Integrating "smart house" technology and barrier free design for housing elderly and disabled persons

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INTRODUCTION

The elderly population in this country is continually increasing in numbers due to medical advancements and the maturing of the baby boom generation of the 1940's and 50's. This significant growth is projected to continue well into the twenty first century. As a result, designers are confronted with the problem of providing adequate housing for this very diverse group of elderly individuals. To compensate for this rapid growth, we as design professionals must incorporate various barrier free design principles into common dwelling design in order to produce a housing stock that is capable of housing the clientele of this particular generation. By consistently constructing barrier free environments we will be able to make accessibility the rule, rather than the exception.

As designers, we are placed in a very powerful position. In essence, the environments we create will influence the very manner in which we live. By creatively challenging the previously established building conventions, we can produce a variety of housing solutions that will satisfy the needs of the elderly population. The design goal of this project is to produce an environment that is capable of sustaining an independent form of living for the majority of elderly disabled individuals.

Purposed in this thesis are two barrier free prototypes, a house and an apartment. These prototypes have developed to solve the following problem. Many of the dwellings within the community setting are not capable of housing the elderly, because they contain structural barriers that restrict the maneuverability of the elderly occupant. By designing a dwelling that provides adequate space requirements and can be dimensioned to suit the specific needs of the elderly or disabled client, we can develop an environment that is sympathetic towards both populations.

Smart House technology has also been incorporated into the design of these prototypes because it can assist the elderly individual in remaining at home. Smart House technology can provide services to a growing number of elderly that are presently not available in the home. For instance, many individuals are currently being forced to move out of their dwellings simply because they are unable to remember when they are supposed take their medication. The Smart House system can be setup to remind the occupant of such things through the use of a whole house automation system.

The Smart House system also could be utilized as a safety feature so that if an occupant were injured and unable to make it to a phone to call for help, he/she would only need to speak a plea of "help" into the air. The voice recognition system of the house would interpret this as a plea for help and relay a previously recorded message to the hospital informing them that there has been an accident and their immediate assistance is required. In this case the individual that is unable to call for an ambulance him/herself because of their physical condition, would still receive the medical treatment they need because of the highly advanced response system of the Smart House.

The ability of the Smart House System to break down barriers in communication that impede the elderly is the systems greatest asset. For instance, an elderly occupant who has experienced hearing or sight loss can be notified about anything from a visitor at the front door, to a life threatening fire, by a series of flashing lights and buzzers. In essence, the system can be programmed to accommodate the occupant's loss of senses and the resulting reduced ability to communicate with ones environment. The system could be used to keep the occupant informed about what is going on around them.

For those with restricted mobility, being able to control a multitude of appliances from numerous locations within the home is a definite plus. Various control centers such as touch tone screens and keypads, as well as movable inputs such as remote controls, allow the occupant to cut down on both the distance that must be travelled to carry out a particular function within the dwelling as well as the time required to do them. Let me describe an incident where a remote control that actually operates an appliance might come in handy.

Imagine if an occupant with highly restricted maneuverability were waiting in the livingroom for water to come to boil in the kitchen. As time passes, the heat from the cooktop causes the water in the pan to begin to boil over. In the normal environment, the occupant would have to cross the livingroom and kitchen in order to turn off the burner. The time that it would take for such an elderly individual travel this distance would not enable him/her to catch the pot before it actually boils over. The same individual in the Smart House could simply grab the remote control, point it at the range, and turn it off from the living room before the pot is able to boil over.

These implications of Smart House technology simplify the life of the occupant. For some elderly individuals Smart House technology may be more than a convenience, it may be a necessity that enables them to maintain an independent form of living. In order to design a structure with a Smart House system that offers the greatest degree of benefits to the elderly population, the composition of the elderly population must first be considered.

The number of elderly people in the United States over 65 years of age is predicted to climb from the current 12% of the population to nearly 20% by the year 2030 (Gunn, 1988, p.246). With more and more people falling into the over 65 category, it becomes imperative that we provide a wide range of living situations capable of housing this particular sector of the population. In order to produce appropriate environments for the elderly, we must take into consideration how everything that we design will affect individuals with a multitude of disabilities often associated with age. After considering the implications of our designs, we may find that we are not only able to create environments that function better for the elderly, but also function better for all occupants.

It would be impossible to develop one housing type that would meet the needs of the entire elderly population, because no two people age in exactly the same way. The aging population possesses a wide range of abilities. As each person ages, he/she may experience disabilities with varying severity. The result is a diverse population that requires varying degrees of assistance.

Just as there is a great variety of abilities within the aging population, there is also a wide range of abilities within the general population. Not everyone is born with the same abilities. For instance, some individuals through their genetic make up and physical stature seem to have the natural ability required to become a professional athlete. Other individuals are born with considerably less physical ability. People are born without the abilities required to live a simple life without a struggle and a great deal of assistance. Others lose some of their abilities over the course of their lives through disease and accidents. Many of these people have been able to overcome what was considered by outside observers to be unsurmountable barriers by shear desire and determination. Only through the exhausting pursuit of trying to "fit in" are they now active members of our society.

As designers, we have the capability of making this transition easier. Although diversity in abilities seems to increase with age, it exists at all ages throughout the population. For this reason such barrier free ideas that assist those with disabilities should not be implemented only in environments designed specifically for the elderly or the disabled, but in all environments. By designing an environment that adapts to the needs of all people with varying abilities, we are insuring that the number of active people within a community will continue to grow.

If we design our dwellings to compensate for the disabilities that are brought about by the aging process, the buildings we produce will not only meet the needs of the majority of the elderly individuals, but also will satisfy many of the requirements of those with disabilities of all ages.

Although many disabilities manifest themselves as a result of the aging process, others may occur earlier in the life-span of an individual. Permanent impairments may render an individual helpless in an environment which does not suit his/her needs. A suitable environment, however, would enable the individual to live a normal life.

Often, a temporary impairment is caused by an accident and affects an individual without warning. The need for a supportive environment in this situation is apparent. For instance, when a resident slips and breaks a leg, he/she will be temporarily handicapped by the event for a given period of time. It would have been impossible to predict such an incident, but it is very important that the design of the home be sympathetic towards such a condition and able to compensate for it. Steps should be taken in the design process of a dwelling to insure that if such an incident were to occur, the dwelling could undergo minimal adjustments in order to satisfy the new needs of the client. This is referred to by the profession as "adaptability".

We should design units that are adaptable and cater to an individual's future needs. By considering all the adaptable options during the design process, a responsive environment can be created before the occupant actually needs the assistance. One need not wait until a disability arises before one designs for it. Rather, we should look at what could happen and what will happen to an individual's health over the years and make sure that the occupant's dwelling will accommodate these changes in an individual's health.

If it were possible to standardize such a housing type that promotes independent living, the general population would probably recognize the benefits of such an environment and require the implementation of its principals in future structures whenever possible. There is a good chance that this type of environment would become an American norm, if the general public were simply informed that such design philosophies exist.

The Americans with Disabilities Act Accessibility Guidelines or (ADAAG) could do just that. ADAAG is a series of standards that have been assembled for designers to use in order to produce accessible structures that comply with the Americans with Disability Act (ADA) of 1990. The ADA is a civil rights act that will give those with restricted abilities the same opportunities to experience public and commercial buildings that were previously off limits to them because of the structural deficiencies of the buildings. The intentions of both the ADA and ADAAG is to remove current barriers from existing public buildings and insure that such barriers are avoided in future building.

If the ADA Accessibility Guidelines that could feasibly be applied to homes were followed during the design process, the accessibility of the housing stock in the United States could be greatly increased. Currently the accessibility guidelines are intended to make public buildings more accessible for people with disabilities, but by introducing these same standards into the home, we could also improve the living conditions of private individuals.

According to the ADA, existing commercial and public buildings must be altered to comply to this law wherever alterations are "readily achievable". In determining what is readily achievable, factors such as cost, financial resources of a facility, number of persons employed, and others are taken into consideration (Mikita, 1992, p.28D). New construction has to comply with ADA if the application for a building permit or permit extension was completed and filed after January 26, 1992, and the facility is occupied after January 26, 1993 (Mikita, 1992, p.30).

ADAAG is comprised of a set of guidelines or suggested ways of designing. The technical specifications section of the document, sections 4.2-4.35, are much the same as those of the American National Standards Institute. They have been slightly altered on a few occasions. These standards are not considered codes and therefore are not enforceable. ADAAG is useful because it provides very graphic examples of good barrier free design which are easy to follow by architects and building professionals.

Following ADAAG, however, does not insure compliance with ADA. It's hard at this point to determine exactly how the courts are going to interpret the Americans with Disabilities Act, so guaranteeing compliance based on ADAAG is not advised. At this time the only way to be sure of what compliance is, is to actually be sued (Jones, 1992, p.36).

In order to design better environments for the elderly, understanding the biological changes that an individual will experience during the aging process is important. A variety of sensory distortions, motor impairments, and emotional and cognitive impairments may develop in elderly individuals as they age (Greer, 1987, p.60). This deterioration of the body is inevitable. We must understand how these biological changes affect the abilities of an individual in order to design an environment which is suitable to their needs. The biological changes that occur in an aging individual are analyzed further in the "aging process" section of this thesis.

There are a variety of ways of making ones environment "barrier free." Most applications are based on common sense design. For instance, structural considerations such as limiting the number of level changes, or widening the doors within the structure are often done for the elderly to ease ones maneuverability within the structure. Specially designed handles make it more convenient for all occupants to use the various devices of the home. Smart house controls enable the occupant to regulate a variety of activities from almost anywhere in the house. Looking ahead to the future needs of the occupant is an important aspect of a successful design. Such design considerations will benefit all users.

In order to design appropriate spaces to conduct a variety of activities, one must analyze every detail of the activities that will be taking place in the space. By setting aside everyday conventions and concentrate on what is actually needed to perform a given function with a variety of disabilities, a compensatory environment can be created. This may require updating some of the present standards which are often minimal.

The latest technology available should be incorporated into these designs in an effort to achieve a sensory abundant environment within the home. Through the use of smart house technology, a variety of barriers within the home can be overcome making it a safer place to live. Sensor triggered smart house warning systems can communicate to the occupants in the case of an emergency, such as a fire, through a series of flashing lights, loud buzzing noises, or eventually a voice synthesis system. The elderly are, therefore, forewarned of such life threatening events that might ordinarily have gone undetected for an extended period of time because of their deteriorating senses.

In this day and age it is important to be able to design with environmental concerns in mind at all times. With our natural resources being rapidly depleted, it is of utmost importance to keep the efficiency of a dwelling in constant consideration. By incorporating passive solar principles into the design of a dwelling, monumental steps towards energy conservation can be taken.

The smart house system in coordination with passive solar design will play a major role in controlling the energy consumption of the two barrier free prototypes discussed in chapter 3. Implementing passive solar principals and Smart house technology into all new homes could literally save American households millions of dollars in fuel savings. The smart house control system, with the central computer at the helm, will be able to allocate when, where, and how much energy a house will be allowed to consume. Through the implementation of passive solar design principles, the amount of energy that will actually be required by the occupants to heat the home will greatly be reduced. Combining the two systems will drastically reduce the occupants operating costs.

By incorporating all of these new technologies and barrier free ideas into the design of a prototype for the elderly and disabled, a self contained form of independent living can be conceived. An occupant will not have to wonder how long he/she will be able to cope with an inadequate dwelling before being forced into moving out by its inefficiencies. Rather, the occupant will have the comfort of knowing that the dwelling was specifically designed to be able to adjust to meet his/her needs in every way technically feasible. The occupant's life at home can be lived to its fullest without being restricted by the environment.

Smart House systems in the dwellings of the future may be able to program themselves according to the tendencies of the occupant. A system may also be developed that will actually alert the proper authorities if an unconscious occupant is detected. Another aspect of the Smart House system may be able to one day acknowledge when an occupant is out of bread or milk and remind the occupant of this in a synthesized voice as the occupant leaves the dwelling on an errand. These futuristic features may give the system a humanistic quality.

Such an advanced highly technical system would almost appear to actually care about the well being of the occupants within, because it will have analyzed many of the needs of the occupants in a sympathetic manner.

I. CRITERIA:
CHARACTERISTICS OF THE
ELDERLY THE DISABLED

The Need for Independent Elderly Housing

The Growth of an Aging Population

The United States For the first time in the history of the United States, people 65 years of age and older out number those 30 years of age and younger. In 1960, 4 percent of the population was 65 and older. Now, 12 percent of the population is over 65. It is predicted that by the end of this century half of the number of people that are over 65 will also be over 75. It is believed that by the year 2030 one out of every five Americans will be over 65 years of age (Architectural Records, Apr., 1988, p.98). This large number of people will have to find a form of housing that will meet their individual needs.

Relatively few elderly Americans require constant medical attention or nursing care. Only about 5 percent of the people in the United States that are over 65 live in nursing homes at one time. The average age of those that enter these homes is 82 (Architectural Records, Apr., 1988, p.98). Many of these people may need the services of a nursing home for only a short period of time, after which they return home and go back to their everyday lives. For others, the nursing home may be the last place they live. That leaves a vast majority that can choose to live in a variety of different housing situations.

Barbara Gunn, a professor and Extension Specialist in Adult Development and Aging for the Nevada Cooperative at the University of Nevada-Reno, believes that much of the elderly population is healthier than typically assumed. Her research findings have suggested that the need for specialized elderly housing is often overestimated. Over three-fourths of the population over 75 years of age can carry out the major activities of everyday life by themselves (Gunn, 1988, p.246). With so many elderly people living independently, perhaps only minimal adjustments are necessary to improve their environments and make their lives easier.

Experts have predicted a 280% growth in the number of nursing homes that will be built between 1980 and 2040. They also advise that a new 220-bed facility be opened everyday from now until the year 2000 (Gunn, 1988, p.246). It may solve the problem According to Wiener (1987), "If we maintain the status quo, total nursing home expenditures between now and roughly 2020, in constant U.S. dollars, will triple to almost $100 billion with medicaid picking up half the tab" (Wiener).

Those numbers seem to be overly excessive. Building this number of nursing homes may be one way of solving the problem of the growing elderly population, but it should not be the only housing alternative. Housing the elderly is simply not a matter of predicting the number of elderly people there will be in the next 10-50 years and then calculating the number of nursing homes it will take to house this number of people. Elderly individuals do not all require the same level of health care and, therefore, should be offered a multitude of housing solutions.

Much of the time and energy that is being spent building nursing homes in this country could be used to develop other means of housing a greater percentage of the elderly population. A form of shared housing may be an alternative that can be offered to some of the elderly that really don't belong in nursing homes, yet at the same time are not comfortable living alone.

The Smart House prototype developed in this thesis is another option that could house a great percentage of the elderly population that simply don't require the services of a nursing home. The Smart House design could offer a number of elderly individuals an environment free of barriers that would allow them to remain living independently. A system that notifies the doctor of health problems, even when the occupant is unable to get to a phone, may be the security the individual needs in order to feel comfortable living at home alone. The number of elderly that must be housed in nursing homes can be limited by providing environments that respond to the needs of the occupant.

Like most new innovations to hit the housing market, Smart House technology may first only be affordable to a sector of the population that is well off financially. A certain percentage of the elderly population could afford to purchase units that offer this technology. The current rate of spending can be maintained by 75 percent of the population over 55 years of age. An average of one third of this spending is discretionary. Many elderly people have managed to save some money over the years. For instance, 40 percent of this countries assets are held by those between age 65 and 75. That comes out to an average net worth of $125,000 per elderly person in the United States. The incomes of 9 percent of the elderly population are below the poverty level, but when the benefits that they are receiving are calculated into this figure, only 3.3 percent of the elderly population are actually living below the poverty level (Architectural Records, Apr. 1988, p.98). The money that many of the elderly now possess makes it economically possible to offer them barrier free Smart Homes in an effort to meet their demands for adequate housing.

Sweden Sweden is experiencing much the same rapid growth of the elderly population that America is facing. Sweden as you may know has the highest percentage of elderly over 65 years of age in the world. In 1986, 17% of Sweden's population was over 65 as compared to the 12% over 65 here in the United States. Consequently, Sweden has a far greater problem of housing the elderly than the United States does at the present time. Sweden is also dealing with their elderly population in a different manner. They are reducing their amount of "category" housing being produced, such as nursing homes, and are trying to "normalize" the housing in their country in an effort to give the aged the possibility of living in their own quarters and experiencing an active and meaningful life with others (Gunn, 1988, p.247). It is this authors belief that they are taking a step in the right direction and that the United States should follow suit.

The prototypes developed in this project will enable the elderly to remain in their communities. By implementing some of the design principals of these units into the building of typical homes in the United States, we will be able to produce more "normalized" housing stock for the country just as Sweden has done.

Many of the facilities that have been built in European countries such as Sweden, Denmark, and England have been designed to fulfill the needs of the elderly for privacy and independence. It is evident that these designs are concerned with sustaining the dignity of the occupants that live in the various housing types. Freedom of choice, such as the ability to come and go as one pleases, instills a sense of dignity to the elderly population. A number of support systems have also been established to enable elderly individuals to remain at home.

What is very important is that a variety of different housing needs are addressed. It seems so typical here in America to reuse design criteria and not try to improve it in anyway. In Europe they are trying to do away with that sort of "rubber-stamped" mentality. In all instances, it is the government which has addressed the various housing and health care issues.

The Aging Process

To be able to effectively design an idealized living unit that will allow many elderly individuals to maintain an independent form of living, the disabilities the occupants are likely to encounter must be considered. Often the types of disabilities that one encounters throughout ones life resemble those that are experienced during the aging process. They tend to limit the physical mobility and/or sensory awareness of an individual. By looking at some of the complications involved in the aging process we will better understand what we will all some day experience (see Figure 1).

Sensory distortion There are three types of disabilities that are frequently experienced by the elderly; sensory distortion, motor impairments, and emotional and cognitive

Sensory Distortion	Motor Impairments	Cognitive impairments
- Loss of eye sight	- Change in posture	- Forgetfulness
- Loss of hearing	- Reduced muscular strength	- Alzheimer's disease
- Loss of the sense of touch	- Loss of flexibility	- Psychological problems
- Loss of the sense of smell	- Loss of the ability to walk	- Dementia

Figure 1. Common disabilities experienced by the elderly

impairments (Greer, 1987, p.59). Let's first consider sensory distortion. As a person ages, various senses start to deteriorate. The elderly individual can no longer perceive the world as clearly as they had earlier in life. Any number of their senses; taste, touch, smell, or sight may no longer be as acute as they once were. For this reason, the environment may appear to contain fewer informative cues for the elderly senses to pick up on. A variety of very subtle everyday environmental stimuli may go completely unnoticed by the elderly. What is needed to overcome this loss of perception among the elderly is a sensory plentiful living environment (Greer, 1987, p.59).

The sense of sight begins to diminish as early as age 45. Eye lenses begin to yellow and thicken. As a result, an 80 year-old person needs about three times as much light to perform a given task as a twenty year-old does (Architectural Record, Apr. 1988, p.104). This loss of eye sight makes it hard for an elderly person to judge perspective in an environment that is lacking contrasting colors or tonal qualities. Glare and sudden changes in light levels can affect the elderly individual's ability to see as the pupils of the eyes adjust. Glare can also cause forms to blend together, making shapes and shadows indistinguishable. The speed at which the eyes of an elderly person can focus on a near object and then one further away is slowed.

There is also often a loss of hearing that is associated with aging. Even a moderate loss of hearing can make it hard for an elderly person to distinguish words that are being spoken to him from the noises being produced in the background. This white noise in the background is usually caused by other voices, traffic sounds, heating and ventilation units, or a number of other sound sources

(Architectural Record, Apr. 1988, p.104).

Sometimes only certain frequencies of sound are lost. If the high frequencies of sound are lost, the individual may only be able to make out the vowels of words which are spoken and not the consonants. With this type of hearing loss, increased volume doesn't make what is said any more understandable (Hoglund, 1985, p.10).

A person's skin may also be less sensitive to pain and pressure as one grows older. This inability to detect a change in temperature may keep an elderly person from realizing that a stove burner is on until he/she has actually burned himself/herself. Very subtle changes in material textures that have been installed in a living unit, so that the elderly individual can differentiate one surface or space from another, may go completely unnoticed by the elderly occupant (Hoglund, 1985, p.11). These changes must be distinct.

Motor impairments The second of these disabilities are categorized as motor impairments. As an elderly person's body becomes frail he/she experiences difficulty maneuvering. These difficulties are often associated with diminished muscular strength, stiffened joints, shortness of breath, decreased blood flow, and the inability to sustain physical stress (Hoglund, 1985, p.6).

Generally as a person ages, his/her body's center of gravity shifts forward. This change in posture creates a very awkward sense of balance (Greer, 1987, p.59). Falls associated with this lack of balance are the most frequent type of accident occurring in the homes of the elderly today (Brent, 1987, p.216). Degenerative bone conditions, and reduced muscular strength make it very difficult for an older person to sit down and stand up.

An elderly person may also be confined to a wheelchair. This brings up an entirely different set of conditions for maneuverability. Floor surfaces, ramps, and accessible spaces all become important considerations. The spaces within the dwelling must be carefully designed taking into account such things as the turning radius and reach limitations of the wheel chair user, so that he/she can easily use all the facilities within the dwelling.

As a person ages he/she may acquire Arthritis which is the term used to describe inflammation of the joints. Rheumatoid arthritis usually starts in the small joints of the hands and feet. Approximately 80% of the cases of this type of arthritis first occur between the ages of 25 and 50 (Goldsmith, 1976, p.468). Affected joints are painful, becoming swollen and stiff. This makes it very hard for an individual to grip and pinch things such as door knobs or kitchen fixtures. Care should be taken during the design process to select lever operated door opening devices, and kitchen and bathroom fixtures that do not have to be grasped in order to operate (Goldsmith, 1976, p.468).

Climate control is also important because cold drafts within a dwelling can cause discomfort for the arthritic individual. The use of double glazed windows is recommended to cut down on these drafts.

<u>Emotional and cognitive impairments</u> The third type of disorder is referred to as emotional and cognitive impairments. Sometimes a person's cognitive abilities clearly diminishes with age. The elderly individual may contract what is known as alzheimer's disease. Alzheimer's disease is considered the most common cause of severe intellectual impairment among the elderly (Parker, 1984, p.99). They lose their cognitive ability to reason. The individual may experience what is known as dementia. The demented individual experiences emotional disturbances which result from an organic brain deterioration. This condition is irreversible.

The individual may simply experience a loss in the ability to remember things. Studies have suggested that this loss of memory is not due to the inability to store information, but rather the inability to access it. This new information is not organized as well by the aging nervous system. As a result, it is hard for certain elderly individuals to recall information unless the person is called upon to retrieve it periodically (Hoglund, 1985, p.7). This memory loss can be very aggravating and stressful to an elderly individual who doesn't want to be labeled senile because of it.

The elderly person may be psychologically affected by elements within his/her surrounding environment. One may positively be affected by pictures from ones past or a quilt that's been in the family for many years. On the other hand, one may be exposed to an environment in which numerous institutional looking mobility aids dominate the decor of the space. This may consistently remind the elderly individual of a loss of certain abilities and the departure from an easier life.

Housing should be supportive of disabilities and medical needs, but it should not appear mechanical and sterile. This could destroy the elderly person's confidence and impression of oneself as being independent. The elderly individual needs to remain in a domestic setting surrounded by personal items that remind them of their hopes, dreams, loves, and sorrows (Hogland, 1985, p.3). If the environment appears only to be "a space that inhibits life" and does not include the things that make life worth living, the elderly individual may experience psychological damage.

Architects have started to address the first two problems through various code requirements that help an elderly person overcome some of the existing barriers, although much more could still be done. We must look past conventional solutions and address the actual problems that exist with housing the elderly. These problems could consist of a compilation of smaller problems within the home that make it impossible for the elderly individual to live at home. It could be that their bathtub is configured in a way that makes it impossible to get in and out to properly bath oneself. Perhaps the door knobs and difficult to use fixtures within the dwelling don't allow the arthritic individual to easily control various devices within the dwelling. Maybe the laundry room or the fuse box is located in the basement and the elderly individual can no longer walk steps. A combination of any number of smaller problems may make the elderly person feel as if they can no longer live in the environment.

Architects should be challenged by the diversity of the elderly population to compile a new set of guidelines and standards to design by.

The third type of disability, however, is often overlooked by architects, especially the repercussions that architecture can have on ones emotions (Greer, 1987, p.60). Architect Michelle Morgan said it best when she said, "Any time a designer provides a solution for a person with disabilities that is of lesser quality and convention than what he would provide himself, he is creating a psychological barrier". By questioning every design aspect that is currently taken for granted, designs that are actually therapeutic tools for the elderly can be established (Hoglund, 1985, p.3)

Sometimes it seems as if being elderly in itself were a handicap. When terms such as incompetent and senile are applied to an entire group of people, a terrible stereotypical reference is created. These descriptions take an elderly person's identity and assigns to them devalued characteristics that are not valid. Granted, there are a number of disabilities that are brought about by the aging process, but simply being an elderly person should not be a disability in itself. The mere existence of certain disabilities commonly experienced by a particular group should not bring about such undeserved ridicule (Hogland, 1985, p.4).

The Swiss psychologist Carl Gustav Jung views the elderly in a different light:

> Jung saw old age as the true pinnacle of an individual's lifetime. He felt that only those individuals who lived in an advanced age could experience the full range of joys, sorrows, and other life experiences that lead to a fully enriched life. He saw old age as a period of personal fulfillment and growth -- a time of true insight and privilege (Hogland, 1985, p.11).

This is a view of the elderly our culture seems to have lost somewhere.

Aging is not a condition, it is a gradual process. It is not a disease that can be cured nor is it a handicap. Rather, it is the result of biological and social changes. As one under goes these changes, a variety of diseases, disabilities, and physical restrictions may concur. The study of life processes, activities, and function, as well as the characteristic afflictions of old age is referred to as gerontology or geriatrics. By using data that is already compiled on the subject of aging, architects can design better dwellings for the elderly.

As the years pass, one realizes that he/she is not able to complete some of the tasks that seemed easy early in life. Simple things that were always taken for granted, become major barriers. Aging individuals must continually adapt to their own changing physical conditions throughout the aging process. Designers must understand how the aging process affects the body before they can design dwellings to accommodate these changes. Time wears down the body, but amazingly it doesn't work at the same rate on all people. We must all learn to design for people with varying abilities.

Thesis Objectives

There are two basic goals that must be completed in order to produce a successful thesis. First, the design of the housing prototypes must be capable of satisfying the housing needs of many of the elderly and disabled individuals who are currently inadequately housed in community settings. These prototypes will provide individuals that might otherwise be forced to move into nursing homes, the option of continuing independent living. The prototypes incorporate Smart House technology as a means of simplifying the lives of the occupants and increasing the efficiency of the units.

The second goal of this thesis is to promote the implementation of Smart House technology and barrier free design in all new houses being built so that as our population ages, there will be a housing stock available that is capable of housing the elderly individual. Dwellings should be designed so that they not only meet the immediate needs of the occupant, but respond to ones future needs as influenced by the aging process. As a result, a housing stock could be produced that is more capable of meeting the needs of an elderly population. By improving the quality of the housing stock through standardization, the amount of specialized housing that is required by our society can be reduced. The idea of designing for the long term could become an American norm that is inbred within society's value system if the public were exposed to such design philosophies.

Every client one designs for will go through some age related changes over the period which he/she occupies a structure. These changes should not be ignored, rather, they should be incorporated into the design. Why must there be a distinct difference between a house that is built for a 30 year old and one that is built for a 70 year old, when it's very possible that the 30 year old person will be living in that same house when he is 70. If the occupant were to move out after a typical twenty year stay, chances are someone would eventually move in and grow old in that particular dwelling. By building a home for a 30 year old individual that is also conducive to the needs of a typical elderly individual the need for one specialized elderly unit may be eliminated.

This brings up the appropriateness of removing elderly people from the diverse population. Removing elderly individuals from their current environments can have direct ramifications on their emotional state and their health. By secluding elderly people from the general population, we are denying them some of the simple pleasures of life that can only be experienced when subjected to a group of people of a multitude of ages. We are taking them away from any sense of family or community that they may have. In essence, we are uprooting the elderly person from the neighborhood they have grown to love (Naegle Associates, 1988, pp.30-31). Figure 2 shows a number of ways that we can improve the housing satisfaction of the elderly population.

<u>Keys to the Housing Satisfaction of the Elderly and Disabled</u>

1. Enabling them to live in familiar communities.
2. Sensitive installation of mobility aids that don't strip the occupant of his/her sense of independence.
3. Removal of all barriers (both physical and psychological)

Figure 2. Means of achieving housing satisfaction for the elderly and the disabled

Often times the elderly are forced to move from their homes because they can no longer get around in that particular environment. They are often relocated in nursing homes that are no where near their original neighborhoods. They return to the neighborhoods where they used to live, however, because that is where their church, or doctor, or dentist is. It is also where most of their life-long friends reside. In essence, a flaw in their home design has up-rooted them from everything that is important in their lives (Gunn, 1988, p.247).

Many elderly will cling to their homes, even as they grow frail. They will do this because they are both familiar with their surroundings, and because they want to hold on to their dignity for as long as they possibly can (Nesmith, 1987, p.62). Their dwellings are not equipped to offer them any assistance. If these homes were retrofitted with various movement and perception aids, they could offer the occupants the benefits that currently only age specific housing does.

Living units should be designed to aid these people in need of assistance, yet will not at the same time tear down their self image of being very independent. Usually when aids such as grab bars are placed in an elderly person's home, they are of a generic institutionalized style that clash with every aesthetic aspect of the house (Greer, 1987, p.59). Everything in the house that suggests the personality and character of the occupant is overridden by these institutionalized and very obtrusive objects (Architectural Records, Apr. 1988, p.102).

This problem can often be overcome by simply installing grab bars made out of a variety of materials. Grab bars could consist of intricate wooden rails that are made on a lathe, as long as they can meet the various strength requirements of grab bars. They could also be given a colored, textured, plastic coating that is consistent with the color pallet of the bathroom. Grab bars should reflect the tastes of the occupants and represent an aesthetic choice that can compliment the rest of the dwellings decor. It shouldn't be a sterile item that reminds one of an institution rather than a home. They should be offered in a number of styles, just as bathroom fixtures are.

Installing institutionalized grab bars could be demeaning to the occupant. Usually grab bars are installed when a loved one feels that they are necessary. This may make the elderly person lose confidence in one's own abilities and feel as if he/she is no longer capable of independent living, when in actuality he/she may be quite capable of it. By installing grab bars in the homes of individuals that are still young and not dependent on them, the image of associating grab bars with old age can be reduced. If grab bars are installed only when they become a necessity, the elderly individual may perceive the installation of the grab bars as a symbol of old age.

Unobtrusive aids to movement in the same character of the rest of the house's decor, will assist the elderly, without visually promoting the reliance on their use. Therefore, these aids can become standard fixtures in all homes to be used when needed by both the young and old, thus making the house "intergenerational" (Architectural Record, Apr. 1988, p.102).

We must now consider designing for the entire lifespan of our clients. By simply designing all homes "smarter" we may be able to house much of our elderly population until they require additional health care. If such an idealistic design philosophy were to be normalized and accepted as standard, it could be implemented in all new construction.

By incorporating these barrier free philosophies into the design of all new homes, environments can be created that work better for all occupants. Environment that incorporates a multitude of devices that are beneficial to both the old and young an "intergenerational" environment. If such an "intergenerational" housing type were to incorporate barrier free principals as well as utilize the latest smart house technology, an environment that can actually react to foreseeable conditions could be established.

We should also be designing living units of this type for the "young old" population. This particular sector of the population consists of a very active group of seniors that still are healthy, and get out of the house quite a bit. Many individuals that have just retired fall under this category. This active group could use the time that they now have available to them to learn the computerized "Smart House" system. This way when they become old, frail, and a little bit less active, they will have had the exposure to the system necessary to reap the full benefits of the system. It would be easier for them to reprogram certain items of the Smart House system if they could spend a considerable amount of time learning about what all the options within the system are.

Once the system is programmed, all users will benefit. Even the individual who knows nothing about the smart house system will benefit from it. Many of the standard functions such as heating and ventilation could be preprogrammed to accommodate the elderly individual's schedule. Some of the more advanced smart house systems may be able to eventually program themselves based on the occupants tendencies or life-styles. If there are any aspects of the system's program that are undesirable to the elderly occupant, and the individual is hesitant to reprogram the system, it could easily be reprogrammed by a family member or a neighbor to better accommodate the needs of the occupant.

There are a variety of products that provide a barrier free environment for the elderly, but which all people can benefit from. Levers instead of knobs on doors is one particular universal advancement. Whether a healthy person who has his hands full and wants to open a door, or an elderly person who has severe arthritis wants to gain access to his/her dwelling, both benefit with the installation of lever handles. Slip-resistant tile for the bathroom can be appreciated by anyone who has slipped and fallen on a wet floor. Those who have ever used grab bars in a bath tub already know how convenient they are to use. Even the ease in operation of something as simple as a casement window helps to make an environment barrier free.

There are many steps that we have already taken toward making an environment barrier free that we now take for granted. Casement windows, for example, is a barrier free idea that has become second nature to us. Low pile carpet and slip resistant floors are other ideas that have satisfied the requirements of their initial instillation to a degree that we hardly notice them as barrier free elements.

People choose to spend a lot of time in their homes and because they do, they should be made to feel as comfortable as possible for as long as they choose to live there. They should be blessed with a house that looks out after them and takes care of their every need. A house that once programmed practically thinks for itself. I believe that by utilizing present day smart house technology and implementing barrier free design one can achieve an environment that is conducive to a long and happy life for the occupant. After all, the home should be a castle you never outgrow.

Americans with Disabilities Accessibility Guidelines

Over the summer of 1991 the Federal Justice Department released a list of ADA Accessibility Guidelines for public and commercial buildings. I have gone through and chosen all of the guidelines covered in section 4 of the ADA Accessibility Guidelines For Buildings and Facilities which I feel are worthy of domestic applications. These guidelines have been implemented into the design of the Smart House prototypes, appearing in the last chapter of this thesis, so that as residential codes become more stringent these prototypes will not have to be upgraded in any way. I believe that residential building codes will become more stringent as our society recognizes the importance of accessibility within the home.

The ADA law which was enacted by congress in 1990 has become stringent towards the accessibility of public accommodations and commercial facilities. It will enable individuals with a variety of disabilities to finally be able to use all aspects of these public structures. In essence, the ADA is a Civil Rights act that will give those with restricted abilities the same opportunities to experience public and commercial spaces that were previously off limits to them because of the structural deficiencies of the buildings. The intention of the Americans with Disabilities Act is to remove these barriers. As a result the ADA will provide all users of public structures with a safe accessible environment.

Shouldn't new housing be designed to the same level of accessibility as is now currently required in commercial structures? After all accessibility is simply a matter of planning ahead and designing with a little common sense in order to create an environment that does not hinder the mobility of the users with varying abilities. It should be a goal of our country to upgrade the quality of our housing.

It would not be economically feasible to go around the country modifying the structural composition of homes to meet such high standards, but I do think upgrading the level of accessibility of new homes is very important to our countries future. As architects and builders we have a certain responsibility to insure that the dwellings we design are able to accommodate the same diversity of people that public and commercial structures are now required to do.

The problems that we are currently facing as a society is trying to decide what is more important to us, individual rights to build what he/she wants in a private dwelling or infringing upon these rights to obtain societal benefits. If many of the ADAAG standards could be applied to the construction of new homes, our society would benefit greatly by the higher quality of housing that is produced, without drastically infringing upon the rights of the owner.

Designers often associate the implementation of a series of standards with restricted design freedoms and an institutionalized look. That doesn't have to be the case. The creativity of the design in no way has to be affected by designing with more appropriate dimensions. A designer can create spectacular spaces even when implementing barrier free design principles. We are just used to experiencing barrier free ideas only in institutional settings. By broadening our horizons and using barrier free ideas and standards even where they are not required by law, we will have a much greater exposure to those design ideas and no longer view them as something to be implemented in "special" instances. These ideas have been demonstrated in the house prototype appearing later in the text.

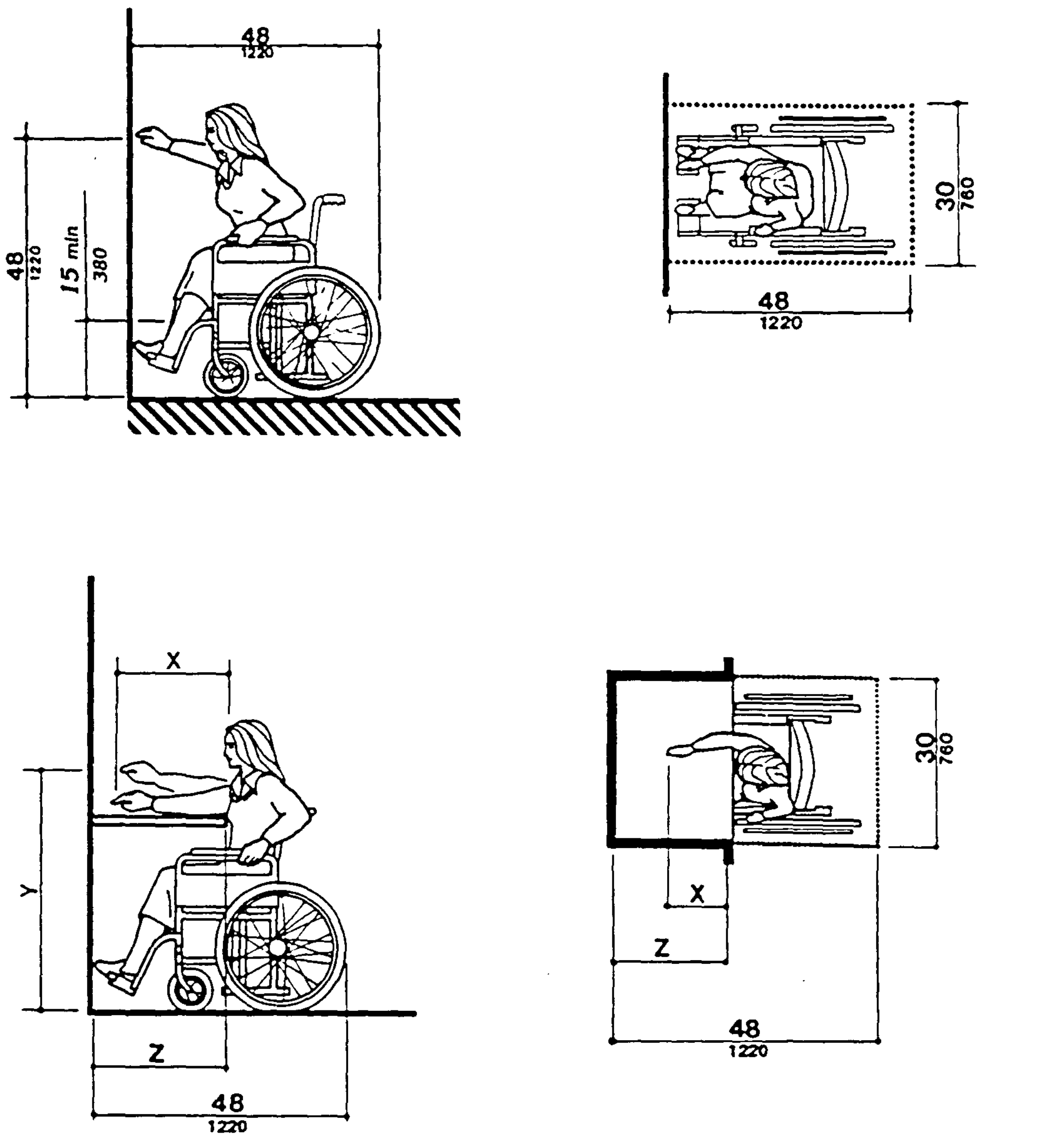
The standards established in the Americans with Disabilities Act Accessibility guidelines of 1991 are all based on adult dimensions and anthropometrics. I have gone through the ADAAG and have chosen some of the standards that could be applied to residential situations. These standards were extracted from ADDAG, reduced and summarized so that all the major points of each reference is easily understandable. The following reference materials, appearing on pages 39-55, show what types of dimesioning can easily be attained in the home.

Forward Reach (ADAAG, 1991, § 4.2.5)

If the clear floor space only allows forward approach to an object, the maximum high forward reach allowed shall be 48 in. The minimum forward reach is 15 in. High forward reach over obstructions is illustrated in Figure 3.

Side Reach (ADAAG, 1991, § 4.26)

If the clear floor space allows parallel approach by a



Note: x shall be < 25 in; z shall be > x. When x < 20 in, the y shall be 48 in maximum. When x is 20 to 25in, then y shall be 44 in maximum.

Figure 3. Forward reach limits (ADAAG, 1991, § 4.2.5)

person In a wheelchair, the maximum high reach allowed shall be 54 in. and the low side reach shall be no lower than 9 in. above the floor. Side reach over obstructions is shown in Figure 4.

Accessible Route (ADAAG, 1991, § 4.3)

The minimum accessible corridor clear width for a single wheelchair is 36 in, while the minimum clear width for two is 60 in. Figure 5.

Protruding Objects (ADAAG, 1991, § 4.4)

Objects protruding from the walls with their leading edges between 27 in. and 80 in. above the floor shall protrude no more than 4 in. into walks, halls, corridors, passageways, or aisles. Objects with their leading edge at or below 27 in. above the finished floor may protrude any amount form the wall as shown in Figure 6.

Head Room (ADAAG, 1991, § 4.4.2)

Circulation spaces must have a minimum of 80 in. vertical clearance. If vertical clearance of any adjoining area provides less than 80 in. head room, a barrier must be provided to warn the blind or visually impaired. One such barrier would be a railing.

Ground and Floor Surfaces (ADAAG, 1991, § 4.5)

All floor surfaces must be stable, firm, and slip-resistant. Vertical changes up to 1/4 in. don't require any edge treatment. Changes in level between 1/4 in. and

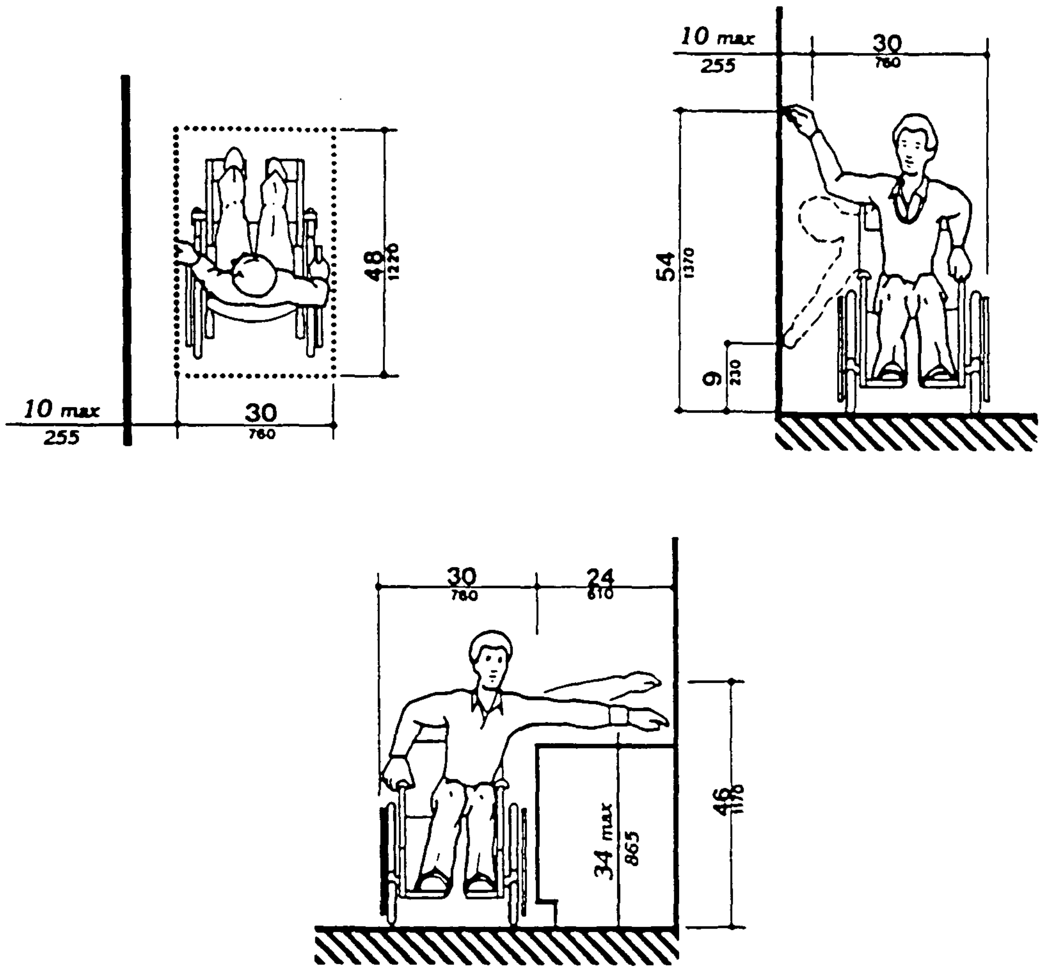


Figure 4. Side reach limits (ADAAG, 1991, § 4.2.6)

1/2 in. shall be beveled with a slope no greater than 1:2. Changes in level greater than 1/2 in. will be accomplished by means of a ramp. When carpet is used it must be securely attached, and have a firm pad if any at all. The maximum pile thickness of the carpet shall be 1/2 in., see Figure 7. Exposed edges of the carpet must be fastened to the floor surface.

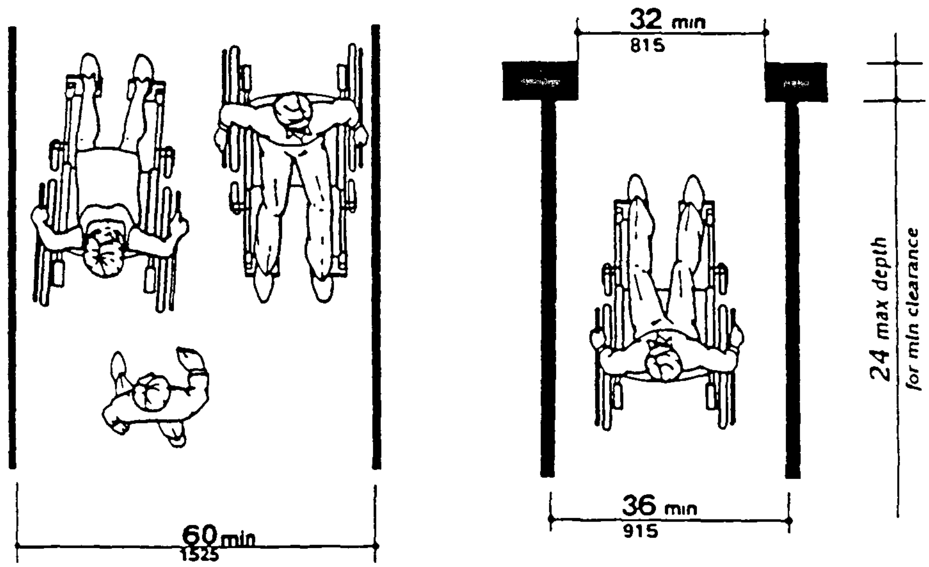


Figure 5. Minimum clear widths for accessible corridors (ADAAG, 1919, § 4.3)

<u>Slope and Rise</u> (ADAAG, 1991, § 4.8.2)

The least possible slope shall be used for any ramp. The maximum slope of a ramp in new construction is 1:12. Any slope less than 1:20 is not considered a ramp. The maximum rise for any run shall be 30 in. The clear width for a ramp shall be 36 in.

<u>Landings</u> (ADAAG, 1991, § 4.8.4)

Landings shall be placed at the top and bottom of each ramp run. The landing shall be at least as wide as the ramp that leads up to it. The landing length shall be a

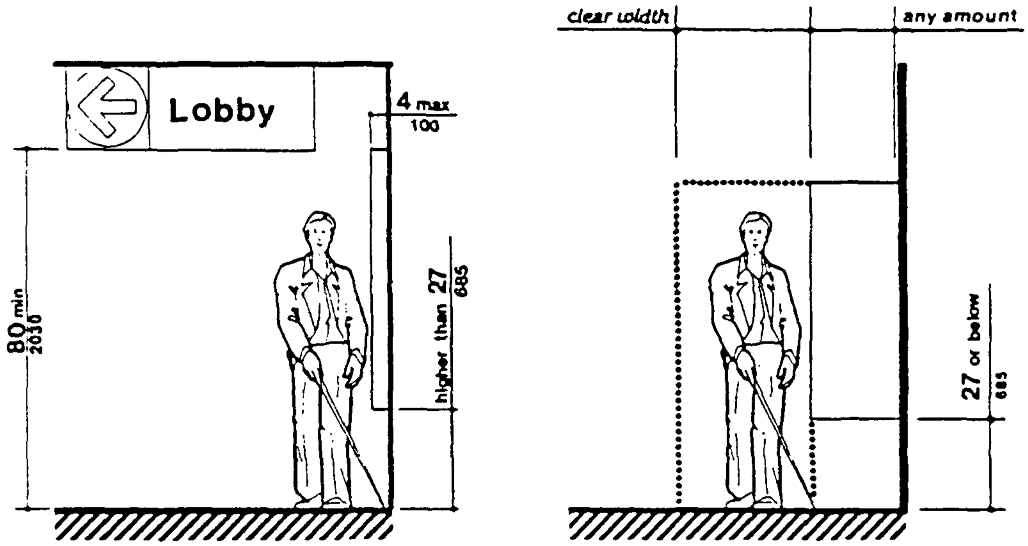


Figure 6. Protruding objects along the walls of corridors (ADAAG, 1991, § 4.4)

minimum of 60 in. clear. If a ramp changes direction at a landing, the minimum landing size shall be 60 in. by 60 in.

<u>Handrails</u> (ADAAG, 1991, § 4.8.5)

If a ramp has a rise greater than 6 in. or a run greater than 72 in., it shall have handrails on both sides. The inside rail on a switchback or dogleg ramp shall always be continuous. Handrails shall extend at least 12 in. beyond the top and bottom of a ramp segment. Handrails shall be mounted parallel to the ramp surface. The gripping surface shall be continuous and located 34 in to

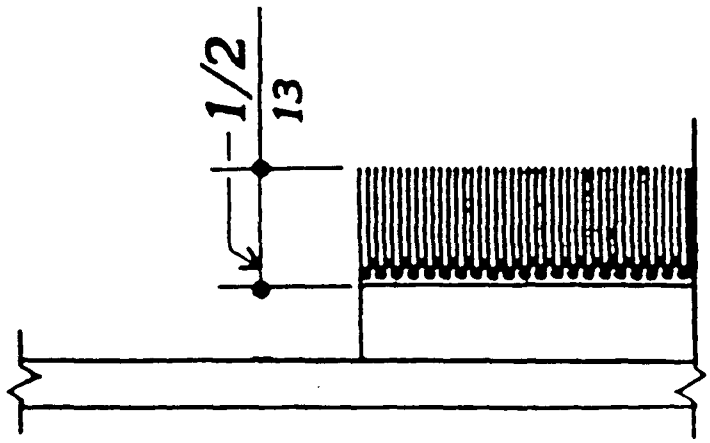


Figure 7. Carpet pile thickness (ADAAG, 1991, § 4.5)

38 in. above the ramp. 1-1/2 in. clear space is required between the handrail and the wall. Ends of the handrails shall be either rounded, or returned smoothly to the floor, wall, or post. Handrails shall not rotate within their fittings. Size and spacing of handrails and grab bars is shown in Figure 8.

<u>Stairs</u> (ADAAG, 1991, § 4.9)

On any given flight of stairs, all steps shall have uniform riser heights and tread widths. Stair treads shall be no less than 11 in. wide. Nosings shall not be abrupt. The radius of curvature at the leading edge of the tread shall be no larger than 1/2 in. The under side

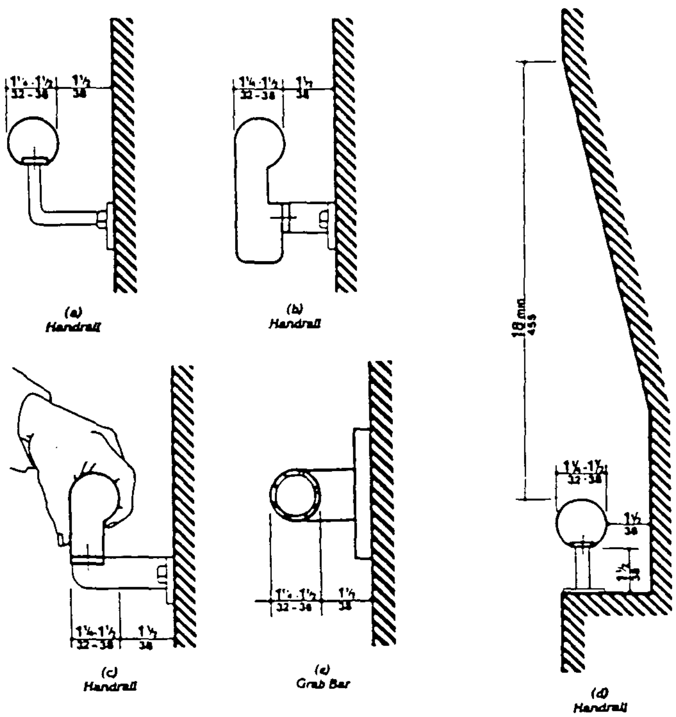


Figure 8. Size and spacing of handrails and grab bars (ADAAG, 1991, § 4.8.5)Stairs (ADAAG, 1991, § 4.9)

of the nosing shall have an angle not less than 60 degrees from horizontal. Nosings shall not project more than 1-1/2 in. as is shown in Figure 9.

<u>Handrails</u> (ADAAG, 1991, § 4.9.4)

Handrails shall be continuous along both sides of stairs. Handrails shall extend 12 in. beyond the top riser and 12 in. and the width of one tread beyond the bottom riser. The clear space between the handrails and the wall shall

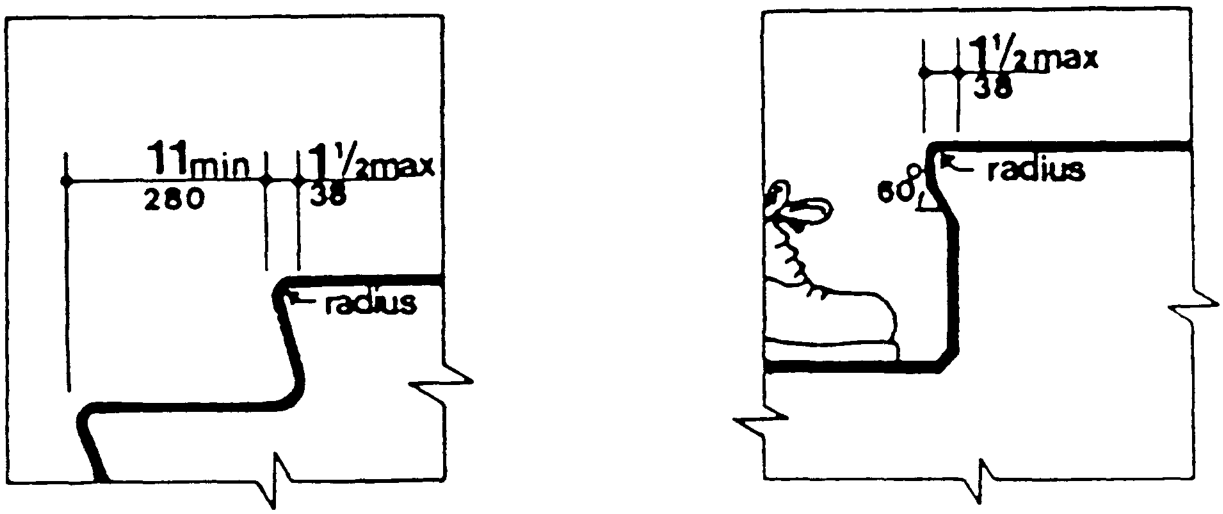


Figure 9. Acceptable nosings and tread widths (ADAAG, 1991, 4.9)

be 1-1/2 in. Gripping surface shall be mounted between 34 in. and 38 in. above stair nosings. The ends of handrailings shall be either rounded, or return smoothly to floor, wall, or post. Handrails shall not rotate within their fittings.

<u>Thresholds at Doorways</u> (ADAAG, 1991, § 4.13.8)

Exterior sliding doors must have thresholds that do not exceed 3/4 in. in height. Other types of doors should have thresholds no greater than 1/2 in. Raised thresholds at doorways shall be beveled with a slope no greater than 1:2.

Door Closers (ADAAG, 1991, § 4.13.10)

Door closers shall be adjusted so that from a 70 degree open position it will take the leading edge of the door 3 seconds to move to a point that is 3 in. from the latch.

Automatic Doors and Power Assisted Doors (ADAAG, 1991, § 4.13.12)

Automatic doors shall not open to back check faster than 3 seconds and shall require no more than 15 lbf. to stop door movement.

Water Closets (ADAAG, 1991, § 4.16)

The height of the water closet measured from the floor to the top of the toilet seat shall be 17 in. to 19 in. Grab bars shall comply with the length and positioning of those shown in Figure 10. Flush controls may not be more than 44 in. above the floor. Toilet paper dispenser shall be installed within reach.

Lavatories and Mirrors (ADAAG, 1991, § 4.19)

The height of the counter or rim of a lavatory should not be more than 34 in. above the floor. There should be a clearance of 29 in. below the bottom of the apron. Knee clearance must be at least 30 in. wide and 19 in. deep. Knee and toe clearance shall comply with Figure 11. A minimum floor clearance of 30 in. by 48 in. shall be provided in front of the lavatory to allow front approach. Hot water and drain pipes under lavatories

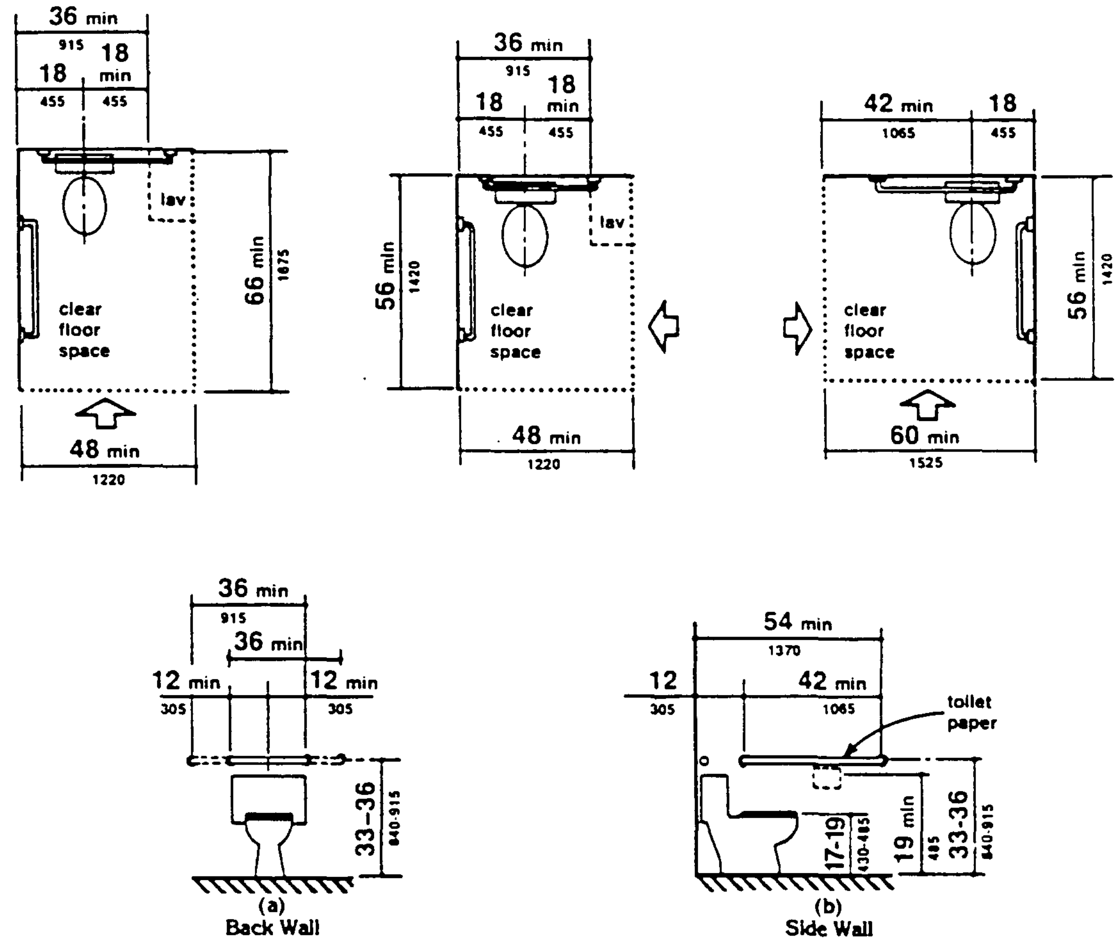


Figure 10. Grab bars at water closets (ADAAG, 1991, § 4.16)

shall be insulated or configured to protect against contact. There shall be no sharp or abrasive surfaces exposed under lavatories. Faucets shall be lever operated, push-type, and acceptable electronically controlled mechanisms. The maximum sink depth is 6-1/2 in.

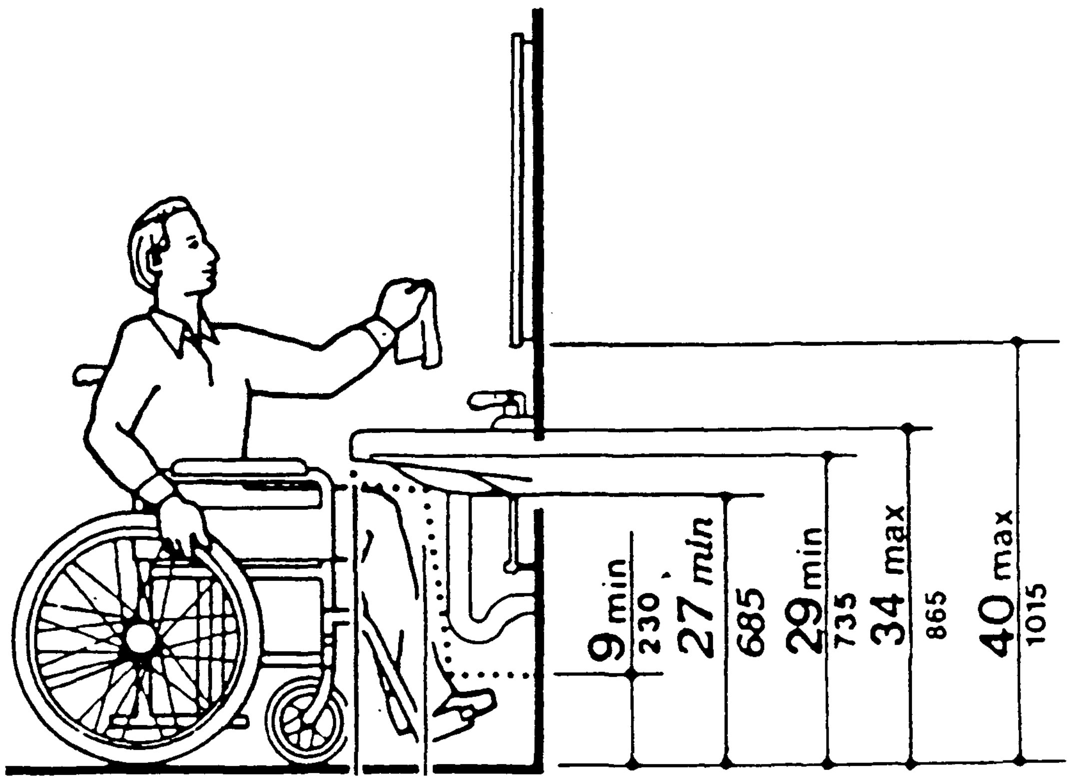


Figure 11. Lavatory and mirror mounting heights (ADAAG, 1991, § 4.19)

Mirrors (ADAAG, 1991, § 4.19.6)

The bottom edge of the reflecting surface of a mirror may not be mounted any lower than 40 in. above the finished floor.

Shower Unit (ADAAG, 1991, § 4.20.6)

The shower spray unit should have a hose at least 60 in. long that can be used both as a fixed shower head, and as a hand held shower unit.

Shower Stalls (ADAAG, 1991, § 4.21)

The minimum shower stall size is 36 in. by 36 in. A seat shall be provided which extends the full depth of the stall which is shown in Figure 12. It shall be mounted 17 in. to 19 in. above the bathroom floor. The fixed seat shall be placed on the wall opposite the controls. Where a fixed seat is provided in a 30 in. by 60 in. minimum shower stall, it shall be a folding type and it shall be mounted on the wall adjacent to the controls.

<u>Grab bars</u> (ADAAG, 1991, 4.20.4)

Grab bars in showers and baths will comply with Figures 12 and 13.

<u>Curbs</u> (ADAAG, 1991, § 4.21.7)

Curbs in shower stalls 36 in. by 36 in. shall be no higher than 1/2 in. In shower stalls 30 in. by 60 in. or larger no curbs are permitted.

<u>Shower Enclosures</u> (ADAAG, 1991, § 4.21.8)

If provided, enclosures for shower stalls shall not obstruct controls or obstruct transfer from wheelchairs into shower seats.

<u>Medicine Cabinets</u> (ADAAG, 1991, 4.23.9)

Medicine cabinets shall be located so that at least one shelf is no higher than 44 in. above the floor.

<u>Size and Spacing of Grab Bars and Handrails</u> (ADAAG, 1991, 4.26.2)

The diameter or width of a grab bar shall be between 1-

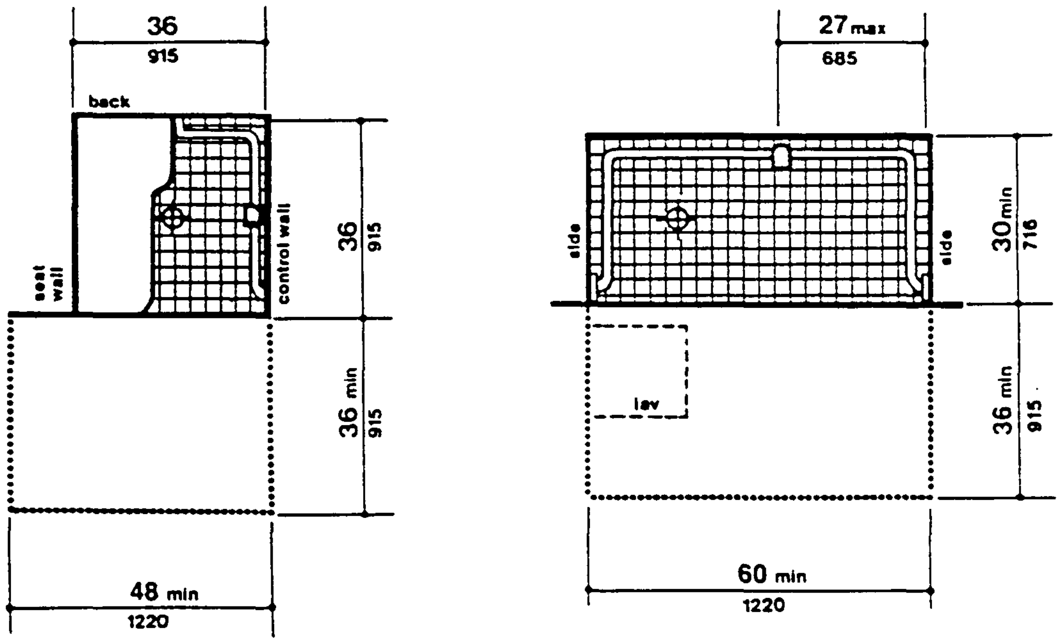
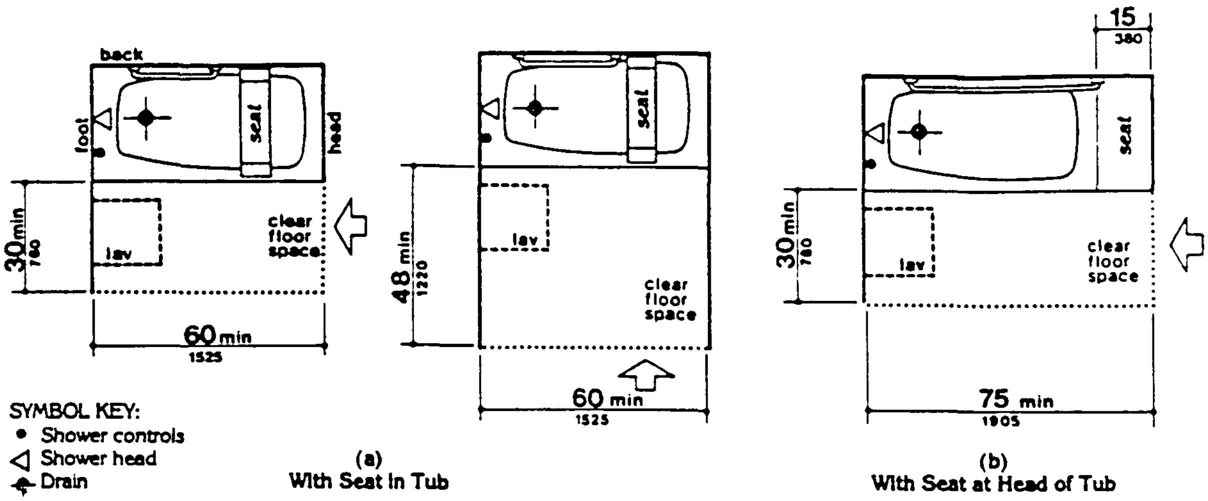


Figure 12. Minimum shower stalls (ADAAG, 1991, § 4.19)

1/4 in. and 1-1/2 in. The space between the grab bar and the wall shall be 1-1/2 in. Handrails may be located in a recess if the recess is a maximum of 3 in. deep and extends at least 18 in. above the top of the rail. Examples are provided in Figure 8.

<u>Structural</u> <u>Strength</u> (ADAAG, 1991, § 4.26.3)

Bending stress in a grab bar or seat induced by a maximum bending moment from the application of 250 lbs shall be less than the allowable stress for the materials of the grab bar or seat. The shear force induced in the fastener or mounting device from the application of 250



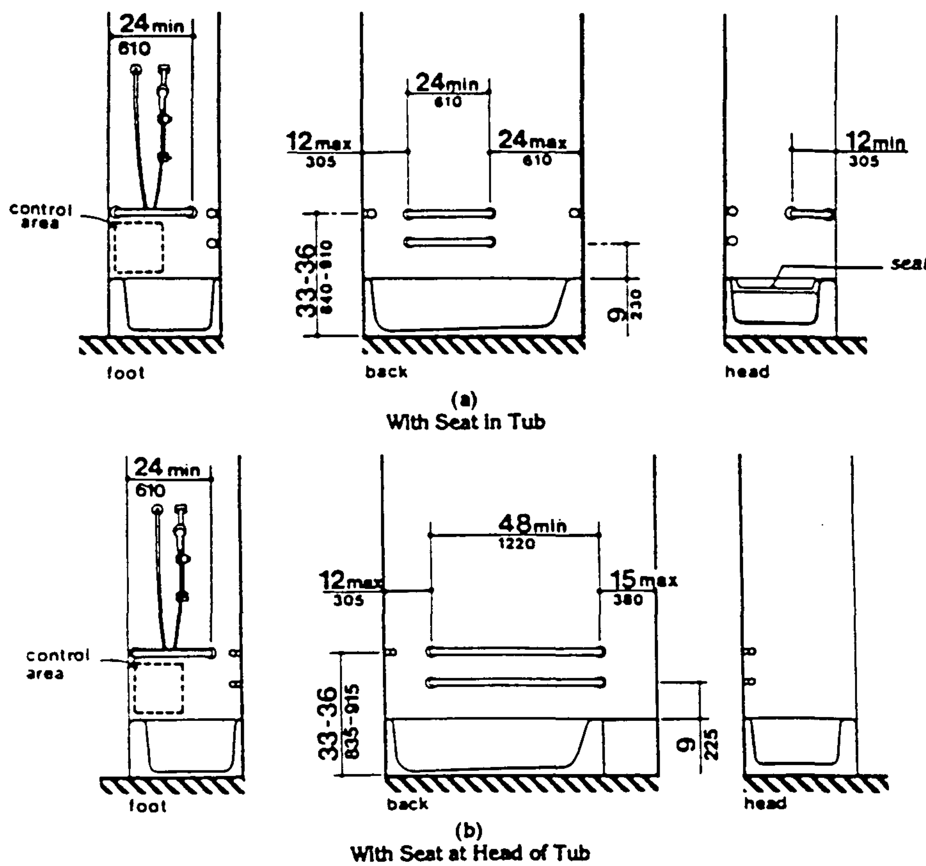


Figure 13. Clear floor space and grab bar positioning for bathtubs (ADAAG, 1991, § 4.20.4)

lbf. shall be less than the allowable lateral load of either the fastener or mounting device or the supporting structure, whichever is the smaller allowable load. The tensile force induced in a fastener by a direct tension force of 250 lbf. plus the maximum moment from the application of 250 lbf. shall be less than the allowable withdrawal load between the fastener and the supporting structure.

Controls and Operating Mechanisms (ADAAG, 1991, § 4.27)

Clear floor space allowing either a forward or parallel approach by a person using a wheel chair to controls, dispensers, receptacles, and other operable equipment must be provided. Electrical and communications system receptacles must be mounted no less than 15 in. above the floor. The highest operable part of a component must be located within the specified maximum forward and side reach of a wheelchair occupant as previously stated in sections 4.2.5 Forward Reach, and 4.2.6 Side Reach.

Audible Alarms (ADAAG, 1991, § 4.28.2)

Audible emergency alarms shall produce a sound that exceeds the prevailing equivalent sound level in the room or space by at least 15 dbA or exceeds any maximum sound level with a duration of 60 seconds by 5 dbA, whichever is louder. Sound levels of alarm signals shall not exceed 120 dbA.

<u>Visual Alarms</u> (ADAAG, 1991, § 4.28.3)

Visual alarm signal appliances shall be integrated into the building alarm system. If single station audible alarms are provided then single station visual alarm signals shall be provided. Visual alarm lamps shall be a xenon type or equivalent. The color shall be clear or nominal white. The maximum pulse duration shall be two-tenths of one second with a maximum duty cycle of 40 percent. The intensity shall be a minimum of 75 candela. The flash rate shall be a minimum of 1 Hz and a maximum of 3 Hz. The appliance shall be placed 80 in. above the highest floor level within the space or 6 in. below the ceiling, whichever is lower.

<u>Hearing Aid Compatible and Volume Control Telephones</u> (ADAAG, 1991, § 4.31.5)

Telephones shall be hearing aid compatible. Volume controls, capable of a minimum of 12 dbA and a maximum of 18 dbA above normal, shall be provided in accordance with 4.1.3. Telephones shall have push button controls. The cord from the telephone to the handset shall be at least 29 in.

If the United States as a nation is going to be able to house the growing numbers of elderly individuals in this country, we are going to have to start building homes that are designed with a higher level of accessibility in mind.

Granted we are going to have to increase production of various specialized elderly housing such as residential care facilities, skilled nursing facilities, and life-care retirement centers, but by simply designing with accessibility in the backs of our minds we will be able to drastically cut this number down. We will create a housing market capable of satisfying the needs of the particular group of elderly individuals that desire to live independently.

It seems like very important issues aren't recognized as being important by the majority until a time of crisis. At that time it's too late to fully develop a plan that will effectively solve the problem at hand, because the problem has become too large. We must be able to analyze our current aging situation and pass policies at the government level that will enable us to prepare for such a crisis in advance.

With an idea as simple as making sure that everything we design is designed to a degree that easily accommodates the changing individual, we can eliminate having to rebuild an enormous amount of structures because the previous ones have become inadequate. A large percentage of elderly individuals in a population should also result in a larger percentage of dwellings capable of accommodating these individuals. We should implement standards that will increase the production of the type of structures that can be easily modified to meet the needs of an aging or disabled individual. By requiring new homes to conform to the same level of accessibility as our current public structures do, or at least be able to adapt to such conditions, we can consistently produce an intelligent architecture that looks towards the future.

II. TECHNOLOGY: SMART HOUSE

What is Available Now

The technology that is required to make Smart Houses possible is here now, and very soon it will be made available to the public. I believe it will gain public acceptance in much the same manner that the last major technical innovation to hit the housing market did in the 1960's. During the 1960's, air conditioning became a very powerful marketing tool in the housing industry. Now it is something that is second nature or expected in a dwelling.

When first introduced, air conditioning was considered a luxury for the elite. Soon after, it started appearing in the homes of the middle class. Now, you wouldn't even consider building a new home without centralized air. It's expected. We have been accustomed to having it and now it's just assumed that all new structures will be equipped with air conditioning. It's become standardized because once Americans were exposed to it and could see (or rather feel) the benefits of it, they placed a very high value on it. This technology that was once a status symbol for the elite, is now a cultural norm that everyone can attain. I believe that smart house technology will be accepted by the public in the same fashion as air conditioning was when it was first introduced.

When the implementation of smart house technology actually becomes a reality all depends on how long it takes various product manufacturers to organize and develop a universal system that can coordinate and accommodate all the products of interested parties. Right now, most appliance manufacturers aren't willing to invest a large amount of money into product development until they are sure that the entire smart house concept will fly with the American public.

The Smart House Development Venture Inc., located in Upper Marlbor, MD was founded in 1984 and is supported by the National Association of Home Builders. David MacFadyen, the president of the NAHB Research Foundation is credited with the creation of the Smart House venture. MacFadyen insists, "Our intent wasn't to do a Smart House per se but to rethink how houses are built so that utilities and product manufacturers could do a better job of satisfying their customers. That is really the concept - a focal point for bringing everybody together. We simply designed a process that appears to be working well" (Taylor, 1986, p.7).

In the latter part of 1984, MacFadyen invited over 100 manufacturing firms, trade associations, and government

Smart House Product Contributors

*AMP, Inc.	Dynamic Computer Products Inc.	Northern Telecom, Inc.
Apple Computer	Eaton Corporation	*Onan Corporation
*AT&T Network Systems	Electromatic Controls Corp.	*Pioneer Electronics (USA) Inc.
Belden Wire & Cable	Emerson Electric Co.	Polk Audio, Inc.
Bell Northern Research	EPE Technologies, Inc.	*Robertshaw Controls Co.
Black & Decker (U.S.) Inc.	Federal Pioneer Ltd.	Sanyo Fisher (USA) Corp.
Blonder-Tongue Laboratories, Inc.	Gas Research Institute	Schlage Lock Company
Bose Corporation	General Electric Company	Sharp Electronics Corp.
BRIntec Corporation	Honeywell Corporation	Siemens Energy and Automation
*Broadband Networks, Inc.	Integrated Communication Syst.	Southwire Company
Broan Manufacturing Company, Inc.	*Interior Piping Systems, Inc.	Square D Company
Burndy Corporation	JAE Electronics, Inc.	Teknika Electronics Corp.
C-COR Electronics, Inc.	Johnson Controls, Inc.	Teledyne Laars
*Canada Wire and Cable Ltd.	Kenwood U.S.A. Corporation	Toshiba America, Inc.
*Carrier Corporation	Kohler Company	Tri-Star Electronics, Inc.
Challenger Electrical Equip.Corp.	Landis & Gry Metering, Inc.	TRS International, Inc.
Computest, Inc.	*Lennox Industries, Inc	*Water Heater Innovations, Inc.
Domestic Automation Company	Molex Incorporated	Whirlpool Corporations
Double Energy systems	Morse Security Group	*Wiremold Company
*Ducane Industries	Nec Home Electronics (USA) inc.	X-10 (USA) Inc.

* Denotes Companies that have signed Research and Licensing Agreements as of 12/29/89.

Figure 14. Manufacturers involved in the Smart House Project

agencies to talk about coordinating and designing a common technical standard for their next-generation products.

Project manufacturers were allowed to buy into the venture. At this point, each manufacturer has access to the protocols that are necessary to develop a multitude of products that will work within the system. By coordinating the development of these products, the 142,000-member NAHB with its extensive network of builders, manufactures, and state trade associations, would be capable of promoting Smart House technology and products to a wide range of interested consumers (Taylor, 1986, p.7). A list of manufacturers that have signed research and development agreements with the Smart House Development Venture and have agreed to develop and produce products and appliances for Smart House are listed in Figure 14.

According to Taylor Moore, a writer for the EPRI Journal,"The goal of the Smart House Development Venture is nothing less than the total integration of microelectronics and power semiconductors into the fundamental design and construction of most of the 1.6 million new homes built annually at the current rate." That is a pretty hefty goal to say the least, but one that is obtainable if the different technologies can be coordinated and these products can be made marketable before the products of the competitors flood the market.

Right now, there are a number of companies that are coming out with their own home automation systems which integrate a variety of products. Many of these systems operate on a conventional wiring system. As the various companies that are manufacturing intelligence systems for the home are discussed, I will refer to the ones produced by the Smart House Venture Inc. as a Smart House system. All other products or systems that are being developed by competitive companies will simply be referred to as home automation products or systems, so that they are not confused with the ones that are being produced by the Smart House Development Venture Inc.

Conventionally wired home automation systems work great for certain applications, but they usually are limited as to what they can do. Often they are only compatible with products that are designed by the same manufacturer. For instance, a person could install a system that coordinates home entertainment, lighting, and security. Once these systems have been installed he/she may want to later add a system to control heating, ventilation, and air conditioning. To do so he/she would once again have to rewire the house which is a very expensive undertaking. Chances are the two systems might not even be compatible. I have provided a list of products that are being manufactured by various companies that are members of the Smart House Venture Inc. in Figure 15.

I believe that the Smart House system being researched by Smart House Venture Inc. is the best system being developed because it truly looks towards the future. The system takes

Products being developed by various Smart House affiliated manufacturers

New gas systems development	American Gas Association
Hybrid cable	AMP Incorporated
Cable Tap	AMP Incorporated
Switch/sensor outlet	AMP Incorporated
Control panel	AMP Incorporated
Wall switch	AMP Incorporated
Telephone gateway	AT&T
Coax Headend	Broadband Networks, Inc.
Hybrid Cable	Canada Wire and Cable Ltd.
Gas furnace	Carrier Corporation
The hydrotech 2000 Heat Pump	Carrier Corporation
Home zone controls	Carrier Corporation
Remotely controlled gas grill	Ducane Industries
Electric utility gateway	Elect. Power Research Institute
Gas systems and product testing	Gas Research Institute
Semirigid gas piping	Interior Piping Systems, Inc.
Heat pumps	Lennox Industries, Inc.
Air humidifiers	Lennox Industries, Inc.
Central air conditioners	Lennox Industries, Inc.
Forced hot air heating systems	Lennox Industries, Inc.
Power generation system	Onan Corporation
Transfer switch	Onan Corporation
Uninteruptable power supply	Onan Corporation
Entertainment (coaxial) adaptor	Pioneer Electronics (USA) Inc.
Gas easy-connect outlet	Robertshaw Controls Company
Whole house shutoff valve	Robertshaw Controls Company
Gas branch controller	Robertshaw Controls Company
Water heater	Water Heater Innovations, Inc.
Wire Management Hardware	The Wiremold Company

Figure 15. Products being developed by smart house affiliated manufacturers

into account what the conditions of the absolute best housing situation would be, and then it tries to achieve it. For instance, although designing a completely different wiring system may really slow down the public's acceptance of such a system, the long term effects of integrating such a system into housing are tremendous. First, it's much safer than any of the current systems being developed that utilize the conventional wiring systems because there isn't constantcurrent running through the wiring. Secondly, it's capabilities of integrating more different kinds of products far surpasses that of any of its competitors. It's simply a better system than any current form of home automation.

Home automation systems that are currently on the market offer immediate gratification, but their capabilities are not as great as the Smart House system, nor are they as safe. Thousands of fires and approximately 400 deaths due to electric shock are caused annually by conventional wiring systems (Taylor, 1986, p.7). The smart house wiring system would virtually eliminate these needless deaths because the system does not energize a line until the product requests power. No current runs through the electrical circuit until an appliance is turned on. If there is a malfunctioning appliance, the Smart House system will sense it and immediately stop the flow of current thus reducing the chance of fire (Taylor, 1986, p.7).

Wiring system

In order to make a house smart, intelligent, or automated, all of which mean the same thing, an innovative wiring system must be installed at the heart of the system. This is the most important step to take when designing a potential intelligent structure, because it enables the owner who may currently be on a tight budget and considering the technology to convert to an automated system at a later date without having to totally rewire the structure. A building which is wired to accommodate smart house technology is known as a "smart ready" structure.

The Brintec corporation produces an integrated wire product known as brand rex cable or tricon. One bundle contains conventional wire for power, one twisted pair for digital and analog communications, and a coaxial cable for audio visual signals. This cable cuts down on both labor and wire clutter. If smart house wiring were to be standardized and modularized, one would eliminate the need to custom design various components.

Safety This wiring system is safer than conventional wiring systems because the outlets are not energized until an appliance is plugged in and "requests" power from the controller. A twelve volt signal lets the controller know exactly how much power is needed. The signal is sent through ordinary 120/240 volt wiring. This smart house wiring system allows the appliances to actually communicate with the controller. Low voltage wiring can be incorporated into a smart house wiring system at a cost far cheaper than the usual 120/240 volt wiring (Stein, 1989, p.72). A frequently requested amount of voltage for many of these new products will be 48 volts, since that's what many DC motors run on. DC motors also provide greater efficiency, result in smaller sizes, offer more versatility in speed control, and produce less noise than the present motors which operate on 120 volts AC (K. Smith, 1986, p.102). Therefore products which incorporate DC motors will be more efficient. A transformer, however, is required to convert alternating current to direct current.

Controller

Now that we've discussed the pathways over which energy and information will be sent, it's time to analyze the two remaining major components of a smart house system, the controller and the appliances. Smart houses are run by microprocessor-based automated systems that control security, lighting, and energy systems. Components of an automated home system provide computerized control of lights, appliances, security devices, and mechanical systems. The major components of the system are a central processing unit (CPU), and a cathode ray tube (CRT), a touchscreen. There are several devices that are wired into the CPU, such as remote entry keypads, motorized dampers, switches and sensors (Stein, 1989, p.72).

To get an idea how a typical system works let's look at the CPU that's been installed in a mountain top house designed by Residential Systems Inc., a Denver based company. The automated system that's been installed here is called the Home Manager, (Unity Systems Inc., 2606 Spring St., Redwood City, Calif. 94063). The CPU in this system is approximately 14in. x 34in. x 7in. deep. It also contains a battery backup. A touchscreen can be placed in a furred out wall that is at least a foot deep. It should be located in a frequently traveled area of the house for convenience. The occupant controls the CPU by touching the screen of the CRT or by using a touch tone telephone as a remote (Stein, 1989, p.72).

One of the things a CPU can control is the temperature for each individual room in the house. To change the temperature of the living room the occupant must first touch the living room floor plan that appears on the touchscreen. The central computer contains a facsimile of each floor plan stored in memory. The times and temperature selections for that zone are also displayed. There are six different temperatures displayed for the week days and six more for the weekends in this particular house. By touching the video key pad for the appropriate time and day, one can revise the temperature in the computers memory. Each display relates only to the function in question and clearly explains all of the options (Stein, 1989, p.72). It is very easy to use.

Sensors

Another way that the CPU can receive information is through the many sensors that are located throughout the house. Sensors can be used to detect many different things in the house. Automated dampers on the ductwork of this mountain home can be used to create 12 climate control zones. The dampers are wired to the home manager, as are the sensors that detect the temperature in each given temperature zone (Stein , 1989, p.75).

There is a radiant floor system consisting of polybutylene piping in the concrete of the kitchen floor that is tied into the hydronic boiler through a small pump in the mechanical room. Sensors connected to the Home Manager detect a drop in the kitchen temperature and turns on the pump. Boiler water and return cool water are mixed to a temperature of 120 F. On cold mornings when the floor can't keep up with its heating requirements, dampers automatically open and allow forced air into the kitchen (Stein, 1989, p.76).

The living room has a special heating system as well. When the temperature in the living room starts to drop, the forced air system is activated. Should it be so cold that the room temperature drops 2 F below the thermostat setting therma-ray electric radiant wall panels heat up and assist the forced air system maintain a constant temperature (Stein, 1989, p.76).

Security systems

Sensors can also determine the amount of pollutants in the air (Stein, 1989, p.76). They can check for carbon monoxide and radon levels and determine when fresh air is needed for ventilation. A louver on the shaded side of the house is then automatically opened by the central processing unit allowing cool fresh air to enter the house. Humidity sensors can be placed in the laundry, the master bedroom, and the spa to detect unwanted moisture. This moisture could be circulated with the air in the rest of the house or simply disposed of during a ventilation cycle. The ceiling could contain dampers that open when the house becomes pressurized, thus allowing unwanted heat to escape (Stien, 1989, p.76).

Sensors are also used in security systems. The two basic kinds of sensors that are used in security systems today to detect occupancy and motion are called infrared sensors and ultrasonic sensors. Infrared sensors can detect changes in the ambient heat pattern of a particular room as a person passes through it (R. Smith, 1988, p.110). The actual heat that is given off by a person's body when entering a monitored room is detected by the infrared security sensors. In this case the detection of an intruder is determined solely by the change in the amount of heat present in the room. The second type of sensor typically found in security systems is called an ultrasonic sensor. An ultrasonic sensor emits high frequency sound waves that produce echoes as they reflect off the surrounding walls and objects and return to the sensor. These sound waves are then analyzed by the system for irregularities that are caused by a moving object (R. Smith, 1988, p. 112).

There have been some horror stories about alarms being set off at all hours of the night by pets walking across the livingroom. I'd like to reassure you that most of the systems that come out today are far too sophisticated to allow that to happen. For instance, a system composed of ultrasonic motion sensors now includes a directional setting that enables the owner to detect only the motions that occur a few feet above the floor plane, thus leaving a shallow zone along the floor where pets are free to roam (R. Smith, 1988, p. 112). Likewise, infrared sensors require a certain amount of heat to trigger the alarm system. The amount of heat produced by a pet would not be a sufficient amount to set off these very sensitive alarms if programmed correctly. Frequently security systems are composed of both of these types of sensors used in combination with one another to insure that a flaw or malfunction in one system will not result in a false alarm (R. Smith, 1988, p.112). In this situation, both systems must indicate the presence of an intruder before any action is taken. These sensors are connected directly to the Home Manager by low voltage wire.

The security system just described can detect an intruder once he is in a particular household. Many security measures can be taken to ensure that the intruder does not get this far. For instance, magnetic contacts can be installed in doors and widows that set off an alarm when the passage of current along a circuit is broken. Seismic detectors that can actually detect the vibrations of broken glass can be placed on windows throughout the house (Stein, 1989, p73). Heat and motion detectors can be placed outside the house and simply turn on exterior lights in response to an approaching visitor.

After a system of detection has been decided upon, the smart house security system must be programmed to respond to a

1. Audio alarms
2. Flashing lights
3. Call police/Recorded response
4. Voice simulated recognition of intruder
5. Restricted access

Figure 16. Security system responses

break-in. as is shown in figure 16. This response depends on both the sophistication of the system, what it is capable of doing, and the desires and needs of the client. For instance, the owner may want to inform the intruder that he has been detected by simply programming the security system to flash lights and sound an alarm in the room that the intruder is detected in (R. Smith 1988, p. 113). The system may be programmed to also call the police with either a previously recorded message or a voice simulated message informing the proper authorities of the break-in. The intruders could also be informed simultaneously by the security system of their detection and notified that the police are on their way (R. Smith, 1988, p.113).

There is one common response to a break-in that I believe could cause more harm than good, because they reveal the location of the owner of the home. Some systems are programmed to turn on the lights in the master bedroom in conjunction with the many other responses it has. Although this may wake up the owner of the house and let him know there has been a break-in, it also lets the intruder know exactly where the owner of the house is. And depending upon what kind of intruder is present in the house, a simple burglar or a deranged killer, one might not want their whereabouts to be so easily accessible. Perhaps another way of notifying the owner of the particular circumstances should be devised. Perhaps if the alarms were sounded in every room in the house, the owner would be awaken and informed by the alarm that a break-in has occurred, yet his where abouts would still be concealed.

Another security system can be programmed to let only certain people into the house at certain times of the day, when no one is at home. A keypad can be mounted outside the front door that will enable a visitor to enter the house provided he/she knows the correct code required to open the door. A service person, for instance, could be issued a code that allows him/her entrance only during a certain time of the day (Stein, 1989, p.73). Family members, on the other hand, would be given a completely different code that works all hours of the day.

As far as fire security goes, the smart house systems will take many steps in response to a fire as illustrated in figure 17. Most systems will turn off the forced air systems and natural gas supplies, set off an alarm, call the fire department, and light exit routes automatically. All the occupant has to do is get out of the house. Everything else

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1. Audio alarm
2. Light exit routes
3. Turn off furnace and natural gas supplies
4. Call fire department/Recorded response
5. Activate sprinkler

Figure 17. Fire security responses

is taken care of.

Security systems that not only detect the problem, but stop it to minimize damage, are called "active" security systems. Another example of such a system is a water sensor located under a spa that not only sounds an alarm after discovering a leak, but also automatically shuts off the water to minimize damage (Stein, 1989, p.73).

The same principle could be applied to a sprinkler system. When the house acknowledges that a fire has been fully extinguished, the water could automatically be turned off, thus minimizing water damage. The only possible problem with such a system would be if the sensors insisted that a fire was out when in actuality it was only temporarily extinguished. The amount of time that it takes for the sensors to acknowledge this new combustion and the possible damage that could occur in the meantime, may out weigh the amount of water damage that the house would have been subjected to if the water would have been allowed to run continuously. As you can see, it would take very sophisticated sensors to determine the point when the fire was truly out and the water could be shut off to minimize damage. There must be a fine line drawn to perfect this system.

Appliances

Lets consider how the available products would function in the Smart House system. Ideally, according to the National Association of Home Builders' Research Foundation (NAHB/RF), each appliance designed to be incorporated into the smart house system would have a silicon chip that identifies the product and prescribes the amount of current required by the appliance. A 12 volt signal will let the controller know how much power is needed, whether it be gas or electric. One example request may be 120 volts AC at 5 amperes (K. Smith, 1986, p.104). The controller in turn would determine authorization to distribute current to the appliance. If there were no restrictions made, the appliance would be energized as soon as it was turned on to be used. The owner, on the other hand, could at any time program the controller to restrict the use of any particular appliance in any outlet, during any period of time. For instance, perhaps a mother doesn't want her children to come home from school and cook on the range before she gets home from work. She could simply program the controller to reject any request made by an appliance for power that is made by the range between 9:00 AM - 5:30 PM (R. Smith, 1988, p. 110). This way the young children would not be tempted to cook on the range without adult supervision and the mother would not have to come home to a mess in the kitchen and a house full of children whose dinner has been spoiled.

Because the smart house's unique wiring system allows a product to communicate through the controller to any other product in the system, stereo speakers and telephones could simply be plugged into any outlet. Speakers that were plugged into an outlet upstairs would be able to communicate with a stereo in the basement without installing any additional wiring (R. Smith, 1988, p.49). A telephone conversation would also have to pass through the controller along the same bundle of wire that supplies power to each individual outlet and to the appliances within the house.

Present day appliances would not have to be abandoned in this Smart House. In order to implement these products into the system, however, an adapter would have to be used which would request the usual 120 volts of AC that is presently required. This adapter would be necessary because present day appliances don't contain the necessary silicon chips that it takes to communicate in this system (R. Smith, 1988, p. 62). The two prong plugs would not work in these intricately designed multiprong outlets.

Although the technology exists to produce products that work within the Smart House system they must be coordinated in a way that every appliance is compatible with every other. The more sponsors Smart House Venture Inc. has working on product development, the more likely they will be able to catch any flaws in the system before it is released to the general public. By testing a variety of different types of products with the Smart House wiring system, they can be sure that similar products that might be developed later by other product manufacturers according to certain Smart House specifications will work with the system.

What is Becoming Available

Voice synthesis

Smart House Venture Inc. is in the process of incorporating voice synthesis into their dwelling designs as a safety device for elderly people. Through the use of voice synthesis, such as is presently being used in the time-of-day information we've all heard on telephone networks, the smart house system can talk to its occupants. In the case of an emergency, such as a fire, this simulated voice could give instructions to the elderly informing them of the shortest means of egress from the building. Because the system is able to detect the location of the elderly individual within the dwelling, it could actually give the individual step by step directions as he/she proceeds closer to the exit. Even small things that could become hazardous, like leaving the stove on could be detected by the system and indicated to the occupant through the use of voice synthesis.

Appliances

There are several products that have been shown at consumer electronics shows that will probably be on the market at about the same time the smart house wiring system is. A stereo is coming out that is basically a smaller version of a commercial jukebox. What this stereo lets you do is play any song in your CD collection remotely. This system could be set up with a motion detector so that as the occupant moves from one room to another, the sound follows. It could also be programmed to turn itself down to a certain level when the door bell or phone rings (Teschler, 1988, p.50).

Such a stereo could function as a security system by playing a certain song if an intruder enters the dwelling after the security system has been set. Or it could play a CD of a dog barking as an individual approaches the house in an attempt to scare the intruder off. The result is an audio watch dog (Teschler, 1988, p.50).

Video technology is becoming less expensive every day. Because this is the case, items such as video picture phones may begin to be placed in various locations within the home. This may make it possible to be able to call home and check the nursery to see if there are any problems. By installing a video intercom at the front door, the owner may be able to answer the door to see who's there from his\her office (Teschler, 1988, p.50).

What is Projected to Become Available

Voice recognition

Smart House is also working on a relatively new existing technology called voice recognition. With such a system, an occupant will be able to verbally communicate with the smart house system. The first step in training this system is to have the elderly person repeat a number of words or phrases to the computer several times. The system will then memorize the word patterns of the speaker. Early systems will probably only be able to recognize the voice pattern of one speaker. The system is then programmed how to respond to given commands (R. Smith, 1988, p.115). Each word or phrase will initiate the system to react in certain ways.

For instance, suppose an elderly person were to fall and injure his/herself and was in need of assistance. The system would be smart enough to recognize a cry for help. The injured individual need only say the word, "help" to activate a voice synthesis reply by the system. This reply may be something like, "Should I call Dr, Johnson?" If the elderly person in turn answers "yes", then the computer would dial up Dr. Johnson and deliver a previously recorded message (R. Smith, 1988, p.115). This system can be a life saver.

Consciousness detection system

There has also been some testing going on to figure out how a system could monitor an individual and determine whether he/she needed help even when in the state of unconsciousness. One system talks about asking a person that has been motionless during the day for five minutes whether he/she is ok. The only problem with this is that you could continuously be waking up an elderly individual that is deliberately taking a nap. If the floor area were monitored for movement over a period of time perhaps an elderly person who has collapsed because of a heart attack could be detected.

Appliances

Washing machines and dish washers are being developed that are not only smart enough to know not to run during the peak demand hours for electricity, but also can let the water heater know how much hot water to produce for a given wash cycle. Appliances that talk to each other is definitely a futuristic idea.

III. DESIGN IMPLEMENTATION OF THE FOLLOWING

Economic Considerations

Public acceptance

The description of this barrier free smart house sounds incredible, but before people can be sold on the idea there are a number of questions that still must be answered. First of all, is it going to be made affordable to the consumer? How much more is it going to cost to construct a Smart House than a conventional house? If this system does catch on with the public, are the rewards that can be obtained from such an intelligent structure worth the additional cost to the consumer.

Let me try to answer these questions by first making some predictions about how I believe Smart House technology will obtain its gradual acceptance by the public. When Smart House Venture Inc. first makes it's system available to the public, it will be initially embraced by a certain percentage of wealthy clientele that I would like to categorize as "risk takers". These most likely will be "electronics buffs" that run out and buy any new electronic gadget that hits the market, or fairly wealthy individuals that want the latest in home comforts. They will be a group with substantial incomes that could stand to lose their entire investment should the project for some reason fall through. In other words, it will first become popular with an elite group that will recognize the potentials of such a system and will be able to afford it. This particular group of risk takers will invest in a new product that has not yet been proven on a wide spread commercial scale and which incorporates an entirely revolutionary way of wiring the home.

I believe that early adoption of smart house technology by the building industry will be a major step in the right direction for the housing industry. If you compare the developments which have occurred in the housing industry over the last thirty years to the strides made in the automotive industry, you will find that the automotive industry is continually up grading their products to a degree that has not been matched by the housing industry. Aerodynamic cars with computerized engines and voice synthesized warning systems are flooding the market. There is nothing comparable to that in the housing market today, at least not yet.

Initially the smart house system might not catch on too quickly. Just as VCR's and color TV's didn't take off right away when first introduced, the smart house concept will take a while for people to get accustomed to. As society becomes aware that the technology exists and has been proven to work, more people will become interested in trying the system out. As various smart house appliances begin appearing on retail shelves, an interest in the system will continue to develop. As more people build smart houses and live in them, more people will be exposed to their capabilities. It will get to the point where nearly everyone will want one.

Michael McGrath the director of consumer programs with Edison Electric Institute makes this prediction, "I think this is really going to happen. I'm not terribly sure when, although I'd say we're probably 5 to 10 from it really beginning to achieve market potential in any significant way. But home automation is definitely a comer" (Lamarre, 1991, p.15). Bill Bryant, treasurer of Southland Development Corporation believes that in the future "100% of new homes will be smart houses" (Lamarre, 1991, p.15).

Initially the smart house system may be on the expensive side due to the fact that there won't be very many homes being built. As these systems begin to be mass produced in various packages, the cost of the mass produced components of the system will come down. There will also be a greater number of people who know how to install the system. When this happens, the Smart House system will become very affordable. The installation of this technology will probably be all but universal within the next 10 to 15 years (Denato, 1989, p.3E).

We have a large group of people in the building industry that must be educated about the installation techniques of this new system. As architects and builders become familiar with the system and the benefits involved, they will begin to recommend the implementation of smart house wiring systems. Builders will be impressed by the simple installation techniques that minimize wire clutter.

If smart house technology under goes widespread adoption many years down the road, houses without smart house systems will greatly depreciate in value. This lower market value may make some home owners second guess their decision not to build a home with a smart house wiring system. Instead of having to buy adapters to run conventional appliances in the smart house system, these occupants may find themselves buying adapters to run smart house appliances in their archaic conventionally wired homes.

Construction costs

One of the barriers that Smart House will have to overcome if it is to be successful is one of cost. First let's consider the costs of actually wiring a smart house to achieve the "smart ready" condition. Because this smart house wiring system is standardized and modularized, the labor costs would be cut down, and the need for customized wiring designs will be eliminated. The National Association of Home Builders' Research Foundation (NAHB/RF) estimates the cost of the Smart House wiring system and controllers to be between \$2000 - \$5000 more than conventional wiring approximately 30% more than present costs). Brintec has already committed to manufacture this cable for the smart house system (K. Smith, 1986, p.103).

Experts estimate that there are currently between 5000 and 8000 whole house automation systems that have been installed in homes in the United States. A whole house automation system consists of the integration of two or more subsystems, such as entertainment, security, heating and ventilation, lighting etc. Approximately 1500 to 2000 of these systems were installed in 1990 at an average cost of \$20,000 (Lamarre, 1991, p.7). This average cost takes into consideration some very extravagant systems.

A basic core whole-home automation system typically costs at least \$10,000 - \$20,000 to install. Complicated systems in luxury homes have been known to cost as much as \$200,000. There are a lot of different whole house automation systems on the market today that are not set up to be able to communicate with a wide variety of products. Such systems are limited as to what they can do because they utilize conventional wiring systems. As the Smart House L.P. system evolves these other systems will probably become obsolete, because the Smart House system will be able to accommodate a variety of products. Until a standard is agreed upon, such as the one that Smart House L.P. is working on currently, home automation systems will continue to be expensive labor intensive products (Schott, 1990, p.39).

The core Smart House system will cost Approximately $8600 for a 2500-square-foot home. This instillation includes the smart house wiring, the outlets, and the controller but not the touch screen nor any of the appliances which the homeowner can go out and buy separately (Lamarre, 1991, p.15). Tom Gratias, the president of the Home Builders Association of Iowa, believes that the system will add approximately $7500 to the cost of "a normal house without all the bells and whistles" (Denato, 1989, p.3E).

Smart House L.P. expects to make "Smart Ready" pre-wire kits available nation wide in 1992. These kits will cost somewhere between $4,000 and $5,000 for a 2,000-sq. ft. home. Smart house outlets and other hardware needed to upgrade to "full Smart" will cost an additional $2,000 - $3,000 and will be available at about the same time (Schott, 1990, p.39).

The most inexpensive way to insure that a homeowner does not miss out on the opportunity to implement smart house technology once it is available in the market is to simply install the system in stages. A client could simply install the smart house wiring in order to achieve a "smart ready" condition. He could later activate the "intelligence" with the purchase of a controller at a time he/she can afford it. Finally, the occupant could start replacing some of his/her current appliances with smart ones as they wear out, or as he/she feels it's necessary. This scheme may be perfect for the client who is trying to build a home on a very limited budget, but knows that he\she would eventually like to convert to smart house technology as funding becomes available.

The number of smart house appliances to first appear in the market place may be very slim. Those who first build smart homes may have to use primarily conventional appliances with adapters at first while certain products are still being developed. They may be able to locate some of these hard to find products through mail order. I wouldn't think many stores would carry smart house appliances until there is a public demand for them. Until then, the smart house dweller may have to rely on regional smart house specialty shops to obtain the appliances they need.

Although typically smart appliances will probably be more expensive to the consumer than contemporary appliances, some of the major appliances may actually be cheaper because of the elimination of unnecessary components that are currently found on today's appliances. For instance, all timing devices would become obsolete because the central controller would be able to perform all the necessary timing functions for every appliance in the house. Another example of a more efficient, less costly product would be the smart house washing machine which would run on a direct current motor instead of alternating current where available. The transmissions that are required to put these machines through their different cycles could also be eliminated (K. Smith, 1986, p.103).

Many of the barrier free concepts I spoke of earlier will not cost significantly more to implement, especially when one considers the price of a new house. Structural concepts such as making doors wider or eliminating level changes will not create any additional costs for the home buyer. Creating the appropriate clear spaces is usually only a matter of planning which does not significantly effect the size of the home. Some aspects of the home, particularly in the heavily designed areas such as the kitchen and bathroom, can be made adjustable at minimal costs to the consumer.

Kitchen cabinets are one such item that can be fairly inexpensive to make adjustable to accommodate the changing needs of the occupant. As knee space is required by a wheel chair user, it is important that we develop a unit where the counter top and the cabinet storage operate independently of one another. In one particular cost study, two suppliers of cabinets in Raleigh, North Carolina were asked to estimate what it would cost to make certain variations to their conventional cabinets in order to produce an adaptable unit.

One of the suppliers was a custom cabinet shop, the other was a supplier of several lines of manufactured kitchen and vanity cabinets. The first cost comparison that was made for a removable standard base cabinet (Bostrom, Mace, Long, 1987, p.30).

The lowest price for a 30 inch base cabinet, as quoted by the custom cabinet shop was $128.00, while the manufactured cabinet price listed for $178.06. Both the custom cabinet shop and the manufacturer of stock cabinets were asked to estimate what it would cost to make the alterations necessary to produce the three type of adaptable cabinets illustrated in figure 18 (Bostrom, Mace, Long, 1987, p.30).

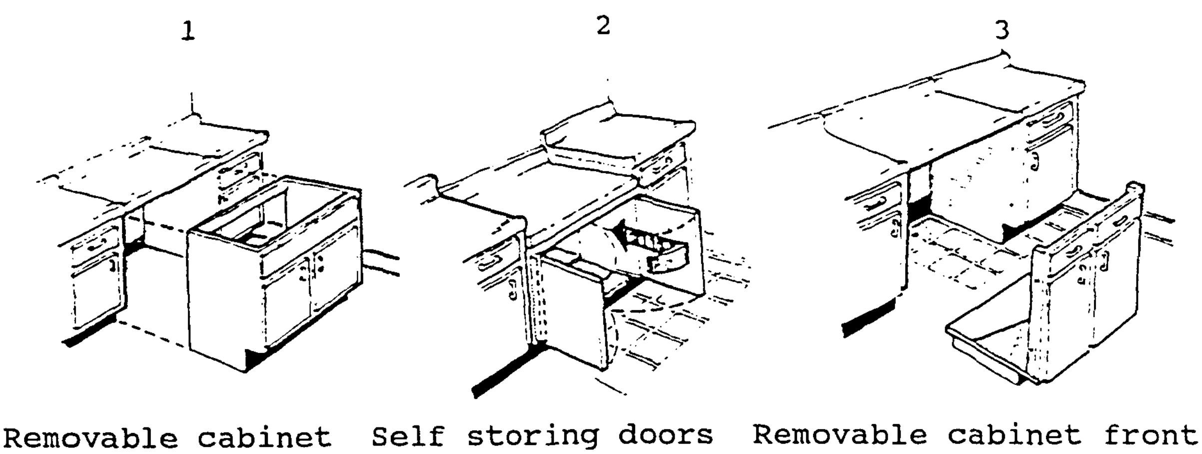


Figure 18. Three types of adjustable cabinets (Bostrom, Mace, Long, 1987, p.30)

The first removable cabinet didn't cost any more at all to produce according the custom cabinet shop, while it was quoted by the manufactured supplier to cost an additional 10%. The second type of adaptable cabinet was more expensive to build according to both suppliers. It was 81% more expensive to make than the standard base cabinet according to the custom cabinet shop, and 75% more expensive as estimated by the manufactured cabinet supplier. Most of this cost, I believe, is do to the fact that the mechanics involved in such a product are more expensive than that of the typical base cabinet. The third cabinet with a removable front and base was estimated at 14% and 10% more expensive respectively according to the custom cabinet shop and the manufactured cabinet supplier(Bostrom, Mace, Long, 1987, p.30). The estimated increase in the cost of these cabinets is shown in Figure 19.

Estimated Cost Increases for Making Cabinets Removable

	REMOVABLE CABINET TYPES		
	1 Standard base cabinet	2 Self-storing doors	3 Removable cabinet front
Custom cabinet shop	no added cost	81% increase	14% increase
Manufactured cabinets	10% increase	75% increase	10% increase

Figure 19. Estimated costs to produce the adaptable cabinets shown in Figure 18 (Bostrom, Mace, Long, 1987, p.30)

The cost to produce a variety of adjustable counter tops was also considered. These prices were compared to a standard 30 inch section of laminate counter top. The manufactured cabinet supplier declined to give an estimate because they felt it would be hard to give precise estimates without fabricating a number of counter tops first. The three methods of adjusting counter tops are shown in figure 19. Figure 20 shows the increased cost of the various methods (Bostrom, Mace, Long, 1987, p.31).

This study has shown how economically feasible it would be to produce adjustable cabinetry for the home. Although it

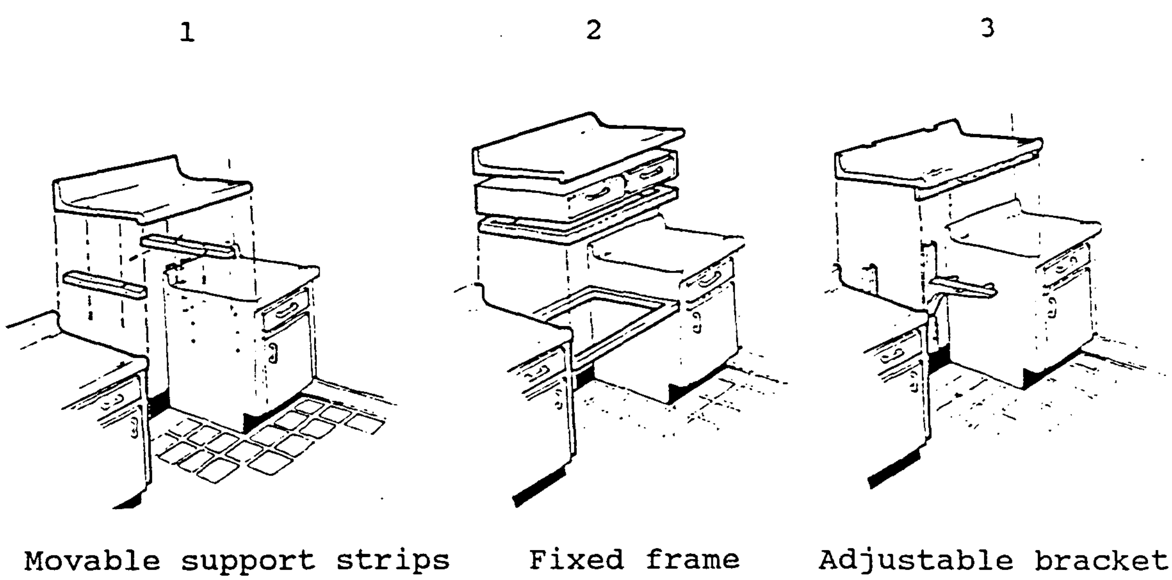


Figure 20. Three methods used to adjust counter heights (Bostrom, Mace, Long, 1987, p.31)

would be slightly more expensive to make the alterations necessary to the base cabinet to produce an adjustable unit, this foresight would surely come in handy as one goes through

	ADJUSTABLE COUNTERS		
	1. Movable support strips	2. Fixed frame	3. Adjustable brackets
Cost of standard section	$40.00	$40.00	$40.00
Cost of adaptable unit	$85.00	$60.00	$95.00
Cost increase	112%	50%	137%

Figure 21. Estimated cost to produce the adjustable counters shown in figure 20 (Bostrom, Mace, Long, 1987, p.31).

all the changes associated with aging. If these adjustable units were to be mass produced rather than alterations of existing base cabinets, they could be offered to the consumer at a price competitive with current base cabinets. Since some of these removable cabinets are actually constructed with less material than the base cabinets, they could actually be less expensive to produce depending upon the hardware required. Mass production would cut down on the labor cost of producing the adjustable product by eliminating the need to altar an existing product.

Operating costs

The implementation of smart house technology in combination with the passive solar design principle may allow these prototypes to consume less than a quarter of the energy required by an average structure of comparable size. Some of the most important factors to consider when designing an energy efficient prototype are as follows: insulation of R-19 in the walls and R-30 in the ceiling; a continuous air vapor barrier; high-performance, double-paned low emissivity windows, southern orientation with passive solar gain; minimal window area on the north; high-efficiency furnace; and landscaping which provides summertime shading on the east and west (Architecture, 1990, p.81).

Everything mentioned above is structural elements or considerations that will reduce the amount of energy required to heat or cool the dwelling. In other words, these things make up an environment where efficient living is possible. Energy usage, on the other hand, is function of the habits and activities of the occupants residing within a dwelling.

Because people live busy complicated lives, they don't have the time or the ability to constantly monitor how every activity within the home directly affects the amount of energy consumed by the home. We have more important things to do with our time. The Smart House system, however, enables us to do just that. The Smart House components actually allocate where and how energy is to be used. The system takes into consideration the life-style of the occupants as well as all economic aspects of energy usage. It considers the cost of electricity during peak hours and eliminates unnecessary energy consuming functions of the home during that period of time according to occupant specifications. Once programmed, it allows the occupant to live as efficiently as desired and make better use of his\her time.

The occupant can, therefore, program the home to use energy according to his\her personal schedule. For instance, if an occupant works from nine to five he may not feel that it's necessary to keep the temperature at 67 degrees all day long. He\she could simply program the system to reduce the temperature to 60 degrees while he's at work and heat back up to 67 degrees a half an hour before he gets off work. This way his life style is not at all effected, yet his energy consumption is reduced. He may also feel that it is very impractical to heat water during the utilities peak hours in the afternoon since he is never around during the day to use it. He could program the system to eliminate that task during those hours of the day.

The central processing unit of the smart house system could also control the temperature in each individual room. The temperature in the bedrooms, for instance, may be kept 5 degrees cooler than the rest of the house until bed time as specified by the owner. This temperature of the house may also be gradually cut back during the early morning hours as the occupants sleep, but warmed up again a half an hour before the first person is scheduled to arise. All of these scheduled temperature changes could be altered at a moments notice.

The smart house system could be programmed to turn off the lights in rooms that are not occupied. The motion or heat sensors of the security system could be used to indicate a persons presence in the room. A light being turned off in the master bedroom at a certain hour could be an indication to the system that the occupants are going to bed which activates the night time heating schedule.

High-energy-use appliances such as the clothes dryer could be programmed to run when electricity is the cheapest. The dish washer could be programmed to run at night for the same reason. The owner can override any of these restrictions at anytime simply touching the appliance on the floor plan of the touchscreen and activating the appliance.

The smart house system could be set up to periodically inform the occupants of their energy usage with the home energy management system. This could be done in a number of ways. It could be programmed to appear on the TV screen during the commercials of the nightly news. These figures could compare the energy usage on this particular day to that of the previous several days. It could also relate these energy usage figures to those on the same date from the previous several years. The system at this time could also make suggestions about what the occupants must do in order to meet the budget they had prescribed for the system for that month.

A home energy management system could tell the homeowner, down to the penny, how much energy the home is using, or how much electricity each appliance has used.

Barrier Free Design

Adaptation of the physical structure

Using the American with Disabilities Act Accessibility Guidelines or (ADAAG) as a reference, many of the barriers that currently exist in housing today have been eliminated in my elderly and disabled prototypes. By eliminating these barriers, an environment that is fully usable to many of the elderly and disabled has been established. Because of the minimal amount of square footage of interior space allotted to each project, 700 sq. ft. and 1250 sq. ft. respectively, I opted to open up the kitchen and living space to form one large community space.

House prototype Let's first analyze the floor plan of the house, as well as the interior elevations of the heavily designed spaces such as the kitchen and the bathroom. The house floor plan is shown in Figure 23.

In the house design, although the dining, living, and kitchen areas are part of one large space each space is distinguished from the others by the manipulation of ceiling

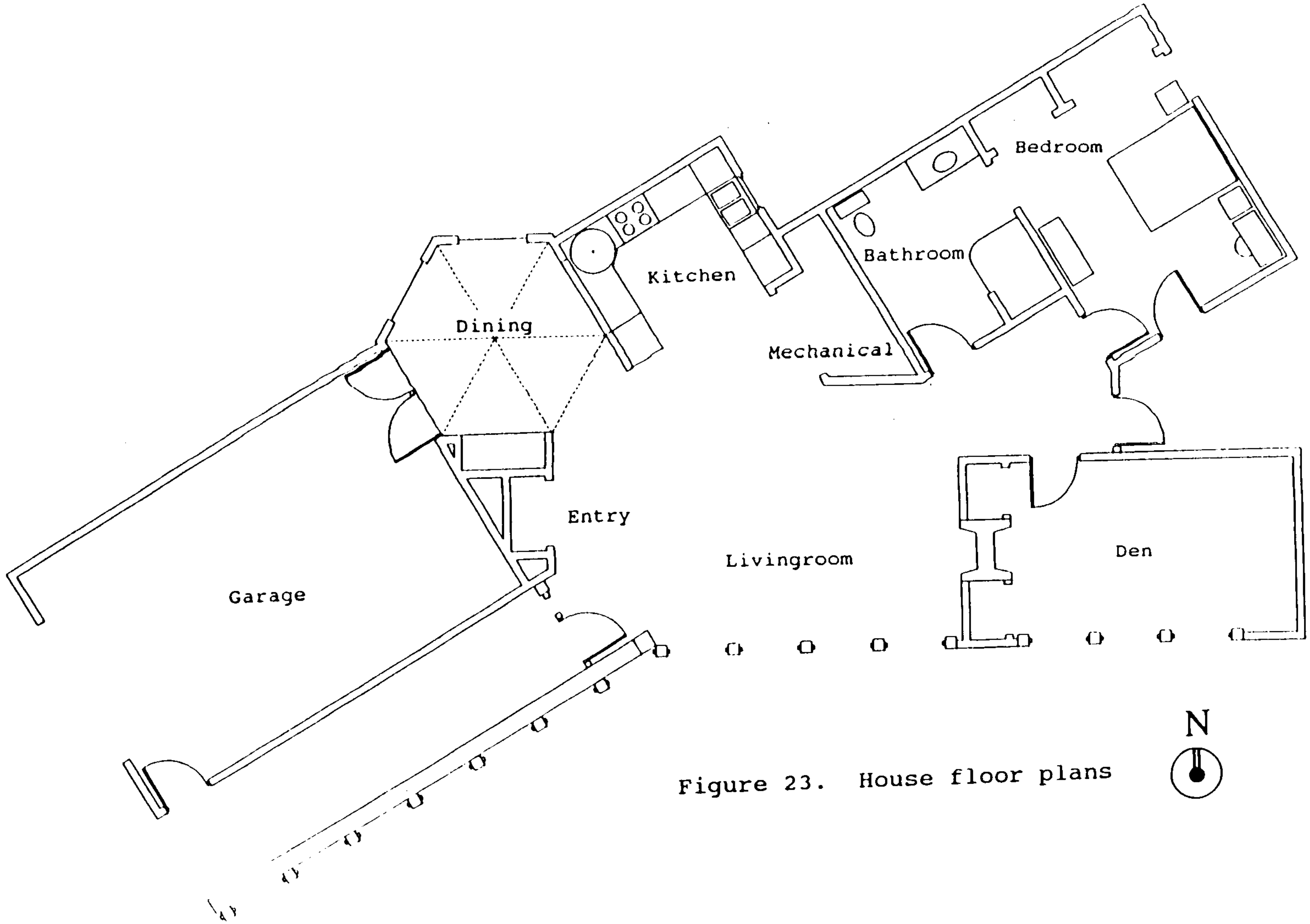


Figure 23. House floor plans

form and heights. This may be evident in the bird's-eye views of the structure in Figure 24. This way each space can have its own identity without using walls to make the divisions. In a project of this size it is important to eliminate unnecessary walls which tend to minimize the amount of perceived space within the dwelling.

All doors have a 2"-0" clear space along side the door on the swing side enabling a wheel chair user to open doors without occupying the area needed by the door swing. There is a double door from the dining room to the garage which makes moving furniture in and out of this unit particularly easy. Levers are used as opening devices on all doors.

There is a keypad located out side the front and back door. Elderly persons who have accidently locked themselves out of their apartment can gain entrance by inputting a four digit code on the keyboard. This code can be something as easy to remember as their date of birth.

The kitchen in the house has been designed to accommodate a multitude of users. It is arranged in a U shape that faces out towards the living area. This makes it feel as if it's actually part of the larger space.

The layout is also very efficient. The refrigerator, sink, and range are all located within close vicinity of one another. The food preparation cycle starts with the refrigerator and works counter clockwise around the plan of

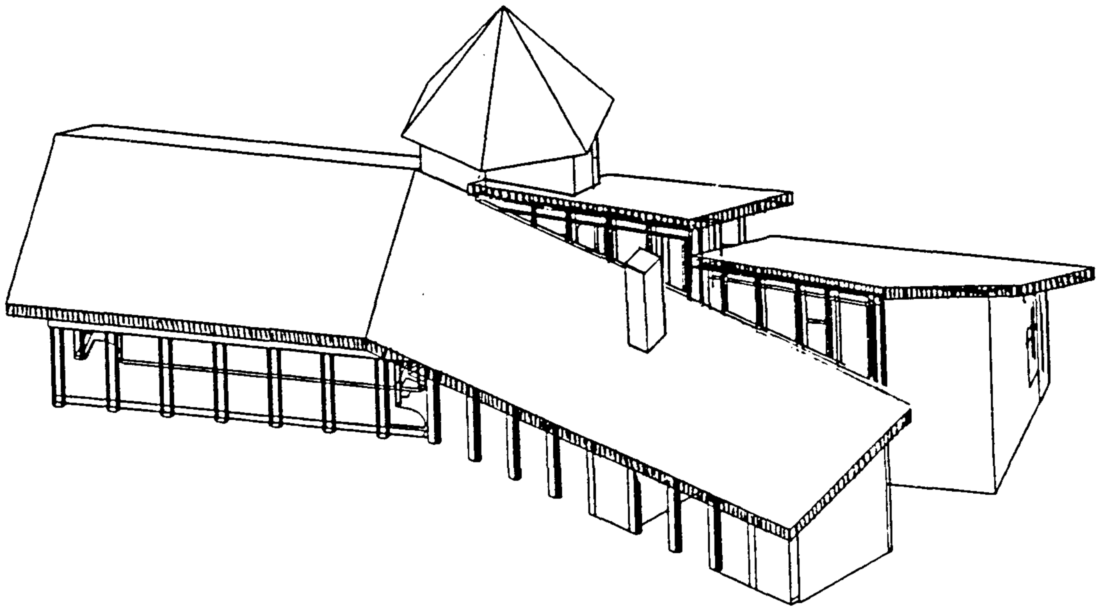


Figure 24. Bird's-eye views of house

the kitchen in the house.

Along the east side of the kitchen in the house design is a refrigerator, a dishwasher, a sink, and a portable storage trolley as is shown on the interior elevation in Figure 25. The side by side refrigerator-freezer has an ice dispenser

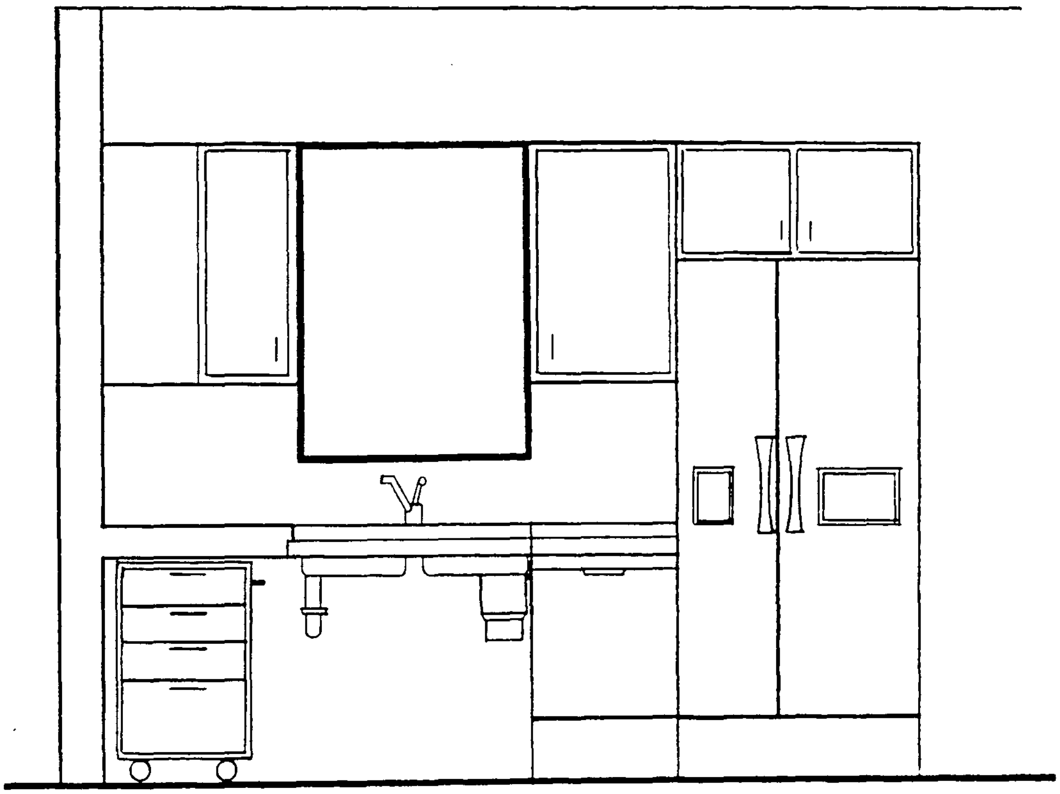


Figure 25. Refrigerator and sink elevation of kitchen

mounted on the exterior of the door as well as a small refrigerated box for frequently used items. This saves money by not having to open the entire door to obtain something that is frequently used. The freezer is simple to get to because it runs the entire length of the refrigerator.

The drains for the sink are placed towards the out sides and back of the bowls so that they don't interfere with the knee space necessary for wheel chair use. The lever that actually activates the draining of the sinks, however, is located near the front. Flexible piping allows the counter to be adjusted to any desirable height. The garbage disposal unit is located in the back corner of one of the sinks so that it too is out of the way of the user.

An 18 inch dish washer is located conveniently to the right of the sink. A storage trolley is kept on the other side of the sink under the counter. This trolley can be utilized by a wheel chair user to transport meals to the dining area or return cleaned dishes to their respective storage areas.

The north side of the kitchen is where the range and a work surface are located as is indicated in the elevation in Figure 26. The electric range consists of three burners placed in a row and set back ten inches from the edge of the counter. This is done so that the user will never have to reach over one burner to get to another. Electric burners are used opposed to natural gas to prevent lose clothing from catching on fire in an open flame. The controls to the range are located to the right of the burners so that they don't have to be reached over to operate, and so they aren't easily accessible to small children.

An electric cooking surface that is mounted flush with the counter top has been specified. Flush mounting decreases

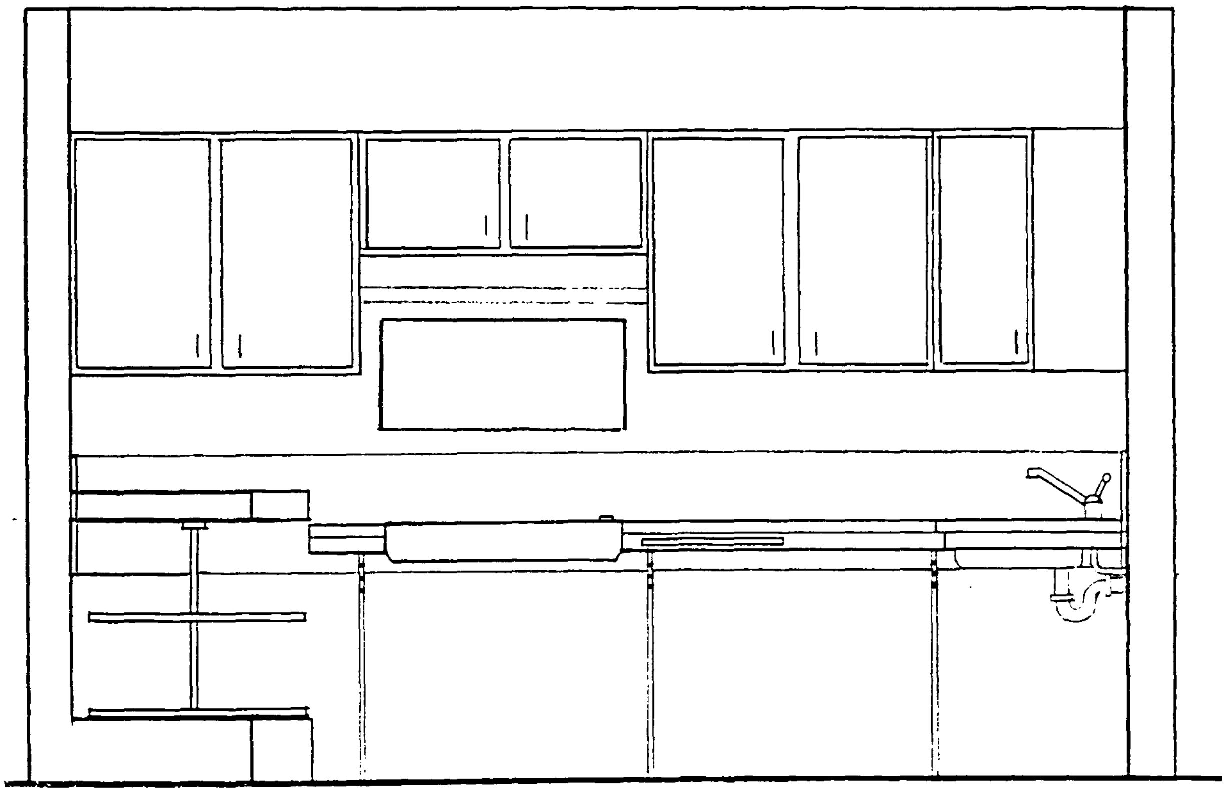


Figure 26. Work space and cook top elevation of kitchen

the likely hood of spilling when lifting from one surface to another. The burners are mounted in a ceramic material allowing the user to simply slide a pot off the burner to cool. A mirror is mounted over the range so that a wheel chair user can easily see the food cooking in deep pans.

Along the work space is a pull out board that can be used as an additional working surface. The bottom of the cabinets above the counter tops are mounted 4'-4" above the floor surface so that they can be accessible to wheel chair users. They are counter balanced to make them easily adjustable. On the underside of these cabinets are mounted various appliances such as a microwave in the corner, a coffee maker, and a can opener next to the stove. A spice rack is mounted underneath the cabinets for easy use.

There is lazy susan along the west wall as is shown in Figure 27. This wall contains a pass through window from kitchen to dining. An oven is mounted at counter height. There is a variety of storage under this counter. Three sided drawers have been implemented for the storage of pots and pans as shown in Figure 28.

The counters in this kitchen are all adjustable depending on the needs of the users. The counter tops are mounted on brackets. If there is one occupant that happen to be a wheel chair user, these counter tops can all be lowered to a height that is comfortable for him\her. If none of the occupants use wheel chairs additional storage can be obtained by installing a variety of removable cabinet fronts in 30 inch segments. If there happen to be a couple living in this home in which one was a wheel chair user and the other is not, a variety of levels must be provided.

In this situation, the "L" shaped counter from the edge of the lazy susan to the refrigerator could be lowered. The

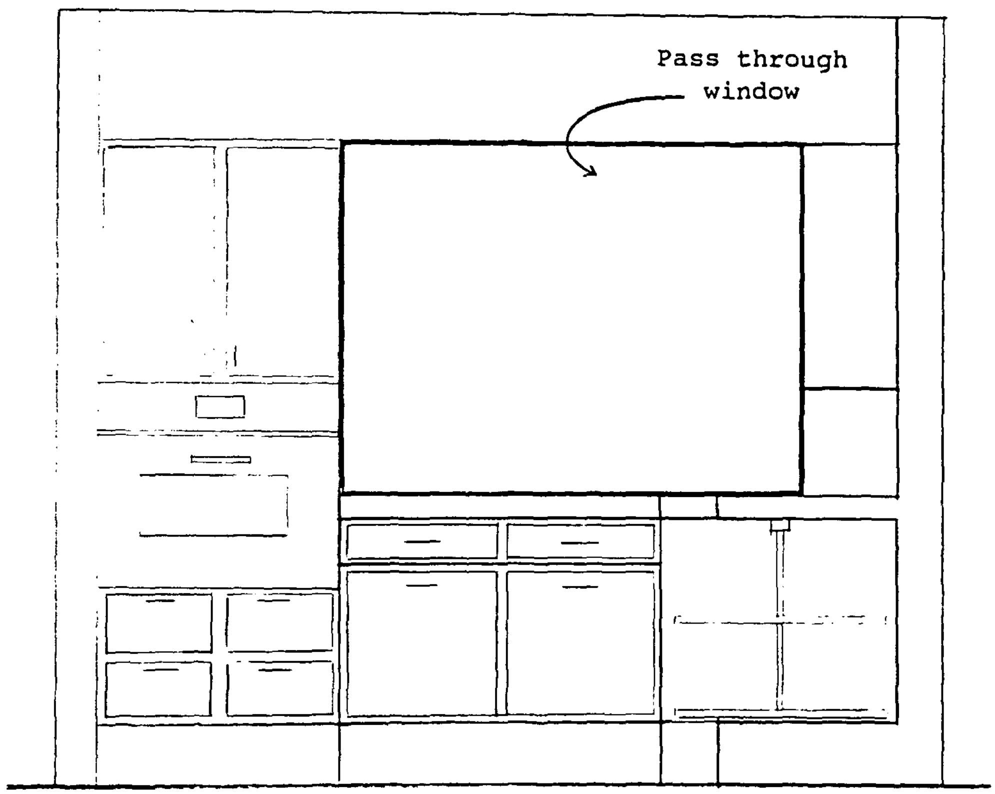


Figure 27 Oven and pass through wall elevation of kitchen

section between the oven and the lazy susan could remain at 36 inches in height. This would provide levels that would be comfortable to use for both individuals. The wheel chair user would also get the benefit of the additional storage under the higher enclosed counter top. To lower this section, the top row of 5 inch drawer units could be removed and the pole suspending the lazy susan could be lowered. A variety of

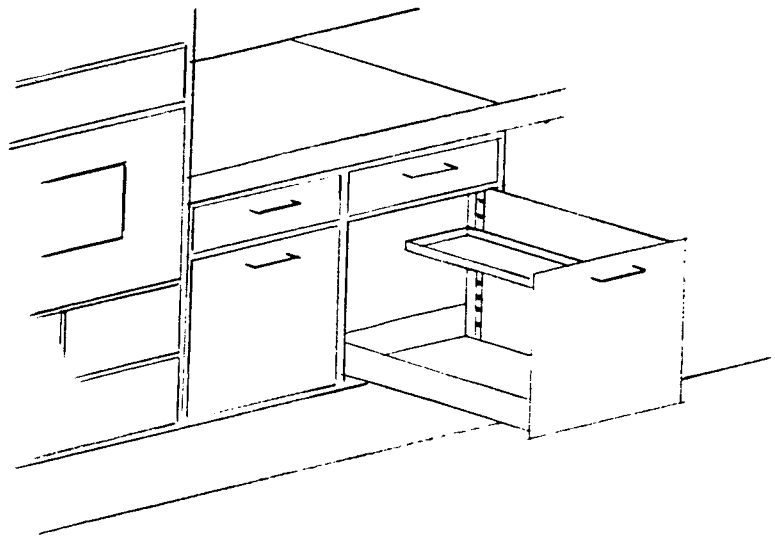


Figure 28. Three sided storage drawers

counter top spacers could also be implemented. It all depends on the needs of the users. Maybe one of the users never cooks. In that case, the majority of the cooking surfaces in the kitchen could be set up at a height that meets the needs of the primary user.

The house design incorporates a bathroom that is accessible from both the master bedroom and the livingroom. This shortens the distance one has to travel should one have to go to the bathroom during the night. The shower is designed so that a wheel chair can be rolled directly into it. There are no curbs around the shower, rather a folding door with a track that is recessed flush with the floor. This door opens from either side making it convenient to use when entered from the bedroom, or when a side transferral is required by a wheel chair user. Two interior elevations of the bathroom ar shown in Figures 29 and 30.

The lavatory in the bathroom is set up in the same manner as the sink in the kitchen. Flexible piping and a counter top that is mounted on brackets allow the occupant to adjust the lavatory to any height desirable. The flexible plumbing is also insulated. This insures that the person in the wheel chair with no feeling in his/her legs would be able to burn oneself by rubbing up against the plumbing after having run hot water. The bottom of the mirror over the lavatory is hung 40 inches above the floor.

Natural wood grab bars have been installed around the water closet according to the standards illustrated in Figure 10, while modern grab bars with a textured plastic coating have been installed in the shower.

The location of the bedroom provides the occupant with a number of benefits. The direct access to the bathroom is beneficial to the elderly occupant. Individuals with reduced maneuverability are provided with a short route to the outside in case of a fire. The dimensioning of the bedroom enables it to accommodate the wheel chair occupant.

One of the truly barrier free ideas within the bedroom that is made possible through the implementation of the Smart House system is located within the closet. The clothes hanger

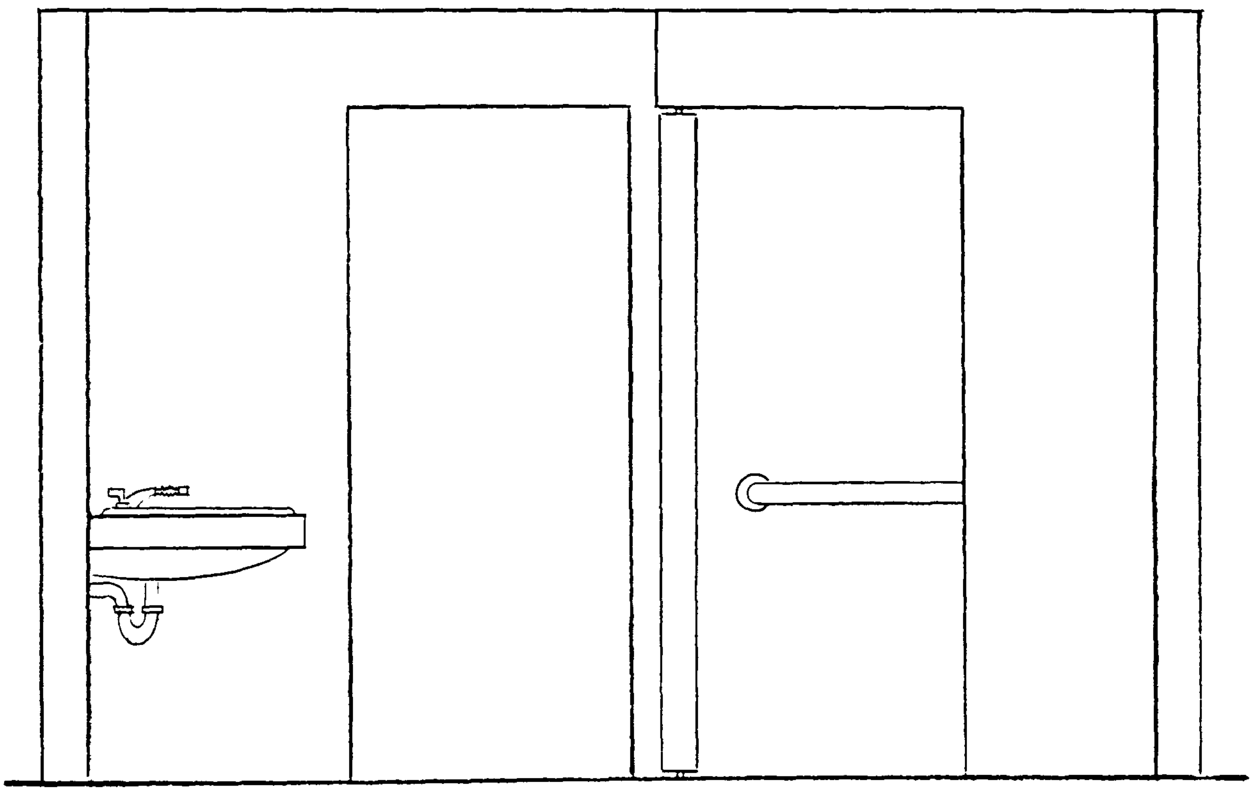


Figure 29. Bathroom elevation with door to bedroom

system that is illustrated in Figure 31., allows an individual to use ones closet storage more efficiently. This system allows a wheel chair user, or an elderly occupant, to easily access their clothes on hangers. With a touch of a button, these clothes can then be stored by smart house system high up in the closet where they're out of the way. This increases the amount of accessible space within the closet.

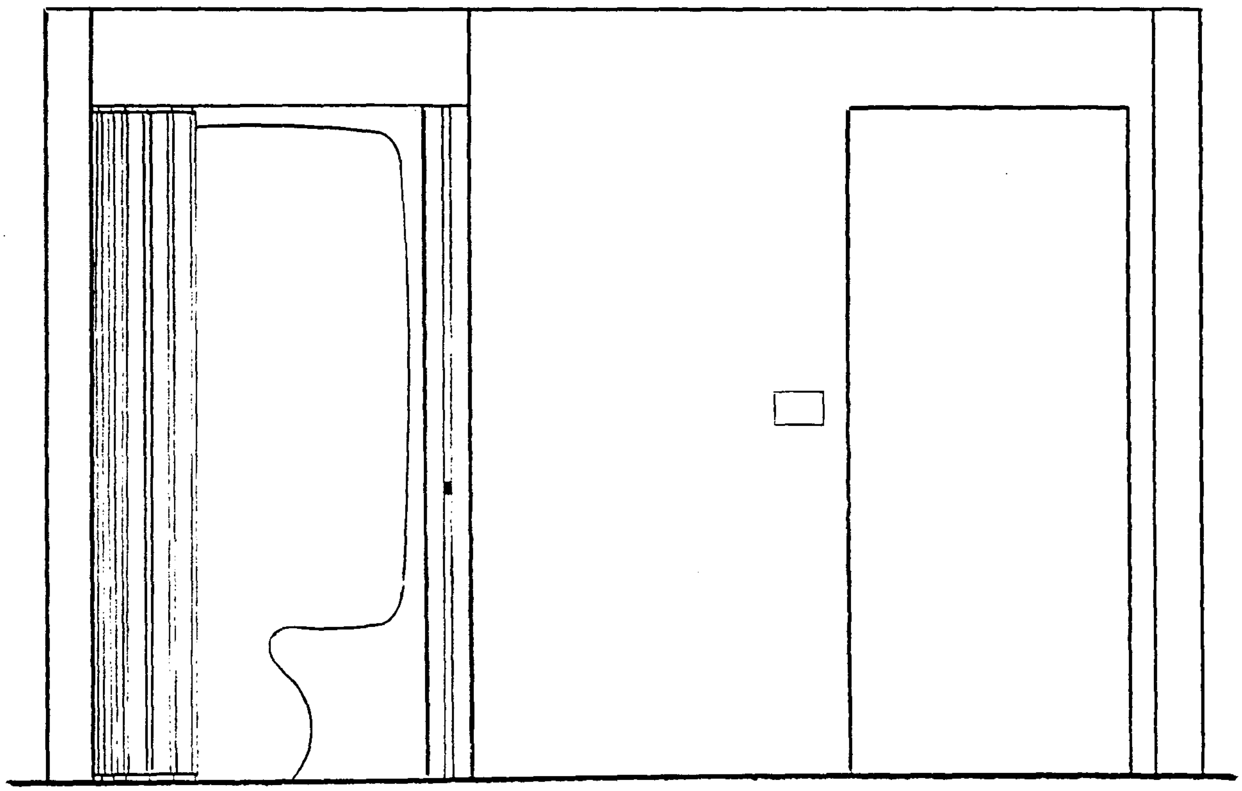


Figure 30. Bathroom elevation

Apartment prototype The floor plan of the apartment is shown in Figure 32. Some of the spaces within the apartment function in much the same way as their corresponding spaces in the house prototype. The floor plan of the kitchen, for instance, is practically identical. About the only difference between the kitchen design in the apartment and the one in the house, is that the dining area is combined with the kitchen

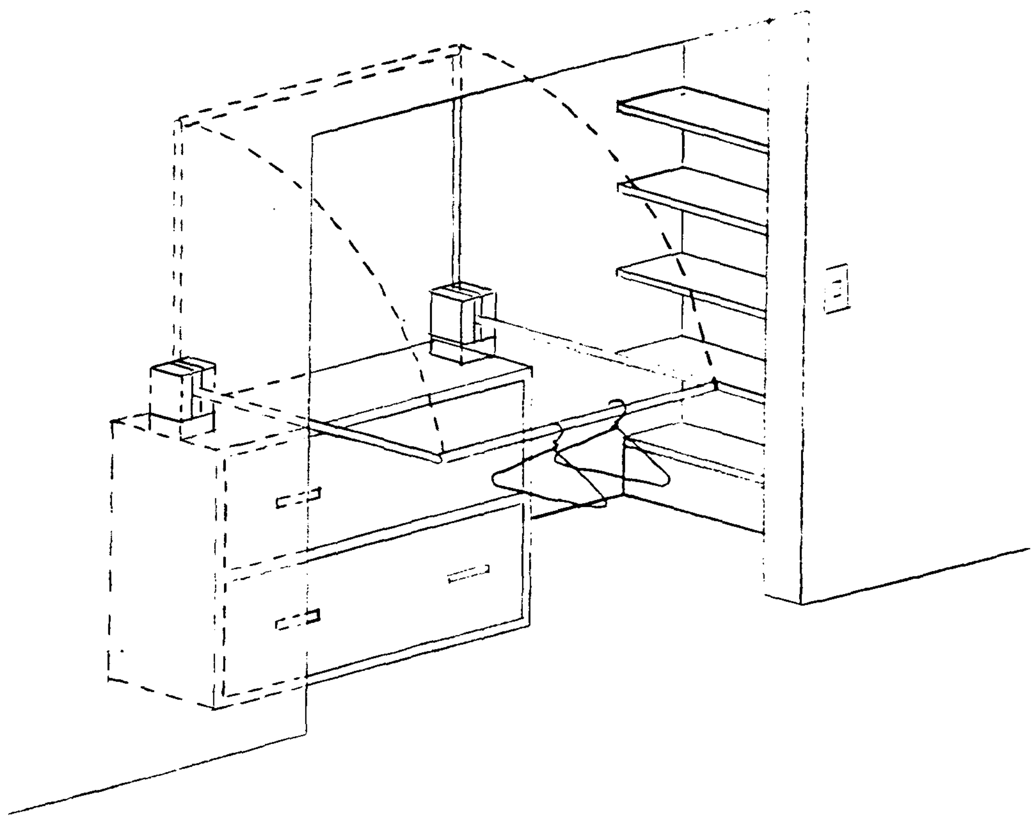


Figure 31. Bedroom storage closet

counter space. This minimizes the distance food must travel from preparation to serving. It also minimizes the amount of space that is dedicated to eating.

The left section of the dining counter is mounted on wheels so that it can be used as a food preparation table in the kitchen. The chair on the right end of the dining counter doubles as an extra seat for dining and the smart house

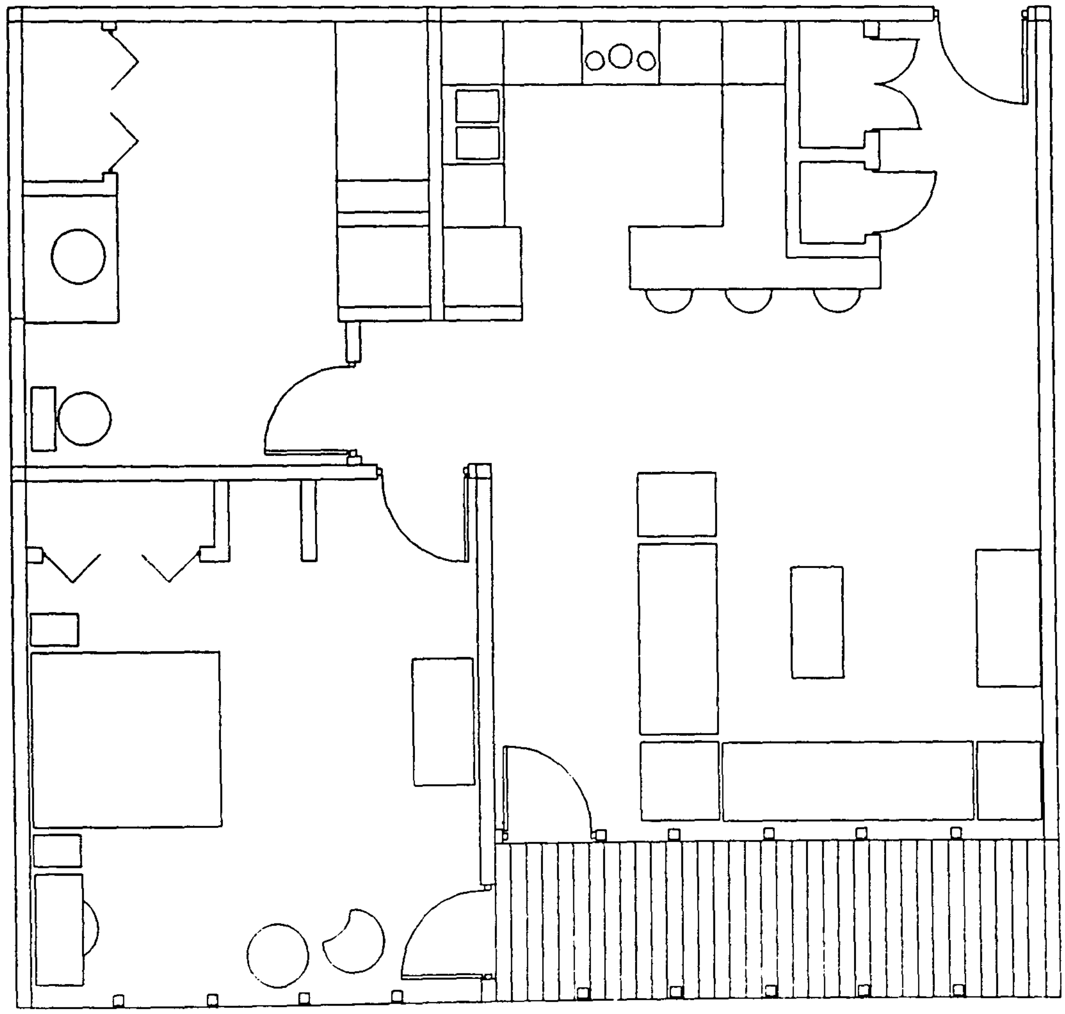


Figure 32. Floor plan for apartment prototype

programming center. There is a touch tone screen that is mounted in this furred out wall. A key board can also be pulled out from its recession and used on this one foot wide counter space.

This Smart House control center is located in a heavily travelled area of the apartment making it very accessible. In this location an occupant can easily check that the system is on as one is leaving the apartment or returning from an errand.

A barrier free bathroom has been implemented into this apartment prototype. A bathtub with a shower has been opted for in this design rather than a walk in shower. The tub integrates a hand held antiscald shower head which enables the elderly individual to bathe him/herself without assistance and without getting completely into the tub. A seat can be installed in the tub which lets the individual get partially into the tub water, but which does not let them sit so low in the tub that it hinders their ability to get out.

Tactile slip-resistant strips have been adhered to the floor of the tub so the user does not slip as he/she gets out of the tub. A rubber floor covering has also been specified for the bathroom floor to reduce the chances of slipping on a wet floor.

The apartment bathroom utilizes an adjustable lavatory, and grab bars in the tub and around the water closet that are comparable to those in the house prototype. This apartment prototype, however, utilizes the generous space available in the bathroom to incorporate a laundry facility. Combining the laundry area and the bathroom limits the amount of space that is required in the unit, and also the distance that dirty clothes have to travel to be washed. A work surface, similar but wider than the one located in the kitchen in Figure 26, can be pulled out from the linen closet and used to sort through the laundry.

The doors as well as all the spaces in the apartment are very accessible to those in wheel chairs. The 16' x 5' deck is accessible from both the livingroom and the bedroom. This makes it not only a pleasant place to go on a nice day, but also an easily accessible place of refuge during a fire. The apartment also incorporates a smoke alarm, an audio alarm, a sprinkler system, and exit lighting.

Materials Material considerations are important decisions that are made by the architect throughout the prototype in an attempt to create an informative environment that is easily navigable. Many of these choices cater to the elderly individuals diminishing senses.

Actual spaces are defined by the use of contrasting colors, or different values of the same color. A change in color and tonal quality enables the occupant to distinguish where the walls meet the floor plane. An emphasis on figure ground contrast throughout the apartment help the occupant over come their lack of perception.

A low pile carpet with a very tight weave has been specified in the living area to reduce the amount of glare produced by the passive solar gain. This type of floor surface treatment does not impede the wheel chair user as long as it is firmly affixed to the floor. The elimination of a carpet pad also lets the concrete slab below readily absorb the radiant energy of the sun. The choice of surface treatment of the furniture can also reduce the amount of glare produced.

Materials can also be specified that reduce the amount of background noise within the dwelling. Acoustical ceiling tile when installed in vaulted ceiling arrangements will absorb a lot of the noise being produced in the room, rather than reflecting it back into the community space. The carpet that was mentioned earlier also reduces the amount of sound that is reverberated throughout the dwelling.

Sometimes sound control considerations conflict with the passive solar concepts of dense materials used to absorb heat. A delicate balance between these two ideas must be accomplished in order for both to be successful. By implementing a rough textured surface on a mass that is designed to maintain heat we can reflect sounds and light in many different directions cutting down on reverberated sound and glare produced by reflected light. Meanwhile, soft materials that absorb sound can be placed in areas where the absorption of radiant energy from the sun is not as important.

By reducing background noise, the architect can make it possible for the elderly occupant to communicate with those around him/her. An elderly person that typically with draws from certain conversations may do so because he/she is unable to hear them more clearly.

Sometime varying disabilities can require considerably different solutions. For this reason not all architectural solutions will be perfect for everyone. For instance, a textured floor surface that has been installed for a blind person may cut down on the amount of traction that a wheel chair user is able to obtain. A gradual ramp that enables a wheel chair user to go from one level to another may be virtually impossible for an elderly individual to walk up. A kitchen counter height that works for one individual may not work for another. Environmental solutions should be based on what does the most good for the majority of users without creating any devastating hinderance for any of the users.

Smart House Technology

Electrical system

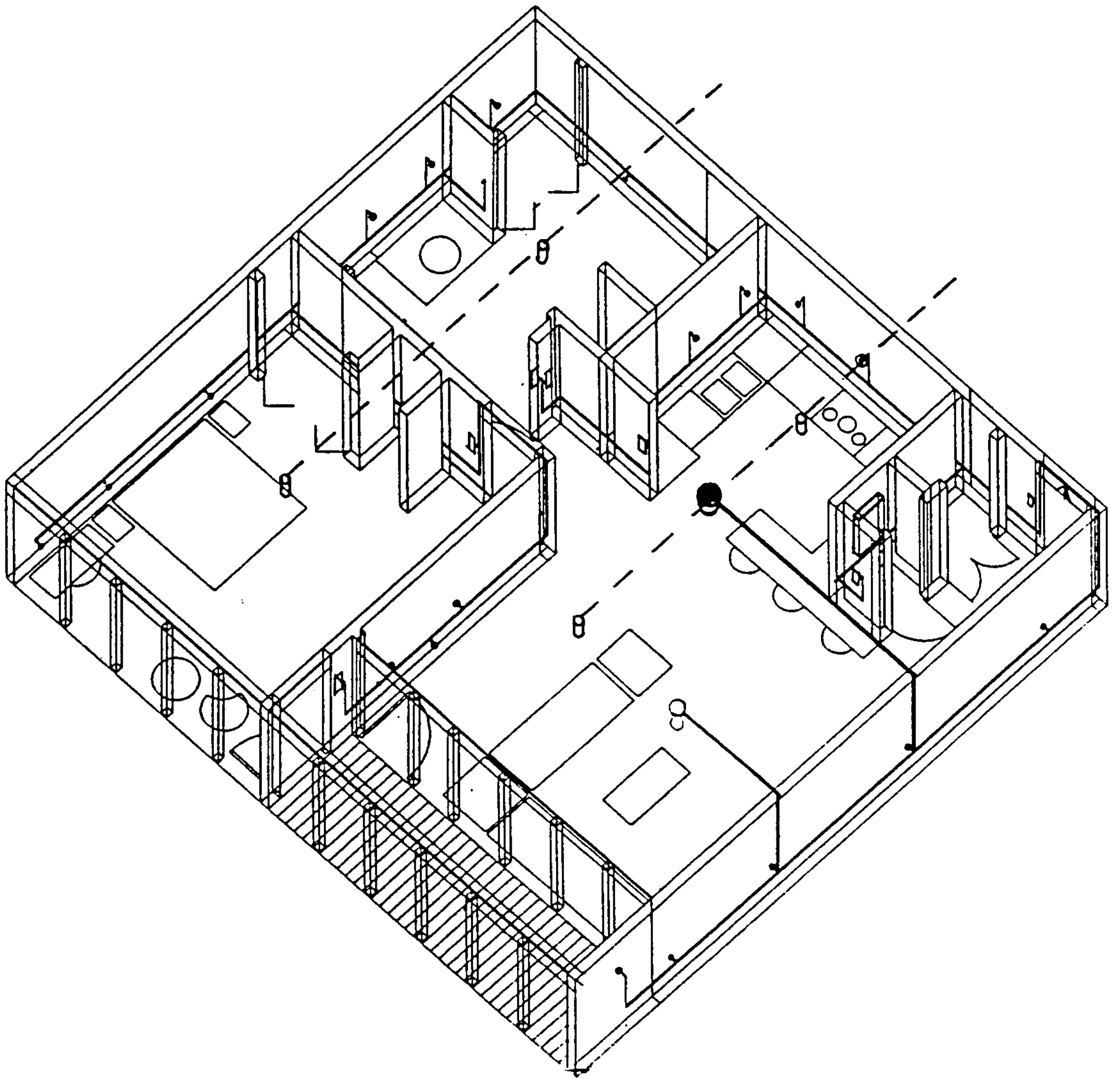
The first step in making a dwelling smart is to develop a wiring scheme. The wiring scheme for the apartment prototype is shown if Figure 33. This wiring scheme will not display every Smart house aspect of the apartment, but it will illustrate the different components of a Smart House system.

The various outlets and switches have been indicated symbolically showing the type and positioning throughout the apartment. It is not possible to see all the switches, outlets, and other smart house devices within the dwelling from one particular vantage point, but an overview of how the system is wired is presented.

The majority of the smart house outlets that have been placed throughout the apartment are duplex receptacles and are located 18 inches above the floor plane. Outlets located over counters in the bathroom and in the kitchen are place 4 feet above the floor plan so that they are within reach of the typical wheel chair user.

All of the smart appliances that are plugged into this wiring system, be it a TV, telephone, stereo speaker, or what ever, can communicate with the controller along this wire network. The controller is located in the closet inside the front door. All of the functions of every smart house appliance in the home is controlled right here. Information that the owner programs into the system, whether it is through a remote control, telephone or touch tone screen, is carried out by the controller. The wiring enables the occupant to reprogram a certain switch to control any specific appliance regardless of what outlet it's plugged in is no problem with this system.

All of the security systems are also wired to the central



Duplex receptacle outlet.......
Switch outlet..................
Range outlet...................
smoke sensor...................
Light fixture..................
Sprinkler system...............
Smart house wiring.............

Figure 33. Smart house wiring topology

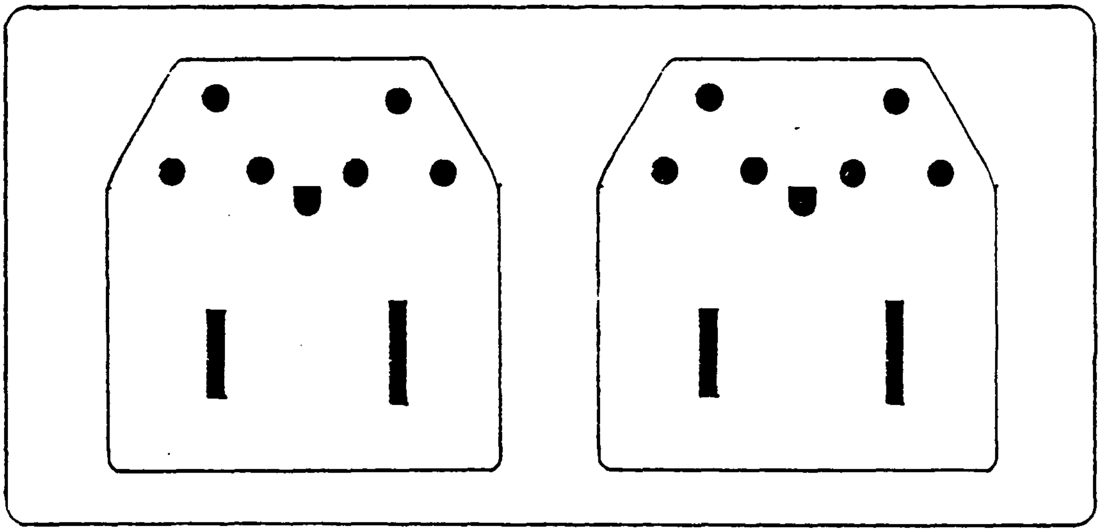


Figure 34. Smart house duplex receptacle outlet

controller. Whether there's a burglar or a fire detected by the sensors within the dwelling, the control system will take the appropriate measures to minimize damages. Developing communication protocols that can communicate with one another is the key to making this system function for a variety of products.

There is a touch tone monitor located in the furred out wall next to the dining area. At this particular station one can control all the activities of the house. A remote control can also be used from in the livingroom area to pull up various menus on the screen and make changes. All of the function of the home can be controlled from a variety of locations within the home.

On the wall just inside the bedroom is a control panel that operates the lights, music, and insulating blinds within the room. It also has a key pad that allows the occupant to program wake up music, or to start the coffee maker for the next morning. The security system can also be activated from here. The appliances within the room can be programmed here, or activated manually by the controls located on the appliances themselves. This way if a person were to be working at his/her desk he/she need not get up and cross the room in order to turn on task lighting.

The control pad in the bathroom controls not only the lighting and exhaust fan, but also allows a person to preset water temperatures for the shower or bath. This temperature, however, can be overridden by the controls along side the tub. There is also an automatic shut off button located near the rear of the tub which can be easily accessed to an elderly individual who would ordinarily have to cross the tub to shut off the water.

All of the appliances in the kitchen can be run by remote control. This enables an occupant sitting in the living room to turn off the range simply and quickly if a pot begins to boil over. The individual that is trying to do two things at once and forgets about water running in the sink or something they placed in the microwave can stop the problem in a hurry.

Many of the appliances that cook things could have a red indicator light that when an appliance is in use. This way the occupant can tell at a glance if something in the kitchen has been left on.

The blinds can be opened and closed automatically by the smart house system as a means of climate control. By doing this the system can minimize the amount of heating or air conditioning that is required by the unit. The occupant can also override this in order to take advantage of the view or obtain privacy. The system can be set up to obtain maximum efficiency, but this should never out way any of the values of the occupant. The system is not set up in way which makes occupant feel as if he\she is being manipulated by high tech machinery, but rather it programmed to meet all his\her needs.

The fire protection system consists of smoke detectors, a sprinkler system, visual and audio alarm, and exit lighting. It also is programmed to telephone the proper authorities and inform them of situation at hand. The alarms can signal the problem early on while the exit lighting gives the disoriented occupant a guide to find ones way out of a smoke filled apartment during a fire. Such a complex system could save the life of an elderly individual who may not be able to sense what is going on until its too late.

The Smart House control system in the house prototype works in much the same way as the system just discussed in the apartment. The touch tone monitor in the house prototype is centrally located to the left of the fireplace in the entertainment center. There is also a control keypad just inside the front door. Control from these two locations enable the occupant to check the system before going to bed or leaving the house. The location of the twenty inch touch tone monitor is visible from as far away as the diving area.

There are also controls just inside the door of every room where light switches are generally located. The controls allow the occupant to program or activate anything within the room. The main lighting in the bedroom, bathroom, and den are programmed to turn on when an individual enters the room, and turns off when they leave. This lighting system utilizes some of the sensors that are part of the security system.

The front door automatically opens after a correct code has been entered into the keypad. This option is very useful to the wheel chair user who can actually velcro the remote control to their wheel chair to insure that they have it at all times.

Half way down the procession to the front door is a motion detector. As a person passes this point, a video camera mounted above the door is activated. An audio tone is also sounded in the dwelling indicating that the occupant has a visitor. The touchscreen will show the image of the individual approaching the front door. An intercom system will allow the occupant to speak with the visitor from anywhere within the house.

Passive Solar Design

Passive solar considerations have been taken into account in these prototypes in order to minimize the operating costs of the units. Its implementation will let in natural sun light which has a positive effect on an individuals psychological state. The incorporation of passive solar energy is one way to reduce heating bills. By designing a structure that takes advantage of the heat produced from the sun when there is a heating load in the winter, and rejects that same energy in the summer when no heating is required, we are using our natural resources to the fullest.

The dwelling must also provide an adequate heat sink to store this radiant energy. This thermal storage mass reduces temperature swings within the home and also stores excess solar heat for later use at night. Cost is an important figure to consider when deciding how much mass to use in a dwelling. If too little is present the occupant will not have adequate storage capacity.

In order to design using solar principles we must know a number of things about the site location. By obtaining the latitude of the site we can calculate factors such as the solar altitude at solar noon. By simply studying the way this angle changes over the course of the year, we can understand what our designs must be able to do to utilize the suns potential.

For instance, we can determine that Ames, Iowa is located at 42 degrees north latitude. Knowing this, we can find out that the highest point the sun will reach in the is an altitude of 71.4 degrees at solar noon on June 21. The lowest level the sun peak out at is an altitude of 24.4 degrees above the horizon on December 21. This kind of information can be used to determine what type of structure could best utilize this energy. We can use these calculations to determine the size of the overhang necessary to shade the south glass in the summer, and let the majority of the solar radiation in during the winter. I have illustrated these principles in Figure 35.

By using vertical panes of glass with overhangs rather than angled glass in the form of skylights we can eliminate the amount of solar gain in the summer and maximize it in the winter. We can achieve some of the same lighting effects, however, by bringing the light in at an angle and letting it diffuse into the space. This is what has been done in the house prototype.

The use of double pane or even triple pane windows on the northern side of the dwelling will provide a greater insulating ability than single pane because the air trapped

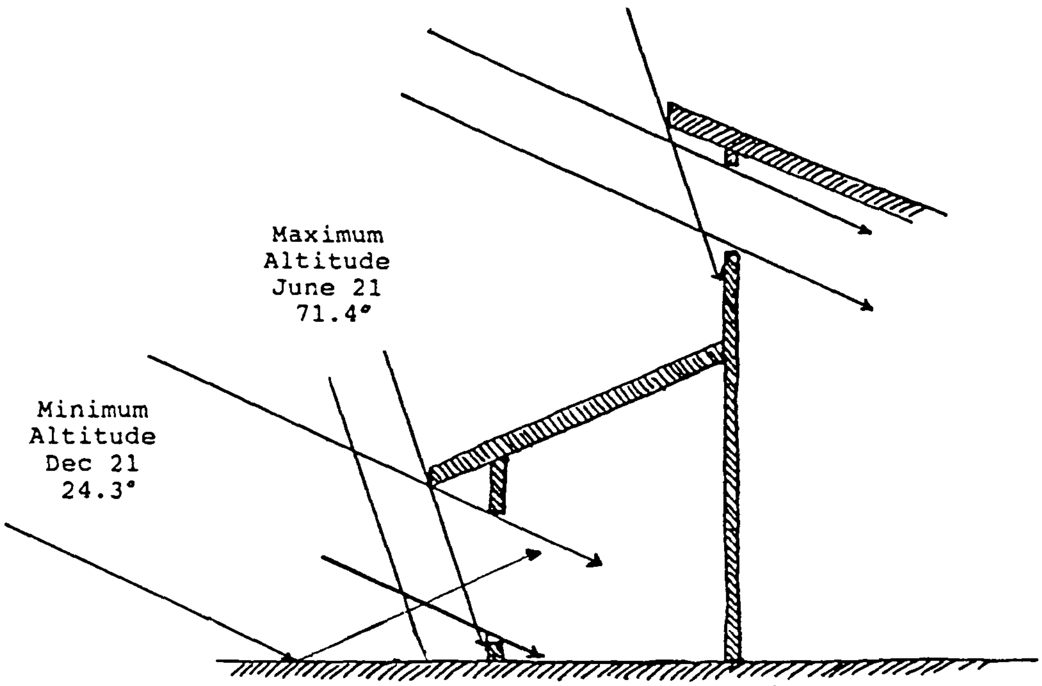


Figure 35. Maximum and minimum altitude in Ames, Iowa

between panes will give the window a greater R value. Double pane glass will also cut down on drafts within the dwelling. The use of a low-e glass especially on the south side will cut down on the amount of ultraviolet radiation allowed into the home.

In order to obtain the maximum benefit from the sun, the south facade of both the home and the apartment unit should face within fifteen degrees of due south. Rotating it any more than that will significantly increase the amount of time that the south face is shaded.

There are insulated blinds installed in both the house and apartment which can be lowered at night by the smart house system to slow down the escape of heat from the storage mass through the windows. These blinds could also be closed if the brightness of the dwelling becomes too stressful to the occupant. These blinds are illustrated in Figure 36.

The windows placed within the triangular shapes on the upper portion of the house provide an indirect light source for the unit. As the light passes through these windows, it is reflected off a wall in the corridor and diffuses along the travel corridor and into the living area. This type of lighting will improve the occupants way finding within the corridor because it reduces the glare experienced by the occupant within the space by cutting down the amount of contrast in light quality.

With more energy conscious individuals living on the planet because of the depletion of natural resources, materialistic waste may become an important issue. Minimizing mans effect on his environment may become highly idealized. Homes may begin to be design to operate like highly functional tools. This prototype is an attempt to show that an efficient barrier free design doesn't have to be typical. Buildings can be sculptural solutions to the problems faced by man.

The aesthetic aspects of the design of this home represents a look towards the expressive high tech homes of the future. The quality of the spaces within a dwelling may become more important than size as the cost of housing increases. Letting sun into a dwelling is lets the occupant feel as if he/she is one with nature.

This prototype represents function in the form of a dwelling. This design displays the consciousness of energy consumption and barrier free design that is the responsibility of all designers in a society that must learn to get by with less. I believe that architecture should reflect both personality of the architect as well as the ideals of society. This building is gesturing towards the sky to signify the importance of the sun as an energy source.

Building Thermal Control Systems

Passive considerations

Lets consider how the air is going to circulate in the interiors of both prototypes. During the average sunny winter day the rays from the sun are going to penetrate the southern glazing. At this point it will make its way across the ceiling, cooling off as it goes. As the air cools it will begin to settle towards the floor in the kitchen and dining area along the north wall. The cooler air along the floor makes its way towards the southern glass as the warmer air vacates. Because an open floor plan was utilized in these prototypes the circulation of the air is not impeded by walls. In essence nature has created its own heat distribution system.

At night this air directly inside the cool glass will move down the surface of the southern glazing, just as it did during the day. The major air masses within the dwelling will, however, work in a reverse circulation loop as it did during the day, if the southern glazing is to remain exposed. system would work in a reversed circulation loop if the southern glazing were to remain exposed. Warm air at the ceiling will move down the surface of the glass as it cools. Warmer air from across the room will move across the ceiling to the cool glass panes. Cool air coming off the glass near the floor will move into the space where it is warmed again, rises, and makes it way back towards the window. In this case, the circulation loop is reversed and the heat that is stored in the mass dissipates through the glass into the cool of the night.

What we would like to due as architects is to slow down the rate at which the heat that has been stored during the winter day is allowed to dissipate from the dwellings interior. After working so hard all day to collect this energy within the thermal mass of the dwelling, it would be a mistake to simply let it dissipate through the windows as easily as it entered. What we have to do is slow down this dissipation. By insulating the windows we are able to slow down the rate at which the hot air within the dwelling is able to dissipate into the cool night air.

By insulating the units well and installing windows with good seals, we can create a tight structure with little air infiltration. One half the heat lost in a home may be due to air exchange. A tight structure such as this can retain heat for a longer period of time than one with a high number of air changes per hour.

This air must be ventilated on a regular basis to get rid of unwanted carbon monoxide and other pollutants found in the air such as formaldehyde from chip board. The smart house can actually analyze the content of the air within the dwelling and schedule necessary air changes according to its make up.

In the summer because we have a cooling load rather than a heating load, we do just the opposite. We are trying to keep as many heat producing solar rays from entering the dwelling as possible. This is accomplished with carefully designed overhangs or by simply covering up the windows. Deciduous trees can also be planted which will shade the home in the summer when they have their leaves, and then will allow the winter rays to enter the dwelling after losing their leaves in the winter. At night, however, we uncover the windows and let the heat dissipate into the night air. As the dwelling cools during the night, our solar mass is drained of all its heat.

Mass which is to be used as a heat sink can consist of a variety of dense materials such as concrete or water and is always a good conductor of heat. The next morning while this large amount of mass is still very cool, we close up the windows with insulation in an effort to slow down the speed at which the warm outside air can penetrate the dwelling and warm the cool mass.

The thermal mass utilized in the home can be a number of different dense materials. What is important here is that these materials be directly exposed to the sun. A bare concrete slab works great as a heat sink. As a rule of thumb for every square foot of southern glass, you should have somewhere between one and two cubic feet of concrete in the slab. It is also important to insulate beneath the concrete slab so that the heat is not conducted through the slab and into a much larger heat sink, the earth.

This same concrete slab when covered with a shag carpeting and a thick mattress pad, becomes insulated from the warming rays of the sun. Heat from the sun is not as readily absorbed by the mass because the carpet and pad are not very good conductors of heat. As a result not much heat energy can be stored.

A low pile carpet with no pad at all will still allow heat to penetrate into the concrete, at a slower rate. In order to absorb the same amount of heat as a bare concrete floor, we could simply increase the amount of surface area of carpeted slab that is exposed to the radiant energy.

Mass can be located in many other architectural elements. Masonry fireplaces or planters provide a good heat sink for solar radiation. Walls that run east and west parallel to the southern glazing can absorb a lot of heat energy if located close enough to the southern glazing.

Mass can be located in remote sections of the house such as a rock pit located beneath it. Hot air generated in trombe walls can mechanically be moved through duct work and pumped through this pit to heat the rocks, or containers of water, or what ever the mass may be. It is important, however, that the air be able to circulate among the mass units in order for heat transfer to take place. This stored heat from the pit is then used to heat the home at night. Although this system works, it has been my experience that the simpler direct systems are more efficient because you don't have to use energy to move the warm air.

Active HVAC systems

For an active HVAC system, a ninety percent gas furnace has been implemented in both prototypes. A furnace with a high efficiency rating will easily pay for itself in fuel saving. The size of this furnace will be relatively small when compared to a comparable sized home that has not utilized passive solar principals in its design. Passive solar houses when designed correctly need little auxiliary heat.

The Laurent Hodges home designed by professor David Block at Iowa State University has never dropped below 52 degree even when unoccupied during the coldest of winters (Block, 1991). It's actually a rare occasion when the furnace is used. I not saying that 52 degrees is a comfortable temperature but it is amazing that a passive solar home can retain so much solar heat consistently. It's also nice to know that you could leave for vacation and know that the plants in the house would not freeze, even if the furnace were to be turned off completely.

The smart house controlled furnace is able to circulate air from a space where a lot of moisture is detected, like the bathroom, and distribute it to other rooms of the house, or blow it out of the home completely.

The system can be programmed to open and close the appropriate dampers in the ventilation system in order to create a variety of temperature zones. Once again it's important to realize that its the controller that enables such an advanced form of temperature control to exist. This would not be possible if the furnace were unable to communicate with the controller. Dampers along the ceiling of the major corridor can be opened, allowing hot air to escape from this pressurized dwelling.

The furnace specified for the house prototype is the Weathermaker Infinity gas furnace made by Currier. This product was designed specifically for the smart house. This efficient furnace will slash operating costs of the smart house. It incorporates humidifiers and electronic air cleaners to keep the quality of the air in the dwelling clean. It has the lowest operating cost of any gas furnace on the market today. It incorporates a variable speed blower and two-stage heat output for perfectly even heat.

Onan Corporation is producing a power generator for Smart House. This product will produce an uninterrupted source of power.

IV. CONCLUSION

Evaluation of Design

Currently the United States is trying to develop alternative ways of housing its elderly population. There are many people in nursing homes today that don't really need to be there. They are living in nursing homes because there is simply no other housing available that can adequately meet their needs. If such housing types were made available, we could greatly reduce the number of individuals that are currently flooding nursing facilities.

There are currently 43 million individuals in the United States that have one form of disability or another. Approximately 20% of the people in the United States have some sort of impairment (Rudi, 1991). That is a rather significant percentage of the population. Many of these individuals are finding it very difficult to locate adequate housing within the community setting. The majority of dwellings that exist have to undergo major renovation in order to be converted into a dwellings that is usable to a persons with disabilities.

The two prototypes presented here can help solve the problem of providing adequate housing for the elderly and the disabled. The diversity of the population in general requires that many solutions be purposed in order to thoroughly address all the existing problems. The prototypes presented here address the needs of a certain percentage of the elderly and disabled individuals that would like to be allowed to live independent lives within the community. They have every right to live such independent lives, but the dwelling capable of making this a reality are very scarce. The prototypes designed for this thesis will not solve all the housing problems of the elderly and the disabled, but it will provide a long awaited solution to many of them that desire to live independently.

It is also very important that building professionals are made aware of some of the new technology that is soon to be made available to consumers in the housing industry. By understanding how the Smart House system works, and all the ways that it can better the lives of both the elderly and the disabled occupant, we can begin to incorporate this system into a variety of elderly and disabled housing forms. This technology can be used in all categories of elderly living form independent housing to intensive nursing care.

This new technology can give the occupant more control over the energy consumption within the dwelling. Our society is becoming ever more conscious of energy consumption as our nonrenewable energy sources such as oil, coal, and natural gas, are being depleted. We must begin to conserve the nonrenewable energy sources that still remain on the planet as we make a transition to cleaner renewable sources of energy. By incorporating renewable energy sources into our dwellings, we are investing in our future.

Future Predictions

Dwellings of the future will begin incorporating large amounts of plastics. Plastics will appear in the housing industry in anything from finish treatments to wall studs. As our timber supplies are reduced, we will begin to rely on a greater variety of plastic building materials. The natural gas Smart House prototype that was built in Maryland by Baltimore Gas and Electric Co. incorporated a variety of plastic features into its design. It has reflected what the future has in store for us.

Recycling will also be an important issue that will effect the design of the home. Trash compactors will disappear from the kitchen and be replaced by storage space for recyclables such as glass, aluminum, plastics, and paper. Dwellings will reflect the way society now views disposable items.

The American dwelling will go through an evolution over the next few decades. The dwellings of the future will generally be designed better than they are today, because there will be a greater concern with their efficiency. As we begin to exhaust our building supply of wood for our stick frame homes, we will have to make better use of materials as well as our dwellings become smaller.

Awareness of accessibility will be heightened as we are exposed to the renovations and new designs that are brought about by the Americans with Disabilities Act. This awareness of building accessibility will be reflected in the designs of dwelling in the housing industry. The installation of Smart House technology will probably become standard building procedure in these more accessible environments.

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