PATH
Partnership for Advancing Technology in Housing

Technology Roadmap:

Information Technology to Accelerate and Streamline Home Building

Year One Progress Report

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

PATH (Partnership for Advancing Technology in Housing) is a private/public effort to develop, demonstrate, and gain widespread market acceptance for the "Next Generation" of American housing. Through the use of new or innovative technologies, the goal of PATH is to improve quality, durability, environmental efficiency, and affordability of tomorrow's homes.

PATH is managed and supported by the U.S. Department of Housing and Urban Development (HUD). In addition, all federal agencies that engage in housing research and technology development are PATH Partners, including the Departments of Energy, Commerce, and Agriculture, as well as the Environmental Protection Agency (EPA) and the Federal Emergency Management Agency (FEMA). State and local governments and other participants from the public sector are also partners in PATH. Product manufacturers, home builders, insurance companies, and lenders represent private industry in the PATH Partnership.

To learn more about PATH, please contact

PATH
PARTNERSHIP FOR ADVANCING TECHNOLOGY IN HOUSING

451 7th Street, SW
Washington, DC 20410
202-708-4277 (phone)
202-708-5873 (fax)
e-mail: pathnet@pathnet.org
website: www.pathnet.org

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PARTNERSHIP FOR ADVANCING TECHNOLOGY IN HOUSING

TECHNOLOGY ROADMAP:
INFORMATION TECHNOLOGY TO ACCELERATE AND STREAMLINE HOME BUILDING

Year One Progress Report

Prepared for:

U.S. Department of Housing and Urban Development
Office of Policy Development and Research
Washington, D.C.

Prepared by:

NAHB Research Center
Upper Marlboro, Maryland

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About the NAHB Research Center

The NAHB Research Center, located in Upper Marlboro, Md., is known as America's Housing Technology and Information Resource. In its nearly 40 years of service to the home building industry, the Research Center has provided product research and building process improvements that have been widely adopted by home builders throughout the United States. The Research Center carries out extensive programs of information dissemination and interchange among members of the home building industry and between the industry and the public.

Disclaimer

This report was prepared by the NAHB Research Center for the U.S. Department of Housing and Urban Development, Office of Policy Development and Research. The contents of this report are the views of the contractor and do not necessarily reflect the views or policies of the U.S. Department of Housing and Urban Development, the U.S. Government, or any other person or organization.

FOREWORD

This document, *PATH Technology Roadmap: Information Technology to Accelerate and Streamline Home Building*, is one in a series of technology roadmaps created to serve as guides to help the housing industry make decisions about research and development investments.

The Partnership for Advancing Technology in Housing (PATH), administered by the Department of Housing and Urban Development, is focused on improving the affordability and value of new and existing homes. To improve America's housing, PATH has identified research and established priorities for technology development that will enable the home building industry to work toward the PATH mission. This priority setting process, known as "Roadmapping," has brought together many industry stakeholders, including builders, remodelers, trade contractors, material and product suppliers, financial representatives, codes and standards officials, and public sector R&D sponsors. To date, the group's work has led to the development of three technology roadmaps: *Information Technology to Accelerate and Streamline Home Building*, *Advanced Panelized Construction*, and *Whole House and Building Process Redesign*.

This document focuses specifically on activities and strategies that will lead to improvements in Information Technology systems for the home building industry. It describes a need to develop a common language to communicate across the residential construction process, streamline the regulatory process, build a non-commercial information portal, and create production management systems from concept to closure.

By addressing these issues through research, the home building industry will continue to play a key role in providing affordable, durable housing for America's families.

Lawrence L. Thompson
General Deputy Assistant Secretary for
Policy Development and Research

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PATH PROGRAM GOALS

The Partnership for Advancing Technology in Housing (PATH) advances technology in the home building industry to improve the affordability and value of new and existing homes. Through public and private efforts in technology research, information dissemination, and barrier analysis, PATH is adding value to seven of the nation's key housing attributes: affordability, energy efficiency, environmental impact, quality, durability and maintenance, hazard mitigation, and labor safety.

As such, three overarching goals have been established that all bear on those attributes:

- **To determine the needs for improved housing technology development and provide relevant strategic services.**

  PATH will investigate the institutional barriers that impede innovation; will propose alternative, improved, or negotiated services to overcome those barriers; and will develop networks and agreement among participants to implement these services.

- **To develop new housing technologies.**

  PATH will support and perform technological research at all R&D levels of the home building supply chain with governmental and industrial funds and resources.

- **To disseminate new and existing technological information.**

  PATH will coordinate dissemination of innovation information (both for specific technologies and for industry-wide technological information) that remains unbiased, technically accurate, and relevant to specific housing audiences to increase the familiarity with, availability, and use of technologies in the home building and homeowner communities.

Partners in the PATH program—the U.S. Departments of Housing and Urban Development (HUD) and Energy (DOE), the Environmental Protection Agency (EPA), the Department of Agriculture (DOA), the Department of Commerce, the Federal Emergency Management Agency (FEMA), home builders, researchers, and manufacturers of building materials and products—have long recognized the importance of injecting current and emerging technologies into the home building process. The PATH program has identified many of the relevant technologies and has facilitated implementation of research, pilot, demonstration, and evaluation projects across the United States. In addition, PATH program partners recognize the importance of planning research and setting priorities for technology development that will enable the home building industry to work toward the PATH mission. This priority setting is known as "Roadmapping."

ROADMAPPING PROCESS

The objective of PATH technology roadmapping is to identify technology areas for immediate technological research in home building to serve as a guide for research investments by government and industry. The PATH Industry Steering Committee (ISC), comprised of builders and manufacturers of building products and materials, oversees the development of all technology roadmaps.

As the primary planning activity for PATH's research, the roadmaps dictate the main areas for research and development in PATH's research portfolio (which includes background, applied, and development activities), as well as provide the home building industry with a strategic plan for future technology development. Roadmaps approved by the PATH ISC will be provided to private sector interests to guide their technology development and to the government to guide its investment in research and development. Through this process, new technologies and additional research work will be generated as the roadmaps are implemented.

The ISC initiated the roadmapping process during the first quarter of 2000. A group of 40 builders, materials and products suppliers, academicians, researchers, and other stakeholders identified and rank ordered technologies that hold the promise of guiding PATH's research. The ISC then assembled the technologies with the highest potential benefits into three technology portfolios as follows:

- *Information Technology to Accelerate and Streamline Home Building;*
- *Advanced Panelized Construction; and*
- *Whole House and Building Process Redesign.*

The PATH ISC recommended development of technology roadmaps for each of the three areas, with *Information Technology* initiated in November 2000, *Advanced Panelized Construction* in December 2000, and *Whole House* in March 2001.

The roadmapping reports are available on both the PATH website (www.pathnet.org) and the NAHB Research Center's ToolBase Services website (www.toolbase.org).

This report deals specifically with *Information Technology to Accelerate and Streamline Home Building*.

VISION

The vision for the *Information Technology* Roadmap calls for information to be available when and where needed by participants in the home building process so they can perform their jobs more accurately, efficiently, and on time.

Realization of the vision will permit designers, specifiers, and consumers to have rapid access to comparative data on product costs, features, limitations, and availability in formats that can easily be compared, selected, and incorporated into computer aided design (CAD) plans. Applications and plans will be submitted electronically without travelling to the permit office or waiting in line. Builders and developers will know their application status at all times, and approvals will be returned electronically. Accurate, up-to-date design details, manufacturers' instructions, safety data, component specifications, and similar information will be available onsite in real time. Change orders, customer option choices, plan revisions, and unforeseen delays will be entered once, then accommodated seamlessly into revisions to working documents and process schedules, with updated information getting to all affected parties. All required inspections for regulatory approvals or loans will be performed on demand, without suspending work or scheduling a site inspection.

The vision will be achievable by small builders as well as by high-volume production builders. Interoperable software available from a multitude of vendors will ensure incremental realization of the vision.

Home building is an important part of the national economy. Today's U.S. home building industry represents about four percent of the nation's economic activity, or more than $230 billion annually. In 1999, 1.3 million single-family and 300,000 multifamily housing starts generated more than 3.5 million jobs.

The home is the centerpiece of the typical American family. In 1999, more than 66 percent of American households owned homes. Homeownership is an important way for Americans to accumulate wealth. Home equity accounts for more than half of the total net worth of the typical homeowning family.

As a business, the home building industry remains highly fragmented and is typified by small builders managing many small trade contractors. According to "Structure of the Residential Construction Industry" (Gopal Ahluwalia and Jo Chapman, NAHB Housing Economics, October 2000), the 1997 Census of Construction shows that approximately 99,000 contractors built a total of approximately 1.2 million units. That averages to about 12 units per builder. The data further indicates that 60 percent of the houses were built by companies who build less than 100 houses per year and have an average of fewer than eight people on their payrolls.

The vast majority of home builders place little reliance on in-house labor crews. Most focus on meeting customer needs by orchestrating the labor of a host of subcontractors and dealing with a wide range of suppliers and third parties. Accordingly, they manage and oversee not only key activities carried out within the firm, but also the activities of subcontractors and other participants in the supply chain. The management of key activities affects schedule, costs, prices, and profitability, as well as performance of the end product. Good management of the home building process easily can make the difference between success and failure in a highly competitive environment.

Figure 1 depicts the home building process. This process typically includes the following participants:

- Land developers—often not the general contractor or builder;
- Plan review, zoning, and code officials;
- Real estate or sales professionals;
- Designers/architects—many small builders buy and modify ready-made plans;
- Subcontractors—responsible for HVAC, electrical, plumbing, cement, framing, siding, roofing, insulation, interior finish, and other categories of work;
- Bankers and lending institutions—construction loans, as well as for consumer loan suppliers—distributors and lumber yards, and also manufacturers; and
- Consumers—home builders increasingly understand the need to satisfy.

In addition to dealing with a multiplicity of participants in the home building process, the builder must coordinate a home's design and later modifications, materials lists, delivery schedules, and subcontractor and inspector schedules.

Although IT would appear to be the ultimate solution for builders managing this complex process, many builders today use the technology very little. Those who do take advantage of available technologies use them for only a few of the steps in the management process. The old standards—mail, fax, and phone—are still the dominant methods of communication. A summary of the current use of IT in the home building process is provided below.

Land Development

The development of large parcels of land, including the construction of infrastructure and the subdivision of land into building lots,

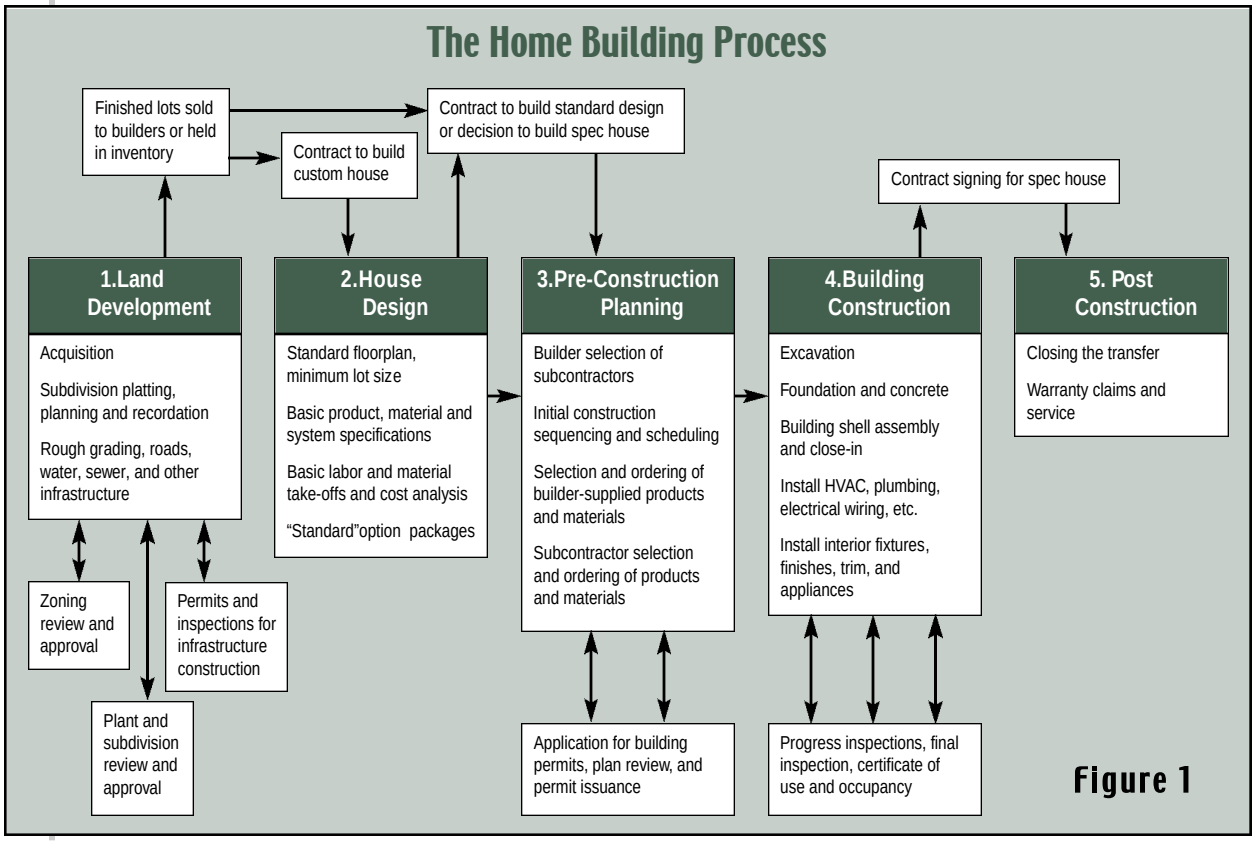


Figure 1

is often the province of firms specializing in land development. Land development activities require long lead times and extensive involvement of design and engineering professionals. Developers recover their up-front investment when they sell individual finished lots to home builders. Some larger builders undertake both land development and home construction. The more expensive online construction management systems (e.g., TrueLine) can address planning and execution of land development activities, but they represent the exception rather than the rule.

Building Design

The design process by architects and engineers has become far more computerized and automated over the last two decades. Production builders often employ in-house architects, whereas most small and medium-sized builders rely on "stock" plans from plan books or previously designed models. Commercial house plan services offer blueprints with lists of materials. With CAD programs, however, users increasingly are able to generate schedules or lists of materials for use in estimating and purchasing. Tying such information directly into standard construction management software remains an important opportunity for the industry.

Purchasing

Typical building companies buy products and materials in various ways. Most commonly, they buy costly items, such as framing packages, trusses, windows, and doors, based on bids from or negotiations with local lumberyards or similar suppliers. They may make other purchases, such as kitchen appliances and fixtures, from hard copy catalogues or manufacturers' literature. It is notable that major subcontractors, such as roofers, plumbers, electricians, and HVAC firms typically buy their own building supplies and products, often from firms that specialize in serving the relevant trade. Regardless of the buyer,

payments overwhelmingly follow paper-based methods. Many builder software systems can integrate purchase orders with other project planning activities, but they do not tie in with supplier systems. Accordingly, most of the data gathering and all of the analysis to support purchase decisions remain manual.

General Accounting

Most builders have computerized their basic business accounting functions. Accounting systems maintain a general ledger, track purchase orders, handle payroll, and generate simple financial statements. They may track specific job costs as well.

Construction Planning and Scheduling

Some business management packages for home builders support planning and scheduling of construction work and may tie loosely to purchasing, procurement, or job cost estimation. Many smaller builders use nothing more than spreadsheet programs. Others still track the scheduling and sequencing of subcontractor operations on paper, based largely on the experience of the builder or site superintendent.

General Communications

With the advent of the fax machine, the pager, and the cell phone, opportunities for communications among the many parties in the industry have significantly improved operational efficiency in recent years. Most builders report that they increasingly use e-mail while a few use instant messaging over the Internet, but others do not find messaging useful in its current state. The automated transfer of information among parties in the construction process is practically nonexistent. Nonetheless, it offers the greatest opportunity for reducing errors, improving efficiency, and speeding the design and construction process.

Site Communications

Communication links between building sites and home offices, suppliers, subcontractors, and others are more extensive than in the past. Superintendents typically rely on cell phones or digital pagers to supplement or even replace traditional telephone lines. Computers for Internet access are a rarity, although personal digital assistants (PDAs) and hand-held computers find some use. Wireless connectivity to several types of networked services should be available in some areas in the near future.

The limited use of computers and software by home builders discussed above is further supported by data. A recent survey of the largest 300 home builders (performed by the Meyers Group and published in the August/September 2001 issue of *TecHome Builder* magazine) indicates current use of software as follows:

Design (CAD) software	43%
Estimating software	41%
Integrated inventory management software	26%
Project management software	39%
Scheduling software	43%

Only 30 percent of these larger builders currently purchase any products online.

Also, several mid-2000 surveys by the National Association of Home Builders (NAHB) and the NAHB Research Center indicated that builders are not using the Internet nearly as much as was assumed.

- While about 85 percent of small- to medium-sized builders had Internet access, about 85 percent of those builders had slow, dial-up access.
- Although up to 50 percent of builders look for product information online, only about 10 percent purchase building materials or products online.
- Approximately 30 percent of builders who have Internet access never use e-mail, and another 35 percent check their e-mail once a day or less.

BARRIERS/CHALLENGES/GAPS

The challenges and barriers for broad infusion of IT into the home building industry are described below.

The Fragmentation of the Industry

Sixty percent of new homes are built by companies with fewer than 10 employees. This means that information technology needs to be adopted by builders who do not have and cannot afford complex, in-house information systems. Although some smaller builders are highly sophisticated, many lack basic IT skills, and builders of this size do not have an IT specialist on staff.

Use of Subcontractors

The vast majority of builders rely on subcontractors who are at least as small and unsophisticated as the builders themselves. Information technology solutions must be acceptable to and usable by these small trade contractors, including drywallers, insulators, plumbers, electricians, roofers, and other trades.

Building Onsite

Most houses today are built on the job site, making implementation of IT a significant challenge. Communications and computing equipment must be rugged. As they are needed in all kinds of weather, communications must be wireless with enough bandwidth to get the information out. Today, most people who work at the site typically have limited information technology skills and interest.

The industry lacks a common language with which people, processes, and software can communicate. Current "standards" are limited to a segment of the industry, such as architectural drawings and parts of the distribution chain. There are also proprietary "standards" that apply to specific companies and their customers.

The costs of new hardware, software, record conversion, and training are high. This is true whether implementing IT solutions in home building firms or local code offices. Financing is problematic for both.

Many industry stakeholders perceive significant risks in sending project information such as plans and financial transactions over the Internet. In addition, stakeholders are not convinced that digital seals and digital signatures are equivalent, acceptable, or available for use.

Many stakeholders lack the equipment and bandwidth needed to use the Internet effectively. This is true especially for many builders, suppliers, and contractors who may not have an Internet-capable computer or lack a broadband connection. In addition, wireless data connectivity is still immature, with no service in most areas, and pockets of limited coverage in even the best-served areas.

There is no single uniform national set of building codes in the United States. Rather, this country historically has used three different regional codes that can be modified by individual jurisdictions. This makes implementation of IT software for plan review, inspection, etc., significantly more complex and costly.

As noted previously, industry surveys show that builders currently are not using the Internet nearly as much as commonly thought. Slightly more than 10 percent of all builders surveyed, both large and small, use the Internet to locate products or manufacturers. Only a few percent use the Internet for buying materials and products. The use of computers and software by home builders, except for general accounting, is limited.

ROADMAP

OVERVIEW

Below are four strategies to advance the *Information Technology Roadmap* and the benefits of undertaking each strategy.

1. **Develop a Common Language.** Enable people, processes, and information technology tools to communicate across the residential construction process.

   ### Benefits

   ✔ Will enable development and application of processes and software that will provide seamless, instantaneous, end-to-end communication across the entire home building process.

   ✔ Will shorten the sales, construction, and mortgage cycles.

   ✔ Will increase builder profit margins and decrease the cost of homes.

   ✔ Will increase productivity and material cost savings.

2. **Streamline the Regulatory Process.** Increase efficiency in permitting, plan review, site inspection, and product approval using information technology to make the processes faster and more convenient, consistent, and reliable while providing the public with a higher level of protection.

   ### Benefits

   ✔ Will significantly reduce the time required for plan evaluation and approval, issuance of permits, and inspections. The resulting reduction in cycle time means not only cost savings, but also quality improvements.

   ✔ Will speed the permit application process, while facilitating application tracking.

   ✔ Will enable simultaneous review of plans by multiple code departments.

   ✔ Will reduce the need for skilled reviewers, improve the quality of the reviews, and speed the approval process.

   ✔ Will improve inspection quality and reduce travel time by applying wireless, location (GPS), and software technologies to enable the delivery of code information to inspectors in the field and remote submission of inspection results.

✔ Will dramatically reduce inspection scheduling problems and delays by employing virtual inspections or self-certification using the above mentioned technologies in combination with digital cameras.

✔ Will speed the approval process by making evaluation and approval reports easily available to code officials.

3. **Build a Non-Commercial Information Portal.** Provide a source for objective, reliable, technical information about home building for builders, trade contractors, and consumers that will allow users to make informed decisions about products, materials, systems, and processes.

Benefits

✔ Will provide information and training on the availability and application of existing and new technologies.

✔ Will allow comparison and selection of products and subsystems that offer affordability, energy efficiency, and durability.

✔ Will provide alerts on material or product failures in the field.

✔ Will allow builders and trade contractors to follow safer procedures because of the increased availability of safety information.

4. **Create Production Management Systems from Concept to Closure.** Link information technology tools and data within and among firms to improve the efficiency of managing the housing production process from start to finish to not only make today's management approaches work more smoothly and accurately, but also to lay the foundation for more productive ways of doing business.

Benefits

✔ Will provide accurate, up-to-date design details, assembly instructions, safety data, and other information in the field.

✔ Will allow change orders, customer option choices, plan and schedule revisions to be entered once, then instantaneously made available to all parties.

✔ Will simplify and expedite the land development process, which is the most lengthy, costly part of home building.

1 DEVELOP A COMMON LANGUAGE

The building process requires the communication of specific types of information among developers, general contractors, vendors, regulatory agencies, lending institutions, trade contractors, distributors, and many others. The information includes designs, schedules, product descriptions, lists of materials, and much more. The information is communicated in face-to-face meetings, by telephone or fax, by mail or hand delivery, and, more recently, over the Internet.

Other industries (i.e., automotive, aerospace, computer, durable goods) have developed IT tools that streamline and connect the design, procurement, manufacturing, and order fulfillment processes with seamless, two-way connectivity. However, home building is in the early stages of adopting information technology and transfer of information is not yet a reality.

Large national building firms, such as K. Hovnanian and Beazer, are implementing IT in their building processes. However, these companies have significant IT expertise and hire consultants and software companies to implement integrated systems. These are not solutions for small- and medium-sized builders who have fewer than 10 employees, yet build the majority of homes in the nation. These builders need software that can interoperate, and that can exchange, interpret, and use information without integration experts.

A common language would span, integrate, and be embedded in each of the current major areas of home building. An appropriate digital environment would allow every activity across those areas to cost-effectively create, store, access, collaborate, manipulate, and exchange data digitally.

As evidenced by a number of efforts that are now underway, the industry clearly recognizes the need for a common language. Most of today's efforts focus on commercial building construction, but certainly a good portion of the work already completed could serve as a useful starting point for the residential construction sector. Some of these are summarized below.

- The UNIFORMAT II building element classification framework describes a breakdown of the elements—building components—in a commercial building.
- An effort underway at the International Alliance for Interoperability (IAI) is specifying Industry Foundation Classes (IFCs) that detail how components and processes should be represented electronically.
- The aecXML (extensible markup language) Working Group, part of the IAI, is concerned with an exchange protocol that holds promise for allowing disparate software packages to share information.
- ConstructionZone.com (C-Z), which provides product information online, has defined an XML schema that is shared with its customers—the manufacturers who are listing.
- ProDealer Exchange (PDX), a nonprofit organization founded by materials distributors (i.e., lumberyards), is also developing an XML schema. One of the stated PDX initiatives is to "develop XML data format and transport standards focused on the specific needs of the construction channel."

- The National Institute of Building Sciences, working with the American Institute of Architects (AIA), the Construction Specifications Institute (CSI), and the U.S. CAD/GIS Technology Center, has developed a U.S. National CAD Standard. The standard includes CAD Layer Guidelines, Plotting Guidelines, and a Uniform Drawing System.

- The OpenDWG™ Alliance is an association of CAD customers and vendors committed to promoting Autodesk's AutoCAD DWG drawing file format as an open, industry-standard format for the exchange of CAD drawings.

- The National Conference of States on Building Codes and Standards, Inc. (NCSBCS) has been leading a multi-year program—Streamlining the Nation's Building Regulatory Process—that is directed at reducing the cost and complexity of regulation while ensuring life safety and affordability. One of the primary issues to be addressed by this program is creating an interoperable platform that will dramatically reduce the cost and time to integrate systems.

The fact that all of these efforts, and doubtless others, are ongoing is evidence that the industry is addressing the need for a common language. However, the effort must be directed to the residential sector and to the entire home building process.

The Roadmap outlined below describes the actions required to achieve a common language that will have two key components:

- A lexicon (vocabulary) that describes and defines the language of home building, and

- Standards that allow the electronic interchange and presentation of information to the users or processes that need it.

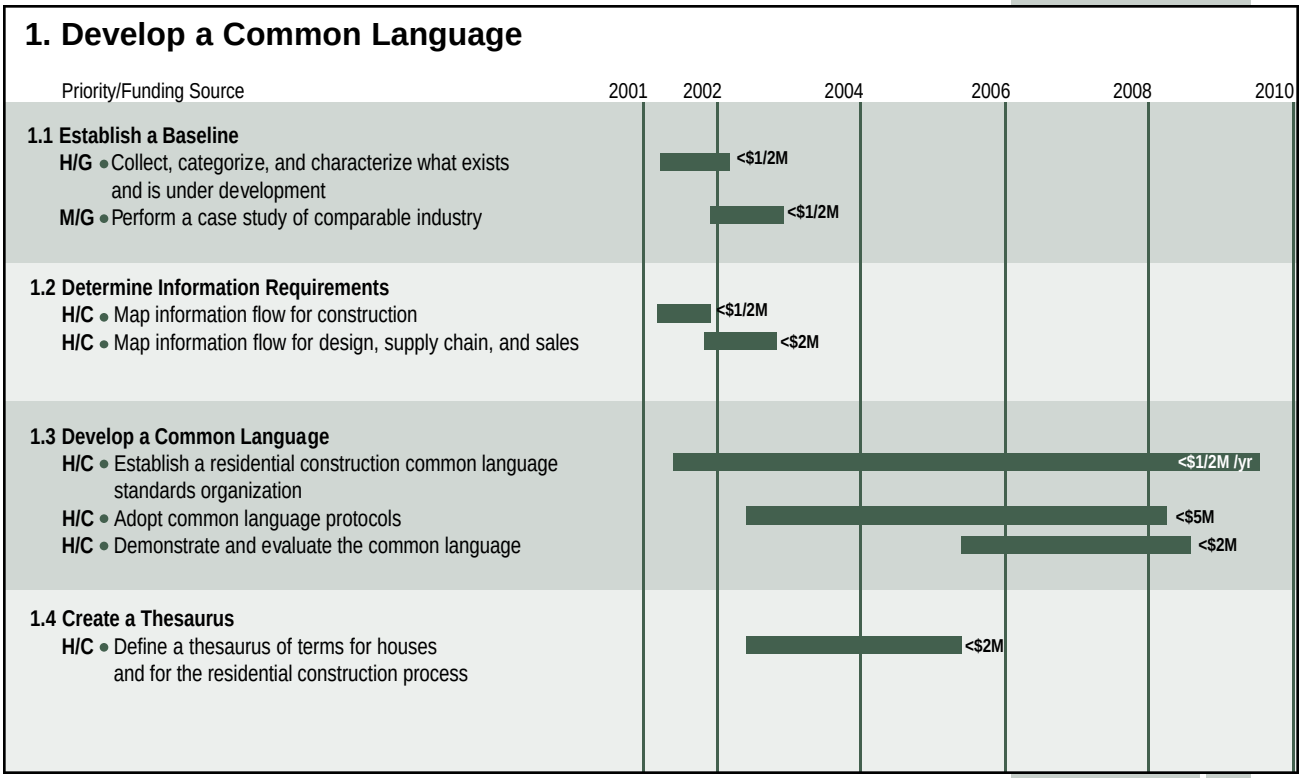
The four areas that require research and development in order to achieve the vision for a common language are outlined below and shown in Figure 2.

1.1 Establish a Baseline

The first step in developing a common industry language is determining what is out there. It will be necessary to collect, categorize, and characterize the "languages," protocols, and programs that are used today and those that are under development by various standards bodies involved in residential or commercial construction. Organizations include the International Alliance for Interoperability, the Organization for the Advancement of Structured Information Standards (OASIS), aecXML (XML for architects, engineers, and contractors), and the OpenDWG Alliance. Also, it will be necessary to look at open standards being developed and used by companies or consortiums, such as C-Z and PDX.

Part of this process is to investigate design, supply chain, construction, and sales and marketing in home building, as well as in the commercial and industrial construction sectors. It is also important to benchmark tools and systems in industries other than construction that seamlessly link design and implementation to sales, marketing, and informational activities.

The next step is to perform a case study on another industry similar in scope and scale to that of home building that has successfully developed and implemented a common language and protocols to provide end-to-end information flow. This will involve identifying the approaches and actions that made the implementation a success. In this effort, those involved should pinpoint the pitfalls or lessons learned by the other industry to avoid the setbacks identified in the case studies.



Key: Priority: L, M, H = Low, Medium, High
Funding Sources: G, P, C = Government (public), Private Industry, Combination
Funding amounts are approximations.

Figure 2

1.2 Determine Information Requirements

Once it's known "what we have," the next phase of work should focus on "what we need." A map of the information flow for the entire home building process, from land development through design, supply, construction, sales, and post-sale warranty support, should be developed. This will help to identify information needs and flows—who needs what information, when, and in what form. Creating the map will require collecting information from the industry by working with and observing the operations of builders, contractors, and others in the office and onsite. A detailed description that includes flow diagrams and that outlines the process around information needs would then be developed. The description can be organized around development, design, supply, construction, sales, and post sales. This mapping should be done for various sizes of builders and for custom as well as speculative builders.

In cooperation with a medium-volume builder, information mapping of the construction stage is currently underway at Virginia Tech. The effort needs to

be continued and expanded to include the other types and sizes of builders, as mentioned previously.

Information mapping of the design, supply chain, and sales processes also needs to be completed in the near term.

1.3 Develop a Common Language

The next step in the process is to develop the actual industry "language" that is needed based on the baseline and needs assessment. A steering organization should be established to take on this task of developing a residential construction common language.

This organization should include stakeholders in residential construction, including builders, trade contractors, architects, product/materials providers, and information technology providers. The organization would provide leadership, and would serve as the keeper, the standard bearer, the shepherd, the integrator, the guide, and the knowledge base for residential construction standards. This advocacy group would represent builders' interests. It would interface with other bodies and organizations that are developing or overseeing standards such as the NCSBCS, National Forum for Improving Regulatory and Building Construction Processes through Uses of Computer Technology, IAI, OASIS, aecXML, OpenDWG Alliance, and the National Institute of Building Sciences - U.S. National CAD Standard.

The organization would facilitate or lead development of standards and protocols that would result in end-to-end integration of the software needed to streamline the industry. It would also have the ability to influence other information initiatives in commercial construction or other industries with the potential for application to residential construction.

Working with existing groups and the steering organization described above, it would be necessary to implement and adopt the common language and protocols. This basically involves defining the necessary protocols and interface standards to allow design, supply, construction, and sales and marketing functions to communicate seamlessly and integrate the entire construction process.

Finally, the steering organization, or a subset thereof, should demonstrate, test, and evaluate the application of the common language to the residential construction process, document the benefits, and identify problems and issues.

1.4 Create a Thesaurus

In the mix of creating the industry common language, it will be necessary to create a central reference document, or thesaurus, to capture the shared lexicon that develops.

As starting points, the Industry Foundation Classes (IFCs) defined by the IAI and the "elements" defined in UNIFORMAT II need to be investigated. The thesaurus should be set in user-friendly terms that can be applied up and down the process chain.

The terms will be used by homebuyers, trade contractors, builders, distributors, architects/designers, code officials, appraisers, and others. All of these

stakeholders must be involved in identifying and defining the terms that they will be expected to use. The terms would include those describing the end product—the house—and those relating to the process by which it is designed, built, and sold (e.g., land development, plan review and approval, design, inspection, financing, scheduling, and purchasing).

2 STREAMLINE THE REGULATORY PROCESS

Fundamentally, streamlining the regulatory process is about increasing the efficiency of permitting, plan review, inspection, and new product approval. Achieving increases in efficiency calls for making the regulatory processes faster and more convenient, consistent, and reliable for all affected parties while providing a higher level of protection to the public.

Today's regulatory processes are the result of decades of evolutionary changes. At each point in this evolution, decisions made at state, county, and municipal levels determined what the codes should require, how building products should be evaluated, and how permits should be issued, plans reviewed, and work inspected. Past decisions and available technology constrained the individual decisions of state, county, and municipal governments. Given the technical developments in computers, the Internet, and wireless connectivity, this industry needs to exploit the tremendous opportunity to make technology work for each person in an orderly process.

IT has the potential to completely change how the home building industry shares information and communicates. A few examples of these changes include:

- Jurisdictions can use the Internet to distribute regulatory information and applications and to receive applications, project information, and plans.
- All parties can use the Internet to track applications or plans, to determine current status, and to learn the scheduled decision date.
- Regulatory processes can be connected to application service providers (ASP) to automatically share information, file applications, order materials, schedule labor requests, schedule site inspections, notify individuals of approvals, or ask key personnel for additional information.

Today's regulatory processes typically require plan reviews, permits, and site inspections as conditions of approval for new construction and renovation. And, in the case of new building products, regulations require the acceptance for use by local code officials on a jurisdiction-by-jurisdiction basis.

NCSBCS has collected specific examples of how jurisdictions have used IT and other process changes to streamline the regulatory process in a program called "Streamlining the Nation's Building Regulatory Process." The program and a database of jurisdictions are available on the NCSBCS website (www.ncsbcs.org). The discussion below outlines the current state of plan review, permit and site inspection processes, and notes how some jurisdictions already are using IT to improve regulatory efficiency.

Permitting: Builders typically obtain multiple permits from one or more agencies by either standing in line to submit basic project information and complete forms, or by dropping the information off and picking up the permit later. Today, a small but growing number of jurisdictions use software and streamlined processes to increase the efficiency of the permitting process.

Review: Following plan submittal, agency review may be completed within hours or weeks depending on how many reviews are needed, how many agencies are involved, and how well the review process is coordinated. If plans fail one review, corrected plans may need to be resubmitted and reprocessed by all parties. Some jurisdictions have used IT to increase permit review efficiency. A small number of jurisdictions have experimented with on-screen, computer-based plan review.

Site Inspection: Government officials must inspect construction work to ensure it complies with the approved plans and all applicable codes. Scheduling and waiting for required inspections can result in costly construction delays, just as correcting problems requires additional time. Some jurisdictions have reduced scheduling delays by allowing builders to schedule inspections through 24-hour automated telephone systems or the Internet. Still others are experimenting with the use of wireless technologies.

Product Approval: The new product approval process begins with a manufacturer performing or sponsoring tests and submitting the results along with an application to a model code product evaluation service. The result of this evaluation is a technical report that describes the product and the conditions necessary with the model codes. Published reports are then considered on a jurisdiction-by-jurisdiction basis by local building officials who determine whether the product complies with their local building codes and how they will allow it to be used.

Realization of the vision for streamlining regulations will require several types of research and development. Some of these R&D needs are common to all four of the regulatory processes, while others are more narrowly focused. The needs are summarized in Figure 3 and described below.

2.1 Identify Common R&D Needs

Just as there are common opportunities for increasing efficiency, there are also common R&D needs. Some of these are described below.

- Identify, document, and disseminate information on the current uses of information technology. It would be helpful to examine how IT is already used by innovative jurisdictions, and what generic types of hardware and software tools are currently available. This effort should also look beyond the site-built home building industry to see how other industries or sectors (e.g., commercial construction) have used technology to streamline the regulatory process without compromising the quality of their output. This information should be documented and disseminated throughout the industry and particularly to building departments and software firms. The results will help users learn about what is already available and set a baseline that can be used to guide future advances.

  The work should be structured around a map of the processes used to bring a home from design to completion. This is addressed under the Develop a Common Language section, but focusses here upon the regulatory part of the process. It involves surveying the software industry and building departments to see what technologies (both hardware and software) are currently available and how they are being used by jurisdictions to streamline permitting, plan review, and inspection.

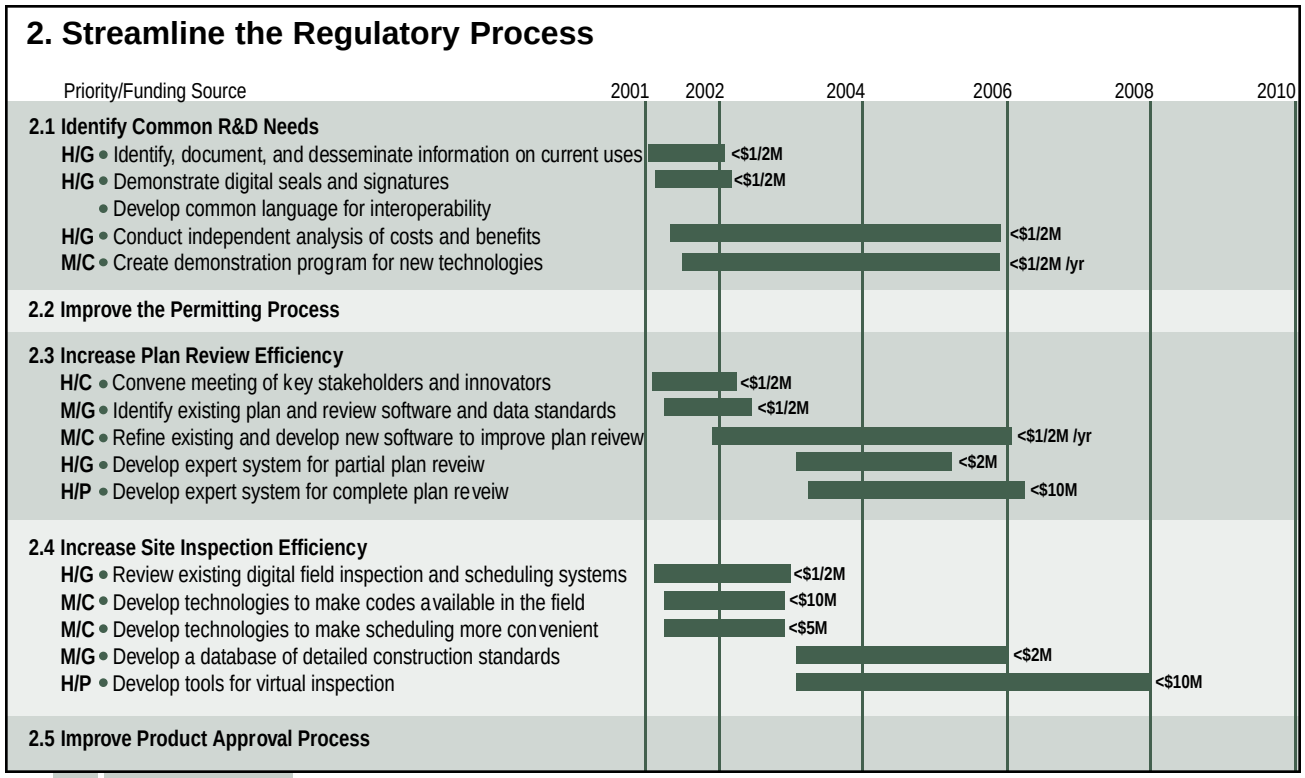


Figure 3

Key: Priority: L, M, H = Low, Medium, High
Funding Sources: G, P, C = Government (public), Private Industry, Combination
Funding amounts are approximations.

The findings should be documented and disseminated broadly. The findings should provide best practice insights into how IT can be used effectively, along with Internet links to successful jurisdictional IT efforts. The final publication should be vendor-neutral and avoid identifying specific software packages. Such an approach maintains a focus on showing what IT can do generally, thereby building a larger market, rather than promoting an individual software package.

- Demonstrate digital seals and signatures. Software tools and applications should be developed and demonstrated to show the industry that digital stamps, signatures, electronic payments, and transmission of project plans and financial information are feasible, secure, and useful.

- Develop an industry-wide common language or standards for inter-operability. Facilitate industry-wide communication through either a common language or interoperability standards that facilitate data sharing and integration. These standards must allow local jurisdictions, ASPs, and construction management software to communicate seamlessly so that each of the regulatory processes can be automated and integrated into other processes. The Common Language part of this Roadmap described earlier is therefore critical to achieving the vision for regulatory streamlining.

- Conduct an independent analysis of the costs and benefits of IT investments. The costs and benefits of permit process improvements must be

examined. This information is crucial to demonstrate to building departments, their customers, and elected officials how and why it is in their best interests to make IT investments. Cost-benefit analyses should examine the net benefits and return on investment for both the jurisdiction and its customers. Until these analyses are available, building departments may not be aware of the benefits IT can offer and they may not be able to obtain the support of their local officials to fund such investments. These measurements and analyses may be needed repeatedly as new technologies are developed.

- Establish a demonstration and evaluation program. A program should be established that will independently test and validate the value and use of new information technologies and their application to the regulatory process.

2.2 Improve the Permitting Process

Since the private sector and several local governments have recently developed software solutions to meet the strategic goal of increased permitting efficiency, the most important R&D needs are those identified in section 2.1 as "Common R&D" categories.

Disseminating what is already available, showing how digital signatures can be used, helping develop interoperability, and showing the value of increased permitting efficiency can stimulate demand for these services, increase market potential, and provide additional incentives for the innovations needed to realize the opportunities described.

2.3 Increase Plan Review Efficiency

Few public or private resources have been dedicated to increasing the efficiency of plan review. The few efforts undertaken to date have had mixed results. Both under-investment and lack of success stem from the high R&D costs and technical risks associated with developing new software and hardware. Cultural risks of motivating building departments to replace their traditional paper-based review techniques with on-screen, computer based inspections also exists. If the strategic goal of increasing the efficiency of plan review is to be accomplished, more cooperative efforts are needed to stimulate stakeholders, facilitate partnerships, and promote cooperative R&D. The R&D needs listed under the "Common R&D" heading provide an important foundation, but other types of R&D are needed as well. The additional needs are described below.

- Convene a meeting of key stakeholders and leading innovators. A need exists to discuss efforts undertaken by jurisdictions, software providers, and hardware manufacturers to expedite permit processing and how PATH can help advance these efforts. The meeting should be used to develop a shared understanding of the current state of technology, to agree on a shared vision, and to develop a specific work plan for how PATH can assist the efforts best. Specific tasks or questions to be addressed include identifying and documenting available software and noting the software currently used by jurisdictions; developing a standardization plan based on what works well to eliminate or reduce problem areas; and determining the impediments that need to be addressed to facilitate adoption of automated plan review.

- Identify and document the industry's full range of CAD and related computer data standards. This task should include all proprietary and open-source or open-system data standards, which stakeholders use the standards, and what the individual standards provide that others do not. Until the full range of standards, features, and user needs is understood, it will be difficult to move beyond today's lack of interoperability. Industry standards should be developed for electronic plan format and pagination so that information is similarly organized on all, thereby allowing designers, reviewers, and trades to find information easily when viewing plans on computers or on hard copy blueprints.

- Refine existing and develop new software to improve plan review. Develop software tools to help plan reviewers easily and effectively review and redline plans and provide feedback to designers. The software should help reviewers step through essential aspects of the code checking process. The tools should be easily customized for different jurisdictions and local variations in the model codes.

- Develop a prototype expert system for partial plan review. This system should show that automated code checking is technically feasible. Land development and setback issues may be the easiest to check and may represent the largest time savings.

- Develop an expert system for complete automated plan review. Following demonstration of a successful prototype, the system should be developed that would review all aspects of a plan and either issue an approval or provide guidance on deficiencies.

2.4 Increase Site Inspection Efficiency

As with plan review, few public or private resources have been dedicated to increasing the efficiency of site inspections. The current process has inherent efficiency limitations because inspectors must be onsite for all inspection activities. While several technologies may increase the efficiency of inspectors while they are onsite, information technology could greatly increase efficiency by reducing or eliminating the need for inspectors to visit the site. Most of the underlying technologies—wireless data communications, digital video devices, portable computers and digital assistants, and location devices—are under development by private industry. The research and development required here is more construction-specific. It requires definition of the specific requirements for residential inspections and developing software and interfaces to integrate the underlying technologies into useful systems.

- Review existing digital field inspection and scheduling systems. Some local jurisdictions already use computer and communications technology to improve the efficiency of their operations. These efforts need to be identified and described and their effectiveness evaluated. The information will provide a starting point for the site inspection research and development.

- Develop technologies to make code text available in the field. The system must be easy to use and affordable. It should be capable of rapidly providing applicable codes with local amendments to both an inspector and a site supervisor.

- Integrate information technologies to make scheduling of inspections more convenient. Construction supervisors, inspectors, and their supervisors need to be able to schedule and re-schedule inspections quickly and easily from multiple locations and using different technologies. Existing software and equipment technologies seem capable of performing this function, but they need to be assembled into a system.
- Develop a database of detailed construction standards. This database could be used to help conduct field inspections. The standards would be available not only to inspectors but also to the construction workers and supervisors at the site so they could do it right the first time.
- Develop new tools for virtual inspection. These tools might include audio, photographic, video, and spatial measurement tools. These tools will ultimately make remote or virtual inspections not only technically possible but also acceptable as or even essential to local building departments.

2.5 Improve the Product Approval Process

The advancements in product approval generally relate to creating linkages between the evaluation service websites and the Non-Commercial Internet Portal. For further discussion of these R&D needs, refer to Section 3, Build a Non-Commercial Information Portal, in this Roadmap. There may also be a role for making evaluation reports readily accessible in the field along with code text as described above.

3 BUILD A NON-COMMERCIAL INFORMATION PORTAL

Builders, trade contractors, and homeowners need objective information to help them make informed decisions about the selection and installation of products used in residential construction. They need product descriptions, warranty and service life information, performance data, cost information, availability information, and installation instructions—all at little or no cost. They need to know about new and emerging product and process technologies as well as how to apply them. Manufacturers need feedback from builders, contractors, and homeowners—information on problems and issues with products used in the field so they can provide timely product improvements. Builders, contractors, homeowners, and manufacturers need an expeditious means for searching building industry-related websites, exploring topics, exchanging ideas, and even learning about foreign developments and technologies. Best practices need to be identified and shared across the industry. Builders need to know what works industry-wide, what does not work, and who uses what tools.

The Internet already offers many Internet portals, including several targeted to the home building industry. They vary in design and function, and they are all commercial sites. Typically, manufacturers or vendors of materials or products pay a fee to place advertisements for their materials and products or their companies on a site, or users pay a subscription fee to use the site. Some sites offer catalogs of building products—for example, Sweet's publishes a catalog of information for specifiers. Usually these sites feature manufacturers' advertising literature and do not provide quick, easy access to the full range of objective information required to compare and select products or materials. Other "commercial" services compile product information from manufacturers, but the much needed objective information is often difficult to locate through a profusion of advertising. Builders and homeowners favor a non-commercial approach, but such an approach has little support from product manufacturers.

A non-commercial information portal can be the first place builders and homeowners will look when they need information about home building processes, products, and technologies. They will visit the portal because they know they will find quickly and reliably the objective, comprehensive information they need for comparing, evaluating, and selecting building products and technologies, or for implementing new management processes and tools. As the technology matures, the portal will include knowledge-based decision support tools and eventually an "agent" that allows the user to communicate in plain English, helps find the information needed, and assists in evaluating and comparing products, processes, and technologies.

Research and development is required in four areas to implement a non-commercial information portal:

- Portal development provides the delivery platform—the framework within which the information would be displayed. The platform would include identification, acquisition, and application of the development tools and software needed to implement the portal.

- Content management collects, organizes, and provides the portal with the extensive technical information that makes the portal worthwhile. The quality, depth, and breadth of content is central to the vision of the portal and will ultimately determine its value to users.
- Decision support tools give users the web-based resources they need to evaluate, select, and implement PATH technologies. These include economic evaluation tools that access, analyze, and interpret cost and technical performance data.
- Education and training is a special form of content that will add value to this portal. It will provide portal visitors with the skills necessary to select and apply PATH technologies.

The specific projects required in each of these areas are shown in Figure 4 and summarized below.

3.1 Portal Development

Phase I implementation of the portal would require the use of current technologies to provide an effective browsing capability structured around a builder, remodeler, homeowner-oriented taxonomy (organization of the information). There should be a focused search capability that provides useful, relevant information, and personalization of the portal by each user should be possible. First-phase portal development would include administrative and publishing capabilities for efficient submission, editing, organization, and management of information.

Phase II implementation would provide the capability for online comparison of products and materials by making use of templates and a common data language, such as XML, for describing all the components in a home. Phase II would also provide basic decision-support tools that will help users with product, material, technology, and process comparisons and selection.

Phase III implementation would be knowledge-based and allow users to pose questions or describe problems and information needs in plain English. The portal would not only deliver information to the users, but it would also help them understand decision parameters and make informed decisions.

A low-bandwidth portal for job site use is needed. It would contain a subset of the information provided by the Phase I portal and minimize the use of graphic files. Its purpose would be to provide essential information that is urgently needed by users on the job site and that can be delivered over the limited bandwidth expected for wireless Internet access over the next three to five years.

Investigate alternative models for funding the portal. The section on challenges and barriers at the beginning of this document identified long-term funding of the non-commercial portal as a major issue. Alternative funding models to be investigated include manufacturer "grants" (currently used by the cooperative government/private industry program, ToolBase Services), user subscriptions (currently used by *Consumer Reports*), or "pay-per-view" (currently used by *USA Today* for archived articles).

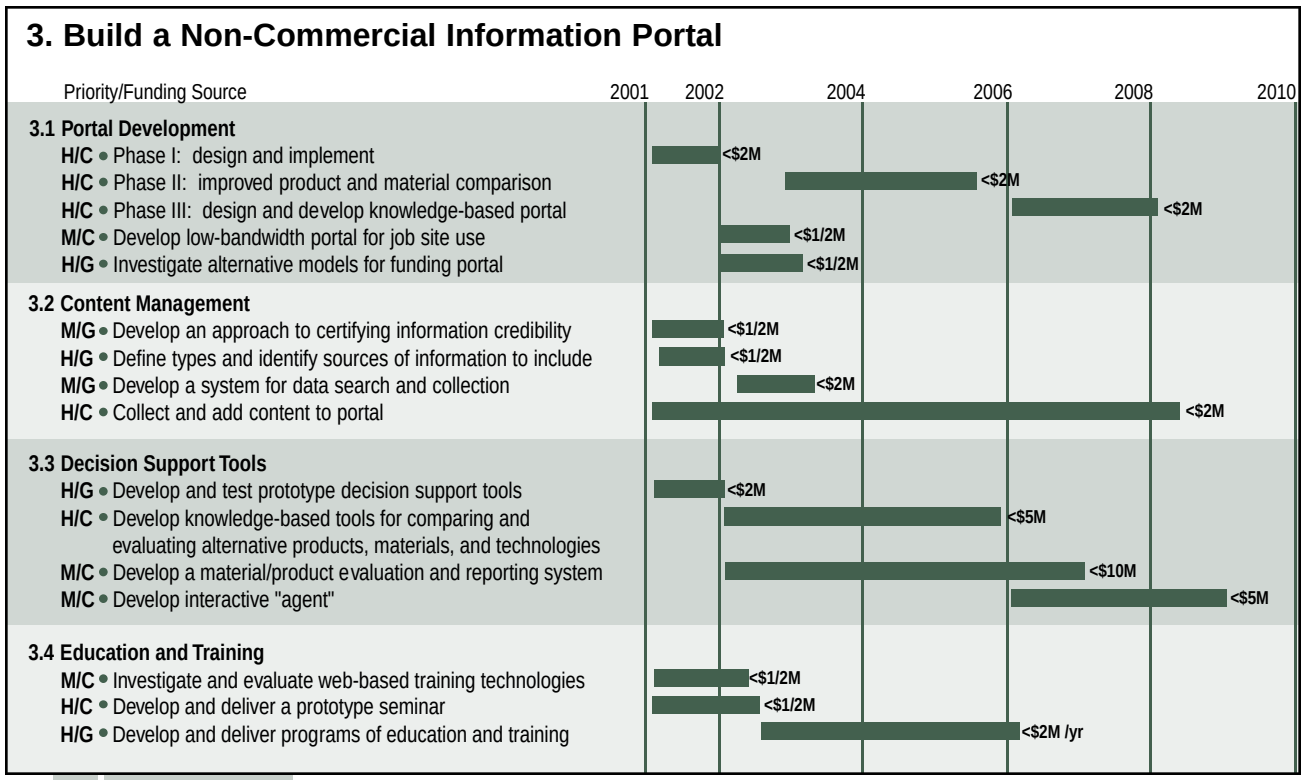


Figure 4

Key: Priority: L, M, H = Low, Medium, High
Funding Sources: G, P, C = Government (public), Private Industry, Combination
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3.2 Content Management

Effective implementation of the portal over time requires systematic procedures for finding, collecting, and certifying or validating the credibility of the information. An approach to certifying information credibility is needed to ensure that information provided by the portal is technically correct, appropriate, and objective. The approach may call for screening of information and sources of information. It may require the creation of a panel comprising representatives of various industry segments to provide oversight and ensure objectivity.

Types and sources of information to be included must be identified, including the development of templates for the various products, materials, and processes to be described. Identification of content should be accomplished with the participation of manufacturers, distributors, builders, and trade contractors to ensure broad support across the home building industry. Portals developed for other industries (e.g., automotive industry) should be examined to evaluate alternative approaches.

A system for information search and collection must be developed as well. The portal's greatest value will be as a one-stop source of reliable, complete, and up-to-date information. A systematic approach is essential to ensuring that the portal provides access to needed information. Such an approach must address how to maintain a database of information sources, implement standard techniques for soliciting information, and provide methods for sources to submit new information.

Collecting and posting information on the portal would be an ongoing activity that must continue throughout the life of the portal.

3.3 Decision Support Tools

Decision support tools directly executable from the information portal would help builders, remodelers, trade contractors, consumers, and other users of the portal make better-educated decisions about products, processes, and technologies. Such tools would help portal users understand what information is important to their decisions, find the needed information, and assist users in making objective evaluations and decisions.

- Development and testing of prototype decision support tools should be initiated as soon as possible. A PATH-funded effort to develop a tool to help homeowners assess the value of more durable residential systems and materials is already underway at NIST. Other prototype efforts along these lines need to be initiated. The resulting prototype tools will need to be tested with focus groups of homeowners and builders. Feedback on the portal will establish the soundness of the concept and provide ideas for improving the design of the ultimate decision support tools to be developed.

- Develop the decision tools and assemble the required supporting data after the prototype tools have been tested. In some cases, the modification of existing tools may be in order. For example, the U.S. Department of Energy has developed a variety of tools for determining the energy efficiency of buildings. These tools could prove useful to designers or builders who need to determine the energy characteristics of a particular design. In other cases, the development and implementation effort may require the support of different government agencies.

- Develop a material and product evaluation and reporting system for use by manufacturers to supply standardized and certified performance data on their products. The system would give users an authoritative and objective means to evaluate products and materials. It would include standard protocols for laboratory testing and reporting of results.

- Develop an interactive agent that is available to each user of the portal. The "agent" would be capable of communication with the user in plain English language syntax; it would know each user's general needs and preferences; and it would be able not only to collect but also to organize and provide comparative evaluations of alternative technologies, materials, and products. Private sector Internet software providers will likely develop the agent capability as a commercial product that will require only some customization to meet the specifications of the information portal.

3.4 Education and Training

The portal will provide education and training over the Internet to help builders and remodelers understand how to select and apply new or emerging technologies.

Investigation and evaluation of web-based training technologies are required to determine effective methods for delivering education and training over the Internet. The selected methods would best exploit the unique capabilities of

the Internet to provide real-time education simultaneously to builders or contractors across the country or to provide variations of self-paced education and training at low or no cost and at times most convenient to the user. Software Wizards should also be studied as a way to present guided tutorials on properly installing or inspecting building systems and products.

The delivery and evaluation of prototype seminars involves delivering seminars to builders and trade contractors and collecting and evaluating feedback about the effectiveness of delivery methods.

Development and delivery of education and training programs would provide builders and others with the knowledge and skills they need for correctly selecting and applying product, material, and process technologies that will contribute to building better homes and achieving the PATH goals.

4 CREATE PRODUCTION MANAGEMENT SYSTEMS FROM CONCEPT TO CLOSURE

The greatest challenges faced by most home builders revolve around execution of a production process that is complex, unpredictable, and always subject to change. Information technology not only can make today's management approaches work more smoothly and accurately, but it can also lay the foundation for basic changes in the conduct of business that will improve productivity.

In coming years, rather than applying multiple incompatible software tools or manual methods for project design, planning, and execution, home builders of all types will make increasing use of integrated or interoperable software packages that reach from end to end of the building process. Elements of these software packages will be able to manipulate data in concert with in-house accounting software and will interface cleanly with software systems used by suppliers, subcontractors, and other participants in efficiently and accurately transferring information needed by each party. Over time, the home building process will evolve and become more efficient by taking maximum advantage of information exchange.

The home building process varies widely across the range of business operations that make up the home building industry. Yet, regardless of business style, special complexities and uncertainties must be addressed both in planning residential construction and throughout its execution. Most home builders place little reliance on in-house labor crews and instead orchestrate the activities of a host of subcontractors and deal with a large number of suppliers and third parties. Effective management and oversight are needed for activities carried out within the firm and also for subcontractors and other elements of the supply chain. Schedule, costs, prices, and profitability, as well as performance of the end product, are affected. Management can make the difference between success and failure in a highly competitive environment.

The development of IT in production management requires a general project-planning framework tailored to the construction of houses. The industry has yet to adopt a generally accepted framework for project planning that defines the functionality to be encompassed with a suite of enhanced tools and the opportunities needed to improve overall integration. Although Figure 1 (page 4) provides a reasonable starting point, several variations may be required to encompass the range of approaches followed by home building companies of different sizes and operational structures.

Information technology will need not only to allow transfer of data back and forth between elements in Figure 1, but also to translate or repackage information in such a way that one element's output is directly usable as the next element's input. This requirement may give rise to a near-term constraint when builders, trade contractors, and suppliers want to interconnect older systems that are functional yet technologically obsolete. Customized translators may be used for interfacing programs, provided that input and output data format specifications are available and adequate. The use of metadata in the

form of XML tags or other common language approaches will provide a more general method for addressing this problem.

Successful implementation will require "open systems" software, whereby vendors publish documentation of their application program interfaces. This simplifies and encourages the creation of interoperable software. This approach has become popular as an aid to developing robust systems whether components are layered or tied together as peers. Examples abound of the resultant synergies.

Implementation of effective, end-to-end production management systems requires the actions summarized below:

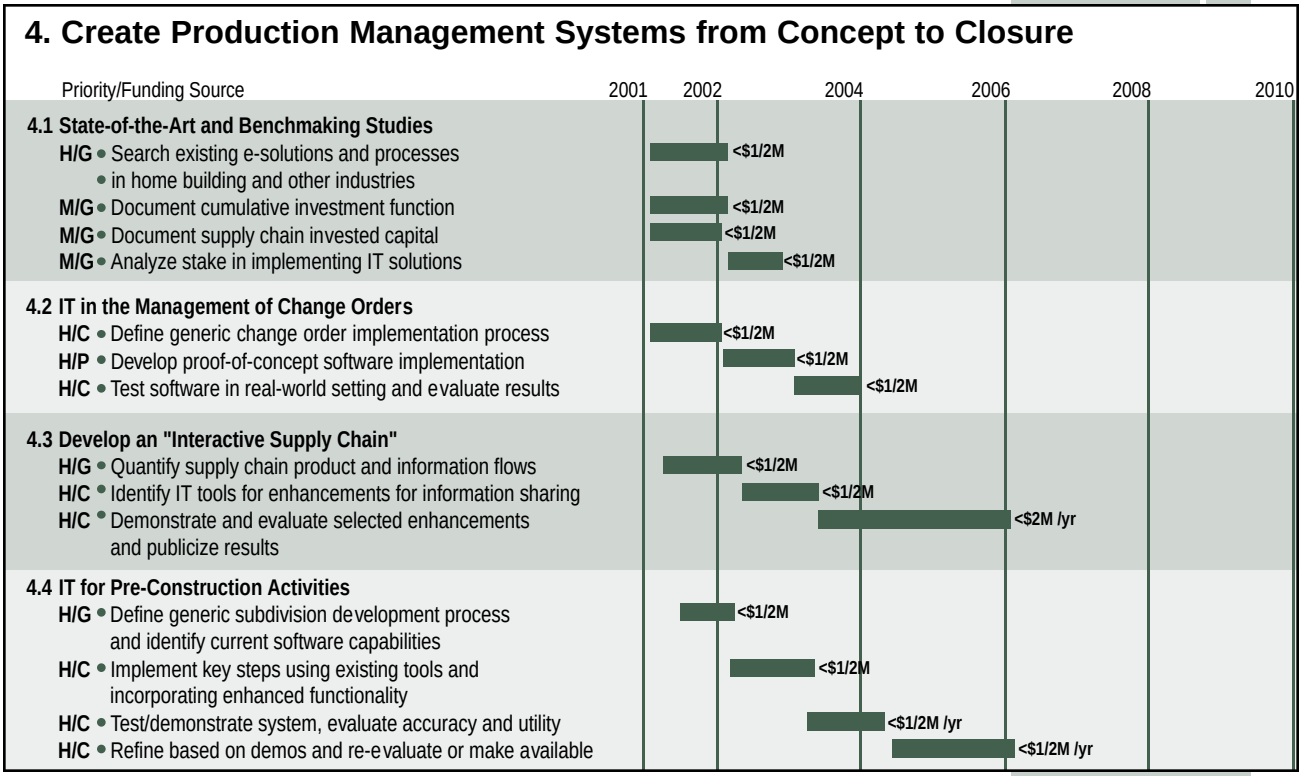
- **State-of-the-Art and Benchmarking Studies:** These research activities will identify approaches that have been used successfully by building industry leaders (and leaders in other industries) to help quantify the potential benefits of IT in the home building process based on the unique economic characteristics of the residential construction sector.
- **IT in the Management of Change Orders:** The second project calls for developing and demonstrating methods for using IT to simplify and streamline the "change order" execution process, a task that remains poorly addressed by most current management tools.
- **Development of an Interactive Supply Chain:** Home building's complex supply chain will be simplified by moving away from today's "reactive" structure to a structure that promotes interaction and more systematic flows of information between buyers and sellers, thereby leading to new ways of conducting business.
- **IT for Pre-Construction Activities:** The process of converting a parcel of raw land into finished building lots is costly and time consuming, but nonetheless essential to the long-term supply of new homes. Comprehensive approaches for expanding the use of IT in the activities leading up to breaking ground for a new house will simplify, expedite, and improve efficiency in the land development process.

Further integration of these and other outputs will be needed to achieve the production management vision, but the above activities address requirements for the near to mid-term. Production management also should incorporate IT-based interaction with regulatory agencies, and create ties to marketing, mortgage financing, and customer interaction. Each of the four project areas is shown in Figure 5 and discussed below in more detail.

4.1 State-of-the-Art and Benchmarking Studies

Development of the next generation of production management systems in home building should begin with a review of the state-of-the-art in home building and in select other industries. An assessment of the financial implications and incentives for broad adoption of IT-based approaches by home builders and other industry players is also needed. Activities include investigating "e-solutions" and related processes in home building and other industries, documenting the "cumulative investment function" for housing production under standardized business approaches typical of the industry, and

quantifying the amount of invested capital throughout the housing supply chain. This information can be used to estimate the economic potential of new IT solutions as applied to home building.



Key: Priority: L, M, H = Low, Medium, High
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Figure 5

A state-of-the-art search of existing e-solutions and processes in home building and other industries should be conducted. Home building has begun to change in response to the availability of new technologies for distributing and sharing information, but the change process still has far to go. Fortunately, a handful of large home building firms has direct experience in leveraging IT and moving away from conventional approaches to production management. Enterprise Resource Planning (ERP) is a method for organizing and scheduling workflows and production and tying them to "back office" procurement, planning, and accounting operations. In the home building industry, ERP approaches have found application in the production of manufactured housing and the fabrication of factory-built components such as roof trusses. Several large home building firms have also implemented various forms of ERP, but the systems still tend to focus on procurement, scheduling, and accounting. The ability of most of these systems to reach further back into the design or development stages, or to interact with the IT systems of vendors and others in the supply chain, is limited or non-existent. Development work in this area is underway.

The effort should begin by tapping the knowledge of home building industry leaders experienced in implementing ERP and learning more about their experiences and the limitations of existing products. A comprehensive case

study in this area would be valuable in itself and would more clearly help identify needs and potential enhancements. Other industries that have embraced IT should be reviewed for relevance to home building, particularly production environments (e.g., automobile manufacturing) and more labor-intensive service industries (e.g., fast food and delivery services). Key points to be considered are what aspects of the business process have changed and how the changes have influenced costs, revenues, labor productivity, profitability, competitiveness, and similar factors.

The next step is to document the cumulative investment function for delivery of a home under basic scenarios. Improved production management, through better flow and use of information, can speed the production process. Often, four to eight months elapse from breaking ground to completion of a new home, not including the years typically required to develop raw land into lots. More rapid production can reduce carrying costs and increase turnover rates and return on invested capital, but the amount saved is highly dependent on how much capital is invested at the point where the increase in speed occurs. The cumulative investment function, which relates total invested capital to passage of time and progress in construction or related milestones, determines the potential for savings. Of course, speeding production offers other direct and indirect benefits as well, but the reduction of carrying costs (or the opportunity cost of investment capital) is fundamental.

Next in the benchmarking process is to document invested capital throughout the housing supply chain. Improving efficiency through better use of information and IT is possible within the home building firm itself, but the opportunities go beyond the individual firm. Additional benefits are available to the degree that IT improves efficiency further back up the supply chain from the builder to the local product distributor (or through individual subcontractors to specialty trade product suppliers), to the wholesaler, to the original manufacturer. Enhanced efficiency in production management can have implications for costs and efficiency at each point in the chain, not just for the building firm or general contractor. Understanding the economic implications of the various impacts and the distribution of overall benefits requires information about how different parts of the supply chain are capitalized as well as the extent to which facilities exist, inventory is maintained, and costs are incurred. Knowing "who stands to gain" and "by how much" will help identify the players with the greatest interest in bringing about change and fostering the cooperation that will hasten it.

Finally, it will be necessary to analyze what is at stake in implementing new IT solutions. The findings from the three projects outlined above will become the basis for estimating a range of impacts, such as improvement in productivity, enhanced profitability, cost savings, and other benefits, that are likely to flow from the application of new IT solutions in home building. The findings will also highlight the possibility of negative economic or other impacts. Results of an authoritative analysis could be helpful in explaining to potential "early adopters" in the industry why they should move forward.

4.2 IT in the Management of Change Orders

Most home builders can claim direct and frequently unpleasant experiences in dealing with the "change order" process. It begins at the point in construction

when a customer decides that a wall should be moved, a floor tiled rather than carpeted, or a bay window substituted for mulled window units. Most builders discourage change orders not only because changes can have so many implications for design and construction but also because they may be difficult to price accurately. Yet, in those parts of the industry that thrive on promoting and providing customer service as a central part of the overall process of designing and building a house, change orders are practically inevitable.

Change orders often have implications for building design details and code compliance. Plans may need to be revised. Lists of building materials and products needed to complete the job are affected. New items are added, or one item is substituted for another. Different vendors may be required or different subcontractors may need to be called in for the work. Updated information must be communicated to the site superintendent, to multiple trades, and to suppliers. Typically, change orders affect the project schedule and generate ripple effects that extend to project completion. The change may even affect scheduling of other projects, as in a subdivision. In addition, questions arise as to how to estimate the costs of the change and set an appropriate price for the customer. In short, the change order raises many of the same issues of production management that generally need to be addressed as part of the process of building homes, only on a smaller and accelerated scale. Builders who handle change orders effectively can profit from the process; others find that change orders translate into slipping timetables and evaporating margins.

Given the above issues, it appears that much can be learned from using change order management as a model for overall management of the home building process. At least one currently available software package for mid- to large-sized builders can handle change order requests. However, the process is complex, is not directly tied to design, and appears limited to "standard" changes, e.g., substitution of one standard option for another. Developing or adapting IT tools to manage a more flexible change order process is both a challenge in itself and a way to identify approaches to achieving the larger production management vision discussed earlier. The actions needed to develop effective change order management tools are described below.

The best way to start this development is to define a generic change order implementation process based on current practice, including required information flows. The implications of a change order extend throughout the three central boxes in the process diagram presented in Figure 1, where a change order can be seen as a loop from step 4, "building construction," back through steps 2 and 3, "house design" and "pre-construction planning." The specific steps in implementing a change order will vary with the builder, the house, and the nature of the change, hence, the need for a "generic" process that encompasses variations. Key steps call for:

- Marking up or revising building plans to reflect the change and securing any necessary code approvals;
- Determining the net impact on products and materials to be ordered by the builder or supplied by subcontractors;
- Revising material orders based on an updated materials list;

- Revising the project schedule based on direct impacts on construction labor, availability of materials, and other factors;
- Identifying all affected trade contractors and communicating to them the changed nature of the work and the schedule; and
- Calculating the resulting impact on total job cost, target pricing, and profitability.

Next on the road to effective change order management is to develop a proof-of-concept software implementation. The purpose of this step is to demonstrate that software can mirror the steps required to implement a change order, even if the software outputs are not automatically integrated into the underlying systems for design, job costing, estimating, and scheduling. This step might begin as an automated checklist of reminders, at least for some aspects of the process, but the goal is to devise software that would tie change order processing into existing design, cost estimation, and scheduling packages.

Once the software is developed, it then will be necessary to test the software in a real-world setting next to conventional approaches, and evaluate the results. The approach for implementing the proof-of-concept task should be tested by applying it to real-world change orders and assessing its accuracy, relevance, and potential utility. The test can be conducted in parallel with whatever approach the builder currently uses in order to assess whether the software would simplify, enhance, or detract from the process when used instead of more conventional approaches. The results would guide follow-up work. Full-scale implementation would require additional IT infrastructure for managing more of the underlying construction process.

4.3 Development of an Interactive Supply Chain

Many of the complexities associated with promoting new ways of conducting business in home building result from the unusually complicated "supply chain" that supports production. Most home builders rely extensively on subcontracted labor. Products used in home building are purchased generally from local suppliers, whether by the builder (for items such as framing lumber, trusses, and windows) or by individual subcontractors responsible for providing their own materials (e.g., plumbers and roofers). The local suppliers purchase their products from wholesalers or distributors who, in turn, purchase the products from manufacturers. Each link in the chain requires labor, capital facilities, and inventory along with order processing, billing, invoicing, collections, and transportation. The long chain is heavy (i.e., expensive to maintain), but it also provides flexibility in an industry that is known historically for its sharp business cycle.

Figure 6 shows some of the several ways that building products flow through the supply chain, with the exact path depending on the material involved, the specific manufacturer's and builder's way of conducting business, and other factors.

Participants term the current industry supply chain "reactive" because it is characterized by arm's-length transactions, a zero-sum mindset that views one participant's gain as another's loss, and little or no information sharing. Such an approach to business maximizes the uncertainty faced by each player. Lack of

information flow can lead to poor decision-making, inefficient execution in the face of special orders, errors in filling orders, and extensive "just-in-case" inventory that must be maintained at each level of the system in anticipation of unreliable production planning or unpredictable participant demands.

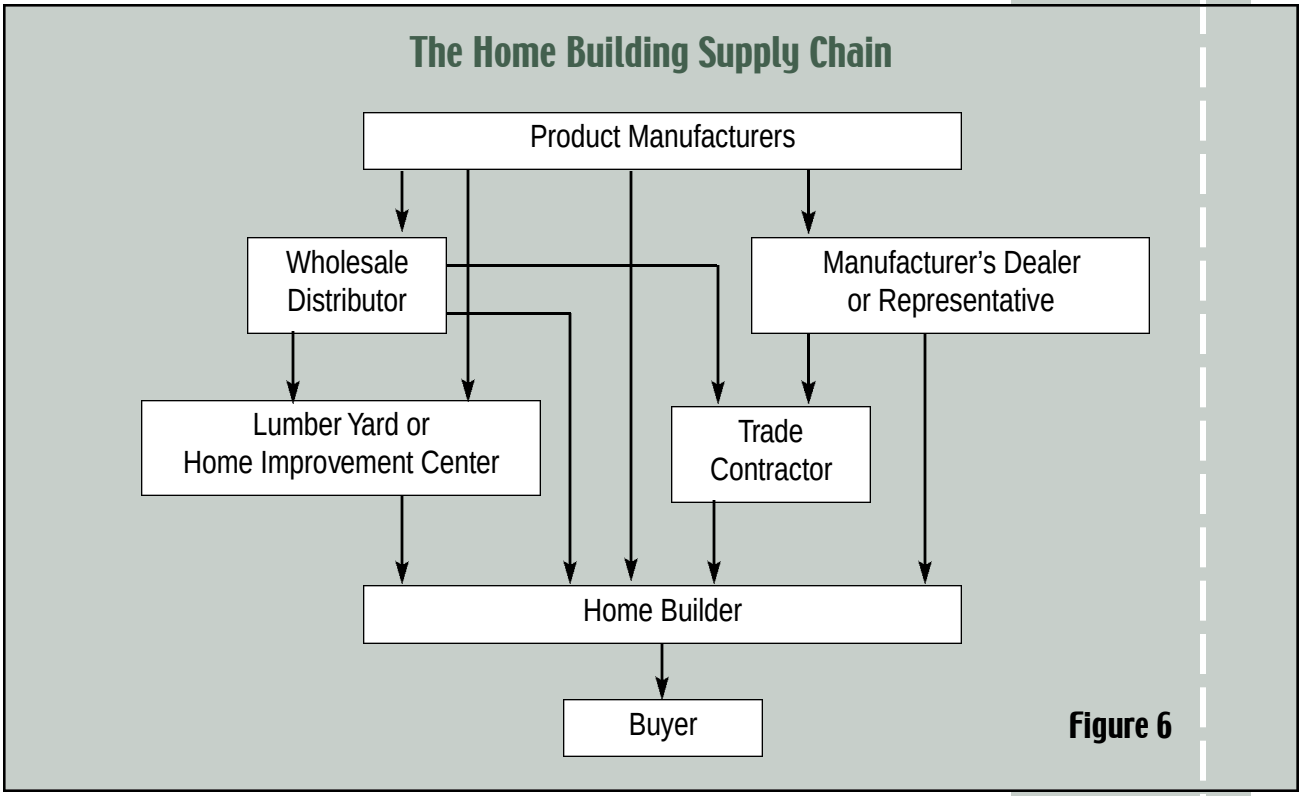

Figure 6

Note that the supply chain shown in Figure 6 is not specifically illustrated in the process diagram of Figure 1. Rather, it is included within, or links to, elements in the other boxes, particularly "pre-construction planning" and "building construction."

Some home building firms have taken steps to solve supply chain problems. For example, some firms exclusively rely on in-house labor, which, though it presents its own drawbacks, reduces the uncertainty and complexity associated with subcontracting. It also provides opportunities to economize on acquiring materials otherwise provided by subcontractors. Large producers, especially factory builders with centralized facilities, can negotiate prices directly with manufacturers and thus eliminate the delivery cost and mark-ups associated with reliance on wholesalers and distributors. Some firms that manufacture and sell commodity building products have gone so far as to integrate vertically with home building operations that serve as captive sales outlets. Finally, some builders actively "partner" with subcontractors, modifying traditional incentive structures and working as a team rather than at arm's length. Each of these approaches helps streamline and simplify the supply chain in an effort to shift or reduce cost and uncertainty.

The alternative to redefining the building firm itself is to work toward what might be called a "proactive" or "interactive" supply chain where needs are

better communicated and even projected. One key to this transition is better information exchange. It is based on the theory that timely and accurate sharing of information will help suppliers accommodate customer needs more quickly and at lower total cost than suppliers who must operate "in the dark." This project involves the activities described below.

- Define baseline current practices, underlying information flows, and typical systems. The supply chain diagram in Figure 6 encompasses many variations that are not now relevant to every product or situation. The chain itself is also in flux, with flows shifting and new paths developing partly in response to new technologies. This step calls for greater quantification of the framework shown in Figure 6, as applied to particular products, to show the most common paths now taken by those products. The figure also shows arrows corresponding to the direction of product flow, but in reality a two-way flow of information at each stage needs to be identified before it can be enhanced.

- Identify IT tools or enhancements for sharing information up and down the supply chain as well as data flows necessary to streamline selected links. Tools will take the form of specific technologies suitable for further study and possible implementation.

- Demonstrate or evaluate selected IT tools or enhancements, assess their effectiveness and other implications in real-world applications, and publicize the results. The simplest way to learn about the likely benefits and drawbacks of a broader move toward an interactive supply chain is to expand communications and end-to-end data exchange among firms that volunteer to participate on a trial basis.

4.4 IT for Pre-Construction Activities

Another opportunity to define and demonstrate IT's potential for improving efficiency in the management of multiple steps in the overall home building process is through IT's application to "pre-construction" activities, that is, the series of steps leading up to breaking ground for construction of a new home. This work falls primarily in boxes 1 and 2 of the process diagram in Figure 1.

Extensive work must be completed well before construction of a home begins. It starts with acquisition of raw land. If not correctly zoned, the property must be rezoned or variances obtained to permit the construction of residential units at some given level of density. The overall parcel must be accessible from existing streets and platted to show the layout of individual lots as well as building restriction lines based on applicable setbacks. A subdivision plan must be prepared and recorded legally, showing how the raw land will be transformed into a finished state through clearing, rough grading, construction of main and collector streets, and installation of underground systems for water supply, sanitary sewer, fire hydrants, stormwater drainage, and the like. Floodplain maps and regulations must be evaluated for the proposed development's impact on community design. Environmental studies of wetlands and the like may be required. Public streets, open spaces, community facilities, and utility easements for electricity, gas, and other services must be laid out and dedicated. All these aspects of the subdivision plan must be approved by the local jurisdiction before breaking ground. Public hearings and opportunities for public comment are

typically part of the review and approval process. Community covenants and plans for creation of a community association may need to be drafted and recorded. Bonds are required frequently to ensure that development work, once started, ultimately is completed to applicable local standards. For larger developments, ordinances may require the upgrading of access roads or other community infrastructure outside the development boundaries to serve traffic and other impacts. The process of pre-construction planning can take several years if it moves smoothly, and longer if delayed by regulatory issues.

Upon securing required government approvals, construction work for land development can begin. As with construction of an individual house, multiple subcontractors are typically involved in land preparation. The local electric and gas utilities, along with water, sewer, and fire authorities, regulate and must sign off on the construction of infrastructure relating to their services. Utility construction must be coordinated with construction of roads, curbs, gutters, and sidewalks. Permits are required for infrastructure, along with plans and permits for erosion or sediment control. The land development process may be phased for economic reasons, with some lots completed before infrastructure is in place throughout the development, although all planning and approvals typically must be completed up front. Eventually, the land developer sells finished building lots to builders (who may have customers already lined up) or consumers (who plan to hire a general contractor to build on the land), or holds the lots for the development firm's own use. Clearly, the high cost of developed land (often 20 percent or more of the cost of a new home) is evidence that improving efficiency in work performed before house construction can yield significant benefits.

Pre-construction activity also extends to the design of individual homes. Factors such as orientation of the house on the lot, access from the street, setbacks from lot lines, utility connections, and easements all grow directly from and relate to decisions made in the development phase. Lot-specific information compiled or generated as part of the land development process should be directly incorporated into design software rather than manually recreated.

There is uncertainty about the extent to which land developers currently rely on computer software to lay out subdivisions, estimate development costs, develop schedules, or track work in progress. At least one package for large- and medium-sized builders is capable of dealing with land development. While the specifics of land development differ markedly from those involved in building and selling homes, clear parallels point to the advisability and logic of using similar types of software for designing, estimating, and scheduling both land development and construction. Land development also presents opportunities for applying global positioning systems (GPS) and computerized topographical mapping data to generate maps, to perform run-off and other calculations, and to evaluate the implications of a plan. Some jurisdictional authorities as well as utility companies are already using these tools rather than relying on conventional surveying, drafting, and analytical methods. Interfaces with local zoning, tax, property ownership, easement, floodplain definition, and master plan databases would help streamline the design and land development process.

The following steps are proposed for development of integrated software tools to manage the land development process.

- Define a generic subdivision development process, including parties involved, information requirements, and flows, milestones, and outputs. Review current software tools for land developers. The generic subdivision development process will serve as the template for development of next-generation software tools.

- Using existing software tools as a starting point, implement key steps of the process, including community layout, plan submission, takeoffs for material and labor to build infrastructure, cost estimating, and master scheduling. This would be a first cut at a coordinated approach to using computer tools for pre-construction development work. As noted, the issues parallel those arising with software for managing home construction. It assumes that there are opportunities to enhance or more closely link such tools as already exist.

- Demonstrate application of the system and evaluate its accuracy and utility compared to existing approaches. Work with land developers on actual projects, running the system side-by-side with whatever other approaches to design and planning are in use. Study the ease or complexity of use of the system and the accuracy of its outputs. Assess in quantitative terms the potential for improved efficiency (time savings, cost savings, ease of revisions) and any drawbacks to this approach. Identify additional outputs or utility for incorporation into the system.

- Refine the system based on what is learned through the demonstration process and re-evaluate or make the system available on a larger scale. Publicize the results and encourage broader implementation.

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