Chapter Three: Integrated Systems for Industrialization of the Residential Construction Site

3

A significant characteristic of contemporary industrialization, be it aerospace, automotive, electronics, or food processing, is the linkage of marketing needs, product design, purchasing, production processes, inventory, and shipping sales.

The construction industry in general and the housing industry in particular have not made these linkages. As a result, productivity in the housing industry lags behind other industries. This has obvious consequences for the performance and affordability of housing.

Linking all aspects of product design, production, and sales to perform as a single system is the essence of systems integration. The current state of systems integration in housing treats each major building system discretely. The structural system is designed and fabricated with little concession to the design and fabrication of mechanical, electrical, and enclosing systems, and little thought to the overall production efficiency. Within each major building system, various stages of component prefabrication, assembly simplification, and labor time reduction are practiced. The plate roof truss is a common example of structural subsystem component integration. Equally common is the modification of these trusses by building trades installing ductwork, plumbing, or electrical wiring. The advantage of this approach is the reduction of development costs. However, this comes at the expense of subcontractors and the homebuilder.

Information integration is the "umbrella strategy" that must become the backbone of the housing industry.

The absence of coordination between subsystems is attributable to uninformed design, the lack of prototyping, absence of production simulation and lack of understanding of the consequences of field modification on performance. This current state is largely a product of reduced design resources and the system of discrete trades subcontractors. Each as a small business whose priority has to be the efficient conduction of their defined contract. These discrete subcontracts are not often coordinated in the design stage. As often, houses are adaptations of models seldom with the full involvement of design professionals. On-site resolution of system conflicts requires the attendance of each (often three or more) subcontractors and a convening (mediating) general contractor. This seldom occurs due to simple scheduling conflicts and slim profit margins which together work as effective disincentives to physical, performance, and production integration.

Industrialization strategies used by major manufacturers have produced tools and processes that promise to enhance the overall level of systems integration increasing production efficiency, performance, and thus affordability. As discussed in chapter two, techniques such as JIT, MRP, MRPII, ERP, and DFMA are the best potential methods for achieving systems integration in construction.

Information integration has been the key strategy employed by major manufacturers to raise productivity while reducing costs and increasing quality. Information integration is the 'umbrella strategy' that must become the backbone of the housing industry to support industrial design, production, and operations methods common to major manufacturers.

The concept of overall process control through information integration, using object oriented design, virtual prototyping, production simulation, design for assembly, supply chain management, cross-trained trades, and sensor networks/system controls for normal and extreme service performance will be described in the following five sections on integration.

THE CONDITIONS OF INTEGRATION

The conditions of integration as applied to housing construction fall into five primary areas of influence:

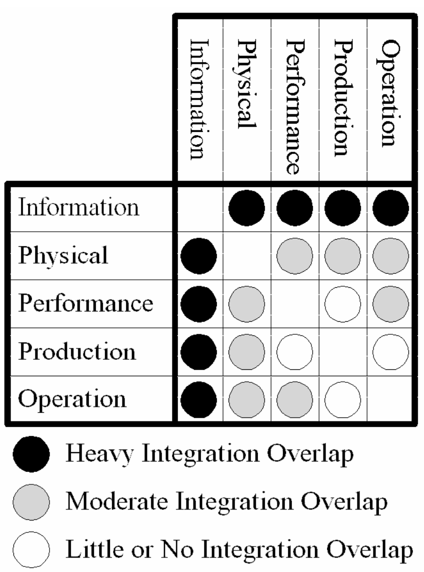

Figure 3.1: Integration overlap

Information integration – making the many pieces of information used by homebuilders accessible as one data source.

Physical integration – making the many parts fit together as one.

Performance integration – making the many systems perform as one.

Production integration – conducting the many processes as one.

Operations integration – operating the many subsystems as one.

These five conditions of integration are difficult to separate in practice. Actions taken to increase the level of physical integration for one subsystem often improve the performance of another subsystem (e.g., by avoiding cutting or notching). Performance integration benefits operations integration (e.g., using shading to reduce heat gain, avoiding increased air conditioning operation). Information integration extends across the process of design, construction, and operations to enable physical and performance integration. Ideally, these five conditions of integration are integrated with the physical materials and labor used to assemble the house, resulting in a house that is a single, integrated system. The following sections present each of these five conditions of integration in greater detail.

INFORMATION INTEGRATION

The order of listing the conditions of integration generally corresponds to the sequence of steps required to achieve an integrated system. A conclusion of our industry studies is that information integration (making the many bits of information that are part of every house into one accessible information resource) leads the way to systems integration and associated performance gains.

One of our major findings from industry has been that both the information and its representation are critical to rapid acceptance by management and labor in addition to improving production, performance, and profit. When industries develop integrated information systems, extensive research and design time is allocated to determining who will need what kind of information and what form that information will take. Depending on the user level, information is presented in text, numeric table, graph, chart, or pictorial diagram in two or three dimensions. The key seems to be not to overwhelm a user with information that is not necessary to the task at hand and to enable the user to customize the information presentation for increased effectiveness. While standard reporting forms are designed for the different user levels, most integrated information systems include some form of "data warehouse" listing all the data fields available to the user, enabling the user to pick and choose what data appears where and in what form.

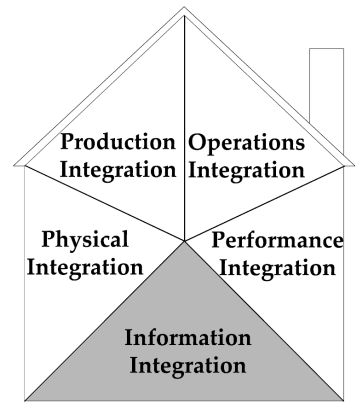

Figure 3.2: Information integration

Given that some 135 people, including order processors and shippers, are involved with the process of making a house from design to final inspection (see Appendix B. How Many People Make a House?) and given that a house is the largest investment most Americans make, changes are requested during the construction phase. Most changes require that the work stop, the change be evaluated, existing work be removed, new materials be ordered and installed, and schedules be pushed back. Many owner-initiated changes can be tracked back to the owners' misunderstanding of what the completed house would be like. Many production builders (those producing thousands of homes per year) currently work to minimize misunderstanding with full-scale model homes used as the sales center. Product upgrades and customization costs are prepared manually (and are often limited to a package of pre-priced upgrades) with the final price taking some days to determine. Recent developments in the three-dimensional visualization of buildings, linked to object-oriented CAD databases, are already enabling owners to view "their" house in its final color, material, and upgrade configuration, with rapid pricing of changes (Evans 1999). This three-dimensional visual presentation can significantly reduce misunderstandings and reduce owner-initiated changes.

This design, personalized for each client and connected to an inventory and scheduling program, provides the builder a fairly accurate projection of completion time, taking into account suppliers' backlogs for materials and labor utilization across the production builder's project list. The impact of design changes can also be evaluated at this point. Monthly expenses for heating, cooling, lighting, and maintenance of the house could be projected at this time by connecting performance analysis software to the database.

The object-oriented CAD tool further facilitates physical and performance integration by rationalizing all subsystems (drawing all required components and finding the most efficient method of connecting like-subsystem components). This rationalization enables the program to check for physical collisions between subsystems, thereby decreasing the need for field personnel to diagnose, anticipate, or guess at solutions to systems conflicts. The process of construction and the design of pre-engineered components for the house can also pass through an interference detector while being "virtually constructed" within a simulation environment.

Simulation environments appear similar to three-dimensional animations but differ in that the degree of movement, speed, mass, of a crane carrying a beam is not controlled by "eye." The behavior of models and machines in the simulation environment are controlled by mathematical formulas,