Supplemental Data #5

Non-Technical Needs and Opportunities for a Whole-House Approach to Home Building

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Prepared by:

Mark Nowak
Newport Partners LLC
Davidsonville, Maryland

Abstract:

The following report addresses the issues that fall into the category of the "non-technical" with respect to the adoption of whole-house/systems approaches to housing. These issues can relate to business practices, the structure of the industry up and down the supply chain or the regulatory system encountered along the way. Pressures from external sources, for example, liability, competitors, or insurance coverage, also are part of the discussion. The report is based on previous work and experience of the authors and on recent literature specifically applicable to innovation in home building.

Introduction

This project - Creating Whole Systems Solutions – is in many ways an exploratory project looking at development of a tool to use in assessing the way in which a home works together as a system. The tool, or calculator as it is called, takes a whole-house, integrated approach to housing, as opposed to the fragmented approach typically used to design and build a home. The project is focused on development of the framework for a whole-house calculator. The calculator is defined around systems and subsystems to address both technology (or product) and process issues.

Development of a calculator, even at the conceptual or "proof-of-concept" stage as in this project, is a complex effort that presents many technical challenges. Perhaps the largest challenge is to bring building science into the design, construction, and operation of homes through an industry that has historically approached these tasks as a series of independent activities by multiple, unrelated parties. Communication between the many parties in the process is very often minimal and sometimes confrontational.

In addition to building science and other technical issues, there are many non-technical issues that can hinder the adoption of whole-house system solutions. Even the most technically-robust calculator or tool may fail if these issues are not taken into account.

This paper addresses the issues that fall into the category of the "non-technical." These issues can relate to business practices, the structure of the industry up and down the supply chain or the regulatory system encountered along the way. Pressures from external sources, for example, liability, competitors, or insurance coverage, also are part of the discussion.

The paper is based on previous work and experience of the authors and on recent literature specifically applicable to innovation in home building. Studies outside of housing, for example those that address adoption of innovation in manufacturing or in general, are not specifically reviewed. However, this "outside-the-housing-industry" literature is summarized in both the Shepard and Koebel studies cited in the references.

Barriers to adoption of innovation

Table 1 identifies the types of issues frequently cited as barriers to innovation in the construction industry in general. These barriers are taken from the literature cited in Table 1, which represents some of the more directly-applicable and/or recent literature on the adoption of innovation in the residential construction industry. A discussion of the issues follows the table.

Table 1 – Potential barriers to whole-house solutions

Issue or barrier	Comments	References
There are few early stage adopters of innovations relative to the overall number of home builders	Larger companies (as evidenced by higher revenues) tend to be one of the groups of earlier adopters.	Shepard
	Builders in multiple markets are more likely to innovate than strictly local builders.	Shepard, Koebel
	Modular or factory-built manufacturers are more likely to be early adopters.	Shepard, Koebel
Tasks are decentralized (lack of design integration, use of many subcontractors)	There is a large dependence on subcontractors and specialized participants in home building.	Newport Partners, O'Brien, Hassell
	Manufacturing processes such as flexible, agile, or integrated manufacturing are rarely used in the home building process.	O'Brien, Newport Partners
	Suppliers often provide design services to increase their value added and to avoid liability.	Nowak
Optimization across systems requires performance requirements that only partially exist	Considerable research is needed to develop procedures for applying systems approaches.	Newport Partners
Regulatory requirements may hinder trade cooperation or force the builder to use subcontractors	Many states have requirements for separate trade licensing that has further encouraged each trade to operate independently.	Craftsman
	Designers are limited to their own specific systems under state professional laws (e.g. PE required for some structural designs, architect required in some states).	NCEES
Liability	Fear of failure and associated liability often prevents new technology from being adopted.	ICC
Lack of return on investment	Many homeowners are not often willing to pay for new technology if it is not reflected in an appraised value. Builders are reticent to adopt new technology that increases cost.	NAHB Research Center
Lack of trained labor often hinders innovation	Labor is generally in short supply, especially in the construction industry. Innovation often requires skilled labor.	Ahluwalia

The issues identified and discussed in Table 1 are not likely the only issues that hinder innovation nor are they universally-applicable throughout the home building industry. No trends or statistical validity are meant to be implied simply because an issue is listed in the table, although the Shepard and Koebel studies both include statistical analysis. Rather, the issues are some of the more common and complex ones observed over the years that can hinder innovation.

If the whole-house or systems design approach is considered a process innovation in addition to a technology innovation, then there is reason to believe the same barriers in Table 1 will apply to the use of a whole-house calculator. A discussion of each of these barriers or issues follows.

Number of early adopters who might use the calculator as a standard assessment tool

The research indicates that the number of early adopters is relatively small. The study by Koebel (Koebel 2004), however, uses Census data to show that the larger builders who are more likely to adopt innovations build about 2/3 of the overall number of single family homes constructed each year. Although the data do not appear to include owner-built homes, even if these homes are considered, nearly 60% of homes constructed each year are still being built by about 10% of the builders. Thus, the issue of a small number of early adopters may actually turn into an opportunity, since the impact of this small group is much greater in terms of the number of homes they build.

In some ways, the motivation for these potential early adopters to innovate may be waning due to issues somewhat external to the house construction itself. At a minimum, it may be harder to get the attention of some of these builders by promising improvements to the home. For example, in some of the hottest markets around the country, the construction of the home has almost become of secondary interest to the largest builders. In these markets, the primary business value is in securing build-able lots, not in the construction of the home. There is not much motivation to invest in improvements to the home that, for example, might reduce first costs or operating costs, when the market is demanding more than you can currently produce with conventional practice. As long as land acquisition drives the process, it may be a challenge to interest builders to adopt a systems approach if the return on their investment is greater elsewhere.

There are also consumer issues that can reduce a builder's motivation to innovate. For example, appraisals may not reflect the value of an innovation, especially something as abstract as applying a whole-house design approach. Some innovations, such as advanced framing, have been criticized as "cheap" construction. There appears to be a need to document the performance benefits and educate the builder and consumer. Further discussions on consumer issues are covered later in this paper.

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Tasks are decentralized (lack of design integration, use of many subcontractors)

This is perhaps the single most significant issue that could hinder the use of whole-house design. Wrapped up in the decentralization of tasks are several inter-related issues.

First, the use of subcontractors who operate independently, including some who perform design services, creates an atmosphere where the communication channels between different parts of the building's design "team" don't have a chance to work because they never really existed. Coordination or communication between the different "designers" is practically non-existent. Many times the different subcontractors can inadvertently (or intentionally) corrupt the design of another part of the home.

Second, suppliers can unintentionally complicate the design process, creating yet another designer who operates separately from the other members of the process. For example, many suppliers of

engineered wood products like I-Joists provide a complete design of the framing package, or at least a large part of it. These designs may not lend themselves to integration with other aspects of the home design. However, suppliers and manufacturers often cite good reasons for designing their products. Liability or concern over someone using their product inappropriately is one concern. Other suppliers claim that their builder clients are looking for anything that makes their life less complicated and providing design services gives them an advantage over more-conventional materials.

Third, the sheer number of participants in the home building process could lead to miscommunications even if all of the players embraced a whole-house or systems approach to home design and construction. At a minimum, a builder will use 10 to 15 subcontractors and more typically 20 or more. The number of specialists seems to be expanding with recent introductions such as security systems, entertainment systems, and fire sprinklers. Coordinating each of these participants will require not only changes in the way they communicate, but possibly in the way they are structured and do business. For example, HVAC contractors may not be too eager to give up or share their role as system designer for a variety of reasons. They often have a healthier margin on larger equipment. Many also believe that over-sizing of equipment is a good practice to reduce homeowner complaints.

Last, there really is no designer of record for a typical single-family home like one would see for a commercial building. This complicates the use of any automated optimization process. There may be an architect who oversees all design and construction on some upper-end custom homes. More typically, a builder may use plans prepared by an architect, a plan service, a draftsman/designer, or even the builder himself. Often, the same plan is used repeatedly or with slight modifications. It is unlikely that these plans will include detailed designs for most of the systems and subsystems in the home. Of course, this varies according to the requirements of the local jurisdiction and the level of sophistication of the builders or their subcontractors.

Optimization across systems requires integrated performance requirements

Results of the literature searches conducted under related tasks of this project confirm that sufficient standards or performance requirements do not exist for a whole-house approach. Those standards that do exist are focused on specific systems or subsystems without much if any regard for the other systems they interact with. Structural requirements and the building envelope are two good examples. Building codes and standards like ASCE-7 or the International Building Code address structural requirements in great detail. Likewise, energy codes are very specific about thermal envelope requirements. How these two systems interact is an important issue that is not addressed. Performance requirements or some other guidelines or standards will need to be developed in order to optimize the design across various systems.

A case could be made that the lack of performance requirements is a technical issue and does not belong in a discussion of non-technical issues. It would be difficult to dispute this argument directly. However, for many of the systems in a home there is no natural proponent who would champion development of performance standards. Even if there were a proponent, for most systems or subsystems, there is little motivation for them to take on such activities. Others would

have good reason to resist creation of standards, especially if the end result may make them less competitive.

Regulatory requirements may hinder cooperation

States and even local jurisdictions have different requirements for the regulation of building trades, general contractors, and designers. For example, a master plumber is required in many areas to pull a permit and must oversee the installation of all plumbing activities. An architect may design structural elements in some jurisdictions, a professional engineer may be required in others, a manufacturer or supplier's design may be acceptable, or conventional construction may be the accepted practice. At the present time, there is no real incentive for the individual participants to work together nor is there any specific requirement preventing them from doing so. However, in practice, the requirements for separate oversight or design at a minimum do not encourage cooperation.

Liability

Litigation can quickly break even the best-run companies. Likewise, no builder or contractor wants to upset their customers by taking on unnecessary risk that creates more call-backs. One has to question if it would it be a wise business decision for builders to take on more liability for the design of the HVAC system or the structure. Likewise, would the HVAC contractor or any other trade or engineer be willing to take on a larger part of the design that they have little or no control over?

This issue also relates to manufacturers and suppliers, who because of the deeper pockets of large companies often become the primary target of litigation. It remains to be seen whether suppliers or manufacturers of I-joists, trusses, or similar products would be willing to let others handle the design of their product. Insurers of these companies may also be resistant to letting their clients remove themselves from the process without some other assurances.

Lack of return on investment

Builders often say they will build whatever a homeowner is willing to purchase. On the other hand, innovations are generally higher-priced than conventional practice. Thus, home owners do not usually demand innovation without a good understanding of the value they get in exchange.

There is some case to be made that emotional appeals on issues like mold may motivate consumers to act differently, but these seem to be the exception rather than the rule. Even if a whole-house approach does prevent problems and/or improve the home's performance over the long term, it may be too abstract a return for the typical home buyer to value. This is similar to the issue of trying to motivate builders based on life-cycle savings if there is not a first cost or other immediate advantage to innovation. The motivation for using a whole-house approach needs to be developed and disseminated to the consumer and builder audience before change will occur in the industry.

Innovation is also not typically rewarded in the home building market in terms of resale or appraised value. More bedrooms, a walk-in pantry, front porches, and similar upscale features are where consumers are most willing to put their dollars (NAHB). Right-sized air conditioners, high

tech structural materials that resist rot or mold, and concurrent engineering practices are seldom if ever found on consumer wish lists. In addition, PATH-supported forums with appraisers indicate that innovative technology does not automatically add to the appraised value of a home. Appraisers don't often have a formula or precedent for increasing appraised values based on the presence of an innovative technology, even if it does have obvious benefits. In some cases, innovation may even have a negative impact on an appraisal.

Lack of trained labor

Lack of labor is probably less important than some of the other issues in Table 1, but it does play a role in innovation and could hinder adoption of whole-house/systems solutions.

Ahluwalia cites labor shortages and specifically a lack of trained workers in a 2000 study of labor issues. There appears to be a risk with doing something different that builders are not willing to take on, even when there is a strong motivating factor to do otherwise. In the same study, the authors conclude that labor shortages are widespread yet builders have not been willing to consider factory-built or even panelized construction to address labor problems. This is consistent with some of the experience on PATH technical support projects. In one case, a builder cited a concern that local framers would not be able to adapt to anything different than 16 inch spacing of studs. He elected to stick with 16 inch spacing despite estimates showing 2x6 studs at 24 inch spacing would cost less to install and save on future energy bills compared with 2x4s at a 16 inch spacing.

Opportunities to Accelerate Adoption of Whole-House Solutions

This section identifies opportunities for motivating the home building industry to adopt a whole-house approach and thus be more likely to seek out a tool like a whole-house calculator. We do not recommend trying to overcome each of the barriers on an industry-wide basis, but rather focusing on some issues and types of firms or individuals in certain markets that represent good opportunities. Some of the issues that can be turned into opportunities are discussed in the following sections.

Energy policy – It appears that increasing energy efficiency will continue to be an important part of home building in the years to come. This will only tend to hasten the need for looking at homes from a whole-house perspective, since many systems interactions are related to either energy, moisture, or both. On the consumer side, there also appears to be continued value on energy efficiency. In fact, a PATH Field evaluation in southwest Pennsylvania (Nowak and Dacquisto) showed energy efficient features were some of the most desired features in new homes, competing with traditional features like location.

Liability – As shown in Table 1, legal liability may prevent builders or contractors from taking risks. On the other hand, some types of litigation may actually represent opportunities for encouraging adoption of a systems-based design approach. Probably the best known example is moisture. Excessive moisture in homes, and the potential for a mold-based lawsuit, can potentially be addressed through a whole-house design approach. Builders, contractors, and insurers may see a

whole-house calculator as a way to provide themselves with some additional protection. Of course, the provider of the calculator may face exposure to liability.

Changing home buyers – Although it would be hard to prove definitively, an argument can be made that today's home buyer is more sophisticated than at any time in the past. At a minimum, the buyer has access to much more information than ever before. With the internet, almost anyone who wants to can become an "expert" or at least believe they are one.

Although it can be an aggravation when the homebuyer is misinformed as a result of their on-line access to information, it also represents an opportunity for educating consumers and contractors. The more that PATH, universities, the U.S. Department of Energy, EEBA and other building and trade associations, and the trade media focus on whole-house solutions as a way to improve homes, the more likely it will be that people get the correct information. This can't be a passive effort, however. PATH can take an active role in making sure consumers and contractors know the importance of considering whole-house issues in design and construction methods.

No time to work on homes – It seems like our lives are busier today than ever before. The U.S Department of Labor (BLS) conducted a time use survey for the year 2003. The respondents reserved about 1.83 hours daily for time devoted to household activities, which included cleaning, lawn and garden care, maintenance, and other related activities. Although data obtained in a comparable fashion for previous years is not available to show whether our lives are indeed getting busier, it is clear that other activities are getting more time in our lives than taking care of our homes. For example, leisure time from the same respondents averaged over 5 hours per day.

In the Nowak and Dacquisto study of consumers at the PATH Summerset field evaluation in Pittsburgh, a home that was durable and had a low maintenance exterior was the highest preference of respondents in the survey section dealing with home and community features. Again, this does not definitively confirm that consumers don't have time to care for their homes, but it at least tells us that they prefer to spend their time elsewhere.

Although the benefits to a whole-house design approach are somewhat difficult to communicate to a consumer, there may be an opportunity to show how using a tool like the calculator can free up time in the long run, in addition to reducing the cost of repairs and maintenance.

Climate – This issue is closely related to the energy and moisture issues discussed previously. Moisture problems may drive consumers, builders and others to value a whole-house design approach. Likewise, comfort issues related to energy efficiency and indoor air quality have the same potential.

Although these types of problems can affect homes everywhere to some extent, certain climates are more likely to see negative influences from not looking at the home from a whole-house perspective. The southeast, for example, is very prone to serious moisture problems associated with air-conditioner and envelope design. Likewise, northern states like New York and Minnesota will be wise to embrace a whole-house approach as the desire to tighten and better insulate homes for energy savings grows.

Consolidation and IT advances – Consolidation in the building industry is increasing the number of homes built each year by the largest home building companies. The information technology boom of the past decade is now beginning to impact home building as tools like concurrent engineering and web-based data storage are being developed and assessed for the construction industry. At this point in time, the largest builders appear to be more capable of investing in IT advances than the smaller builders.

When these factors are considered with the previous conclusions from the studies in Table 1, the timing for the early innovators to be attempting to adopt something as complex as whole-house design appears to be better than ever before. Opportunities for coordination and communications between the different subcontractors and designers will only improve in the next few years.

Conclusions and Recommendations

The major non-technical needs related to furthering adoption of a whole-house approach to housing design and construction can be summarized as follows:

1. Homes are designed and built in a very non-integrated way. Design responsibility can be spread among the builder, different trade contractors, suppliers, architects and engineers. Methods need to be developed to facilitate communication between those who have design responsibility. These methods can consist of process improvements and tools such as integrated design software. As yet, these types of tools are not available for full integration although some partial integration tools such as those that combine structural and architectural plans are available or under development.

2. Early innovators represent a small percentage of the overall number of home building firms. On the positive side, these relatively small numbers of companies build a majority of site-built homes in the United States.

3. The motivation to develop the necessary performance requirements for many system interactions does not exist. Someone will need to step up and champion development of standards if the ultimate goal is to embrace a comprehensive whole-house approach to housing.

4. Other issues including fears over increased liability, regulatory limitations, and consumer issues also play a role in influencing adoption of innovation. In some ways, these may be secondary to the issues in Items 1, 2, and 3, but they will need to be addressed.

Following are recommendations on how to address non-technical needs and encourage the industry to embrace whole-house systems solutions:

- It is not necessary to address every need identified in this paper. The choice of approach renders some of the issues moot. We suggest that PATH and their partners should not encourage radical change to the way the industry or even individual companies are structured. If a manufacturer has legitimate reasons to retain control over the design of their product, they should continue to do so. Likewise, it is probably not feasible to remove

the design responsibility for the HVAC system from the mechanical contractor. Rather, PATH should facilitate the coordination between the different parties who have design responsibility by supporting the tools they need to do so.

- The national production builders appear to be the best target for accelerating adoption of whole-house design. They build nearly 60% of all site-built homes, there are far fewer of them to influence, and they have more resources. It also helps that these builders often can be categorized as early adopters of innovation. PATH should focus on these builders. At the same time, narrowing the target by working with these builders in areas where there is pressure to adopt a whole-house approach may be more productive than trying to work from a national perspective. Some possibilities include hot, humid climates or northern climates where tight construction for energy conservation makes systems engineering more important.

- PATH should play a role in facilitating the development of performance requirements for homes, especially in regard to optimization across systems and subsystems. There are large gaps in this area and it will require a long-term commitment. Further, PATH should pioneer tools for whole-house analysis until the private sector can commercialize this approach.

References:

Shepard and Blackley, Department of Economics, Le Moyne College, *Diffusion of innovation in home building*. Journal of Housing Economics, 1996, p.303-322.

Koebel et. al., VA Tech Center for Housing Research, *The diffusion of innovation in the residential building industry*, HUD Partnership for Advancing Technology in Housing, January 2004.

Newport Partners LLC, *Whole-House and Building Process Redesign*, *PATH Roadmap*, HUD Partnership for Advancing Technology in Housing, 2003 update.

O'Brien et. al., VA Tech Center for Housing Research, *Industrializing the residential Construction Site, Phase III Production Systems*, HUD Partnership for Advancing Technology in Housing, June 2002.

Hassell, Scott et. al., Rand Science and Technology Policy Institute, *Building Better Homes, Government Strategies for Promoting Innovation in Housing*, HUD Partnership for Advancing Technology in Housing, 2003.

Craftsman - Each state has its own website that identifies contractor licensing requirements. These can be accessed through a web site operated by Craftsman Book Company of Carlsbad, CA at http://www.contractors-license.org . Site last visited December 2004.

NCEES, The National Council of Examiners for Engineering and Surveying maintains a web site at http://www.ncees.org/licensure/licensing_boards for licensing requirements for professionals involved in design. Site last visited December 2004.

Nowak, Mark, unpublished summary reports conducted for multiple private sector clients and industry forums conducted in support of the PATH Advanced Panelized Construction Roadmap during 2002-2003.

ICC, International Code Council, *Removing Building Regulatory Barriers, PATH Roundtable on Codes*, HUD Office of Policy Development and Research , January 2004.

NAHB Research Center, *Housing Innovation and the Appraisal Process, Building Industry Roundtable*, HUD Office of Policy Development and Research, December 2001.

Ahluwalia et.al., Economics Division of National Association of Home Builders, *Labor Shortage Study*, May 2000.

NAHB, *Housing facts and figures*, National Association of Home Builders, 2004.

Nowak, Mark and Dacquisto, David, Newport Partners LLC, *The Influence of Technologies on the Homebuyer's Purchasing Decisions: A PATH Field Evaluation at Pittsburgh's Summerset at Frick Park*, U.S Department of Housing and Urban Development, November 2003.

BLS, *American Time Use Survey*, U.S. Department of Labor, Bureau of Labor Statistics, 2003, (available on-line at www.bls.gov/tus/ last visited December 2004).