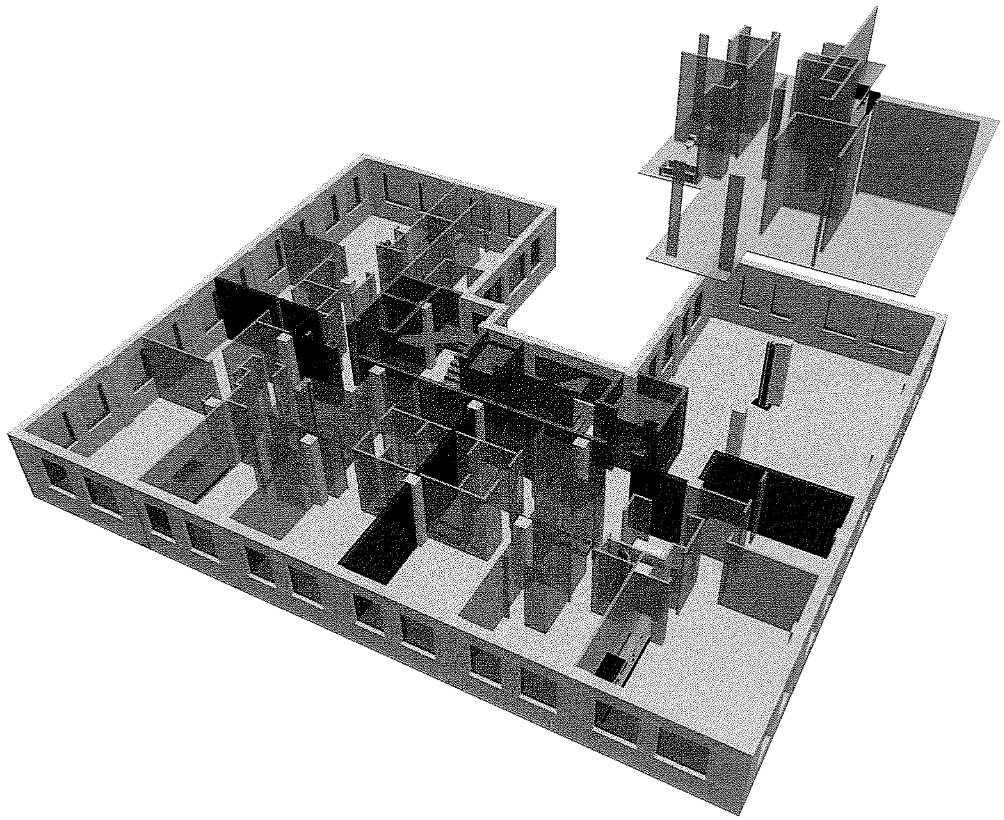

An Open Building Strategy for Converting Obsolete Office Buildings to Housing

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Adaptable, multi-family housing—row house, walk-up and elevator types—must sooner or later become an attractive alternative in the United States to detached housing "sprawl". To help, the housing finance industry must offer financing instruments focused on the continuous process of "stock-maintenance and upgrading". Further, the building design, construction and logistics systems must implement practices and processes to match this perspective. These changes are important in respect to two kinds of constituencies at work in multi-family housing. One is the market of large investors, developers and public agencies, its own forces and decision-making processes to contend with. This market seeks uniformity and resists change. The other is the consumer market, having its own dynamics and forces. This market seeks variety and capacity for "fine-grained" change suiting individual households. These two markets are related, like highways [public goods] and the vehicles running on them [private goods], and both must act to make healthy housing processes and environments. But they must be distinguished (disentangled) to optimize the effectiveness of each.

Given these premises, a study was undertaken between 2001 and 2004 on the subject of the conversion of obsolete office buildings to residential uses. The study was undertaken from the perspective of the development, design and construction fields. The process we report on will result in greater physical and legal autonomy to the individual unit in multi-unit buildings, in the conversion of existing buildings (e.g. office buildings) to housing. Many of the lessons can apply in new construction. What is reported on is suited to the problems "one-unit-at-a-time gut-rehab" and long-term sustainability—that is, balancing supply and demand over the long term with minimized disruption, waste and conflict.

For rehabilitation processes to become aligned with the two constituencies mentioned above, technical and organizational rigidity and entanglement, so characteristic of multi-unit buildings, need to be overcome. It is well known that condominium and other multiple occupancy residential projects are more prone to legal conflict, difficult remodeling, renovation and upgrade processes, than any other occupancy type. This can be largely attributed to physical "entanglement" of the "common elements", the "limited common elements" and the "individual elements"—that is, their physical and thus decision-making "integration". Technical, economic and spatial decisions about one unit are far too entwined with decisions about other units, bringing about conflict and overlapping spatial and technical claims during a buildings' useful life. It is therefore important to design and rehabilitate multi-unit buildings to avoid such conflict, thus reducing dependencies among and between stakeholders, including occupants, and the parts of the building they control or use. The point is to make a clear distinction between the "shared" parts and the "individual" parts.[1] This will go a long way toward making living in multi-unit buildings more attractive to households who now enjoy the relative freedom of living in detached houses in typical suburban developments.

The housing rehabilitation approach reported on in this paper—given the name "open building" in international theory and practice[1]—can be one part of the effort to make urban living attractive and affordable to a variety of households—thus it can serve as part of the bundle of strategies serving as an antidote to sprawl.[2]

This approach can also be a tool for achieving—over time in a given building—the goal of income mixing and community stability. That is, instead of building (or converting) housing according to initial household income (assuming fixed incomes subsequently), an open building approach enables a more dynamic balance between physical assets and changing household income over time. It helps us avoid the trap of real estate development and building practices based on (income) class. It also is a tool in adjusting our practices from a "scrap and build" approach to a "sustainable stock" approach.

In our study, we examined related topics including legal issues, labor, product manufacturing, product bundling, diffusion of innovation in the construction sector, the public policy environment for urban regeneration, and issues related to a new hybrid business that may help to solve some of the widely experienced problems in the construction processes in conversion. We examined legal issues surrounding conversion, and speculated about the relevance of a financing strategy used in the Netherlands and its possible use in the US. We also sketched out a business plan for a "fit-out" company. We also speculated on the problems of the diffusion of innovation in the construction industry, and placed the proposal in the context of "systems innovation" and current trends in "product bundling". Only some of this work is reported here.

BUILDING CONVERSION

"Across the United States, vacant office buildings, warehouses, department stores and hotels are getting a second chance at life as a new housing stock. By nature, adaptive reuse is time consuming, complex and costly. However, that has not stopped an increasing number of developers from pursuing housing conversion projects."[3]

"Office vacancy rates have been rising across the country. Older Class B and Class C buildings in most markets have been hit particularly hard, because so much new or nearly new Class A pace is available for lease or sublease. At the same time, many cities are struggling with significant housing shortages, because residential construction and renovation have not kept up with demand, and because many cities have started growing again after years of stagnation or decline."[4]

Conversion—or adaptive reuse—is one of a number of processes available to developers who seek profit from investing in and improving existing properties. Housing rehabilitation more generally is a normal if under-studied economic activity of significant magnitude in the United States.[5] Conversion is just one of many rehabilitation strategies in which a previous use is changed to a new use suited to changed market conditions. Normally, this process involves real estate assets of some historic value or at least of salvageable value, where the alternative of "scrap and rebuild" is not possible, is prohibited or is more expensive.

Complete conversion of an existing building from one use to another, as noted above, is widespread in the United States and has been increasing. If an American Institute of Architects projection is accurate, in two decades 75 percent of architects commissions will involve conversion,adaptive reuse and rehabilitation of existing structures, and only 25 percent will be "new" construction.[6] With increased incidence of conversion and the need to address the structure of regulations and incentives available to spur and guide such work, a number of national organizations have produced useful guidelines. One such guideline is the recently published NARRP guidelines for building rehabilitation.[7] It offers an important tool that addresses the wide range of magnitudes of conversion or rehabilitation work.

THE CONVENTIONAL PROCESS

The initial rationale for development—new construction of conversion—is based on a preliminary building analysis, projected market demand, financing availability, and regulatory constraints. A "pro-forma" giving unit mix and layouts is made. Building design and cost estimating follow the packaging of the financing and public approvals, and construction follows.This sequence can present difficulties because the time between decision to convert and actual lease-up or sale of units can take several years, during which time the market, interest rates,investments, prices on construction labor costs, and other factors such as regulatory constraints may and usually do change. Since the conventional process assumes a complete"program" of decisions about unit mix, layouts and equipment, it does not easily lend itself to the kind of "agile" decision process needed; decision processes that are well understood in office and retail developments. This makes the entire process overly rigid and prone to waste, conflict, and excess costs. It also offers no place in decisions for individual occupants, thus keeping this process outside the consumer market, where it should be.

This process may work well in a stable context, but in dynamic markets such tightly sequenced decisions are ripe for difficulty. Where social and technical dynamics are fast paced, it is not unusual in a conversion process for the unit mix and unit layouts to change several times before construction begins, requiring extra work for the design team, estimators, and developer. These consultants are not always compensated, nor are they well equipped to manage these dynamics. Knowing that these changes are inevitable, only schematic work is done requiring many "rules of thumb" for estimating purposes and excessive dependence on guesswork. Delaying the building's technical decisions until the last minute produces conflict, waste, mistakes and increased quality control problems. These problems arise because the design and decision processes assume the building as an integrated whole, in which decisions are highly interdependent, producing an overly rigid state of affairs in which the resulting decision process is unable to account for change on the various decision levels involved.

AN OPEN BUILDING APPROACH

These problems pose new challenges and opportunities for architectural and engineering knowledge, as well as business practices, construction management, the building trades, supply channel logistics, and information technology. Based on our studies, we believe there are two key questions these fields now have to address:

1) "How can we adopt the most advanced processes of design, manufacturing, and construction in the conversion and upgrading of existing buildings - and the construction of new buildings -prepared for inevitable change?"

2) "How can we organize these processes with full recognition of the individual household—the basic social and economic unit of society—thus balancing the requirements and preferences at the community level with those of individual households in control of "everything behind their front door?"

Our research addressed these questions by means of a study of the conversion of an 18-story office building in Detroit into residential units. The conversion is actually being undertaken using conventional means, thereby affording us a useful basis for comparison of the alternative strategy described in this report. Our near-term goal is to accurately describe how this process works, in sufficient detail that the "open building" process makes sense to professionals in the business of bringing residential projects to market.

The study focuses on an innovative strategy, including a new way of outfitting residential units by means of fit-out packages. A fit-out package allows the rapid installation of partitions, heating and air conditioning, kitchen and bath equipment, and finishes with all the piping, wiring, and ductwork related to this equipment. Installation is done per unit according to the floor plan selected for that specific unit.

The fit-out approach is of interest for two reasons. First, it offers an individualized approach to large residential conversion, rehabilitation or new projects. Second, it is arguably close to being economically competitive compared to existing strategies of outfitting dwelling units, while offering much needed decision flexibility and quality control. We hope to show that it, therefore, constitutes a breakthrough combining improved decision flexibility, work structuring, materials flow reliability, and consumer orientation with more efficient production.

THE PROBLEM OF DIFFERENCES OF SUPPLY AND DEMAND

From a residential developer's perspective, one of the most difficult problems is matching supply with demand, both initially and over the life of the investment. Given the complexity and high risk of residential development and conversion of older buildings to housing in particular, and given the often lengthy development process, developers typically seek methods that enable decisions to be deferred and options to be kept open as long as possible without leading to increased cost and risk. In respect to developers' efforts to provide residential properties that meet actual (not statistical) demand, it is well known that consumers in the "for-sale" market frequently prefer changes of the standard floor plans normally offered to them. Even if a specific floor plan is preferred from the menu of options, a customer may want to change a door's location to enable the family to move in a favorite piece of furniture. Or, the customer may want to move a wall. Frequently, consumers want to select their bathroom and kitchen layouts, equipment, and finishes.

If competition in the market is strong, developers will have to give in more quickly than when demand is weak. But if they could, developers would not offer any choice, because it will cost them money. It is not clear that the cost of customization can be passed on to the buyer. The contractor's pricing is based on fixed floor plans and specifications. Any change will be disruptive to their estimating, delivery, and management processes. Contractors also know that developers frequently demand floor plan changes, because they fear that otherwise some units will not be sold or rented. This puts them at an advantage over the developer to negotiate prices. But it is also true that it is difficult for the contractor to manage such changes and to determine their exact costs. Prices will be established—usually increased—accordingly, to cover uncertainties. This situation puts developers, homebuyers and builders on a collision course. The tensions and conflict that are so familiar come from the "disconnect" between demand for customized units, the desire for decision deferment, and the ability to deliver. The second source of tension comes years later when the units and the building as a whole must be adapted to meet changed homeowner preferences, standards and codes, and the building is found to be so technically entangled, that sought-after adjustments cause excessive difficulties and costs.

Figure 1. The Kales building, downtown Detroit

RECONCILIATION OF CONFLICT

The Open Building approach uses a design method—"capacity analysis"—and a new logistics strategy using fit-out kits. The developer asks for bids only for a "serviced shell" or "base building". The developer gets a finished building complete with windows and exterior finishes, public circulation spaces and all of the "shell" mechanical systems and services. The base building establishes the kind of lifestyle and quality of services that the buyer or renter needs to know before deciding if the location is interesting. But the inside of the units will be empty and ready to be filled in. Floors are smooth. Ceilings and base building walls are finished and painted. At one or two fixed places in each unit there is access to electricity, water, gas, and sewage for the fit-out "kit" to connect to, for further distribution in the dwelling unit.

Constructing this base building should not present difficulties to the builder. The builder is, infact, freed of the part of the construction process (the unit fit-out) that usually constitutes the greatest risk and takes most of the overhead for on-site management and coordination of subcontractors. It is well known that money is easily lost on finishing the interiors of units, while it is gained in constructing the base building. The builder, in short, can now do more with lower overhead.

For his part, the developer knows precisely what to expect from the builder in terms of product and timing. For the fit-out "kit", he contracts a qualified "fit-out" special-purpose company, and is now in a position to offer the home buyer exactly what they want and can structure prices accordingly. In the case of a rental development, the developer can defer decisions about both the size of units and each unit's layout and level of finish until the last minute, contracting the"fit-out" company to deliver what the developer believes will attract leases.

This approach liberates all parties involved: the buyer, the project developer, and the contractor. The approach is a technical innovation, but has very important commercial implications, putting the developer and the builder in a mode of operation that offers superior service to the buyer in a way that can be well controlled financially. This gives a decidedly competitive advantage over those operating in the traditional mode.

A CASE STUDY: THE KALES BUILDING

In 1990, Mansur Residential Development (based in Indianapolis, Indiana) began assembling the financing to acquire and convert the historic 18 story "Kales" building in downtown Detroit. The financing was originally, and remains, a mix of state and national historic tax credits and bank loans. Early in this process, Mansur conducted a market analysis to determine a unit count, mix and layouts, as well as rents. An architect began to design the floor plans for the conversion. Cost estimates were made based on schematic architectural and engineering designs. Difficulties were encountered in the financing scheme, and other conditions in the market changed, such as interest rates and competition in the local market. These uncontrollable circumstances forced the marketing plan for the building to change. The architect completely revised the number of units, the unit mix, and floor plans, with the normal consequences to the mechanical, electrical and plumbing designs and cost estimates. Initially, five units were planned for each floor; later this was increased to seven, and later reduced to six. Each floor was identical. At a certain point, a decision was made to "freeze" the design, to enable construction bids to be obtained and construction undertaken. Construction was expected to take 12 months.

With the opportunity to conduct a study of an open building approach to conversion, parallel to the actual conversion of the Kales project, we set out a number of objectives:

1. *Offer methods providing the developer with decision flexibility in meeting current and future markets.*
2. *Enable the developer to defer decisions about unit mix and layouts without risk.*
3. *Address the extremely limited space on the site for logistics of construction.*
4. *Enable maximum use of off-site "controlled environment" facilities to prepare ready-to-install "interior fit-out kits".*
5. *Enable subsequent adjustments to the building on a one-unit-at-a-time basis, including conversion to condominium units.*

CAPACITY ANALYSIST

The first step in converting an existing building using an open building strategy involves a design process in which a typical floor plate is analyzed to determine an optimum variety of unit sizes. We applied this method to the Kales Building with results shown below. A series of design studies were made in which vertical MEP "stacks" (mechanical, electrical and ventilation risers)were positioned, and the capacity of the resulting "served" space was evaluated. The purpose was to investigate a range of unit sizes and layouts that could be laid out. This process was repeated several times, each time adjusting the constraints (principally the MEP stack) until an "optimum" number of layouts were demonstrated.

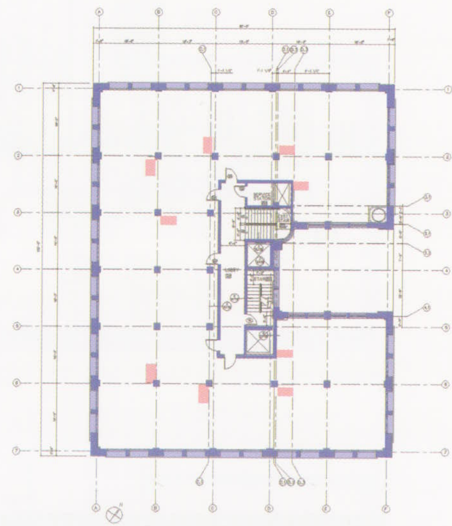


Figure 2. A typical floor showing the new plumbing cores and the existing building

Figure 3. 3-D view of one floor, with the structural columns and MEP shafts, public circulation,elevators and fire stairs

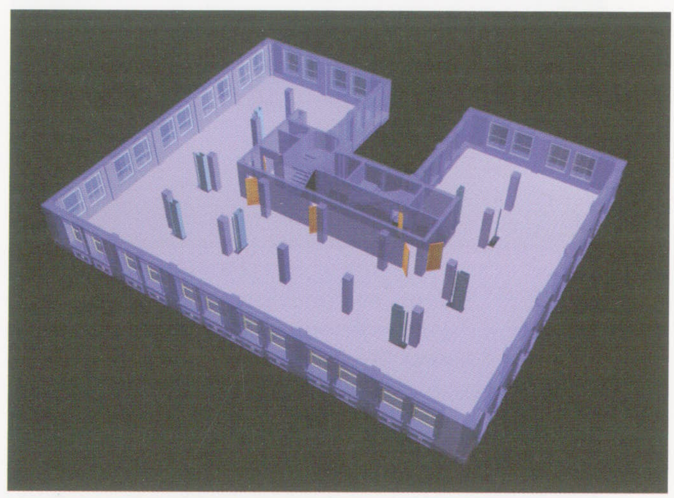


Figure 2 is a typical floor of the building. Its structure and envelope—protected by historic guidelines—and the building's elevators, fire stairs, central MEP shaft, and public corridors, are in blue. They have not changed. The "final" positions of the new vertical MEP shafts (shown in pink) are indicated. We decided to retain as much of the existing building as possible. The existing vertical circulation, main MEP shafts, and public corridors are retained.

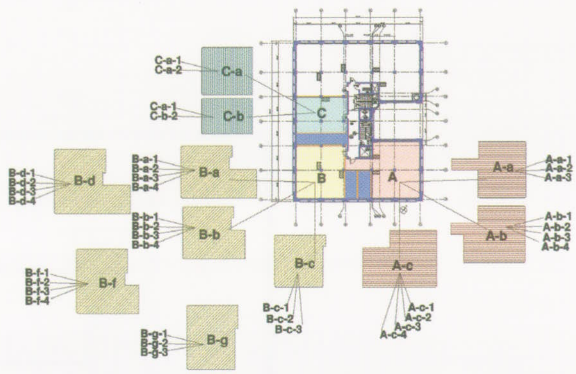


Figure 4. Capacity analysis diagram of a typical floor

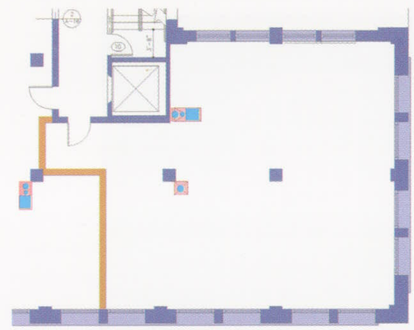


Figure 6. Unit A-b empty, ready for fit-out installation

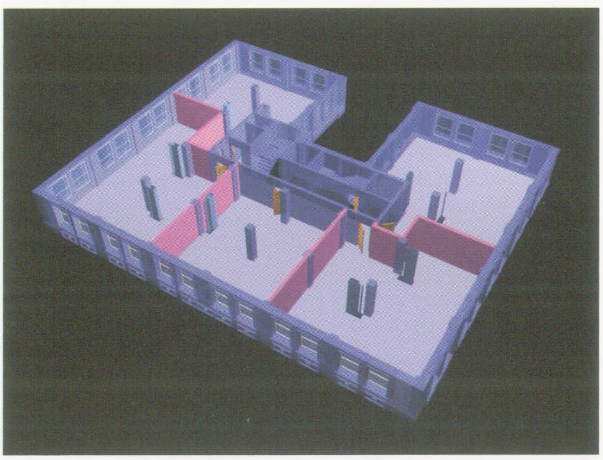


Figure 5. Demising walls based on a specific decision about unit sizes on this floor

Figure 3 shows the full capacity of a given floor plate in the building. Given fixed vertical MEP stacks, a variety of dwelling unit sizes are possible. A "margin" between units A and B and B and C allows their respective sizes to vary. This diagram shows the many unit size variants possible on any floor. Each unit (e.g. A-b) can accommodate a variety of floor plans. This enables the developer, in the case of a for-sale project, to offer a "menu" of choices and to offer occupants the opportunity to make fully customized units exactly meeting individual preferences and budgets. In a rental property, the developer can retain great decision flexibility, and, if the building is to be converted to condominiums later (as the Kales building will be), offer greater customization with less risk.

Figure 6 shows unit A-b empty. The parts in blue are base building elements, including two MEP shafts. The demising wall separating units is yellow.

Figures 7 and 8 are two variants and their horizontal plumbing systems in red. It is important to note that we have avoided any vertical penetrations through the floor, except at the base building MEP stack. The result is that any unit's floor plan is entirely independent of any other, enabling design, pricing, and "kitting" of each unit to be entirely independent.

The above outlines briefly the architectural design process. It uses a design process of initially "fixing" certain constraints (e.g. position of vertical piping chases, assumptions concerning routing of pipes in walls and so forth) and then exploring the capacity of the constrained space to accommodate a variety of reasonable unit sizes and layouts. This process is repeated until agreement is reached that an optimum number of variants are possible, at which point the base building can be constructed with assurance that the developer can maintain decision flexibility.

Once the base building is ready, the developer can decide the preferred unit mix. Because decisions on unit mix and layouts on one floor are independent of those on other floors, the developer can effectively "market" the building unit-by-unit and floor-by-floor. Thus, as the fitout is installed unit-by-unit, the development team can learn what the market demands and can adjust accordingly without risk of disturbing the build-out efficiency.

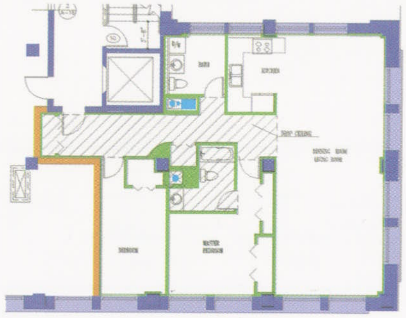


Figure 7. Variant A-b-1

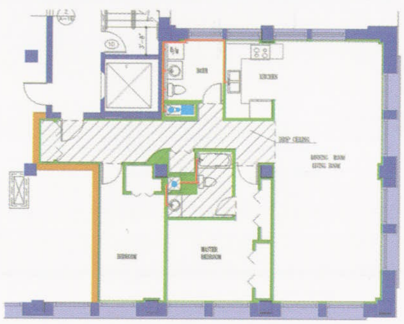


Figure 8. A-b-1 w/ horizontal piping

DESIGN OF CONSTRAINTS FOR CAPACITY ANALYSIST

The evaluation of capacity, described above, is a basic design operation in open building practice. But capacity analysis is impossible without explicit statements of constraints—conditions governing the position and organization of the elements deployed as base building parts and as fit-out parts. Thus the design of such constraints as such is a prerequisite, and deserves special attention. A full capacity analysis requires a number of constraints concerning a range of technical and organizational problems, including the complete description of all MEP(mechanical, electrical and plumbing) systems, their positions, and dimensions in three dimensional space.

Among the many constraints, we have specifically focused on the design of constraints concerning the routing of drainage piping inside a given dwelling unit. All of the MEP systems require careful planning, but we have focused on this because drainage piping is well known to be one of—if not the most difficult—constraints on achieving "flexibility" (variability) of floor plans in residential construction.

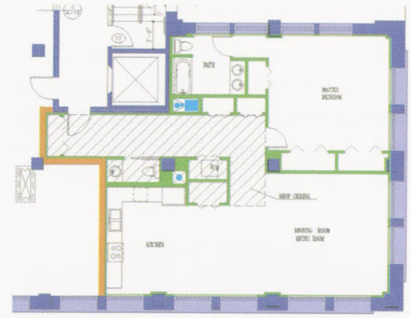


Figure 9. Variant A-b-2

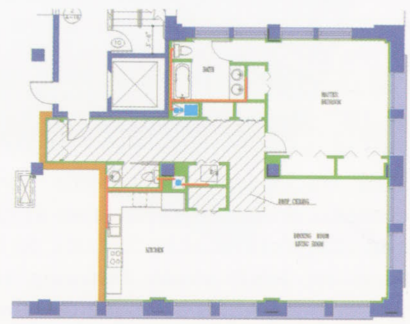


Figure 10. A-b-2 w/ horizontal pipes

The reason for this is that, in order to achieve complete autonomy of dwelling unit decisions, all piping (and cabling, ductwork and other MEP systems) that are part of a unit's layout must not cross into another unit's space, beside, below or above. Therefore, the routing of such drainage lines within the dwelling unit is critical and must be systematically organized. Since the variables are finite and the rules of positioning explicit (based on slope, diameter, and venting rules in building codes), it is possible to notate the constraints that any floor plan must follow to achieve the desired unit autonomy and drainage performance.

First, we adopted the use of floor mounted rear discharge water closets (produced by several major United States plumbing fixture manufactures). We also required that bathtubs and showers be installed at the height needed to enable their traps to be installed above the base building floor. Alternatively, we required use of new "low profile" or "in-line" traps such as manufactured by Hepworth for the European community market.

Second, we defined three horizontal "zones" in fit-out partition walls, in which drainage lines are conventionally positioned: "lower" and "middle" and "high" zones. The "lower" is reserved for drain lines serving WC, shower and bathtub. The "middle" zone is reserved for drain lines serving lavatory, sinks or washing machines. An additional "high" zone nearer the ceiling is needed in some cases for sprinkler lines, and still other zones are needed for horizontal routing of water supply lines, and so forth.

The "lower" zone contains the horizontal drainage lines within 6" of the base building floor. Given the slope of the drain lines as defined by the standard United States plumbing codes (1/4" or 1/8" per linear foot), this defines the distance any of these fixtures may be positioned from the MEP stacks serving that unit. The "middle" zone contains drain lines that start at higher elevations and therefore enable fixtures to be more distant from an MEP stack. Defining these horizontal zones enabled us to make another diagram that serves as a catalogue of routing variations for all horizontal drainage lines—gray and black water—contained in any of the dwelling unit layout variations we studied. Based on the above information, we could make the following diagram.

This diagram displays the variety of layout conditions and the variety of drainage lines and their connectivity rules. In some cases, double walls are required. With these rules, systematic preparation of all piping parts, connections, fasteners, and the partition elements (studs, brackets, holders, and so forth) can be prepared per dwelling unit, supported by dedicated software. These are part of the ready-to-assemble "fit-out kit", prepared off-site at a distribution facility, and contain parts needed to complete a dwelling ready for furniture. Many thousands of discrete parts, in perhaps 30 different product categories, make up a single dwelling unit's fit-out kit. The concept of fit-out kits, similar to "design for supply channel management", is not new, but has not yet been successfully implemented at the level of complexity this project entails.[8] In this sense, their search is proposing an innovation in linking design to production to installation.

Presently, two basic kinds of "bundling" can be observed in construction. One we call "project independent"; the other "project dependent". The first is the result of initiative taken by the producer. The second is the result of initiative taken by the user who orders the "bundle" or "kit". Project dependent bundling or kitting is similar to prefabrication. Elements are assembled off-site for a specific project, to be installed as a whole, when it reaches the construction site it was prepared for. But product bundling or kitting is different, since it concerns the delivery of packages of parts ready to assemble, connoting the idea of boxes of parts small enough for a pick-up truck and to fit through the front door of the house.

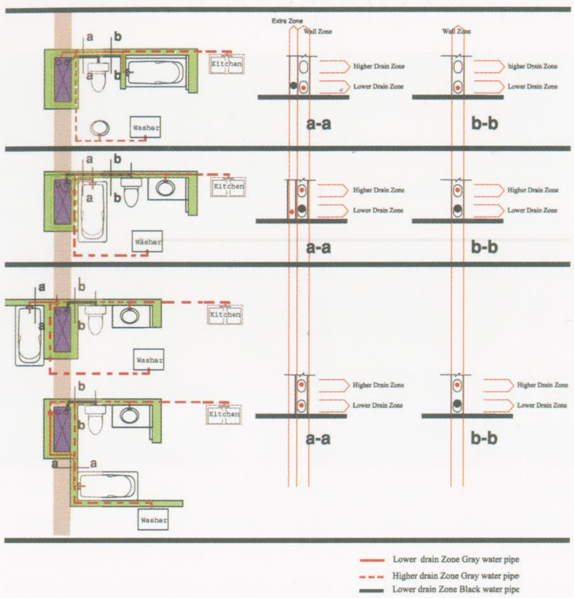


Figure 11: Diagrammatic layout of all variants for the routing of horizontal drainage lines

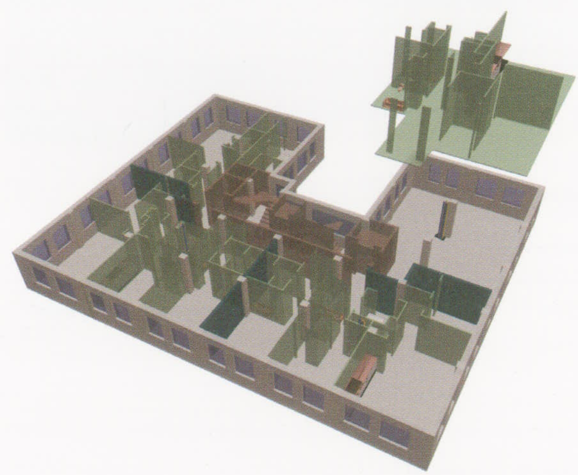


Figure 12. One "product bundle" schematically "lifted out" to show its independence

FIT-OUT CONCEPT FOR THE KALES PROJECT

The kind of kitting we are developing here is project specific. This is an image of the total contents of the fit-out package for one of the units in the Kales building.

Once design specifications for a unit's fit-out is known, the data is transferred to a fabrication center. There, all parts needed for that project are prepared—cut to size, preassembled, or otherwise prepared in the correct number—and delivered to the building. This maybe done in one container, or, in our case, the deliveries are made in several "packages"; following an optimum site installation management schedule. Because of its urban location, the site has limited space for containers to remain in-place during the 3 weeks needed to fit-out a unit. We project a sequence of JIT deliveries to the site from the fabrication facility.

LOGISTICS

The key to this strategy is good logistics. The following diagram, developed in the Netherlands as part of a business strategy for residential fit-out, shows three logistics strategies.

In a conventional supply chain for providing parts for fitting out the empty shell of a building, each subcontractor is responsible for bringing the materials to the job-site and for installing them, in the management process we are familiar with. There is no central information management required, nor would it be easily developed. In a fit-out approach, the flow of information is different. Design, fabrication and installation are integrated. This begins with a clear organization of the parts making up a fit- out package. The diagram above compares the traditional supply and logistics chain (used in the actual conversion process, as well as conventional new construction) with an intermediate and a new logistics strategy. It is the latter strategy we are studying.

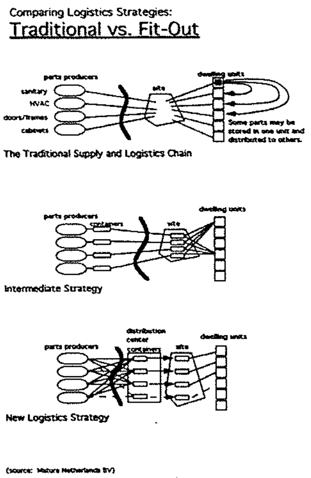
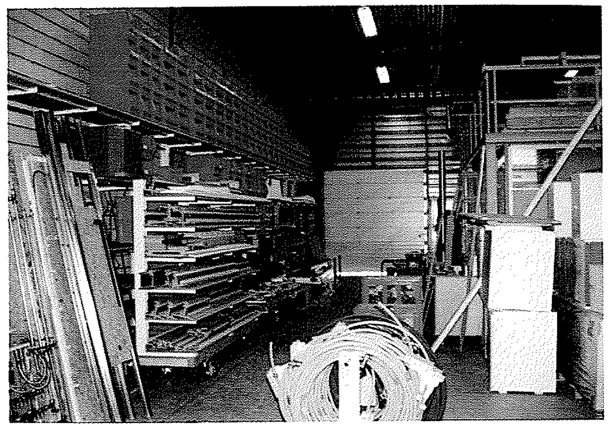


Figure 13. A diagram used to explain the Matura Infill System[9]

Figure 14. View of a fit-out kitting facility



CONCLUSIONS

We have given an indication of the architectural design process needed to prepare an old building for fit-out on a unit-by-unit basis. We have also suggested that this process can be supported by the use of "interior fit-out kits", prepared "ready-to-install" at a central distribution facility set up specifically for such "kitting" processes. A powerful motive in the developments discussed here is to harness the full capacity of industrial production in support of more consumer-oriented and more adaptable housing. Doing so requires that more of the "value-added" in housing processes and products be separated from the part of the house known as "real property". Real estate is deeply political, related to local geotechnical and climatic conditions, to the local sense of place and urban design, as it should be. But an increasingly large part of the "whole house" can be uncoupled from these conditions. This formulation is the open building approach—distinguishing the decisions (and systems) made for the "public" from the decisions (and products) made in respect to the individual occupant. This means the evolution of two distinct markets, mentioned above, and two distinct processes, not in conflict, but in coordination.

Studies on the implementation of the open building approach in the United States indicate that the design knowledge needed to provide architectural services in tune with "capacity analysis" is not difficult to learn. Engineering consultants can design mechanical, electrical and plumbing systems in line with the principles of open building. Contractors understand issues of pricing and logistics, and developers find value in the decision deferment benefits of distinguishing a base building from its more variable fit-out. The one dominating issue now is the organization of skills related to the concept of "kitting" or "product bundling". To implement this approach we need to organize multi-skilled teams of trained installers who do not organize their work along the traditional lines of carpenter, electrician, plumber, sheet rock installer, tile setter, and so on.The building industry—as the automobile industry has learned in the production of the Saturn—now needs assembly teams. Supported by advanced software, the introduction of these design methods and the re-skilling of workers installing fit-out are the next frontiers in the organization of the building process for a more agile, sustainable building stock.

Figure 15. Containers transporting kits

THE PARTICIPANTS IN THIS STUDY

This work has been strengthened by the active participation of several local sources of expertise. First of all, academic colleagues at Ball State University and at Indiana University Purdue University/Purdue School of Technology have added depth and breadth to the study. Second, three companies committed staff to the project, giving us practical knowledge and experience without which the study would have remained academic. Third, a number of students in the College of Architecture and Planning have contributed to the effort, in preparing technical drawings, delineating legal issues involved, in helping to prepare the design, visualization and animation to the study. And finally, a group of students in the MBA program at Ball State have used the project as a case study by producing a business plan for a fit-out company.

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Notes

1. See John N. Habraken, *Supports: an Alternate to Mass Housing* (Urban International Press, 2000).
2. See Stephen Kendall and JonathanTeicher, *Residential Open Building* (London: Spon, 1999).
3. See "Housing Conversions," in *Urban Land* (October 2003).
4. See "Converting Commercial Space to Residential," in *Urban Land* (January 2003).
5. See *Rehabilitation Data Needs: A Building Industry Forum*. (Washington, D.C.: U.S. Department of Housing and Urban Development, 2002).
6. See *Environmental Building News* 12 (February 2003).
7. See *Nationally Applicable Recommended Rehabilitation Guidelines*, (Washington, D.C.: U.S. Department of Housing and Urban Development, 1997).
8. See William O'Brian, "A Call for Cost and Reference Models for Construction Supply Chains," IGLC 11 White Paper (December 2002).
9. See Age van Randen, *Matura Infill System*. BV product literature.