Concept Home Principles -

Flexible Floor Plans

Research Summary

July 2005

Acknowledgements
Preparation of this report was coordinated by Dr. Carlos Martín of the U.S. Department of Housing and Urban Development's Office of Policy Development and Research. The text was developed by Tate Era, Christine Barbour, and James Lyons, P.E., and reviewed by Mark Nowak of Newport Partners, LLC.

Table of Contents

Concept Home Principles – *Flexible Floor Plans*
Research Summary

Background

To meet consumer demand, new homes in the U.S. have steadily increased in physical size[1] and design complexity over the last 30 years. Homes today have larger floor plans, more extensive mechanical systems, more amenities like fireplaces, a greater number of bathrooms, larger garages, and specific-use spaces such as family rooms, laundry rooms, and home offices. Despite all of these new features and amenities, modern homes are designed and built with little consideration of the future. Houses are built as static objects; they are not easy to customize or modify beyond surface finishes. This impedes the future repairs, renovations, and expansions that all households experience, especially those faced with the inability to move due to affordability constraints.

In fact, the popular media, major shifts in home-buying demographics, and almost one-quarter of a trillion dollars in remodeling expenditures (JCHS, 2005) indicate that there is a strong desire among consumers for flexible houses that more readily adapt to their changing needs. In 2004, *Better Homes and Gardens* conducted a large survey on homebuyer and homeowner priorities. Editor-in-Chief Karol DeWulf Nickell concluded: "…affordability and flexibility top America's wish list when it comes to their homes…People are hungry for ideas that fit their budget, and they want their home to work through all the changes their families go through."

Changes in households that carry significant floor plan implications can include the addition, growth, and departure of children, elderly relatives, or domestic caregivers, not to mention changes in occupants' interests and needs (such as home offices). The addition of children to a household can have implications on the layout of bedrooms and common areas, in addition to a number of safety concerns (e.g., stairs, appliances, windows). Noise issues and the layout of interior partitions also can become important in a household with children. For households with young children, open areas with clear sightlines on the same floor are particularly important, especially in the vicinity of the kitchen. Households with older children may decide to convert basements, bonus rooms, or attics to play areas or extra bedrooms. Elderly and disabled relatives may need first floor bedrooms, while in-home caregivers may require an accessory apartment. Even the prospect of disabled *visitors* to a household can create basic design needs such as a zero-step entry and wider doorways.

The tract housing designed and built for a preconceived market may not fit the needs and desires of a changing home-buying population. In addition to the well-publicized baby-boomer population, many of whom will make floor plan changes to enable them to age in place, other demographic changes include a growing share of non-family households, recent immigrants, and minorities (Ahluwalia, 2005). Homeowners living alone or with other adult non-family members may desire multiple master suites, home offices, or other special-use spaces. Immigrant and minority households also may have different spatial and floor plan needs based on a larger household size[2] or cultural conventions.

---

[1] According to NAHB (Ahluwalia, 2005), the average square footage of floor area in the U.S. in 2003 was 2,330. The average square footage in 1973 was 1,695.
[2] The NAHB study indicates that Hispanics have a larger household size (3.6) than Non-Hispanic Whites (2.4).

Yet another indicator of the desire for more flexible floor plans is the amount of money spent each year to remodel homes. According to the Harvard University's Joint Center for Housing Studies (JCHS), remodeling expenditures to "modernize or improve the livability" of homes has reached $176 billion. Forty-five percent of these projects involve "changes to interior spaces and other structural changes." JCHS also reports that there is a growing Do-It-Yourself (DIY) market among immigrants and younger homeowners with a strong desire to remodel their homes but with less expendable income than other groups. A more flexible floor plan, in combination with other Concept Home principles, makes it easier for DIYers to make changes to their homes.

Currently, significant changes to a home's floor plan are complicated by structural implications, the need to locate and re-route mechanical systems, and impacts on interior finishes. These constraints are barriers to reconfiguring a home's floor plan as occupant requirements change over time or when new owners acquire an existing home. These same constraints can impede a builder's ability to readily change the layout of a given design during the initial construction process to meet different buyer preferences.

Products, materials, designs, and construction processes have long existed to achieve some measure of flexibility in floor plans, although their application has largely been limited to high-end custom homes. Also, many of these approaches have been geared toward creating flexibility in the public spaces of a home such as living rooms and dining rooms. They are less effective in promoting flexibility in private spaces such as bedrooms and bathrooms.

Outside of residential construction, some of the best examples for creating flexible spaces are found in commercial construction, where non-load-bearing walls and accessible services can be readily reconfigured to meet the needs of new tenants. In their book, *Residential Open Building (2000)*, Kendall and Teicher recognize this trend in commercial construction and remark on its cost advantages in supporting flexibility:

> "… commercial buildings and structures are typically built without a predetermined interior layout. It is not until the lease period that interior partitions and walls are added to suit the needs of individual tenants…The need to churn commercial spaces on a regular basis has prompted the commercial sector to adopt this Open Building practice. The more flexible a building and its floor plan, the lower the cost during tenant turnover."

The authors then continue to describe how these same practices can be used to construct homes with flexible spaces to cost-effectively meet the changing needs of their owners.

Commercial systems, as well as currently available residential products and methods that make floor plans more adaptable, are explored in this paper, but there are many opportunities for manufacturers and designers to create new systems. And, it is important to note that while homeowners stand to benefit a great deal from flexible floor plans, builders and remodelers also gain from this concept. During initial construction, the flexibility afforded by many of the systems highlighted in this report simplifies and organizes installation. This results in reduced scheduling problems, higher quality installations, and reduced impacts from design changes. Likewise, when a building is modified or remodeled in the future, flexibility in the floor plan eases the complexity and cost of making changes.

Performance Objectives

This report focuses on creating homes in which interior spaces can be reconfigured in a relatively straightforward manner as occupant living requirements change over time. These changes may involve the addition of young children or an elderly relative, aging in place, or other household shifts that require residents to use their home differently. Numerous building systems and design issues impact how interior space is arranged and how readily this arrangement can be reconfigured. Therefore, achieving flexible floor plans may involve a wide range of design approaches and building technologies that influence a home's structure, mechanical systems, and interior finishes and partitions.

This principle is very closely related to the principle of organized and accessible systems. To minimize redundancy, information on these principles is arranged in a complementary manner. The Flexible Floor Plans report discusses floor systems, ceilings, attics, expandable spaces, interior partitions, and flexible finishes. The Organized/Accessible Systems report covers approaches to organizing and accessing systems and minimizing their physical interdependencies. And while these areas are summarized in individual reports, in practice they are very much related and a single design approach or technology may support both objectives simultaneously.

Supporting Technologies and Design Approaches

The topics described in this report represent different approaches to flexible floor plans and should be viewed as a cross-section of what is possible. The intent is not for all of these measures to be used in a single home, since many of the tools provide overlapping functions. Further, the style, design, and location of a house will dictate which approaches are most appropriate in many cases.

Floors Systems

The space between the different levels of a home offers a potential zone in which building systems can be located and distributed horizontally to end points and fixtures. Commercial construction practices can be viewed as a potential model, since raised and accessible floor systems have been increasingly used in this sector to accommodate extensive wiring and frequent floor plan reconfigurations. Using accessible floor systems to host mechanical systems (i.e., HVAC, plumbing, and wiring) not only makes these systems readily available for repairs/upgrades, but also can help keep interior partition walls free of utility runs. This supports flexible floor plans by creating an indoor floor plan with partitions that are not heavily intertwined with mechanical systems. Further, mechanical system lines in exterior walls also can be minimized, which offers energy-efficiency and durability benefits. Examples of approaches to using floor systems in this manner follow.

Open Web Floor Trusses

Open web floor trusses have become an increasingly popular floor structure for houses due to their span capabilities and the design flexibility that they lend to a home's mechanical systems. Open web trusses typically consist of wood top and bottom flanges, usually 2x4

Open Web Floor Trusses
Image Source: PATH (www.pathnet.org)

material, and wood web materials connected at joints with metal plates. The open web provides space to run mechanical systems through the trusses, instead of running lines below the trusses (in a soffit or bulkhead) or having to drill through solid floor joists. Some truss designs offer openings large enough to accommodate even the largest mechanical system lines, such as an HVAC trunk. For example, one manufacturer offers a 9.25" deep truss with a 6"x18" rectangular pocket at one point along the truss' length.

Trim-able open web floor trusses are a variation of this technology. Trim-able trusses have special features at the ends of the truss to allow installers to trim trusses down to the exact length dimensions needed for framing. This feature simplifies field adjustments to account for issues such as dimension changes or out-of-square foundations.

There are at least two main types of trim-able floor trusses on the market. The first is a hybrid of truss and I-joist technology. The main part of the truss has steel webs with the top and bottom flanges made from Laminated Veneer Lumber (LVL) or 2X lumber. The web material for a short distance on each end is made from OSB, effectively forming an I-joist on each end that can be trimmed as needed. The second type of trim-able open web floor truss is an all wood truss. This product has a section of dimension lumber on the ends as opposed to an I-joist. It does not rely on truss plates for connections like most open web wood trusses. Rather, the flanges and webs are connected using finger-jointing technology.

Pre-punched steel floor joists are another variation of the open web floor trusses. These steel components are fabricated in 12- through 18-gauge steel and offer long span capabilities (the highest rated joist can span over 36 feet). As with open web wood products, steel floor joists offer the ability to run mechanical systems through the joists, although there is less open space in the web area. The Dietrich TradeReady® Floor System, for example, is available with 6 ¼" x 9" pre-punched oval holes located every 48" along the joist.

Requirements to consider when using open web floor trusses or one of the variations include:

- *Layout:* Special attention may be required for the layout of joists if large openings in the web need to align from one joist to the next.
- *Fire code*: In attached dwellings fire blocking may be required on large floor systems.
- *Rim Joist*: For metal floor systems that use a rim joist with pre-spaced tabs for joist connections, the rim joist should be carefully located and installed.

Pre-Punched Steel Floor Joists
Image Source: PATH (www.pathnet.org)

Raised Floor Above Joists

Raised Floor Above Joists
Image Source: Bensonwood Homes (www.bensonwood.com)

The Bensonwood Homes Open-Built® Floor System extends the space between the floors of a home to create an 8" open space for routing the mechanical systems in a home. The floor system is based on timber floor joists, above which are stand-offs that elevate the sub-floor system and create an ideal area to locate horizontal utility runs for plumbing, wiring, and HVAC.

The utilities located in this cavity can be easily accessed from below by pushing up the finish 3'x4' ceiling panels on the lower level. These ceiling panels rest on top of the joists and are made of ship-lap boards connected together on the back with steel stiffeners. The panels are installed after the mechanical systems.

Requirements associated with this approach include the use of exposed joist members, which works well in the timber frame approach that Bensonwood employs. Fire code requirements, such as fire blocking, also may apply to large installations.

Accessible Ceiling Panels
Image Source: Bensonwood Homes (www.bensonwood.com)

Raised Commercial Floor Systems

Commercial floor systems have adapted in recent years to accommodate "churn" – the continual re-arranging of office space as user and technology requirements evolve. Adding cables for new network or communication systems or relocating workstations have become common exercises in many office environments. Many types of commercial floor systems now allow for organized and efficient installation of communications, data, and power cables. These floor systems also are accessible so cables are easily reached when changes need to be made. A few examples of the many systems available include the following.

Nexus Flooring
Image Source: Haworth (www.smednet.com)

Nexus Flooring from Haworth. This floor system (image shown at right) elevates the finished floor 2.5" or 4" by using steel support cylinders (see below) and steel wrapped medium density fiberboard (MDF) panels for the floor. This system can expedite the installation of cabling, eliminates the need for cable trays, and permits up to 156 Cat 5E cables in each cableway.

Another commercial sector product from Haworth is the TecCrete 1250 Floor System (http://www.smednet.com/products/nexus/teccrete/tecCrete.asp). This system uses steel-and-concrete composite panels for the finished floor surface, which sits upon steel pedestals. The pedestals are available in heights as low as 2.5" or up to 30", and offer an adjustment range of 1"-2" for uneven surfaces. The TecCrete floor system also has the option of adding an air seal strip if the under-floor system will be used as a forced air plenum. This approach is discussed more in the next section.

TecCrete Floor System
Image Source: Haworth (www.smednet.com)

Applying commercial raised floor systems in a residential setting would require addressing the following issues:

- Impacts on wall heights and exterior elevations
- Consumer perceptions (finishes and floor sound characteristics)
- Cost implications
- Approaches to non-concrete floors (e.g. pedestal connections)

Various companies contacted as part of this research claim to be developing and testing raised/accessible floor systems for the residential market. These new systems may address some of these challenges.

Underfloor Plenum Systems

Underfloor plenum systems – or underfloor air distribution systems (UFADs) – hold several potential benefits for designing flexible floor plans. Underfloor plenum systems can create spaces for organized and accessible utilities, remove utility runs from interior partitions, and create a forced-air supply system that can easily adapt to different register locations.

UFADs have received increased attention in the last 10 years as a design approach for *commercial* buildings. The University of California at Berkeley's Center for the Built Environment (CBE) states that: "By combining a building's heating, ventilating, and air-conditioning (HVAC) system with all major power, voice, and data cabling into one easily accessible service plenum under the raised floor, significant improvements can be realized in terms of increased flexibility and reduced costs associated with reconfiguring building services." CBE maintains the Underfloor Air Technology Web site, www.cbe.berkeley.edu/underfloorair/Default.htm, which provides design guidance, case studies, and links to related UFAD information. CBE reports that UFAD systems were originally introduced in the 1950s in spaces having high heat loads and were used in office buildings beginning in the 1970s. UFAD systems have achieved considerable acceptance in Europe, South Africa, and Japan for more than a decade, but the market has grown more slowly in North America.

Commercial Raised Floor System Installation
Image Source: CBE (www.cbe.berkeley.edu)

While the image above shows an underfloor system with hard-ducted HVAC supplies, UFAD systems in commercial buildings may use three different approaches for the distribution of conditioned air (Bauman & Webster, 2001):

1. Supply air from the air handler is hard-ducted through the underfloor area to supply outlets (as shown in the image above).
2. A zero-pressure plenum is used, with air supplied to outlets through the use of active, fan-assisted registers. (This approach minimizes air leakage to/from the plenum).
3. The underfloor area is pressurized by the central air handler, and air is supplied to the conditioned space through passive supply registers, modulated diffusers, and/or fan-powered mixing boxes. This is the most frequently considered approach.

Resources such as the CBE are providing guidance to help overcome barriers to the adoption of UFADs in commercial buildings. Commonly cited challenges to commercial applications include fire code issues (Rospond, 2003), lack of familiarity and design guidance, and cost concerns. Such efforts as the development of ASHRAE's Design Guide on Underfloor Air Distribution Systems are attempting to provide useful design guidance, while other research studies have focused on cost issues. One study, sponsored by Carnegie Mellon University, concluded that an underfloor system featuring a raised floor and structured wiring would initially cost slightly more in a commercial building, but that a savings worth seven times the additional investment was realized the first time the office space was reconfigured (Loftness et. al, 1999).

Most information related to the design and application of the UFAD system concentrates on commercial buildings. However, at the Susquehanna Prototype House sponsored by Armstrong World Industries, floor plenums were used as air distribution plenums for the second and third stories of a research house (Lee, circa 2000). To supply air to the second floor of the home, forced-air was supplied to the sub-floor system, which was made up of open web floor joists. This plenum area underwent extensive air-sealing to improve its performance, but this proved to be a challenging detail. Part of this difficulty arose from the selection of materials (a porous envelope sheathing material was used) and air-sealing would have been made easier by using expanding foam instead of caulk.

The third floor of the Susquehanna Prototype House was essentially a conditioned attic area. HVAC supply air was distributed to this level via a plenum area that was built into the bottom chord of the roof trusses. The trusses, called “plenum floor roof trusses,” provided an underfloor area into which supply air was delivered and then routed to floor diffusers. By providing supply air to the second and third levels of the house through a pressurized plenum system, register locations on these floors could be readily changed since there was no duct to locate and re-route. The underfloor space also was convenient for routing other mechanical systems.

This project concluded that the underfloor air plenum system, in conjunction with the open web floor joists, was deemed to be a successful approach to design and floor plan flexibility, although the sealing details for the plenum area were referred to as problematic.

Based on challenges cited in commercial applications of underfloor plenum systems and residential case studies such as the Susquehanna Prototype House, requirements for residential UFAD designs include:

- Addressing potential fire code issues (which were not directly addressed in the Susquehanna Prototype research)
- Effectively air sealing and insulating the underfloor cavity to reduce system losses, including exterior surfaces as well as vertical penetrations such as stacks and chases
- Addressing the potential for condensation issues during cooling cycles
- Addressing potential radon issues

Further, *any* type of raised floor system also will impact wall heights and the required size of framing members.

Removable Floor Coverings

Removable floor coverings allow easy access to the sub floor below. If used in conjunction with an accessible sub-floor system (e.g., raised floor panels on pedestals), removable floor coverings can allow access to utilities that are run below the sub floor. Removable flooring comes in many different materials including carpet, wood, cement, and MDF. Removable carpeting typically is used in residential applications, while materials such as cement panels are used in the commercial raised floor systems discussed above. Self-adhering carpet tiles with an integrated foam pad can be placed directly over the sub-flooring without glue, and the squares can then be easily removed and/or replaced. The styles of carpet available include commercial grade, plush, and berber, and most can be installed on a DIY basis. A floor covering with an acceptable finish for the residential market offers several potential benefits for flexible floor plans:

- Access to sub-floor systems and underfloor utilities
- A floor covering that can be used in conjunction with commercial-style raised floor systems

- Potential for straightforward reconfiguration when interior partitions are relocated, so that previously covered floor areas (interior wall, cabinet), or areas with an HVAC register, could be covered with new panels

Requirements for the use of removable floor coverings in residential settings include:

- Acceptable finish for a home setting
- Application to a flat and dry sub floor
- Acceptable performance in terms of durability, joint integrity, and the ability to lay flat

Ceiling Systems

Hung/Suspended Ceiling

A hung or suspended ceiling is a system of lightweight gypsum or plastic tiles inserted into a frame that is hung from the support beams of a structure. Many commercial buildings, such as schools and office buildings, use suspended ceilings. This design allows space above the ceiling tiles for horizontal runs of heating and cooling supplies, electrical wires, lighting fixtures, and other mechanical systems. The tile-based ceiling covering also permits easy access to mechanical systems throughout the building and allows space for new utilities to be installed.

Hung ceilings have been used in residential kitchens and finished basement areas, typically with grids and panels. While these systems are effective solutions, especially for basement areas that are finished, they are sometimes viewed as having a “commercial” appearance. Newer products for the residential market have been developed in smaller tile layouts or faux-wood planks. Some of these systems, however, may not be “dropped” (i.e., they are mounted up against an existing ceiling or sub-floor structure), which limits the clearance for mechanical systems. The primary challenge (and opportunity) for hung ceilings in the residential market is to develop systems that permit space and access for utilities above the ceiling, with an acceptable finish appearance for occupants.

Interior Partitions

Interior partitions are a primary feature of a house’s floor plan. They are used to define spaces as well as provide for privacy and noise attenuation. Partitions also are used to conceal numerous mechanical systems in homes, such as electrical wiring. Since partitions are the primary means by which the spaces in a home are defined, they are a critical element to address when designing for flexible floor plans. Key features of partitions that support flexible floor plans include the ability to move the partitions, the use of alternatives to full height walls, and methods for making utility runs in partitions adaptable and accessible. The first two features are discussed below, while utility strategies are discussed more in the Organized and Accessible Systems report.

Partition Alternatives

While traditional floor-to-ceiling walls are a common way to divide the living space into separate, well-defined areas, there are certainly several alternatives to this approach. For example, in timber frame homes built by Bensonwood, room areas in an open floor plan are defined not by walls, but by exposed timber members (posts, beams, rafters) at the perimeter of the area.

Defining spaces without wall partitions is particularly useful when an open floor plan is used. Spaces within the floor plan are open and connected to each other, but still require some unique definition for psychological comfort. One method involves varying the ceiling height of particular areas to set them off from adjoining spaces. For example, Sarah Susanka uses differing ceiling planes to provide definition in open floor plans. A standard ceiling height of 8' or 9' can be lowered in sections through the use of soffits or dropped ceilings to differentiate parts of an open area (Susanka, 2003).

Given consumer preferences for open floor plans on the main living area of a home, techniques that can separate and define spaces without the use of full walls are particularly useful. Also, with respect to flexible floor plans, it is typically easier to *add* walls in the future than to remove them, so using alternatives to full wall partitions can be helpful. In addition to varying ceiling heights to define a space, other techniques include the use of different floor coverings, different wall treatments or finishes, and half-wall partitions or railings.

Commercial Partitions

Moveable interior partitions used in the commercial sector illustrate key features for flexible floor plans and offer some potential for carry-over applications to the residential market. Numerous lines of commercial partitions feature integrated chases for utilities, offsite prefabrication of panels, and the ability to readily relocate walls as floor plan needs evolve. One example is *LifeSPACE® Walls* from Haworth (www.smednet.com/products/lifespace/lifeSPACE.asp). This moveable wall system accommodates voice, data, and electrical wiring, and also can accommodate plumbing and even lead lining (for X-ray rooms). LifeSPACE® Walls are prefabricated and arrive at the site ready to install, equipped with quick-connect voice, data, and electrical. They are fully finished, including doors and hardware.

Commercial partition systems are typically mounted and held in place by tracks installed above and/or below the wall. In some applications, extensive track systems are pre-installed within a space, so that wall panels can be readily moved to define the space in whatever layout is needed. The wall finish materials range from gypsum, plastics, and fabric to metal. The internal wall frames are often fabricated with steel. Commercial wall systems are also specified for their sound rating, or Sound Transmission Class (STC), which may influence the choice of the finish material.

Several features of commercial partition systems appear useful for residential applications. These include built-in, accessible utility chases and quick connections. Other features like finish appearance and the use of track systems are likely to present challenges in residential applications.

Residential Partitions

Residential partitions that may be readily moved have been investigated for decades, as this flexibility was seen as a key element in allowing occupant customization (especially in multi-family buildings). For instance, a 1966 project in Wolhen, Switzerland, featured moveable interior partitions. The partitions could be assembled and configured by tenants in the 49-unit building by using their choice of five different gypsum wall panels. The panels were stored in a common area of the building and came in widths of 60 cm (~ 24") and 90 cm (~36"). Residents were provided with installation instructions, as well as sample floor plans that illustrated possible wall configurations. It was not clear how mechanical systems interacted with the wall systems once they were erected. This is an important issue to consider, given that modern building codes will require electrical outlets (and, therefore, wiring) at a minimum length increment along wall surfaces. Several other case studies involving moveable partitions in multi-family buildings are also reviewed in this same reference (Kendall & Teicher, 2000).

Despite these efforts, broadly accepted, moveable interior partitions for modern single-family housing present a challenge. Recent projects investigating floor plan flexibility, like the Susquehanna Prototype House project, have arrived at this same conclusion. The challenges to implementing such systems include:

- *Mounting Systems*: Developing attachments to ceiling and wall systems that are acceptable in a residential setting and changeable without creating extensive finish work.
- *Finish Materials*: Identifying acceptable finish materials for residential applications, possibly other than gypsum.
- *Utilities*: Accommodating utility runs in wall systems, yet also making them accessible and easy to reconfigure should a wall location change.

Market research conducted in an earlier phase of the Concept Home program indicated that consumers would place a high value on the ability to reconfigure their walls and interior floor plans. Segments of the construction industry also recognize this value, and some manufacturers of commercial wall systems are investigating models for moveable residential walls. Also, innovative builders like Clever Homes are considering the use of moving walls in future demonstration homes.

Expandable Spaces

In addition to technologies and designs that permit *finished* spaces to be readily reconfigured, areas such as attics, basements, spaces above garages (bonus rooms), or even garages themselves, can be designed as unfinished spaces that may serve as storage areas in the near-term and potential places to expand the living space in the future. This approach to flexible floor plans has several advantages:

- Lowers initial construction costs (compared to finishing the expandable spaces initially)
- Provides expandable space within the existing building shell, which reduces remodeling costs and also maintains the architectural integrity of the home
- Offers homeowners the ability to eventually finish areas according to their specific needs, possibly performing a portion of the work themselves

Market research on this idea indicates that homeowners strongly value this strategy. For example, in a survey that asked consumers about different ways to make a new home more affordable, incorporating unfinished spaces was the most acceptable approach, with 41 percent of respondents willing to accept this measure. Other means of keeping a new home affordable were less acceptable, such as a smaller lot (29 percent), a smaller house (29 percent), or fewer amenities (15 percent) (Ahluwalia, 2005). In terms of builder perspectives on expandable spaces, many builders are familiar with this concept and have applied it to a limited extent. However, they are also eager to identify strategies that would create an expandable space without performing a large extent of the work (e.g., partial mechanical rough-ins) associated with actually finishing the space entirely. Different types of expandable spaces are discussed below, along with relevant design considerations.

Expandable Attics/Lofts

Expandable attics and lofts (including bonus rooms) have been showcased in housing research projects such as the Grow Home project in Canada (www.cmhc-schl.gc.ca/en/imquaf/afho/afadv/cohode/buhoic/case1.cfm#full). This project featured lower first-cost houses that included finished areas on the lower level (bathroom, kitchen, and living spaces) as well as an unfinished upper level that was designed to be readily finished in the future.

Grow Home Project
Image Source: CMHC (www.cmhc-schl.gc.ca)

Residential builders have also used expandable floor plan designs of this type in an effort to provide buyers with a functional living space and expandable unfinished space at an affordable initial cost. Unfinished areas within the building shell can subsequently be finished at a reasonable cost because provisions were made during the initial construction to insulate and condition these spaces and run mechanical system lines to them. Story-and-a-half floor plans where the upper level is left unfinished serve as a good example. This design approach affords flexibility and provides the potential for additional living space at a lesser cost than expanding the building's footprint. Builders are also considering living spaces in the attic as an approach to providing more square footage without increasing the roof area of the house, especially in locations where impervious areas (e.g., roof surfaces) and their impacts on storm water runoff are strictly regulated.

Market research conducted as part of the Grow Home project in Canada found that the concept of expandable space resonated with consumers. Visitors to the demonstration unit of this project related that 93 percent approved of a second floor that could be finished according to their needs. Follow-up research on the project conducted by McGill University also illustrated that residents used the potential of the unfinished upper levels. Within a few years of the initial construction, roughly three-quarters of the Grow Home owners had finished the space on a DIY basis.

The Canadian Housing and Mortgage Corporation (CHMC) has also explored the building requirements and economic costs and benefits associated with creating living areas in attic spaces under a research program called Flexible Housing (www.cmhc-schl.gc.ca/en/imquaf/afho/afadv/cohode/deflho/index.cfm). This program has explored the opportunities to design homes with expandable spaces that possibly could be used as rental units once finished.

Attic or loft areas that are initially constructed as unfinished spaces but are designed to be readily finished in the future require attention to several issues, including:

- Use of dimensional lumber rafters, attic trusses, or engineered lumber components that provide an open attic area
- Insulating at the roof line of the attic or loft area to keep the unfinished area within the thermal envelope of the building
- Addressing roof ventilation issues; options include the use of ventilation baffles or an unvented roof design, which may lead to code and shingle warranty issues
- Pre-installing feeds for mechanical systems (i.e., plumbing, electrical, HVAC, and communications), while also laying out mechanical systems that service the floors below such that they do not impede the eventual finishing of the attic space
- Providing access to the attic area--this can be accomplished by installing a staircase, or installing just the rough framing for a future staircase in the ceiling system; if an attic area is located above a garage adjacent to the second floor of a home, then access can be gained through the second floor of the house and an additional staircase is not needed

Expandable Basements

Expandable basements are a common application of expandable spaces in residential construction. However, when the future expansion of this space is accounted for, the design and construction of a basement can include several measures that will simplify and enhance the eventual finished space.

A readily expandable basement was featured in the PATH MADE Homes (Marketable, Affordable, Durable, Entry-Level), a recent demonstration initiative sponsored by HUD. Several basement features in the MADE houses were integrated to streamline the eventual finishing of this space for living area. Features included:

- Strategically locating structural support columns, as well as HVAC duct work, at locations that accommodate a pre-planned basement finished floor plan; this required sizing floor joist spacing and depth so that ducts could be fully integrated into the joists and not hung below them
- Providing an egress window for the eventual living space

- Using pre-cast foundation wall panels that offered exterior insulation, cavities for adding additional insulation, and an integrated stud surface to simplify finish work in the basement
- Installing a plumbing rough-in for a future bathroom

Additional features to consider for expandable basements include initial installation of an egress door and enhanced exterior insulation levels to provide added thermal comfort when the space is finished. When these spaces are eventually finished, they may undergo finish work with traditional materials or a prefabricated package such as the Owens Corning basement finish system. This system, which offers ongoing access to the foundation and in-wall utilities, is described further in the Organized and Accessible Utilities report.

Other Expandable Areas

While basements and attics (including the space over a garage) are fairly common approaches to creating expandable spaces, other options exist. One variation of creating low-cost indoor spaces that can be finished at a later time is conducted by Proyecto Azteca, a non-profit housing developer in the southwestern United States. Proyecto Azteca assists low-income residents along the Texas-Mexico border region by helping them to finance land and low-cost housing. While some of the projects mentioned above created expandable spaces in the attic or basement, this group offers homebuyers the simple option of cascarones, or shells. These homes are roughly 80 percent completed to minimize costs, and come fully framed and enclosed along with the mechanical, plumbing, and electrical systems installed. Items such as flooring, insulation, wallboard, and kitchen cabinets are not installed, but can be added later based on the resident's financial resources. The construction of these units also uses a large degree of sweat equity on the part of the buyer. These cost-savings measures result in cascarones that sell for about $12,500 (HUD, 2004-a).

Beyond basic house shells, other expandable areas within the original envelope of a house include attached garages or a screened-in porch area. In both of these cases, the spaces may not initially be intended for living space, but if certain provisions are made during design and construction, they can be converted at a later time. Considerations include:

- Mechanical Rough-Ins: Provisions for electric and HVAC (and possibly plumbing) should be considered. At a minimum, access to the main house systems should be provided.
- Insulation: Areas should be included within the thermal envelope of the building or at least be able to be insulated at a later time.
- Framing: The structure of these spaces should be adequate to meet building code load requirements.
- Parking: In the case of an expandable garage, alternative parking areas should be considered, possibly to the side of the house or in front of the garage.

Finally, expandable spaces do not necessarily have to be contained within the original shell of the building. External additions to houses also may be considered and accounted for during initial construction. One key consideration is the siting of a house on the lot. While the typical approach will site the house near the center of the lot, this can later result in a planned addition not fitting within the site setbacks. As an alternative, a house can be built slightly off center in a manner that will allow for a future addition to fit within the setbacks. While all of these expandable options may not be applicable to all housing types or even allowed by local building regulations, they pose numerous options for both far-thinking and potentially feasible construction.

Flexible Designs

While the ability to expand the living space to other parts of the home is important to groups like growing families, many other homeowners are focused instead on maintaining full and unrestricted use of their home in its current configuration. This section discusses viable technologies and design approaches to achieve this goal.

Framing for the Future

During initial construction, framing details can be incorporated that will allow specific changes to take place more easily in the future. For example, a load-bearing wall can be built with a header that is not structurally necessary, but is included to facilitate the future addition of a fireplace. Infill framing fills the opening in the meantime.

Forward-looking framing can also support other future changes, including the addition of:

- A staircase to access expandable attic space
- An elevator
- A door that leads to a future addition
- A window
- Aging-in-place features such as grab bars or a chair lift for a staircase

Builders state that many of these "extras" – such as blocking for grab bars – can be easily provided by simply using scrap lumber on the site.

Residential Elevators

Residential elevators can enhance the ability of accessibility-limited residents to stay in their home or allow people with accessibility needs to live with other family members (e.g., elderly parents living with their children). While residential elevators range in price from $12,000 to more than $50,000, an alternative approach that supports floor plan flexibility is installing the necessary structural components for an elevator in new construction – but not the actual elevator system (Striegler, 2005). The "elevator rough-in" approach has several benefits:

- Defers the cost of adding an elevator to when it is needed, but establishes the infrastructure for the elevator unit at the most cost-effective point in a building's life.
- The space that is "reserved" for the elevator can still be used effectively– stacking closets on multiple floors is the most common design technique to install an elevator rough-in.
- Installing the rough-in for an elevator and planning on this approach to maintaining accessibility provides design flexibility for a new house (e.g., multiple stories can be used instead of a ranch-style house with a much bigger footprint).

General requirements for roughing-in a residential elevator system include:

- Framing out an elevator shaft and finishing with fire-code drywall
- Adding a mechanical room for the pump or motor next to the elevator shaft on one level (usually in a basement or attic)
- Running a circuit (typically 30A/230V) to the mechanical area
- Designing the lowest level that the elevator will serve to accommodate the bottom of the elevator cab; this means designing a slab or floor system with a 5" or 6" pit

Other Aging-in-place Features

Many other design details can make a home more accommodating and flexible as occupants age and develop different accessibility requirements (e.g., wheelchair access). As noted above, the features mentioned here are those that offer the potential for future accessibility enhancements that are most effectively addressed during the initial design and construction of a house. Many other aging-in-place features can be considered for a home specifically designed for aging occupants (which is not the sole focus of flexible floor plans). Information on such features is available from the Center for Universal Design (http://design.ncsu.edu/cud/), which is also the primary source for most of the information listed below. It also should be noted that a few of the design details listed below might benefit aging-in-place residents, but could actually present a problem in houses with young children. Examples include lower window and lower electrical panel heights.

Aging-in-place features to consider during the initial design and construction of a home include:

Entrance Features:

- Level area inside and outside the entrance for turning and maneuvering (minimum 5'x5' space)
- Maximum vertical change of ¼" at thresholds (applies to all floor surfaces)
- Covered access points to the house (i.e., attached garage, carport, and porch)
- Zero step entry to house (e.g., driveways or garage at the same level as the house)

Interior Floor Plan Features:

- At least one bedroom and accessible bathroom on the entry level (or the ability to readily transform rooms on the entry level)
- Turning spaces of 5' diameter (minimum) in all rooms
- 42" (minimum) clearance in hallways
- 32"-wide (minimum) doorways
- On the pull side of doors, a 24" space (18" minimum) on the latch-side of the doorway
- Bottom of windows between 18" and 36" above floor
- Stairs with space at the bottom to accommodate later installation of a lift

Controls and Switches:

- Light switches 36"-44" above floor
- Electrical outlets 18" (minimum) above floor
- Electrical panel with top no more than 54" above floor

- Thermostats and controls 44” (48” maximum) above floor
- Remote controls for heating, cooling, and selected lighting

Kitchen Features:

- Counters with pullout shelves
- Lazy Susan cabinets in corners
- Cabinet doors that slide or use spring-loaded hinges
- Adaptable, removable base cabinets
- Minimum 5’ diameter turning circle

Bathroom Features:

- Minimum 5’ diameter turning circle
- Reinforced walls to accommodate grab bars
- Layouts that accommodate a 3’x3’ shower, a conventional tub/shower with transfer seat, or a roll-in shower

Conclusion

Flexibility in a home’s floor plan involves a combination of design considerations and technologies that promote the ability to change building systems and layout. While not often considered in the modern construction process, flexibility is a key element to enabling changing households and new owners to individualize their homes. As one of the more prominent themes of the Concept Home, flexibility will be showcased in the Concept Home plans using a selection of the approaches discussed in this report.

Bibliography

Ahluwalia, Gopal. “Homes and Home Buyers of Tomorrow.” National Association of Home Builders, presented at International Builders Show, January 2005.

Bauman, Fred P.E. and Tom Webster, P.E. “Outlook for Underfloor Air Distribution Systems.” *ASHRAE Journal*, June 2001.

Joint Center for Housing Studies of Harvard University. *The Changing Structure of the Home Remodeling Industry: Improving America’s Housing 2005*.

Kendall, Stephen and Jonathan Teicher, *Residential Open Building*. London: E & FN Spon, 2000.

Lee, Stephen. “Demonstrating Design for Flexibility in the Susquehanna Prototype House.” Center for Building Performance and Diagnostics, Carnegie Mellon University, circa 2000.

Loftness, Vivian et. al. “Sustainable Development Alternatives for Speculative Office Buildings.” Center for Building Performance and Diagnostics, Carnegie Mellon University, April 1999.

Nickel, Carol DeWulf. “America’s Home.” *Better Homes and Gardens*, (February 2005): 88-92.

Rafter, Dan. “Building Blocks for the Right Playroom.” *Washington Post.* (March 26, 2005).

Rospond, Kathryn. “Fire Down Below.” Consulting-Specifying Engineer. (September 2003).

Striegler, Gary. “Home Elevators.” *Fine Homebuilding*, No. 169. (February/March 2005): 84-87.

Susanka, Sarah. “Rooms Without Walls.” *Fine Homebuilding,* No. 156. (June/July 2003): 66-71.

U.S. Department of Housing and Urban Development. “A Community Guide to Basic and Cost-Saving Construction in the American Southwest.” Partnership for Advancing Technology in Housing, U.S. HUD (2004): 110-112. Available on HUD User: www.huduser.org

U.S. Department of Housing and Urban Development. “Organizing Residential Utilities: A New Approach to Housing Quality.” (November 2004) Available on HUD User: www.huduser.org