answer.

- ***Product liability***

The specter of a lawsuit hangs heavily over the EIFS experience. Despite little discussion on this topic, participants acknowledged the potential legal proceedings as a significant issue and noted the usefulness of some "no-fault" type insurance that would allow remediation of problems long before a situation gets out of control.

6.2 I-joists

I-joist participants identified the following issues, some of which had positive as well as negative impacts on the commercialization of the product:

- ***Framers' skill levels inadequate for successful installation of I-Joists***

The introduction of I-joists meant a great opportunity and tendency for misuse of the product in the field. "Framers were used to working with 2 by 10s and memorized very simple rules of thumb of cutting drilling and notching, but you cannot use the same set of rules for cutting, drilling, and notching I-joists." When installing wiring and plumbing, subcontractors often drilled through the web in the wrong places. Many times, the manufacturers or their representative had to tell workers in the field to remove incorrectly installed joists. The tradition of inspection of jobs in the field in the commercial market did not transfer to the residential market. It was said that "today builders are paper builders" and do not have an understanding of construction technology. These builders often subcontract out everything, including rough framing. In general, an aging labor force, a poor work environment, and fragmentation of work among subcontractors contribute to a low level of skill. Participants noted that consolidation of subcontractor trades under a super-subcontractor could avoid some of the fragmentation. This approach is finding application in the United States. Early on, producers recognized the need for training workers to develop new skills in installing I-joists.

- ***Negative perceptions of I-Joists in regard to quality and price***

Negative perceptions of I-joists prevailed from the distributors down through the builder and to the consumer. Perceptions were at variance with the "real" benefits of I-joists and required education and public relations programs with an emphasis on transmission of objective research and demonstration. Builders perceived the price of I-joists as high, focusing on the price per linear foot instead of on less visible and more indirect benefits compared with conventional products as related to strength, reduced use of materials, and wider spacing of framing members.

A public relations program aimed at consumers emphasized that I-joists have a favorable impact on the environment through the reduced use of fiber. Based on focus group results indicating that consumers want a floor that does not squeak, Trus Joist developed a "silent floor" campaign that was successful in pulling the product through via the consumer side of the market. Demonstrations at the NAHB Builders Show and objective research performed by the University of Maine and the Forest Products Laboratory to compare the costs and benefits of I-joists with conventional products were helpful in selling the product. As one of the participants at the workshop said, "The product was marketed to high-volume builders whom everyone looks to. They'd say, 'if so and so is using it, it must be a good product.' We always said if we could get the guy to use it twice, maybe first, but twice, we had him hooked." It was in the interest of both manufacturers and builders to reduce costs through reengineering the producer's production line to achieve higher volumes.

- ***Government issues and related policies outside the manufacturers' control had a positive impact on the I-joist market***

Government policy restricting the availability of high-grade lumber is a good example of "making something good out of something the wood industry generally thinks is bad." As a result of government restrictions on timbering, the quality of available timber deteriorated and created the need for higher-quality materials for flanges. The timber issue increased the value of fiber, and the Forest Products Laboratory showed that I-joists would use 40 percent less fiber while providing greater strength. Environmental groups demonstrated that I-joists and other engineered lumber had a lower impact on the environment by using fewer trees to do the same amount of work. The attitude of I-joist firms toward government policy was, "If change is coming, …how do I minimize my pain and maximize my gain?"

- ***Joist depths were incompatible with some elements of residential dimensional lumber in use***

One participant said, "When you look at an I-joist system from a framer's point of view, installing an I-joist versus installing a 2 by 10, a 2 by 8, or anything dimensional, there really is not that much difference. They are very, very similar, which has helped the I-joist industry because the training does not have to start from ground zero. The framer already knows how to install 2 by 10s, so installing an I-joist is a little more technical, but is not a big mountain to climb." On the other hand, a framer "cannot go with a header of 2 by 10s and put it into an I-joist system, because it does not fit in a flush floor system. That is a problem. If they do put in 2 by 10s and they rip them to fit a 9 1/2-inch floor system, they change the grade and that also is an issue." Moreover, builders have grown accustomed to buying a prefabricated box stair system, which does not fit the I-joist depth. A builder therefore must either change the I-joist depth, which will not work, or forgo the prefabricated stair unit. Framers and lumberyards complained about having to rip 4 by 8 sheets of plywood for rim boards to match the depth of the I-joists. Manufacturers recognized the problem and responded. To save the builder time and avoid such complaints, I-joist manufacturers supplied rim boards and other components as part of the system, often charging a premium for the added components.

- ***In transitioning from the commercial to the residential market, manufacturers of I-joists needed to produce at a larger scale***

Even when producing I-joists for the commercial market, manufacturers recognized the necessity of producing larger volumes if they were to market their products profitably. Entry into the residential market exacerbated the problem. Initially, only about three manufacturers produced I-joists, and the number of producers was too small to justify service from equipment manufacturers. Thus, the manufacturers were forced to design their own equipment. At that time, it was easier and more profitable to manufacture 60- to 80- foot lengths. As a result, producers tried to make it mandatory that distributors stock longer lengths. Distributors, on the other hand, found it difficult to store or inventory such large members. In response, producers provided ancillary equipment such as saws to cut long joists into the shorter members required by residential buildings. As production volume increased, equipment and the production process were reengineered so that it was possible to cut shorter pieces and at the same time maintain a large inventory.

- ***The transition from commercial to residential markets created other problems for manufacturers***

I-joist manufacturers' management realized that the residential market was a different "animal" from the commercial market. Initially, manufacturers were reluctant to change procedures to accommodate the special perspectives and characteristics of the residential market. Those familiar with the commercial market were unfamiliar with the residential distribution system and were accustomed to dealing on a job-by-job basis with the commercial market's more sophisticated general contractors, designers, and architects. The jobs with builders and contractors in the much larger residential market were less complex. The residential builder's staff was less sophisticated in its needs and often used in-house or standard house plans. As a result, changes in the management mindset were often required to cater to the residential market, and I-joist firms stumbled into the residential market on a trial-and-error basis rather than by undertaking advanced strategic planning or conducting studies of the market.

Distributing products in large volumes to the residential market required an understanding and creation of new channels of distribution. It was too expensive and cumbersome for I-joist manufacturers to deal directly with builders to distribute their products; therefore, they initially dealt with large retail lumberyards. These retailers, who served and acted as intermediaries for larger volumes in predominantly urban markets, understood their markets but had problems in adjusting their inventory to larger lengths of I-joists (see above). Eventually, producers created wholesalers who served as part of a two-stage distribution system that dealt with smaller, more rural lumberyards catering to the large number smaller builders. Producers also created a separate sales force to deal with residential lumberyards and that would understand the different demands of the residential market.

- ***Manufacturers had to adjust quickly to the changing requirements generated by the demand for larger and more spacious houses***

Larger houses favored the use of I-Joists. Informal feedback from retailers and builders on the new demand for larger homes required manufacturers and distributors to monitor changing demand and adjust their production and inventories to larger-size I-joists. Closer inventory control and better monitoring systems would allow a faster response to changing requirements. Large integrated I-joist manufacturers were able to use commercial staff and inventory to respond to a portion of the demand for larger structural members.

APPENDIX A: Scope and Methodology

The study was undertaken in four tasks as follows:

Task 1: Identification and Selection of Candidate Innovations
Task 2: Preparation of Draft "White Papers"
Task 3: Conduct of Discussion Groups or Workshops
Task 4: Preparation of Summary Report

Task 1: Identification and Selection of Candidate Innovations

Staff of the NAHB Research Center and the University of Maryland with law, engineering, marketing, and economics backgrounds convened to select from a variety of successful innovations as well as innovations that encountered problems.

The group discussed the following successful innovations as possible candidates:

- Oriented Strand Board
- Wood Roof Trusses
- Wood I-Beams or I-Joists
- Vinyl Siding

The group next discussed as possible candidates the following innovations that had encountered commercialization problems:

- Exterior Insulation and Finish Systems (EIFS)
- Solar Water Heating Systems
- Fire Sprinkler Heads
- Polybutelene Piping
- Fire Retardant Plywood
- LP Innerseal Siding

The project staff selected **I-joists** for a case study of a successful innovation and **EIFSs** for a case study of an innovation that found commercial success but encountered difficulties. Both innovations most closely met the following selection criteria:

- Affect a cross section of the housing production chain;
- Involve a variety of external agents such as code officials, insurers, engineers, designers, builders, contractors, and laborers;
- Achieved substantial market penetration;
- Illustrate product performance and installation issues;
- Demonstrate documented experience; and
- Affected by changes in external conditions such as market shifts, new environmental or building regulations, changing material or component prices, changes in residential construction, other outside influences, and so forth.

Task 2: Preparation of Draft "White Papers"

Based on staff's experience with selected innovations and literature searches, the Research Center collected information and data for a report explaining the factors connected with the innovations' relative success or problems, quantifying impacts where possible. The Research Center provided the reports or "white papers" to workshop participants to serve as a basis for later discussion when the groups convened. Although the scope of the papers varied according to the nature of the technologies and circumstances surrounding their introduction, the Research Center attempted to identify the following for each innovation:

- Motivations behind each innovation;
- Circumstances surrounding their introduction;
- The principal parties involved in commercialization;
- Successful or flawed solutions in overcoming obstacles;
- The impact of the innovation on users and purchasers; and
- Factors cited as contributing to success or problems.

The white papers served their function of starting discussion and therefore are not included in this report.

Task 3: Conduct of Discussion Groups or Workshops

A wide variety of stakeholders from the housing production chain and those providing support services to the industry were solicited for participation in the workshops or discussion groups for each innovation. Candidates included builders, manufacturers, subcontractors, wholesalers, insurance companies, code officials, HUD staff, designers, testing agencies, and standard groups. Appendix B to this report provides a list of participants in the respective discussion groups. The white papers submitted in Task 2 formed the basis for initial discussion. The discussion focus for each innovation was as follows:

- For EIFS, the principal question asked, *Knowing what is now known, what could be changed or done differently to improve EIFS in residential structures?*
- For I-Joists, the core question asked, *What worked well that accounted for successful innovation?*

The different focus of investigation for each innovation necessitated a different organization for discussions in the respective workshops, but both groups identified the following:

- History of the innovation's introduction into the market;
- Principal parties involved with the innovation;
- Key issues encountered by each innovation;
- Significant obstacles and opportunities; and
- Potential solutions.

Task 4: Preparation of Summary Report

A review of the relevant housing innovation literature combined with the white papers and the results of the discussion groups are summarized below in this report as follows:

- Explanation of Technologies—common and contrasting attributes

- Review of Innovation in Housing—relevant knowledge of innovation in housing derived from a review of the literature that provided a framework for this study
- Outline of the Commercialization Process—the timeline or key events, how each innovation was introduced, when issues were encountered, and take-off in production or demand
- Issues Encountered—definition of issues and key factors
- Approaches to Overcoming Issues—strategies for overcoming issues and reasons for successes or shortcomings

APPENDIX B: Participants in EIFS and I-Joist Workshops

Participants EIFS Workshop, April 19, 2001

- Peter Balint (Dryvit Systems, Inc.)
- Jack Cox (Circle Supplies of the Carolinas)
- David Engel, (U.S. Department of Housing and Urban Development)
- Bill Freeborne, (U.S. Department of Housing and Urban Development)
- Jay Graham (New Hanover County Inspections, New Hanover, North Carolina)
- Tom Kenney, (NAHB Research Center)
- Ray Kothe (Coventry Homes)
- Dean Potter (Gateway Development)
- Dave Conover (National Evaluation Service)
- Ron Miller (Zurich North America)
- Andrea Vrankar, (U.S. Department of Housing and Urban Development)

Participants I-Joist Workshop, April 26, 2001

- Peter Aman (Trus Joist)
- Gary Broughton (American Plywood Association)
- Bill Freeborne, (U.S. Department of Housing and Urban Development)
- Mike Hunsaker (Willamette Industries)
- Bob Higgins (Weyerhaeuser Inc.)
- Andrea Vrankar, (U.S. Department of Housing and Urban Development)
- Steve Zylkowski (American Plywood Association)