OPEN BUILDING:
DISENTANGLMENT and FLEXIBILITY AS
KEYS TO SUSTAINABLE MODULARITY

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ABSTRACT

Modular construction's success lies in the ability to complete a maximum amount of construction work off-site in quality controlled and economically advantageous conditions. Achieving high-performance building envelopes – key to meeting energy conservation goals – is also enhanced in controlled production processes. While these are clear advantages, modular building design and decision-making have till now inhibited real contributions to the goal of built-environment sustainability. The reason is the adherence to the widespread and flawed principle of deciding space plans first and then locking-in those decisions by means and methods of construction. Specifically, MEP (mechanical, electrical and plumbing) systems are conventionally buried inside walls and floors. Being buried, the possibility to defer decisions about or change the location of plumbing fixtures and electrical terminations - during construction or to upgrade later during use - is greatly inhibited. This is especially so in multi-floor, multi-tenant buildings. We know that developers like to defer decisions as long as possible. We also know that user and building owner preferences change. With buried MEP systems, the possibility to adapt buildings to new functions, new layouts, and upgraded MEP systems is greatly inhibited. Therefore, the full potential of modular construction to meet the sustainability and flexibility agendas is not being achieved, and its competitive advantage not fully exploited.

The solution to this dilemma is introduce a new "decision/product bundle" into modular building design. This can be called MODULAR FIT-OUT. The principle objectives are to disentangle the longer-lasting part of a modular building from the shorter-life-span parts by making cabling and wiring connections accessible, and by removing the piping from its usual place hidden in walls and inside the floor sandwich of modules. This is essentially a change in design decision-making. Such decoupling and disentanglement will unleash new products to provide solutions. Two such product solutions are now available: INFILL SYSTEM US's CableStud and Matrix Tile System (http://www.infillsystemsus.com). Their application in modular construction will provide a competitive advantage in the race to achieve a sustainable and adaptable building stock.

This paper offers a brief history of the evolution of this decision-making model; shows an example of a townhouse organized in an open building way; and illustrates the advantages of INFILL SYSTEM solutions.

KEY WORDS: Open Building, Modular, Sustainable, Flexible, Disentanglement

THEORY of OPEN BUILDING

Our building stock was always sustainable when it could adjust by means of "fine-grained" transformation, adjusting part-by-part to new user requirements, and changes in life-styles and cultural norms. In the late 19th century, this changed. The basic unit of adjustment –the individual living "cell" (house, shop, office) – changed and large buildings became the investment unit of choice for large corporations and large governmental agencies. Large office and apartment buildings were constructed without recognition of the individual unit of occupancy as the vital living cell of the city. Individual units of occupancy were aggregated together into unified, rigid constructions. Conflict and waste of resources resulted under conditions of inevitable social dynamics and technological change.

This reduction in granularity was not only related to investment decisions by central governments and large companies. It was also attributable to the introduction of utility systems into buildings. Water pipes, drainage piping and gas lines as well as electrical cables began finding their way into buildings, hidden inside walls and floors. This was supported in no small way by the parallel introduction of steel and wood framing, construction methods that offered hollow walls and floors into which these utility systems could be routed and conveniently hidden. The problem was that, being hidden, they escaped attention by architects and also presented many problems to their maintenance and replacement when they became defective or needed to be upgraded.

Starting in the decade following the end of World War II, office building and shopping center developers began to revise their investment and decision-making strategies in response to new market forces. Base buildings (often called "core and shell" buildings) were planned and built to accommodate a variety of rapidly changing occupancies. This shift in patterns of control arose in the office and retail sectors with an explosion of small businesses supported by new transport systems accompanied by cheap energy, new logistics, innovative financing tools, the growth of the consumer market, and so on. The emergence of the base building as a new force in the real estate market forced building investors to revise their contracts with architects and engineers, who developed the skills needed to deliver new services.

The separation of base building and fit-out is now conventional practice; design practices (architects, engineers, interior designers) have methods for managing this separation; contractors specialize in these two decision levels; products aimed at these two markets are widely available internationally, and finance and regulation have adjusted accordingly.

This is OPEN BUILDING. What started in the office and retail sectors is now increasingly evident worldwide in the residential market (Holland, Finland, Switzerland, Russia, Japan, Canada and the US) and in healthcare facilities (US, Holland, Switzerland, among others).

Open Building is now poised to become part of the sustainability agenda, providing methods and processes to help investors – and users - achieve long lasting buildings - long lasting because they are flexible and recognize highly disaggregated and varied demands. As usual, demand continues to shape supply.

WHY OPEN BUILDING MATTERS TO THE MODULAR INDUSTRY

Off-site production of PARTS of buildings is already well organized in the modular industry. Software-driven supply chain management and bulk purchasing, efficient logistics and on-site construction management are already familiar. The long-heard criticism of structural redundancy (and thus higher cost) has been met and is often successfully offset by offering advantages of reduced time on-site, project speed to market and quality control.

However, unlike the streamlined separation of BASE BUILDING and FIT-OUT found in most speculative office building and shopping center building processes – and now found in leading-edge residential and health care facility projects - modular construction remains stuck in the obsolete paradigm of "whole building integration." The choice is clear: OPEN BUILDING vs. WHOLE BUILDING INTEGRATION."

The separation of BASE BUILDING and FIT-OUT suggests the following:

1). Clear separation of the BASE BUILDING from the FIT-OUT enables design and production of FIT-OUT systems independent of specific projects. Their components can be true manufactured products, like products found in building supply company catalogues.
2) Installation of separate FIT-OUT systems not only offers developers decision flexibility and users choice, it improves quality and saves time and labor on-site.
3) FIT-OUT systems can be improved over time and new ones can be installed in older buildings to give higher performance.
4) If several FIT-OUT companies are in the market, competition will drive down prices and offer greater choice to decision-makers including users.
5) Use of FIT-OUT systems means that installation of individualized floor plans is just as easy to implement as uniform floor plans.
6) Individual units of occupancy can be changed and improved over time.
7) FIT-OUT depends on good logistics and software, as well as adjustments to some building codes and building permitting processes. Unified installation teams will add to the efficiency, quality control and speed, just like in the automobile industry.
8) FIT-OUT can be financed separately from the BASE BUILDING, with different financing instruments, interest rates and pay-back periods.

In an OPEN BUILDING, we say there are LEVELS OF INTERVENTION (see figures 1-3 below).

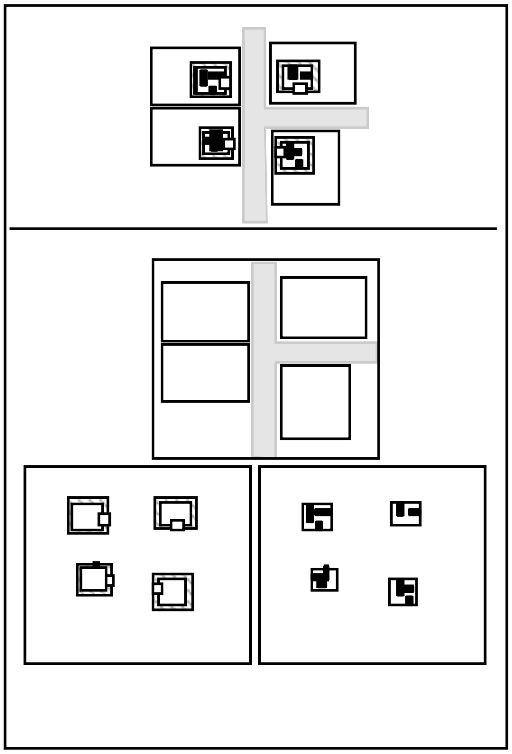


Figure 1: three levels in the built environment.
(The public street and lots; the building;
the fit-out)

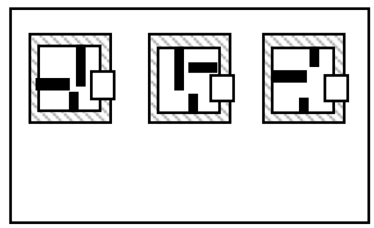


Figure 2: Two-level organization;
building with fit-out variations

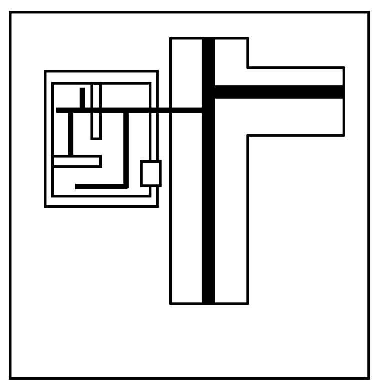


Figure 3: Two-level organization MEP (mechanical, electrical, plumbing) in the street and in the building. The MEP in the building can change independently of the MEP in the street (with certain "capacity" limitations).
(Figures 1-3 from Habraken)

A MODULAR OPEN BUILDING

Imagine a multi-story residential project built as a modular project using OPEN BUILDING principles.

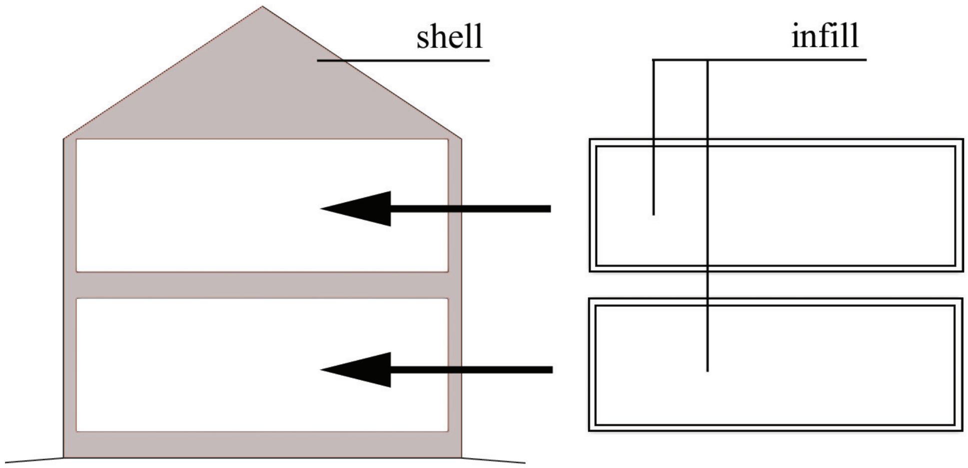


Figure 4: Separation of Shell (Base Building) and Infill (Fit-out)

This separation, applied to a townhouse constructed using MODULAR BUILDING PRINCIPLES, could look like this:

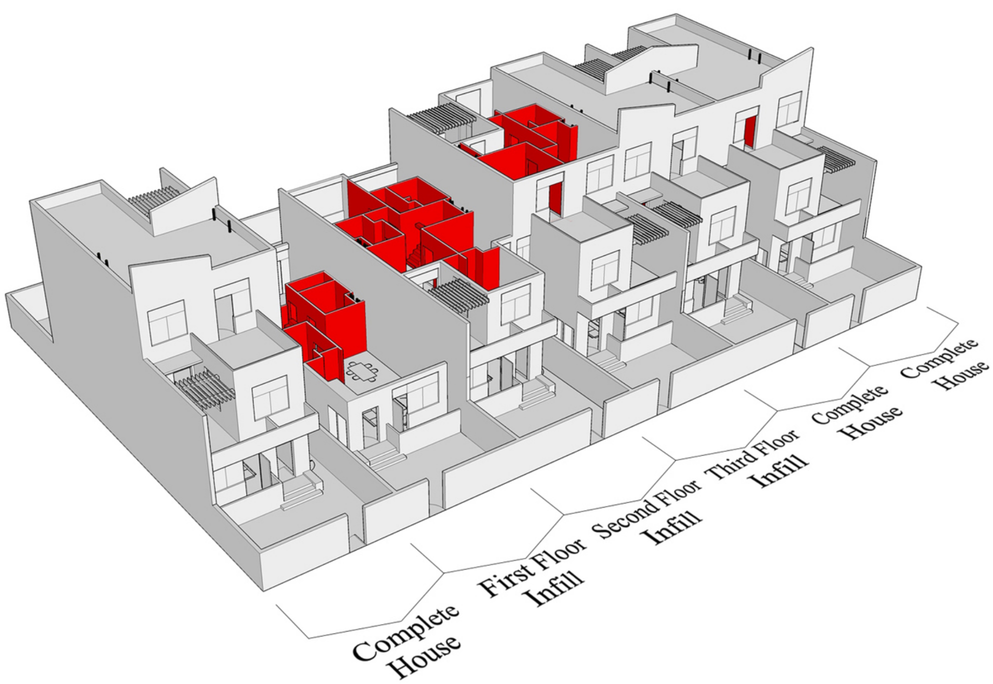


Figure 5: A townhouse solution can use MODULES and INFILL or FIT-OUT for customized interior layout and equipment.

Use of a separate FIT-OUT or INFILL system is shown in the following diagrams, indicating the range of decisions that are possible. The first floor plan of one example of a "whole house" is shown, followed by the SHELL (Base Building) with all windows and façade elements and fixed MEP system parts delivered as part of the MODULAR UNITS built in the factory. The configuration of MODULES will comply with local building codes, urban design layout and architectural themes, climatological constraints, and developer preferences.

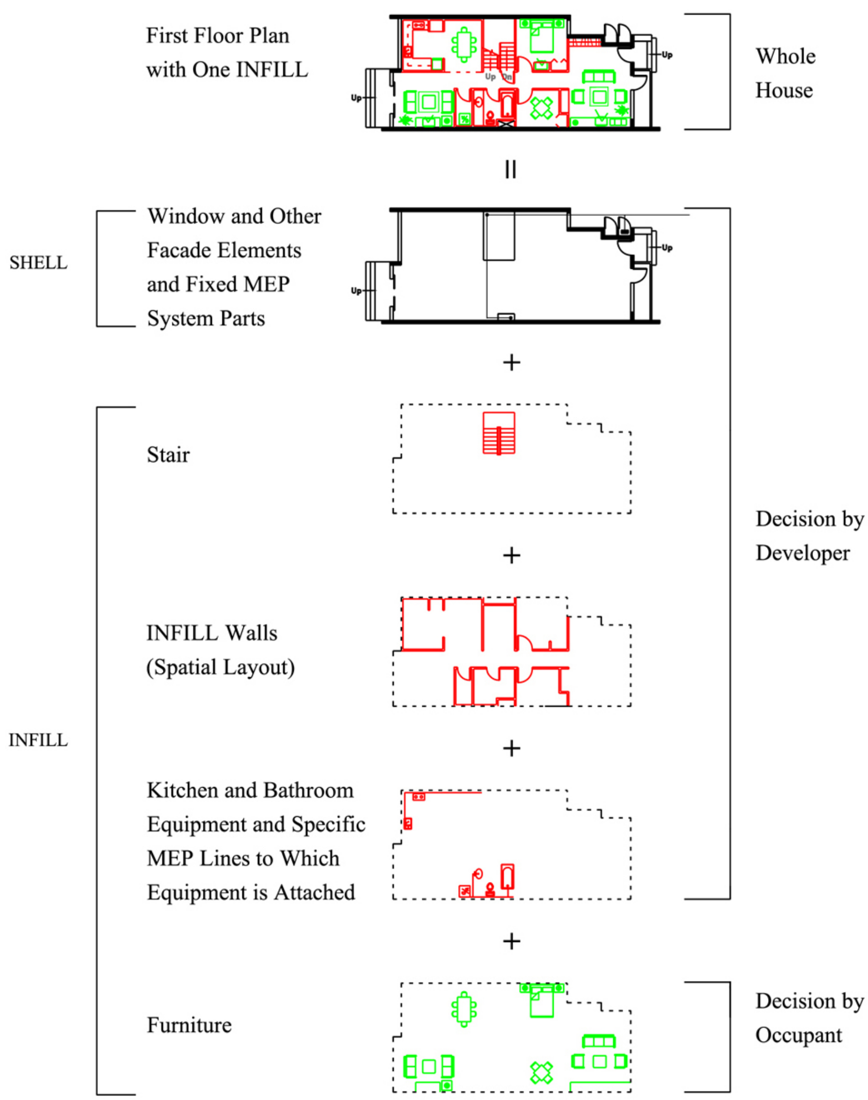


Figure 6: Scenario A – Here, the developer decides not only on the SHELL (Base Building) but also all of the INFILL (Fit-Out). The occupant decides the furnishings only. The INFILL (Fit-Out) SYSTEM conforming to the developer's decisions can be installed either in the factory, or as a kit-of-parts prepared off-site, once the modular building has been erected at the site.

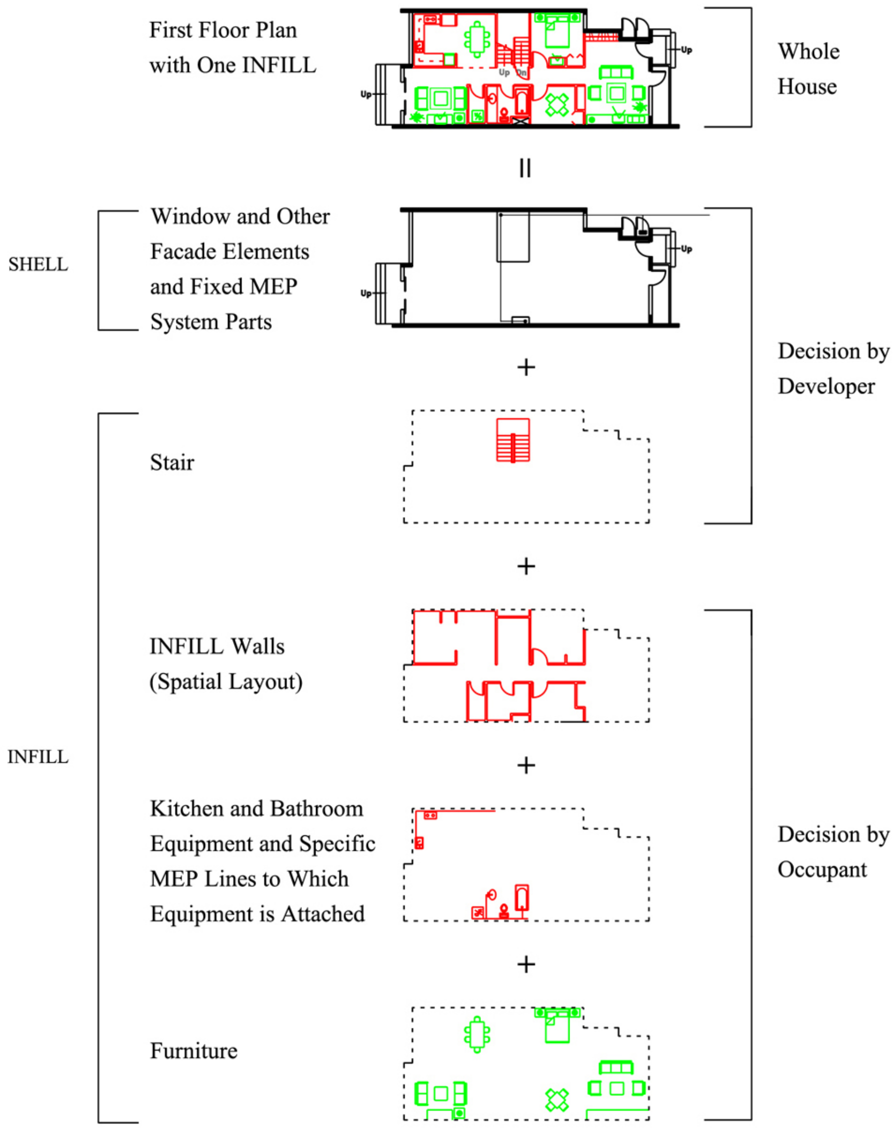


Figure 8: Scenario B – Many intermediate scenarios are possible. In this example, the developer decides not only on the SHELL (Base Building) but also the stair of the INFILL (Fit-Out). The SHELL (Base Building) is designed so that a variety of stair designs can be installed, each enabling a different floor plan on both floors. This is accomplished by sizing the “stair opening” not for one stair, but for a variety of stairs. The occupant decides the interior layout (partitions), the MEP and equipment corresponding to the layout, and the furnishings.

The stair is installed after the modules have been erected, because it connects two separate modules. An INFILL SYSTEM conforming to the occupant’s decisions can be installed either in the factory or once the modular building has been erected.

INFILL SYSTEM PRODUCTS

The separation of SHELL and INFILL (Base Building and Fit-Out) can be accomplished using ordinary and familiar products. However, international experience shows that the disentanglement of piping and wiring from its standard place - buried inside walls and floors - is a prerequisite to more efficient decision making and construction, not to mention offering benefits to longer-term building management.

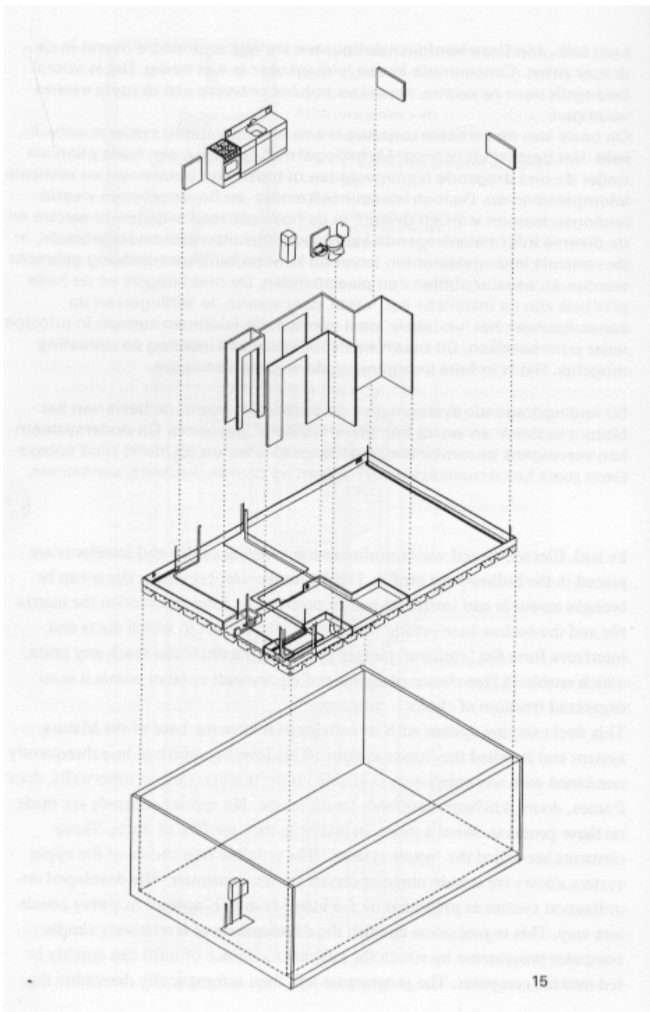
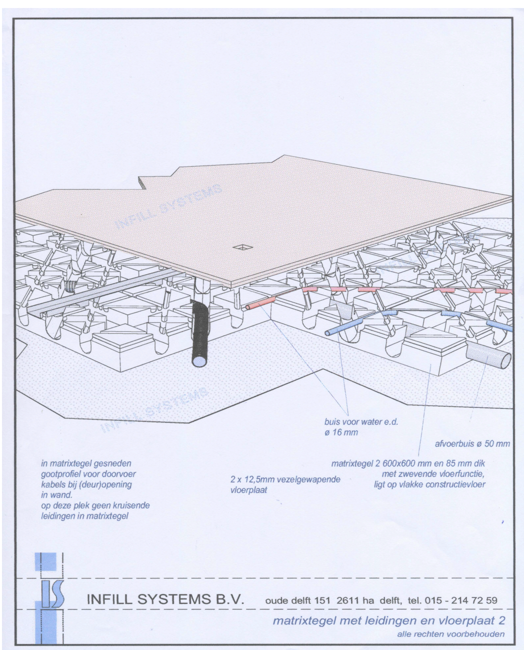


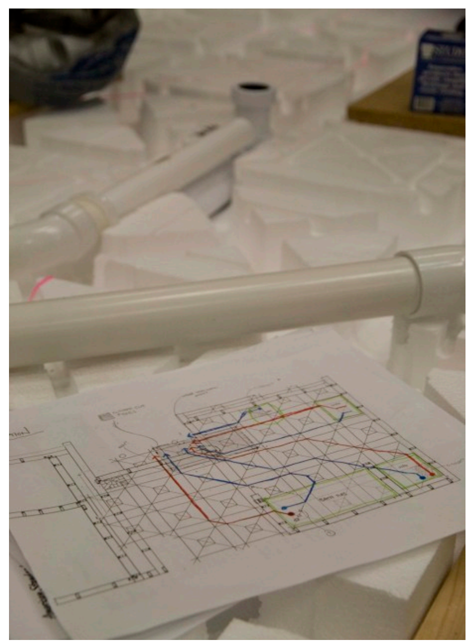
Figure 9: An empty SHELL (Base Building) space is shown with a service point from which MEP systems are connected to their respective equipment in any floor plan layout. The SHELL can be a MODULAR UNIT. Figure 9 also shows the disentangled subsystems of the INFILL (Fit-Out) System.

Several products now coming to market facilitate this OPEN BUILDING process. They are the MATRIX TILE SYSTEM and CABLESTUD. These products were developed in the Netherlands. They are invisible – like the INTEL microchip – but powerful, improving efficiency, decision flexibility and quality control in pre-construction project phases and during installation. They also offer positive ROI over short, medium and long-term cycles of churn, including adaptive reuse of old buildings. CABLESTUD is marketed in Europe by GYPROC, a company in the Saint-Gobain family of companies. They are backbone products for full, slab-to-slab fit-out systems, but are also effective as stand-alone solutions.

MATRIX TILE SYSTEM

The **MATRIX TILE SYSTEM** is a standard, injection-molded 4" thick medium density polystyrene "tile" (32" square) applied on top of a leveled base building floor. Grooves of various sizes - located in several horizontal "zones" formed in the top of the tile - allow the secure placement, without interference, of lines or conduits for various services, such as hot and cold water, gray-water drainage (0-slope), hot water piping to radiators, floor heating, flat ventilation ducts, gas pipes and so on. A 1" thick fireproof floor layer is placed after pipes and other utility services are installed. Non-loadbearing partitions are erected on this floor covering along with any finish floor covering.





Figures 10 and 11: The Matrix Tile is shown on the left with gray-water drainage lines (shown in black and gray) and domestic water pipes (shown in blue and red). The fireproof floor layer is also shown. To the right is an installation drawing showing the layout of the gray water drain lines, as well as the standard schedule 40 PVC piping and fittings. The "0-slope" gray water system is officially certified in the Netherlands and Germany by European Community-recognized testing and certification agencies, when used in the Matrix Tile. This system has been used in more than 100 dwelling units in the Netherlands and no problems have been reported after 10 years of use. Recognition of this certification is being sought in the United States as an approved alternate to standard practice of sloped gray water drain lines.

CABLESTUD

CABLESTUD is a U.S. patent-pending CLASS-A engineered-plastic construction accessory that facilitates the routing and connection of electrical and low-voltage cables at the bottom of non-loadbearing metal or wood-stud partitions, behind a removable baseboard. The installation, addition or relocation of switches, electrical outlets or data ports becomes child's play. Thanks to CABLESTUD, all wires remain inside the partition but in known locations, and connections are easily accessible.

CABLESTUD is in the market in the Netherlands, Belgium and France under the GYPROC label. GYPROC is a company in the Saint Gobain family of companies. Since metal studs are of different dimensions in different markets, the CABLESTUD products are designed to fit each markets' metal studs. Versions for several metal stud sizes and for wood-stud framing are being introduced in the United States.

Figures 12 and 13: On the left, Cablestuds are used in standard metal studs. The removable baseboard (used on one side of the partition only) is shown removed, revealing the special clips used to attach the baseboard in place. Outlets for low-voltage, power, switches and wall lighting fixtures are installed after the drywall is installed, using standard "rework" boxes. Connections are made behind the removable baseboard, in standard connection boxes or using the MOLEX self-tapping connector product as shown (approved only for use when accessible). Where NM (non-metallic) cables are not permitted, MC (metal clad) cables can be installed. On the right, the CABLESTUD for wood-frame construction is shown. Low-voltage wiring (CAT 6 or fiber optic or cable-TV) is installed in the upper portion of the CABLESTUD, and 110/220 power cables are installed in the lower portion, meeting electrical codes for separation. The current design of the CABLSTUD for the US market has capacity for 6 NM or 3 MC cables passing at each stud. Careful planning is required and where cable density is high, sub-breaker panels (e.g. in the kitchen) may be needed.

CONCLUSIONS

Modular construction is poised for active contribution to the sustainability and flexibility agendas. Long-lasting real estate assets are needed – that means they must be flexible – able to accommodate varying cycles of change and technical improvement. In our dynamic society, where change of use, upgrading of technical systems and change of preferences are normal, decision-making, building design and construction need to enable incremental and dispersed upgrading to buildings. Especially in multi-floor/multi-tenant buildings, entanglement of the MEP systems makes this difficult. Therefore, the OPEN BUILDING principle of separation of SHELL (Base Building) and INFILL (Fit-Out) is the first strategy that needs to be adopted. When this is shown to make sense, then new products such as MATRIX TILE SYSTEM and CABLESTUD will enter the market to make this more agile way of building better. Conversely, these new products offer new solutions that, when applied, will accelerate adoption of OPEN BUILDING as a general strategy.

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Infill Systems US LLC; http://www.infillsystemsus.com