CONFERENCE PROCEEDINGS

RAND

The Role of Information Technology in Housing Design and Construction

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Science and Technology Policy Institute

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Preface

This Analysis

This conference proceeding summarizes a November, 1999 roundtable discussion on the role of information technology (IT) in housing design and construction. The roundtable was the first in a series of discussions sponsored by the White House Office of Science & Technology Policy (OSTP) to explore how IT can transform and improve American homes and the home building industry. A second workshop will be held in the Spring of 2000 to discuss the role of IT in the home and what the proper role of the federal government should be in bringing the benefits of IT into America's homes.

This conference proceeding is intended to share the roundtable discussion and provide information that can be used by interested parties to advance the use of IT within the housing industry. This document solely reflects the author's efforts to summarize the discussion that occurred and to provide a limited amount of additional information on related activities. This document does not constitute analysis of that discussion, nor does it represent validation of the discussion or the recommendations by RAND. Similarly, the information contained in the Appendix does not constitute an endorsement by RAND.

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Introduction

In 1998, single family home starts reached their highest level in more than 20 years and home ownership hit an all time high of 66.8 percent. The housing industry also made significant contributions to the national economy with residential investment amounting to nearly 5 percent of GDP and 10 percent of recent GDP growth. Despite the strength of these numbers, there are reasons to believe the current trends may not continue due to changing economic conditions such as a decline in the supply of skilled labor. If conditions continue to change for the worse without increases in efficiency and cost reductions, the cost of new and existing homes may increase, new construction may slow, and home ownership rates could fall thereby eroding much of the progress the current economic boom has brought. The possibility of such change is a cause for concern given that the housing industry has historically been very slow to innovate and adopt new products and processes. While the industry's large size, fragmentation, and diversity explain these trends, these traits suggest the industry may not be able to respond quickly or effectively to this mounting challenge on its own.

At the same time, however, there are reasons to be hopeful. The industry has time to develop and diffuse new technologies. In order to promote a strategic approach to seizing these opportunities, President Clinton launched the Partnership for Advancing Technology in Housing (PATH) on May 4th, 1998. PATH is a public-private partnership that seeks to accelerate the creation and widespread use of advanced technologies to radically improve the quality, durability, environmental performance, energy efficiency, and affordability of the Nation's housing. PATH pursues these goals through a combination of technology development, demonstration and evaluation, and information dissemination.

In order to supplement PATH's ongoing efforts, OSTP sponsored this roundtable to explore the potential contributions of IT to the home building process. This was felt to be particularly worthwhile given the size, fragmentation, and decentralization issues that characterize this industry. Furthermore, the success of IT in other sectors of the economy suggested that similar potential may exist in the home building industry, if the opportunities and barriers presented by IT could be brought into focus. In so doing, it was hoped that this roundtable would help the industry to adapt to changing economic conditions while

continuing to build better homes at lower cost. More specifically, the roundtable set out to answer a series of questions that would help provide guidance to PATH, industry, and all levels of government. The questions the roundtable set out to address included:

- What are the current and future concerns facing the industry?
- Where are the sources of cost and delay throughout the design, permitting, and construction phases of the home building process?
- Where are the opportunities for IT be used to reduce or remove these problems?
- What barriers could prevent these opportunities from being realized?
- What are the most important steps that should be taken to accelerate the development and diffusion of IT within this industry?

Roundtable Organization

To answer these questions, RAND worked with OSTP, PATH, the National Association of Home Builders (NAHB) Research Center, and the Department of Housing and Urban Development (HUD) to convene leaders from a broad cross-section of the housing industry. Participants included those who were willing to think creatively about how IT could be applied throughout the industry. Participants represented production home builders, building material suppliers, product manufacturers, building code representatives, software companies, the National Laboratories, and government agency representatives among others. While the discussion primarily revolved around large- and medium-sized production builders, the discussion is also relevant to smaller custom builders, home renovators, and commercial builders.

Conference Proceeding Contents

This conference proceeding is organized into five sections and two appendices. Following the introduction, the second section describes the discussion of the general processes involved in building a home and where the sources of cost and delay frequently occur. The third section discusses where IT could be used by various stakeholders throughout the home building process. The fourth section describes the barriers and synergies that will influence the usage of these technologies and the role that communication standards will play in overcoming the barriers and capturing the synergies. The final section consists of the

recommendations issued by the roundtable participants to PATH and to the housing industry itself. Appendix I contains a list of the roundtable participants. Appendix II contains an overview of efforts to apply IT throughout the building industry as well as an assortment of press coverage listings. Where possible Internet addresses are provided where more information can be found.

Home Design and Construction: Sources of Cost and Delay

Design

The amount of time required to prepare a basic home floor plan varies depending on the size and scale of the home builder. It can be as short as two days to as long as two months. Builders said they generally try to reuse their base plans, but they must always be modified to meet legal requirements, environmental conditions, local ordinances, and customer preferences. In many cases, the magnitude of change requires so many changes that each home is essentially unique.

While the time needed to modify plans varies with the size of the design firm, there was agreement that these changes can be made more quickly than the necessary approvals can be obtained. This is especially true at the local level. One builder described a request to make a base plan look more Spanish. This required altering the pitch of the roof and the shapes of the windows and doors among other things. These types of plan modifications require anywhere from one day to several weeks, but even the longest time was deemed short relative to getting the needed approvals from government officials.

Accordingly, it was agreed that the cost of design is small relative to the cost of the delays associated with getting new approvals. Based on the potential speed with which initial design and revisions can be made, and the fact that permitting takes much longer, it was felt that new IT innovations to accelerate the design process are less important than using IT to improve the pre-construction approval processes.

Land Development Approval, Permitting, and Zoning

Many types of code and regulatory approvals must be obtained from different jurisdictions before a home can be built. These requirements originate from all levels of government including federal, state, county, and city, as well as local zoning restrictions. The discussion was generally organized into three categories: land development approval, permitting (e.g., building codes), and local planning/zoning requirements (e.g., appearance and style guidelines).

Regardless of the level of jurisdictional approval, it was generally agreed that the approval processes can be delayed by a negative synergy. For example, the distribution of plans throughout the various approval processes (as many as 15 according to one participant) is often slow and unreliable, with plans sometimes getting lost or delayed for extended periods of time. At the same time, requirements are often poorly known and change with time. In some cases, requirements change while plans are passing through the approval processes. This means that when plans emerge from one part of the approval process, they may fail another due to new rules that were not initially required. This cycle of inefficiencies can potentially be repeated when a builder re-submits revised plans. The extended delays can become costly to builders who must pay interest on loans for large tracts of land while plans are re-designed and approval is sought. In some cases, this can result in large financial losses and even the cancellation of the development.

Land Development Approval

As citizens are becoming more involved in local land-use and development decisions, it was agreed that the development approval process was the most appropriate forum for the resolution of such issues. However, it was also felt that inefficiencies in the current process could be reduced without compromising the ability of communities and their citizens to control development. In particular, large builders said that poorly communicated and changing development requirements often caused significant delays and increased costs. These problems could be avoided if requirements were continuously accessible and up-to-date.

Permitting

Permitting and local planning/zoning (see next section) were agreed to be the most costly and time consuming bottlenecks in the pre-construction phase. Once again, the size of a builder influenced how quickly it was able to move through the permitting phase. Large builders were more capable of preparing plans *en masse* and submitting them all following development approval so that permits could be obtained quickly. Smaller builders on the other hand move more slowly, meaning that they were more likely to experience greater delays and greater expense while passing through the permitting process.

To illustrate the complex and numerous rules that pertain to builders, Los Angeles County was described as having 89 cities, each of which has its own city council and building officials. If builders working in Los Angeles County hope

to minimize permitting difficulties, he/she must stay aware of changes in codes at all levels including those in the county, the individual cities, and specific communities. Regardless of a builder's size, this is very difficult because changes can occur frequently and building codes may be issued in hardcopy only once a year. One participant said that in some cities, it can take a building department three months to complete its first plan check. And while the second check is typically faster, the whole process can take five to six months.

While builders clearly felt the permitting process was a problem, they also stressed that local building departments were not necessarily to blame for the delays and inefficiencies. This is because local building departments often operate on small budgets due to the fact that they compete for scarce public funds against fire departments, schools, and other vital city services. In most cases, the building department loses out to higher profile city services. Faced with under-funding and expanding approval processes (e.g., California's seismic codes became more rigorous following the Northridge earthquake), inspectors often get overwhelmed by the number of plans and plan checks. As a result, delays are inevitable.

Zoning

Local zoning requirements typically aim to ensure a nice looking community, but they often go about achieving this end through different means. Ranging from ordinances on roof shingles to exterior façades, these requirements may be expressed in different ways, they may be unclear, and they may change frequently. As a result, it can be hard for builders to meet these requirements without costly iterations. And the more communities a builder works in, the more requirements there are of which they must be aware. This is especially difficult for smaller builders.

Construction

After obtaining all needed permits, both large and small builders said it typically requires 4 to 6 months to build a new home. Of that time, about 10 to 20 percent is due to material delays, incorrect materials, lack of skilled labor, re-working of sub-standard work, and other problems with inspections and local officials. Many of the builders in attendance indicated that in recent years they had attempted to become more efficient and reduce cycle-time using a variety of techniques to improve scheduling as well as materials substitution; however,

many of these efforts have been limited by the declining availability of skilled labor.

In fact, in many parts of the country, it was felt that the last half of 1999 had seen a further significant decline in the availability and skill level of the labor pool. This lack of skills, along with language barriers, has made it difficult to meet quality standards on time and within budget. As a result, work is frequently redone one or more times resulting in lengthy and costly delays that are borne by the builder who is ultimately responsible for the quality of the home. While all builders were affected by this trend, smaller builders seemed more affected than larger builders. But as bad as the current labor situation was perceived, one participant explained that the US Department of Labor has predicted that the labor shortage in the building industry will increase by 240,000 people annually for much of the next decade.

Site Inspection

Site inspection was another problem area in the construction process. While there was a general sense that sit inspections often introduce lengthy delays, it was felt that the root cause of those delays and the resulting added costs was largely sub-standard workmanship and quality. While improved inspection scheduling was thought to be beneficial, it was also felt that the root causes needed to be addressed for the inspection delays to be significantly reduced.

Opportunities for Information Technology to Reduce Cost and Delay

Given these sources of cost and delay and the prospects for an increasing labor shortage, the roundtable recognized that the home building process may need to change in the future. It was also recognized that the use of IT in other sectors of the economy has begun to change traditional business models while improving quality, lowering costs, and increasing the speed at which products are brought to market. These realizations prompted several questions:

- How might the housing industry change?
- Are those changes already underway?
- What role can IT play in bringing these changes about?

To address these questions, the group re-affirmed that information and communications technology within the industry is generally limited to telephones and fax machines. With this in mind, it was agreed that increased use of IT could play a significant role in reducing the previously described delays and bottlenecks. In fact, one participant said that a European study has found that up to 30 percent reductions in construction time and cost should be possible through better communications and increased use of IT.

Participants discussed many opportunities for IT use ranging from email to automated code checking and paperless offices. Central to these ideas were two characteristics that would increase the value-added by employees:

1. Use IT to automate simple tasks, thereby freeing people to address higher-order tasks.
2. Use IT to let individuals and groups work more productively by giving them efficient access to critical information and each other.

While it was recognized that IT could be used to automate and make marginal improvements in existing processes, it was also recognized that the true benefit of IT comes from creating entirely new ways of doing business. It is these *revolutionary* changes as opposed to *evolutionary* changes that have brought the largest benefits to other industries.

While much of the discussion was structured around whether a given use of IT could be used by the public or private sector, there was recognition that innovations often cross the boundaries of responsibility or who traditionally provides a given service. For example, many of the innovations that could be used by the public sector may be developed by and possibly even financed by the private sector. For this reason, the organizational structure of the balance of this section should not be looked at as strict opportunities for the given sector, but rather as a loose framework that is based on traditional responsibilities. In addition to the following discussion, several ongoing efforts by public and private entities are briefly presented in Appendix II.

Private Sector Opportunities

While the housing industry is generally slow to innovate and embrace technological change, some private sector firms are already beginning to capture the benefits of IT. From the adoption of electronic mail, to bringing laptops into the field, to integrating design and manufacturing processes, the varying degree of IT usage is to be expected given the number and diversity of private sector firms and the hard to quantify benefits such investments will yield. Even so, several participants emphasized that their firms are beginning to make large investments in IT because they believe it will provide benefits similar to what other sectors of the economy have experienced.

When the group discussed why some firms embrace IT and others do not, two main explanations emerged: a visionary leader and the threat of intense competition. Regardless of the specific cause for change, it was agreed that IT tends to strengthen communication within the firm and between suppliers and customers. This improved communication was believed to result in improved products and lower cost. Some felt that those who embrace IT earlier will benefit the most, especially for those firms most likely to be affected by the previously described labor shortage.

Communication, Networking, and Integrated Manufacturing

While email may be perceived as the most common form of Internet communication, it is only a small portion of what IT can offer. The true benefit of IT comes from the integration of information and control that a network can offer. For the private sector, one of the most common uses of IT is to link key individuals and systems so that all phases from design to production can be coordinated and optimized. For example, a firm could replace numerous

training-intensive "legacy" computer systems with standardized, networked systems that can be monitored and operated in an integrated fashion. Such systems could even be designed to allow suppliers and customers to see when the next shipment of raw materials are needed or when finished products are scheduled for delivery. Ultimately, such interactions could be automated so that new orders are placed and processed automatically.

One participant from a firm that manufactures roof trusses explained that they invested in an Enterprise Resource System (ERP) that fundamentally changed how they operate. The ERP system linked all processes from design to manufacturing so that they can now accept computer-aided design (CAD) files, compare those plans with database of regional and state code requirements, and then automate as much of the manufacturing processes as possible through computer-aided manufacturing (CAM) systems. In the end, this investment in IT reduced the number of workers needed to manufacture roof trusses from 12 people to less than four.

Project Collaboration, Management, and E-Business

Just as firms can benefit from internal networks, so too can the builders, architects, material suppliers, trade crews, and inspectors that depend on each other to bring a project to completion. From designing blueprints to ordering materials to scheduling mechanical and electrical crews, these parties need to coordinate their activities with each other, and their schedules can change frequently depending on plan revision, inspections, inclement weather, etc. Accordingly, a number of dot-com companies have been founded to try and improve communication and cooperation among these diverse and fragmented parties. Most of these firms are developing Internet web sites that utilize a client-server model where the dot-com company hosts project documents and schedules on their web site so that all parties can access up-to-date information and even revise that information asynchronously or concurrently from one or more locations.

These dot-com companies are also in the process of developing a variety of web-based applications that offer value-added services such as project management, product databases, and even online marketplaces and commercial hubs. Often referred to as application service providers or ASPs, these firms could soon be offering a full suite of e-business capabilities. Already companies such as BuildNet and BidCom among others are vying to link suppliers, builders, and consumers through business-to-business e-commerce systems that will transfer the communication, ordering, and scheduling activities involved in the building

industry onto the Internet. While several of these companies are focused on the $900 billion domestic commercial construction market, the underlying software could easily enable similar transactions for the $300 billion domestic residential construction industry. In the future, it may even be possible for plans to be submitted to a website and various product manufacturers could automatically compete to supply all of the material and products needed for a given set of plans. A number of these firms are discussed in the "Project Collaboration, Management, and E-Business" section of Appendix II.

Product Promotion, Education, and Support

Many new housing technologies are slow to succeed in the market because it is difficult for home buyers, designers, and builders to learn of these products. Furthermore, assessing the cost and quality of these products can be problematic as is finding a local supplier, and having it successfully installed. IT provides a way of reaching out to all of these parties and providing each of them with the promotional, educational, and support materials (e.g., product specifications, installation instructions, repair guidance) needed to use products, materials, suppliers, and methods. Examples of such uses can be found in Appendix II under the "Internet Portals" section and portions of the "Project Collaboration, Management, and E-Business" section.

Investing in Worker Training and Productivity

Some participants felt that the industry's labor problems were better looked at as a combination of a skill gap and a labor gap. It was suggested that training and capital investment are tried and true methods for improving worker productivity. While some felt that this model was not appropriate for construction, others stressed that firms that do not invest in their workers are unlikely to succeed in any industry.

Two examples of how capital investment in IT could be used to boost productivity were offered. The first example of "augmented reality" technology (as compared to "virtual reality" technology) was developed by Boeing to assist workers who install miles of electrical wiring throughout their planes. An "augmented reality" helmet supplements the worker's field of vision with computer images that show how the wiring should be configured. The second example was a similar helmet-based system developed for the Department of Defense. This system shows workers how to install equipment several seconds before the actual installation. It was stressed that these kinds of investments

should not be looked at as lowering skill requirements, but rather as a way to increase productivity and have a more trainable, more transferable workforce.

While it was agreed that IT cannot make an unskilled worker into a craftsman, most questions focused on asking "Why would a homebuilder invest in these kinds of capital-intensive tools, especially given the cyclical nature of the industry?" Such investments run against the conventional thinking that typically calls for builders to reduce their investments in equipment, training, and personnel as so as to limit risk in this traditionally boom-bust industry. This led some to suggest that subcontractors should make these investments while others raised the possibility of creating a new business model. For example, a new type of firm may be needed that brings together investment capital, training, and a highly transferable workforce.

It was also recognized that computer software offers a broader range of options at much lower cost. For example, software could be designed to print out a daily list of tasks, needed materials, and images of what a finished detail should look like for each member of a work crew, and in multiple languages if needed. This type of software could also be integrated with scheduling software thereby boosting productivity at a relatively low cost.

Increased Use of Manufactured Components

Another means of addressing the labor gap is to substitute factory-built manufactured components for on-site construction. This is advantageous because it shifts portions of the construction process from the site to the factory where worker productivity is increased, quality is higher, and costs are lower. In so doing, the overall need for labor is reduced. Much of these improvements are accomplished because factories can offer better working conditions, automation of some tasks, fewer scheduling and weather-related problems, and simplified inspection processes.

As an illustration of the productivity differences between on-site and factory production, it was noted that a double-wide "HUD-Code" or factory-built manufactured home that uses the same techniques as on-site construction can be built in one day. Furthermore, in HUD-Code homes, labor costs represent about 8 percent of the total cost as compared to almost 40 percent for on-site homes.

While factory-built components such as roof trusses and kitchen cabinets have become commercially successful, other components such as wall panels have had more limited success. This is because builders and home buyers do not perceive components to offer the same level of quality and customization that on-site,

stick-built construction can provide. While the component industry has made progress in these areas in recent years, it was still felt that components cannot compete with custom-built homes. (This is true even after the previously described quality, re-work, and inspection problems associated with on-site construction have been taken into account). Until these concerns are addressed at both the real and perceived levels for both builders and customers, it was felt that components will continue to play a limited role.

Among the key steps that were identified as needed to expand the role of components was for the industry to think creatively and ask "what can be mass produced and what cannot?" Some felt that everything that could be mass produced should, though it was recognized that this would require mobilizing new investment capital. Furthermore, it was realized that success would require more than mass production, it would require mass customization. As with the automotive and computer industries, IT was seen as a key enabling technology that could streamline design, automate manufacturing, and ensure precise measurements and fit during on-site assembly.

Public Sector Opportunities

As with the private sector, IT could be used within the public sector to reduce or remove many sources of cost and delay. Opportunities discussed ranged from posting codes and special documents on the web, accepting plans electronically, automated code checking, developing virtual or remote inspection technologies, and a public information portal. These possibilities could benefit the public and private sectors by reducing the cost of building a home for customers and allowing all employees to focus their time on higher value-added areas.

Posting of Codes on the Internet

Designers, builders, inspectors, and suppliers would benefit if all regions, states, counties, and cities were to put their codes and regulations on the Internet. This would allow governments to update them instantly while allowing firms real-time access to the most recent information available. And as wireless technologies improve, this information would even be available in the field. This would reduce the time for inspection as well as the number of times plans had to be sent back to the builder to correct problems. This approach would be particularly valuable in reducing the cycles of delay that plague the current system. The result would be fewer delays for builders, reduced time for plan checking, and lower costs to consumers. An additional idea would be to put the

International Code Council's new codes on the Internet. While new pricing strategies would need to be developed (i.e., the codes are usually sold as bound volumes), posting these codes online while Internet access is becoming increasingly common could speed the diffusion and adoption of the new codes nation-wide.

Electronic Distribution and Processing of Plans and Permits

There is great inefficiency in distributing and processing plans and permits at local agencies. If builders could submit plans and permits electronically, that would eliminate the delays associated with physically mailing or carrying plans from location to location. Enhanced distribution using IT would make it easier for building departments to work with other state, county, and city agencies to work together efficiently. Some participants noted that the new internet-based, application service providers may represent the first step in transitioning from paper-based offices to digital, paperless offices. While substantial work remains to be done, some communities have already attempted to develop such systems. An example is the Smart Permit program in Silicon Valley. Smart Permit seeks to use IT to streamline development applications, permit processing, and drawing submittal for this fast evolving region. Other cities and counties have undertaken similar efforts on their own, or with the help of the private sector. In addition, significant new efforts are beginning in several areas including Fairfax County, Virginia. These and other efforts are described in Appendix II under the section titled "Electronic Distribution and Processing of Plans and Permits".

Automated Plan Checking

The approval process could be radically accelerated if plans were automatically inspected by computer programs. The time savings would benefit builders, consumers, and the government. It could even be possible for code checking software to "grade" the plans, identify what needed to be changed, and provide a link to the relevant code. Furthermore, designers could use the code checking program prior to government submittal thereby reducing or eliminating problems all together. This would transform a time- and labor-intensive process into one that would allow plan checks to be near instantaneous, thereby changing the current processes of sequential plan checks and revisions into a much faster concurrent process.

There are numerous technical challenges to be overcome before automatic code checking can be realized. These challenges include developing object-oriented CAD programs and file formats. This shift toward object-oriented programs and

files is needed so that computers can treat doors, windows, and walls as objects with specific properties (dimensions, cost, structural performance, fire resistance, etc), rather than as a collection of lines and text characters. At the same time, these programs must also filter this information and provide only that needed by the specific user. This is crucial to prevent overloading the user with information and to limit storage and bandwidth requirements. While the ASP business model may make this possible, additional software innovations are needed to ensure that interoperability exists between different hardware and software platforms, including a future generation of wireless devices.

Yet another major challenge to be overcome is the development of performance-based codes that would check performance characteristics rather than proscriptive standards. Such codes would continue to protect the public, but remove the inflexible requirements that prevent designers from meeting client needs or preferences for non-traditional structures (possibly due to innovative designs, materials, or needs).

Site Inspection

New technologies for remote or virtual inspections were also discussed. For example, remote stationary cameras can allow constant monitoring while mobile cameras with high-speed internet connections can be moved around a site under the direction of a inspector seated at their desk at the building department.

While these technologies are possible today, some questioned whether remote or virtual inspections could truly substitute for an inspector walking the site to ensure that it is safe for workers and meeting code requirements. Conversely, a mobile camera system could be used to remotely follow-up on problem areas identified during earlier on-site inspections.

Public Information Portal

Finally, it was noted that private sector websites hold great potential for educating designers, builders, and customers about new products and processes. But it was also noted that those websites will generally be oriented toward selling products rather then on broader issues and objective information. This led to a discussion of establishing government-supported information portals to share information without commercial influences or advertisements. While several portals already exist, they touch the surface of what could be done. An expanded portal could provide all stakeholders with quick and easy access to objective information and links to suppliers and products. Two examples of such

portals are Pathnet (www.pathnet.org) and ToolBase Services (www.toolbase.org). These are described in greater detail in the "Internet Portals" section of Appendix II.

Barriers, Synergies, & Standards

Barriers

While there are many opportunities to harness IT, so too are there many barriers to realizing that potential. Not until these barriers are overcome by *both the public and private sectors* will the industry get the maximum benefit from IT. For this reason, discussion focused on these barriers and the benefits that could be realized if the barriers were overcome. Once again, the size, diversity, and fragmentation of the industry emerged as a major barrier. This is because the impact any one party can have on the overall industry is very small. Furthermore, the fewer parties that use IT, the more limited are the benefits of the investment. More specific barriers focused on the resistance to cultural change, well established supply networks, the uncertain payoff of IT, and the lack of budgetary support.

For example, much of the industry's design and management-level workforce for the coming decades are those who are already participating in it today. Most of these workers have little to no experience with CAD and other computer programs. As a result, even recent graduates familiar with these tools will have a limited impact for many years. (It is important to note that the these labor-related problems are very different from the skilled labor problems described earlier in this proceeding).

Another consideration that reduced enthusiasm for IT investments was the feeling that many builders are comfortable with local suppliers and subcontractors who have well established distribution and support networks that sometimes include customization and installation of windows, electrical systems, plumbing, etc. While other industries are using the web to reduce the role of these "middlemen," it was felt that many builders and product manufacturers see local suppliers and subcontractors as a crucial and irreplaceable link in the supply chain.

In addition to preferring the local supplier oriented business model, it was clear that many managers do not perceive capital investments in IT to be profitable. This perception may flow from the industry's highly cyclical, boom-bust history that has rewarded those builders that minimized their investments in equipment and employees. Furthermore, some firms perceive themselves to be sufficiently

competitive already and do not think they need to become more "high tech" or efficient. (Others cautioned that this perception could be the result of record-breaking demand rather than some firms being more competitive than others). Finally, there was concern that large publicly-traded firms may be hesitant to make large investments in IT without reassurances that it will be profitable. For managers at these companies to act without such assurances could have a negative impact on shareholder value. For these reasons, until firms feel that the benefits of IT are clear and low-risk, it was felt that relatively few firms will embrace these advances.

Just as convincing private sector firms to make IT investments requires showing they will be financially profitable, convincing governments to invest in IT requires showing appropriate benefits as well. Unlike the private sector which often focuses on profit and rate of return, the public sector focuses on a wide range of constituent needs. In the case of county and city budgets, this often requires funding vital city services such as police departments, trash collection, and schools well before the building department. For this reason, it may be much more difficult for a building department to obtain funding than it would be to technically develop such a system.

Synergies

While these barriers pose significant obstacles to the growth of IT, there are reasons to be hopeful as well. For example, as each obstacle is overcome and each new IT capability is offered, the value of shifting more of the industry onto the internet and other IT-enabled systems become larger. Often called "network effects" or "synergy," this phenomenon leads the network to become more valuable as more information, people, and processes join the network. As more companies, job-sites, and application service providers go on-line, the more the public and private sectors will work together to overcome their respective barriers. However, if all parties do not join the network, then it may never achieve its true potential thereby imposing added costs and inconveniences to all parties. For this reason, the question becomes, what are the key developments that will promote this synergy? Or alternatively, what barriers and bottlenecks are most likely to deter this synergy? On numerous occasions, the key to developing true synergy seemed to be communication standards. More specifically, the group stressed that industry-wide standards were needed to allow both people and processes to communicate effectively and efficiently.

Communication Standards

All of the IT opportunities described in this proceeding require communication between people and processes. For this communication to occur, the people and processes must share a language that allows interoperability between numerous systems and stakeholders. Unfortunately, the housing industry has no communication standards because there has never been a common communications infrastructure for this large, fragmented, and geographically decentralized industry. Until such standards are developed, the opportunities described herein and the resulting synergy will be slow in coming.

This realization led to a discussion of who could fund and develop these standards. Some asked if there was a role for the federal government or an association to play in facilitating the development of these standards. It was generally felt that without such support, the required resources would be beyond all but the largest building departments. Several participants suggested that it is more important to focus on identifying who stakeholders trust to develop the standards rather than who funds a given effort. In other words, for the effort to succeed, it must be carried out by people who are trusted by the community, not just those who have the funds to develop such a system. Representatives from the software industry further clarified that software companies cannot develop these standards on their own. Rather, the larger industry needs to do much of the work itself, but in close partnership with the software industry.

Several participants familiar with standards development also explained that industry standards are typically developed through an open process that includes all parties rather than being developed by a single organization. In general, these efforts were either self-organizing or facilitated by an open, accredited, independent body such as the Institute of Electrical and Electronics Engineers (IEEE). Another possible forum is the International Alliance for Interoperability (IAI). The IAI is an open, non-profit organization with more than 600 member companies that is focused on developing communication standards for commercial building design in general. One participant felt that IAI could facilitate a similar effort for the housing industry or at least provide insights into what works and what does not. (More information on IAI can be found at http://iaiweb.lbl.gov/).

A final standards-related issue that was discussed focused on the recent development of "meta-data." Meta-data are essentially information on information. They offer a means for organizing data in ways that help people find data and aggregate them in ways that meet their needs (e.g., product specifications, local ordinances, installation instructions). In other words, meta-

data provide a faster and more direct route to obtaining knowledge from what is otherwise an overwhelming amount of raw information. If standards were developed that were amenable to the construction of meta-data, then it would be easier for others to develop tools that would provide significant value and benefit to the industry.

Roundtable Recommendations

The roundtable yielded a rich discussion of the current sources of cost and delay, how IT might be used to ease or overcome these problem areas, and where the most significant barriers are to realizing the benefits of IT within the residential construction industry. While it was difficult to identify the individual steps needed to realize this potential, the participants did issue three recommendations that would advance the use of IT and contribute to its growth and development within the industry.

Demonstration of Public Sector IT Benefits

The shortage of financial resources and the absence of a strong will for change were recognized as making innovation unlikely to happen at the local government level without additional specific support and assistance. This is particularly true because the private sector builders who depend most on local government approvals have little leverage in convincing those same government officials to change their processes and become more efficient. Accordingly, a pilot project sponsored by industry, state and local government, PATH, and other federal government agencies would stand a good chance of demonstrating that the technologies exist to make these improvements a reality. The roundtable suggested that PATH pursue such an effort in several locations, perhaps with several pilot demonstrations in different parts of the country.

Demonstration of Private Sector IT Benefits

The roundtable also recommended that PATH fund demonstrations of how IT can be used to design and build homes more efficiently and at lower cost. Such demonstrations would help show the value of IT to builders who would then be more likely to make such investments on their own.

Formation of a Communication Standards Development Group

Recognizing the importance of industry-wide communication and connectivity, the roundtable recommended forming a communication standards development

group. While there was disagreement over who should initiate the effort (i.e., government, a self-organized industry group, or a private firm), the participants agreed that the standards should serve the interests of all parties.

Given the fragmentation of the industry, the slow rate of IT innovation and diffusion, and the pre-existing public-private partnership represented by PATH, it was recommended that *industry collectively ask PATH* to provide a forum for initiating this effort as well as to provide the funding needed to bring it to fruition. It was further recommended that the effort be broad-based, inclusive, and draw on other groups and individuals that are familiar with such efforts. Finally, the participants also stressed that while PATH and the federal government can be a catalyst for this process, the effort must be embraced, owned, and led by industry for it to succeed.

Appendix I: Roundtable Participants

Home Builders
Manuel Gonzalez, Kaufman & Broad Home Corporation
Charles Irsch, Centex Homes
Jeff Lee, The Lee Group
Jim Murar, RGC

Material & Product Suppliers
Doug Arent, Lucent Technologies
Steve Arnholt, Honeywell
John Edwards, Honeywell
John Evans, Andersen Windows
Phil Zurowski, Wickes Lumber

Building Code Organizations
Paul Armstrong, International Conference of Building Officials

Software Companies
Wayne Hodgins, Autodesk
Jimm Meloy, Autodesk

Academia
Murilo Coutinho, Information Sciences Institute, University of Southern California
Ron Wakefield, Department of Building Construction, Virginia Polytechnic Institute and State University

National Laboratories
Ren Anderson, Building Energy Technology Program, National Renewable Energy Laboratory
Steve Selkowitz, Building Technologies Department, Lawrence Berkeley National Laboratory

Government
Cathy Creswell, Department of Housing and Community Development, State of California

Dave Engel, Office of Policy Development & Research, US Department of Housing and Urban Development
Henry Kelly, Office of Science & Technology Policy, Executive Office of the President

Consultants, Contractors, ad Other

Mark Bernstein, RAND
Scott Hassell, RAND
Ross Heitzmann, National Association of Home Builders Research Center
Deana Perlmutter, The Dutko Group

Appendix II: Related Resources

This appendix is organized into the following sections

- Internet Portals
- Project Collaboration, Management, sand E-Business
- Electronic Distribution and Processing of Plans and Permits
- Industry-Related Media Coverage and Resources
- General Media Coverage

Internet Portals

Pathnet

www.pathnet.org

The PATH website hosts a broad range of resources aimed at accelerating the creation and widespread use of advanced technologies to radically improve the Nation's housing. The website is designed to help both housing industry professionals and consumers quickly and easily find news and information, learn about new technologies and field assessments, discuss ideas online, and learn about programs and initiatives, upcoming events, and funding opportunities among other things.

ToolBase Services

ToolBase Services is maintained by the NAHB Research Center in conjunction with PATH. ToolBase provides the housing industry with practical solutions to construction problems, technical information on building products and systems, and benchmarks for quality business practices. By communicating the latest research results, and reporting on industry benchmarks, ToolBase Services provides builders and remodelers with information from manufacturers, trade associations, universities, laboratories, and the federal government to make housing safer, more durable, more energy/resource-efficient, and more affordable. In return, ToolBase Services provide feedback to the industry about what really works in the field.

Improvenet

www.ImproveNet.com

Created in 1996, ImproveNet is a nationwide team of home improvement experts whose mission is to make the home remodeling process more successful for both homeowners and service providers. ImproveNet helps homeowners through

every step of their home improvement projects and gives them the information needed to make their own decisions. ImproveNet does this by providing homeowners with a wide array of how-to advice as well as a service that is free to homeowners to match them with qualified remodeling professionals who are interested and available to help them.

ImproveNet strives to be an independent authority in the home improvement industry and has no ties to trade groups, associations, manufacturers, vendors, advertisers, banks, mortgage companies, builders, contractors, subcontractors, or realtors. Rather, ImproveNet exists to serve the consumer only. ImproveNet has a comprehensive network of over 600,000 independent, prescreened contractors and designers to supply top quality service. Coupled with that are the resources of more than 2,000 national manufacturers whose home improvement products are showcased on the site, both in a product-specific showcase and in an architecture-driven design showcase.

Project Collaboration, Management, and E-Business

BidCom

www.BidCom.com

Founded in 1997, Bidcom provides e-business services to the global building industry. Bidcom's suite of e-business services is a complete, integrated work environment that integrates standard business practices with Business Process Models (BPMs) that cover the full lifecycle of any building project from design and planning through construction and closeout. Delivered through the Bidcom e-Marketplace, these services help companies manage risk, drive down costs, and complete building projects on time.

In January 2000 Bidcom announced the completion of its third round of financing, totaling $46 million. Bidcom will use the investment to aggressively grow the Bidcom e-Marketplace to include additional process management applications, and to expand the existing commerce and content services. Bidcom's investors include Internet Capital Group, GE Capital, and Oracle Venture Fund among others. Customers and users include Ford Motor Company, Visa, Stanford University, Sun Microsystems, Siemens, Trammell Crow Company, Daimler Chrysler, Ziff-Davis, Turner Construction, and HOK.

BuildNet

www.BuildNet.com

BuildNet provides e-business, technology, and project management systems to the home building industry. BuildNet's five project management systems currently manage the construction of nearly one in three homes built in the U.S. Later this year BuildNet will expand its offerings to provide the first integrated Internet-based e-business platform for builders, suppliers, and manufacturers.

This effort will provide home builders with access to an integrated on-line network designed to change the residential construction market by availing every aspect of a building project to real-time, on-line, integrated e-business.

BuildNet completed its third round of private financing amounting to $104.7 million in January, 2000. This investment is being used to complete the e-business initiative so that it can be introduced in select markets later this year. BuildNet's investors include builders, distributors, and building materials manufacturers including Beazer Homes, Kaufman and Broad Home Corp., Pulte Home Corp., Toll Brothers, Kohler, Lafarge Corp., and Owens Corning. BuildNet is also actively building alliances with the building industry's manufacturers, suppliers, and large builders, and has recently signed e-business agreements with such companies as GE Appliance, Owens Corning, and CertainTeed.

Buzzsaw

www.buzzsaw.com

Launched in late 1999, buzzsaw.com provides Web applications and services to the building design and construction industry. buzzsaw.com provides an Internet hub that provides integrated business-to-business collaboration and e-commerce services in the near future. It also provides building product information, news, services and tools to streamline the building process including design collaboration, construction administration, and ongoing management. With its free project hosting and online industry resources, buzzsaw.com hopes to be the premier online hub for the building, design, and construction industry. In its first three months, the website has attracted tens of thousands of architects, engineers, general contractors, and owner/developers worldwide. This has led to more that 2,000 projects being hosted in less than three months. buzzsaw.com, inc. is a privately held company that is affiliated with Autodesk.

Cephren

www.cephren.com

Announced in January 2000, Cephren represents the merger of Blueline Online and eBricks.com. Blueline Online was a leading provider of Internet-based project collaboration services for the global building and construction industry. eBricks.com was a leading e-commerce company providing product and equipment procurement services for the construction industry. Through this merger, Cephren combines Internet collaboration and e-commerce into a single framework to provide customers with a more efficient and streamlined way to do business.

Cephren currently has customers in more than 800 firms and 10,000 registered users on five continents, representing a construction value of more than $40 billion. Cephren's framework is being used by Bechtel, Webcor Builders, Gensler, and HOK among others. During its merger announcement, Cephren

also announced that it had completed a $41.5 million private fund raising effort. Investors included GE Equity Investments, GE Power Systems, and Goldman Sachs & Co. among others.

USBuild

www.USBuild.com

USBuild.com is an e-commerce company that focuses on the needs of production homebuilders. USBuild seeks to bring Internet and supply chain advances developed by other industries to production homebuilders and in so doing, develop stronger, more profitable relationships with their supply chain partners. USBuild is developing their products and services with the help of leading homebuilders, manufacturers, and dealers.

USBuild.com enables production homebuilders to reduce the inventory, purchasing, and distribution costs by taking advantage of their size and dealing directly with manufacturers through their Internet-based procurement system and advanced distribution network. This system also helps manufacturers take advantage of the lead time between selling and building homes by communicating information on upcoming demand from builders.

Electronic Distribution and Processing of Plans and Permits

Accela.com

www.accela.com

Accela.com uses the internet to automate the administration of land use, building, and safety permits. They also offer inspection information and building supplier information online. Accela.com is the result of a recent merger of several companies. Accordingly, their next generation of software is still in development, but their family of software products are currently in use by more than 300 municipalities.

Fairfax County, Virginia

www.co.fairfax.va.us/gov/dem/

Fairfax County has implemented a number of information management systems to help with zoning and the processing of construction plans. This includes two systems that allow remote entry of inspection data that can later be synchronized with the county's larger databases. Much of this data is already available on the county's e-government website and efforts are underway to do the same for all other data. Ultimately, Fairfax is trying to make all government functions available over the web via an easy to use, citizen-oriented web-site. In addition,

the county has recently launched an effort to develop an open, computer-based technology platform for integrated land development and permitting.

Las Vegas, Nevada

www.ci.las-vegas.nv.us/building_and_permits.htm

The City of Las Vegas uses the Internet to provide information to developers, thus facilitating the permitting process. By accessing the City's web page, prospective developers can obtain permit application forms and fee and payment information, and developers can determine the status of any pending building permits. The City has created a Visual Interactive Zoning Ordinance (VIZO) which is accessed through the City web page and helps visitors understand the City's zoning ordinances. In addition, geographic information such as land use codes and zoning categories for specific parcels can be found using the City's Geographic Information System (GIS) that is also accessible through the Las Vegas web page.

Netclerk

www.netclerk.com

Netclerk is an online system that allows cities to post permit forms on the internet where contractors can download, complete, and electronically submit them. The system also has the capability to provide quick access to frequently used forms as well as "auto-complete" capabilities for frequently used information. Netclerk is currently used by the cities of Phoenix, San Diego, and Seattle.

Online Permits!

www.onlinepermits.com

Online Permits! provides online permit applications, electronic fee payment and online inspection scheduling. Online Permits! is currently being used by the cities of Cincinnati, Houston, Sacramento and Santa Rosa.

San Diego, California

http://www.ci.san-diego.ca.us/development-services/

The City of San Diego's "Process 2000 - Customer Service through Innovative Project Management and Technology" program has undertaken an effort to create the software for an integrated project management system. When finished, the software will be able to track all permits for any given project and will allow City personnel to have access to current permit and project management information. The software will be Internet-compatible so that eventually developers will be able to determine their project's permit status

online. Ultimately, this system will also be integrated into City's GIS system which contains information on zoning designations, land use, and flood plains.

Savannah, Georgia

www.ci.savannah.ga.us/cityweb/siteplan/index.html

The Development Services Office (DSO) of Savannah streamlined the permitting process by disseminating information via the Internet, installing project tracking software, and appointing a project manager to serve as the key contact for each development project. The implementation of these components has enabled the DSO to perform a third more work with fewer people, and with very small capital investment.

Smart Permit

www.jointventure.org/initiatives/smartpermit/index.html

Smart Permit is a project of Joint Venture: Silicon Valley Network. Smart Permit brings together the public and private sector in an effort to expedite the permitting process through the use of innovative information technology. A fundamental goal of Smart Permit is to enable developers to conduct all permitting activities online, from plan submission, to review, fee payment and inspection scheduling. While significant progress has been made, additional work remains to be done. Currently, most of the Smart Permit cities have systems for online permitting and several have the capability to accept electronic plans. In addition, all the Smart Permit cities are working on other aspects of the Smart Permit project, including online scheduling requests, digital signatures, and online payment. As such, progress has been made, but much more remains to be done before Smart Permit's vision is realized and productivity increases.

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NAHB Research Center, "Increased Efficiency Predicted Through E-Commerce," *ToolBase News*, Vol. 5, Issue 1, Winter 2000.

> To access past issues, go to www.ToolBase.org, click on "ToolBase Services", and then "ToolBase News".

National Conference of States on Building Codes and Standards, Inc. (NCSBCS)

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