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Future Housing in the United States: Senior's Housing Demand

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FUTURE HOUSING IN THE UNITED STATES: SENIOR'S HOUSING DEMAND

by

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In the United States, persons born between 1942 and 1964 are within 10 to 15 years of traditional retirement age and are identified as baby boomers. The data shows that the number of persons aged 65 years and older have grown from 10 percent of the population in 1970 to nearly 13 percent in 1996. Furthermore, the population that is 65 years old or older is projected to be 20 percent of the population in 2030. As a result, the demographic change nurtures a demand for senior's housing.

On the other hand, the concern is for the elderly living in nursing homes. Today, there are around 1,032,000 people aged 85 and older housed in nursing homes, and there will be an additional 3,336,000 people aged 85 and older requiring nursing home accommodations in 2050. To accommodate 3,336,000 people, the United States has to build and place in operation a 183-bed nursing home everyday for the 50 years between 2000 and 2050. The research is concentrated on investigating the requirements in a house to suit the needs of elderly people and developing construction management strategies for implementation in the construction of future housing.

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CHAPTER I

INTRODUCTION

PROBLEM BACKGROUND

In the year 2001, the first step has already begun for the Baby Boomer generation turning 55 years old and reaching a figure of 3.2 million people. For the next two decades, millions of baby boomers across the nation will reach 55 years of age. The Census Bureau projects that by 2030; the elderly population in the United States will be doubled. As per the survey of AHEAD (Assets and Health Dynamics Among the Oldest-Old), it estimates that America's elderly population will comprise of twenty percent of the population. The population growth predicts a heavy demand of millions of houses for the senior's across the nation. Also, the older structures need a hand to meet the needs of aging homeowners. The research is concentrated on to investigating the requirements in the house to suit the needs of the elderly people and developing construction management strategies for implementing in the construction of future housing. The research will be a step towards meeting the immediate housing demands for elderly persons and developing a multi-generation *"Building System"*. The "Building System" will also be helpful in reducing the proportionate overall expenditure on the remodeling of houses. Throughout the thesis, the term "seniors" and "elderly" has been used interchangeably for referring to people aged 55 or older.

Demographic changes in America indicate that the percentage of people aged 65 years in the United States is expected to double in the next thirty years. The percentage of people aged 85 and above is projected to increase by three fold. These sections of people are very much in need of senior's housing (Regional Science & Urban Economics, 29.5, 1999).

On the other hand, the number of elderly persons living in nursing homes is also increasing steadily. According to the U.S. Bureau of Census 2001, there was an increase of elderly persons by 55 percent from 1970 to 1980 and an increase of 29 percent from 1980 to 1990. For many years now, academic gerontologists refer to the term 5 percent fallacy in order to mention that 5 percent of the population aged 65 and older resides in an institutional setting, primarily nursing homes at any one time and the proportion increase dramatically as age increases (Atchley, 2000).

AIMS AND OBJECTIVES

The research objective is to formulate methodologies to develop a "Building System" that could be used to build multi-generation housing all across the United States. This will be a kind of housing that could be used by people of all ages taking into consideration elderly persons. Furthermore, this kind of future housing will also reduce proportionately remodeling cost in the United States that accounts for two percent of Gross Domestic Product every year and amounts to as much money as on new construction.

The anticipated results of the research are to achieve a universal type of “Building System” that provides barrier free circulation, minimized maintenance and operation costs. Finally, the future expansion of the house should accommodate the requirements of the growing family, and higher health and safety standards.

The anticipated results of the research should benefit as a direct impact on the overall economy of the United States as follows:

a) The Building System proposed would add to the comfort level and the real needs of elderly people, which would minimize accidents and provide a favorable living environment. The minimizing of accidents and increased level of comfort in the house will reduce the overall burden on emergency services and nursing homes.
b) The Building System as a prototype, which will be used universally, will benefit the housing industry economically, in terms of manufacturing homes at mass production level.
c) The Building System proposed, as a multi-generation concept will be used by all generations that would reduce the proportionate cost on the overall remodeling industry.

RESEARCH METHODOLOGY

Stage 1 - Literature Review

The study reviews the relevant literature and present research on “Housing for the Elderly”. The basic concern throughout the review stage is to understand the

basic requirements and considerations of the elderly people. Also, the concern is to analyze a common factor to achieve universality in building a house for individuals of all ages. That kind of house will be helpful in transferring, sharing or renting among all groups.

Stage 2 – Evolvement of criteria for Senior's Housing Design

The main purpose of evolving the criteria would be to set up the components for the building system. These components of the building system should satisfy the needs of the elderly people. The system should also set up methods to industrialize the residential construction and derive methodologies of flexibility for the elderly people.

Stage 3 – Development of the Building System

At this stage, the findings and the conclusion will be presented as derived from the problem identification, literature review, and supported by criteria build up. The development of the building system would include main considerations adopted for senior's housing design. The system would finally present a model as a "Senior's Home Building System" to be adopted for the development and construction of the house. The conclusion of the research should facilitate a house that should satisfy the needs of the elderly people. In addition, this chapter will also highlight issues, achieving overall research conclusions and proposing recommendations for future research.

ORGANIZING THE THESIS

The first chapter provides a brief introduction of the problem and describes aims and objectives for the research. The second chapter is a discussion about the problem identification and importance of senior's housing demand. The third chapter deals with the historical perspective and the current trends in housing. The fourth chapter is the evolvement of the criteria for senior's housing design summarizing the context from literature review and research. The final chapter will be the process of developing the building system and presenting the final model. The final chapter also describes the conclusion and recommendations for future research.

CHAPTER II

THE SENIOR'S HOUSING

INTRODUCTION

In the United States, the number of person aged 65 years and older has grown from twenty million in 1970 (10 percent of population) to nearly thirty four million in 1996 (13 percent of the population). The population aged 65 years old and older is projected to be 58.9 million in 2030 (20 percent of the population). The persons born between 1942 and 1964 in the United States are within 10 to 15 years of traditional retirement age and identified as baby boomers. As a result, the demographic change nurtures a demand for elderly housing and a steady growth of senior citizens. The elderly persons are geographically distributed in proportion to the population at large. However, the western, southern and eastern coastal states have the highest elderly growth rates and live in approximately 16.4 million households. According to the survey conducted by the American Association of Retired Persons (AARP) for Americans over 50 years old, it shows that over 80 percent of the households prefer to remain in place, so-called "aging in place" (Schafer, R., 1999). And in the most recent survey happened in 1996 by AARP, it asked respondents their reaction to the statement: "What I'd really like is to stay in my own home and *never move*." The positive response was shown by 89 percent of the households aged 65-74 years and people aged 75-84 years. Also, 96 percent of those aged 85 or older agreed to

the statement (American Association of Retired Persons, 1996). At this point of time, it is worth to recall the recent observation of the American Association of Retired persons (AARP, 1999):

> *The idea of the Baby Boomers as a homogenous group is more myth than reality. With its members spanning nearby 20 years of life, Baby Boomers are represented by a wide range of life stages, life experiences and life values …… one of the key characteristics of the Baby Boom cohort is its diversity.*

The diversity predicts the behavior and the development of communities more challenging (Haas and Serow, 2002). Moreover, the ability of the elderly to perform daily living activities is an important factor of their selection for the living arrangement. The most reliable approaches to measure frailty is the number of Activities of Daily Living (ADLs) that the elderly persons in the household require assistance with and are categorized as six ADLs: walking, dressing, bathing, eating, getting in and out of bed, and using of toilet. An additional feature is also widely used is the five categorized number of Instrumental Activities of Daily Living (IADLs) that the person needs help in: preparing meals, grocery shopping, telephone use, taking medicine, and Money management. In totality, the research indicates as follows (Schafer, R., 1999):

1) About 19 percent of people aged 70 to 74 year olds or older had difficulty with at least one ADL.
2) About 74 percent of people aged 90 years old or older had difficulty with at least one ADL.

3) Women have a higher incidence of having at least one ADL than men, 33.1 percent compared to 24.2 percent for men.

4) For IADLs, the percentage having difficulty with at least with one IADL increased from 20 percent to 74 percent over the same age range.

The first measure for the housing type and need for assistance is combined number of ADLs of elderly respondents in a household. The percent of households having at least two ADLs for alternative housing types is 37.4 percent, which is much higher than conventional housing of 14.1 percent. The next lowest incidence of two or more ADLs is 26.3 percent found in assisted living communities. Shared housing and supported housing have 39.4 and 56.1 percent, respectively, of their households with two or more ADLs. Another measure of the need of assistance is the number of IADLs. The pattern is the same found for ADLs. The correlation between combined ADLs and combined IADLs is 0.68 (Schafer, R., 1999).

Other concerns are for the elderly people in general living environments and aging-in-place. When the individual's health matter get frailer, issues of senior housing and senior health cannot be dealt in isolation. Because when the monthly bill grows for an elderly person, the senior is less likely to afford a leaky roof or inadequate heating, which can further compound health concerns. A housing problem can create a health problem and a health problem can create a housing problem. The problem lies in, where the private sector has developed a greater number of models to combine the two, while the public sector has

continued to separate the two (Lawler, K., 2001). This is true for all age groups, but is really true for aging adults. The concern is for the next 55 years, when the number of people aged 65 and over will be more than double, the number of people aged 75 and older will be tripled and the number of people 85 and older will quadrupled (Burkhardt, J., 1999).

THE SENIOR'S HOUSING DEMAND

With the growing number of the elderly people, the needs of the senior's are bringing the housing market new challenges. The growth of the senior's required that the needs and the desired services to be combined with the housing features. Several surveys show that the elderly at an older age have increased wealth, from earnings and from social security. The monetary advantage provides the senior's to purchase specialized goods and services to help themselves from limitations and frailties (Schafer, R., 1999).

The baby boomers are still 10 or more years away from normative retirement age. In fact, this is the most important time for the gerontological community and the construction industry to develop a structured consideration for the retirement of the baby boomers. Elderly housing is one of the gerontologically concept, which requires its own definition and meaning, and is indistinguishable from general housing patterns. (Folts and Streib, 1994; Golant 1992; Lawton 1975; Magnum 1994; Pynoos 1990; Strib et al, 1984). Some gerontologists in housing for a long time always believed the concept of "continuum of care" but that never existed (Folts and Muir, 2002). Nevertheless,

the important words of Wilma Donahue, who with characteristic prescience, cautioned the gerontological community as follows:

> *It would be relatively easy at this time for the "experts" to write a prescription for housing older people which would take into account the changes in physical status, health, and social circumstances which accompany aging. To do so, however, without knowledge of the consumer's wants, would be short of folly. (Donahue 1954)*

In the United States, development of elderly housing has adopted two distinct paths. The first is a decidedly proprietary direction involving active marketing of various housing alternatives, which resulted in communities such as at Sun City and Leisure world of 1960's. These kinds of ventures get developed around set of amenities to enhance resident's enjoyment of living. The second is the developmental path with a large array of alternatives to meet the demand of housing needs locally. This kind of situational path is characterized by openness and need specific amenities package (Folts and Muir, 2002). Beyond these conceptions, there is something more that needs to be considered for elderly persons. They are issues of emotions, ideas, perceptions and most important is people and their relationship with one another. The other most notable issues, which were from the non-progressive concerns of the developers and residents interviewed in the late 1970's, and early 1980's, which were the elderly housing issues identified in the early 1960's. In overall, 20 year's problem issues were discussed in 1980's and still in 2002, the issues are under discussion about

whether elderly housing can ever met the housing needs of the older adults That list included such questions as follows (Folts and Muir, 2002):

1. Is the age segregation that is implied by retirement communities a good thing or a bad thing?

2. Are age restrictions only a modified form of the “separate but equal”mentality?

3. Will the “promise”of continuing care retirement communities (and the continuum of care) ever be realized?

4. Is the modern version of the retirement community a viable alternative to either living alone or in an institution —or both?

5. Can (and should) the commercial model of retirement communities be adapted for any but the wealthiest of older adults?

6. Will intergenerational living arrangements ever be acceptable to large numbers of people?

7. Will “not in my neighborhood”ever cease to be the mantra of those who oppose the establishment of “group living arrangements”in residential areas?

And these questions remain important till today as each of them identify a real barrier to the realization of expanded housing opportunities for the elderly people who might chose to live in them (Folts and Muir, 2002).

According to U.S. Bureau of the Census (2001) and as shown in figure 1, there were about 900,000 individuals of aged 85+ alive in the United States in 1960. In 1990, the number has reached to 3 million people in just a span of 30 years. Furthermore, the number of individuals aged 85+ counted in the 2000 census, had increased to 4.3 million people (i.e. an increase of 1.3 million people

in 10 years). Finally, the Census Bureau's mid range projections suggest that by 2050, there will be around 18.2 million people aged 85+ or older living in the United States. These data suggest a housing problem (Folts and Muir, 2002).

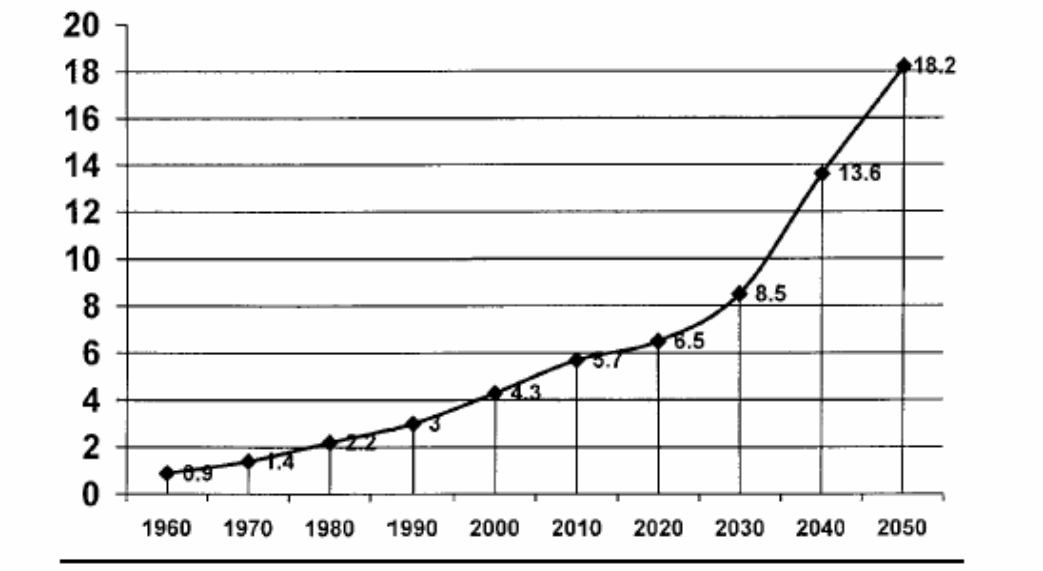

Figure 1: Census Counts and Projections for the 85+ population (in millions)

Source: U.S. Bureau of the Census, 2001.

On the other hand, the number of elderly person's living in nursing homes is also increasing steadily. According to Figure 2 of Census Bureau data, the population aged 85+ increases so rapidly that about 24 percent of the populations have to reside in nursing homes. Today it is around 1,032,000 (0.24x4.3 million) people aged 85 and older that are housed in nursing homes. According to Census Bureau projections, there will be an additional 3,336,000 [(0.24x18.2 million)-1,032,000] people aged 85 and older that will be requiring nursing home accommodations in 2050. So, it is envisioned that to accommodate 3,336,000 people, the United States will have to build and place in operation a

183 bed nursing home everyday for the 50 years between 2000 and 2050 (Folts and Muir, 2002).

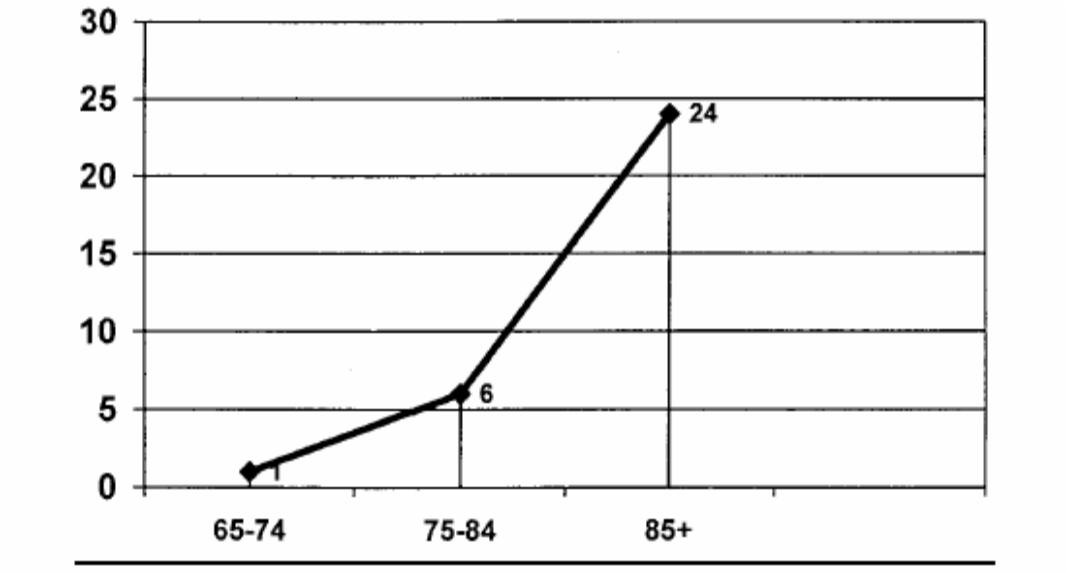

Figure 2: Percentage of Elderly in Nursing Homes in 1990 by age

Source: U.S. Bureau of the Census, 2001.

A health concern can compound a housing concern and a housing concern can compound a health concern (Lawler, K., 2002). All these combined concerns intensify the demand for the senior's housing.

CHAPTER III

HOUSING TRENDS AND THE NEEDS OF TODAY

HISTORICAL PERSPECTIVE

In the early 1960's, Leisure Oriented Retirement Communities (LORC's) were introduced by Ross Lortese (Rossmore and Leisure World) and Del Webb (Sun City) as developers (Strevey, 19898). The concept was to build an inexpensive small living unit supported by a rich environment such as a pool, a clubhouse, a golf course and other leisure activities. And because of federal loan guarantees for long term financing, many of these communities were developed as co-operatives.

Later in the late 1970's and early 1980's, several types of housing emerged that have caught attention of both developers and gerontologists. One of the housing came in to scene was the Granny Flats, which were basically based on Australian model of portable housing. The Granny flats consists of small, recyclable and relatively inexpensive living spaces designed to serve as temporary housing for an older relative. In Australia, the Granny Flat unit was supposed to be delivered to a site located on a relative's property until it remains suitable for the older person's needs and thereafter taken away, refurbished and used again. But on the understanding platform in the United States, various things were either ignored or misinterpreted because of incomplete official reports of the Australian experience (Streib et al, 1984). Also, the difference

emerged in terms of understanding for cultural differences. Finally, the Granny Flats resulted in an unattractive proposition in United States. The major reasons were that U.S. adults look to bigger spaces for living and it did not appeal to older adults who view property ownership as an important component of their quality of life (Folts and Muir, 2002).

Haas and Serow (1993, 1997) has shown importance to awareness of possible retirement destinations and communities and highlighted on various programs such as Alabama Advantage for Retirees, Historic Retirement destination and communities in Florida, Arizona and California, because of their climate, amenities tax rates and cost of living. Also, some destinations emerge in Sunbelt and coastal states opting for aggressive marketing to attract retirees (Frey 1999).

Another approach included the various forms of shared housing which were in two forms: Home-Sharing and a more standardized proprietary approach called Share-A-Home. In the concept of Home-Sharing, a person as an owner of the house provides space to one or more people for a place to live. Finally, the Home-Sharing concept did not work and it finally resulted in a cheaper way for college students and other young people (Jaffe, 1989).

Unlike Home Sharing, the Share-A-Home concept was more complex. In this type of sharing, a group of older adults have to rent or bought a large house and hire a house manager to shop, cook and clean. The problem arises from the salary of the house manager as different individuals have wide range of need and resources. The job description of the house manager lacked specificity that

was part managerial and part domestic servant with no opportunities for career growth. Also, the concept faced legal challenges by neighbors who typically supported the concept but firmly objected to the location of Share-A-Home facilities in their own neighborhoods and it also did not achieved success (Streib et al, 1984).

Another form of category was intergenerational housing that is not appropriate to define as a category. As all housing is intergenerational, until the children leave home and there is something that is culturally appealing about a household made up with individuals of different ages. But the problems of intergenerational housing appear to be more related with the practical application of the intergenerational concept than to the concept itself. Based on the site visits of intergenerational facilities, it was discovered to divide them into three main categories. First type, it was the housing where residents had invested heavily and the residents appear to expend great energy for the success of both the household and the model. Second type, it was where the residents supported in so far to achieve less expensive or more secure alternative to other living arrangements. Third type, it was where the groups appear to act negligible about either the presence of others or their ages. This particular group finds the household as an inconvenience necessary for inexpensive housing. Based on these models, three main conclusions have been achieved (Streib et al, 1984):

1) Despite the organizer's general belief that the residents shared what was described as "a common belief in the dignity of all humans and a desire to help others realize their potential", the only thing most of the

residents had in common was the fact that they needed an inexpensive place to live,

2) The “house events”, as organizers called the meetings and the common meals, were seen by residents as part of the cost of living there, and
3) The organizers saw nothing odd about requiring unrelated people to interact in a way what was consistent with the organizer’s own conception of family.

CURRENT TRENDS

Most seniors own their homes. As per the department of Housing and Urban Development records, the home ownership rate is as follows (Lawler, K., 2001):

- 81.2 percent for seniors between the age 62 and 74 years of age,
- 76.9 percent for seniors between the age 75 and 84 years.

For living arrangements of the elderly population, five types of system are delineated for the analysis: assisted living communities; unassisted 60 plus communities; shared housing; supported housing, and conventional housing. As per the data collected from the recently available survey by Assets and Health Dynamics Among the Oldest-Old, it figures the choices of America’s elderly household as below (Schafer, R., 1999):

- Around three percent of the elderly reside in assisted living communities designed for the elderly

- About ten percent live in shared housing, where a move has happened in order an elderly person can live and get help from a non-elderly person
- About seven percent live in 60 plus communities without assistance
- About five percent live in supported housing, where the elderly household is receiving support services from outside the household
- And three quarters of the elderly live in conventional housing, where also the survey shows that the elderly strongly desire to age in their own homes. Even the conventional housing has the choice of other elderly who have moved recently

A “conventional housing” is a one-storey single-family owner occupied structure and has more space than any other housing types. The “Assisted living 60 plus communities” is described as apartments / condominiums and has got the smallest number of rooms found in various housing types. The occupant in multi-storey structures rents it. “Shared housing” is mostly found as part of single-family one-story structures and is described as neither owing nor rental. Supported housing is predominantly in one-story single-family structures as ownership.

As a result of the survey, it is concluded that the elderly people desire to “age in place” independently in their own homes. The “age-in-place” desire becomes an important objective for the design and implementation of support services, and thus the need of a building system that could incorporate the needs of the elderly persons (Schafer, R., 1999).

The concept of “age in place” depicts that a lot of elderly people live in homes with special features. It is not surprising in the United States, where independence and self-sufficiency are highly valued. According to the data collected in 1990 from the National Health Interview Survey on Assistive Devices (NHIS-AD), the results identified are as below (LaPlante et al, 1990):

- 3 million elderly people had some type of accessibility feature in their home
- Over 1.8 million had handrails
- Over three quarter of a million had a raised toilet
- Over half a million had a ramp in their home

On the other hand, the retirement community industry has its own place in the United States because of two reasons. Firstly, the United States is a country of open areas with vacant land and resources. Secondly, it has a range of climates with an opportunity to migrate in sunny locations of the south, which are preferred by older persons who live in colder areas. Some elderly people moved by selling their houses and buying a smaller house in the Sunbelt, and others who have more assets tend to maintain two homes (Streib, 2002).

RESIDENTIAL MOBILITY

Mobility is the most important means of adjusting to the house in terms of meeting the needs and desires for living. Here, the mobility refers to the movement of households from one location to another for the primary purpose of changing one’s housing consumption, as opposed to migration, which refers to

movement for the purpose of changing jobs or employment opportunities. These classes of moves shall be referred to as consumptive and productive respectively (Reschovsky, 1982).

The historical proportions of retired persons tending to migrate out of their state are marked as less than five percent. Over the past four decades, it has not been seen that the individuals at retirement age moved between states (Longino, 1995 shows the share varying from 3.9 to 4.6 percent). Also, data from the U.S. Bureau of the census (2001) indicates a stable interstate yearly migration rate of 2.5 to 3 percent during the years from 1947-48 to 1998-99. The elderly population wants to remain in place and for the most successful “aging-in-place” programs, four key elements play a major role in assisting the elderly people (Lawler, K., 2001):

- *Choice*: Affordable health care and housing options with various alternatives should be provided for the diverse need of elderly people and their caregivers.
- *Flexibility*: Flexibility requires the range of services for health and housing that can be applied in a variety of contexts adjustable to elderly living in any kind of setting such as single family home, rents a privately or publicly managed apartment or resides in an assisted living facility.
- *Mixed Generations*: Senior’s citizens are experienced and can contribute to the community. They often provide day care, tutoring etc. to young families. And young families in return taking care of elderly and providing them a active living. For the intergenerational mixing go naturally,

proactive planning is required to ensure that communities have the opportunity for generations to mix.

- *Calibrated Support*: Calibrated support requires the ongoing assessment of an individual's health and housing condition in order to prevent under care and over care of the required needs.

Only about three to five percent of the elderly move annually and are less mobile than younger households. Four types of moves are being identified: buy or rent; move in with another person; nursing home; and retirement home or community. The findings of the research compiled from the 1993 AHEAD survey data is as follows (Schafer, R., 1999):

- Youngest group expected to "buy" or "rent" (65.9 percent)
- Oldest group expected to move to a nursing home (28.8 percent) or to a retirement home or community (38.4 percent)
- About nine percent expected to move with another person, with 80-84 year olds at 16 percent and over 90 year olds at 14.4 percent

The motivation to move is prompted by changes. The change could be either endogenous or exogenous to the household itself, which result in a divergence between desired and actual housing consumption (Reschovsky, 1982). The change also depends on neighborhood characteristics and accessibility to shopping or place of employment as a percipient to mobility (Wolpert, 1966; Moore, 1972; Weinberg, 1977). The desire to move does not lead necessarily to mobility. It can be two additional stages to the decision making process once the development of a desire to consider moving is made: (1) the selection of an

alternative location, and (2) the decision whether to move or stay (Speare et al, 1974).

The U.S. housing stock is growing old along with time. Today, the medium-aged house is over 30. The average house was built in the 1970's and many of the homes in the older suburbs were built in the 1950's or before. As the population is growing older, baby boomers may buy one or more house, but most of decided to age-in-place. A recent survey, of people 45 years of age and older, by the American Association of Retired People (AARP) found that the older the Americans are, the more firm their conviction that they do not want to move (Glenn Haege, 2002).

CHAPTER IV

EVOLVEMENT OF CRITERIA FOR SENIOR'S HOUSING DESIGN

INTRODUCTION

Looking into the present scenario that depicts the senior's housing demand and nursing home demand for the Elderly person of the United States, a major step is required to build a multi-dimensional housing concept that could be comfortably used by elderly persons. By this principle, we can reduce the overall burden on the nursing homes and provide more individuality to the elderly persons. In return, it will affect the overall economy of United States. On the other hand, this new concept of housing should be called a multi-generational housing concept. This multi-generational concept could be used by people of all generations and as a result, it would also reduce the overall burden on the remodeling industry.

The traditional homes built in an average fashion generally limit the independence of the aging persons after a period of time. Entrances steps and narrow doors are a problem for people using wheel chairs. Turning faucets and rotating door handles are difficult for people of arthritic hands. Light switches are a problem for an elderly individual with limited reach from a wheel chair. Thresholds are a trouble for people using crutches, canes, or walkers. Bathtubs and showers are slippery and nothing to grasp.

Surveys strongly show that people of United States want to grow old at home. Today, 12 percent of the U.S. population is over 65 and census

projections estimate that in 30 years, more than 20 percent of the population will be over 65 years. And in the next 40 years, the 85+ population is expected to be tripled. Also, the survey says that 49 million people have a physical disability at the current moment. And most have impaired mobility or dexterity, including 37 million people with arthritis (21 million under age 65). (U.S. Department of Housing and Urban Development, 1996)

The proposed building system would help in developing multi generational housing that could be used by people of all generations. The multi-generational housing concept will also helps in reducing the remodeling cost and decreasing the special demand of senior's housing. Based on the literature review and research, a criterion is developed for the building system that should satisfy the needs of the elderly persons and mentioned as below:

I – Mobility

II – Accessibility

III – Serviceability

IV – Controls, Signals and Automation

V – Manufactured Housing

VI – Flexibility

VII – Aesthetics

The entire selected criterion is inter-related and is supported by literature review and research and is described in the subsequent description of this chapter.

CRITERIA FOR THE SENIOR'S HOME BUILDING SYSTEM

I – MOBILITY

Mobility is defined as an external mobility and an internal mobility. External mobility comprises of movement in places such as entrances, decks, patios, walks and parking areas. Internal mobility is the in house movement. Thus, mobility is an important factor to determine the components of the building system.

II – ACCESSIBILITY

Accessibility is another key important criterion of utmost importance to be considered as part of the building system. It includes movement inside the house and primarily comprises of doors, cloth closets and so on.

II – SERVICIBILITY

Serviceability areas comprises of ease of maneuvering in spaces providing services. These comprises mainly of kitchens, bathrooms, laundry areas and so on.

IV – CONTROLS, SIGNALS AND AUTOMATION

Controls, Signals and Automation signify usage of switches and other service equipments.

The entire above-mentioned criterions selected for the building system are inter-related. And have mobility as an integral part of their definition. On the basis of data collected in 1990 from the National Health Interview Survey on Assistive Devices (NHIS-AD), researchers have reported with estimates of elderly people in U.S. living in homes with accessibility features such as handrails, ramps and raised toilets (LaPlante et al, 1992).

According to U.S. Census Bureau's Survey of Income and Program Participation (SIPP), there were 31 million people aged 65 or over in U.S. in 1994. Over half, or 52 percent were classified as having some kind of disability (Mace, 1998). Furthermore, Census Bureau projects the doubling of elderly persons by the year 2030. If this rise keeps persistent, there would be a subsequent rise of older persons with disabilities.

Figure 3 as below shows the percentage of U.S. population with disabilities with respect to age in accordance with Survey of Income and Program Participation (SIPP). As per the Survey of Income and Program Participation (SIPP), the terms used in disability function have very specific meaning such as follows: "*Functional activities*" include seeing words or letters, hearing normal conversation, speaking to understand by another individual, lifting and carrying 10 pounds, climbing stairs without resting, or walking three city blocks. "*Activities of daily living*" (ADLs) includes movement inside the home for getting in or out of the bed or chair; eating; dressing; or using toilet and bath or shower. "*Instrumental activities of daily living*" (IADLs) includes moving outside the home for to shop or visting a doctor; keeping track of money and bills; preparing meals;

doing light housework such as washing dishes, sweeping floor or using telephone. The Census Bureau define a individual as “severely” disabled, those who are unable to perform one or more functional activities, need personal assistance with an ADL or IADL, use a wheelchair, or are long term users of a cane, crutches, or a walker (Louie, J., 1999).

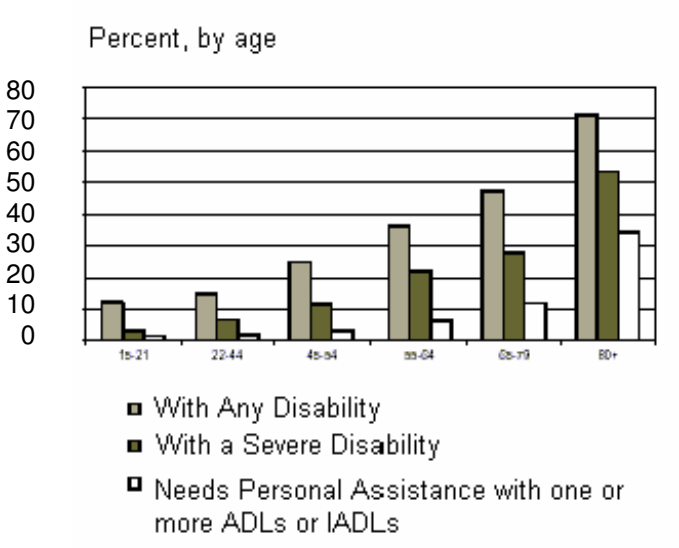

Figure 3: Share of U.S. population with disabilities

Source: Louie, J., 1999

Many disabled elderly people live in homes that become more difficult to navigate or even obstruct their daily activities. And many of the experience in disabilities affect their mobility and dexterity, leading to direct implications for how homes serving this population should be designed (Louie, J., 1999).

As per the data collected from the 1991-1992 SIPP report, there is shear importance of mobility in the life of elderly persons. The disabilities among the elderly people are directly related to mobility and accessibilities issues. Also, the report highlights that share of elderly people has an ADL limitation, which goes

up to approximately ten percent for movement in toilet areas and specifically while taking a bath or shower (Louie, J., 1999).

	Number (000's)	Share (%)
Total Households with Elderly People	22,790	100.0
Households with Elderly People who have difficulty		
Entering and exiting the home	1,586	7.0
Going up and down steps	2,095	9.2
Opening and closing or going through doors	647	2.8
Moving between rooms	873	3.8
Reaching bathroom (Tub/shower, toilet, sink)	1,134	5.0
Reaching kitchen (Sink, stove,referig.,cabinets)	794	3.5
Cooking and preparing food	1,255	5.5
Feeding themselves	268	1.2
Bathing, getting in and out of the tub or shower	1,864	8.2
Grooming and dressing	881	3.9
Doing housework and laundry tasks	1,874	8.2
Seeing, even with glasses or contacts	1,568	6.9
Hearing normal talk, even with hearing aid	1,612	7.1
Households where an elderly person needs special equipments, or assistance of another person around the home	1,815	8.0
Households where an elderly person has any disability	5,028	22.1

Figure 4: Households with disabled elderly people of age 65 or over

Source: Louie, J., 1999

The survey done by Assets and Health Dynamics Among the Oldest-Old (AHEAD), which suggests at the household level that 35 percent of households with a age of 70+ have at least one ADL. Figure 4 as below is the 1995 American Housing Survey done by Joint Center for Housing Studies at Harvard University. The survey also supports the importance of mobility for elderly people in different areas of daily life. Any disability for the survey is defined as having any of the difficulties listed in the table, including the need for special modifications, equipment, or personal assistance. Furthermore, figure 4 shows the numbers of households around the country with disabled elderly who have accessibility modifications in their home (Louie, J., 1999).

V- MANUFACTURED HOUSING

In the United States, “Manufactured Home” is a home built entirely in a factory under a federal building code administered by the Department of Housing and Urban Development (HUD). The HUD code applies to all manufactured homes built in the United States (Syal et al, 2001). The benefits of the manufactured housing are stable workflow, material availability, ease of quality improvements, less waste, and lower labor costs (Homebase, 1999). The manufactured part of housing is considered part of the criteria because of the reason that its role is important in building a house. The cost of the house is known before execution. The manufacturing process is less labor intensive providing a clear understanding of the requirements and the appearance of the house before building it.

Industrialized construction techniques have grown rapidly through the postwar period and factory built housing has gained significant importance in many industrialized countries. The term “industrialized housing” at the turn of the century generally refer to use of framing lumber produced in a lumber mill instead of the hand crafted site assembly of logs. Today it is called as “stick building” and factory prepared housing is called as “industrialized". In the United States, various factory construction techniques have been used such as precut systems, paneled systems, manufactured housing (mobile homes), modular systems, wet core modules and wood components.

Panelized Housing consists of housing components manufactured in a factory. The components are then transported to the site, assembled and laid to a permanent foundation. The housing system consists of panels as open walls, closed walls, and structurally insulated panels. The material is manufactured as maximum sizes up to 8 feet wide by 24 feet long.

Precut Housing is a kit made at the factory. The building components are cut at the plant, manufactured and get ready for shipping. The components are then shipped to the site for assembly on a permanent foundation.

Manufactured Housing is defined as a factory built home construction. The components are as one or more units are transported to the site on wheels and usually installed on non-permanent foundations. The units are typically constructed on a steel chassis using conventional platform framing techniques.

Modular Housing is factory built homes. They consist of typically one or more units and use platform frame construction. These units are three-

dimensional units that are pre-assembled completely with trim and finishes. After getting ready at the factory, these units are shipped to the site for installation on permanent foundations.

In general, the home building industry is very dependable on manual labor and labor-intensive processes. So, in comparison to other industries, home industry is visualized as of low production, more wastage and based on antiquated technology. Although, there is already a move towards industrialization in manufacturing modular homes innovations, and various pre-fabricated structural panels. At the national level, the development of advanced materials and construction techniques for housing has been successful but has not been able to significantly shorten adoption times due to extreme fragmentation in the materials production and construction industries. To bridge this gap, manufacturing sector has adopted strategies such as Just-in-Time (JIT) supply, and Design for Manufacture and Assembly (DFMA) to reduce production cost, improve productivity, and improve product quality. The keystones of these strategies were information systems that were fully merged with the business enterprise, had given way to the development of Enterprise Resource Planning (ERP) systems. On the same pattern, Object Oriented CAD software is a key step towards information integration in the housing industry. However, it still needs to be developed as a comprehensive information model, viable linkages to field operations, and real time tools for analysis of structural, mechanical, production and economic performance. The application of advanced industrialization resources varies accordingly to the size of the builder's business.

A small volume builder who produces less than twenty homes per year does not have resources to develop a full ERP. Regional and national supply building companies could generate the industrialization effort by linking the object oriented CAD files to the component design software.

A medium volume builder who builds several hundred homes per year in regional markets is more likely to influence their supply chains by producing wall panels and roof trusses. They are more likely to have company wide purchasing and accounting systems, lacking only design production modeling and field production modeling and field construction information tools to have an integrated ERP system.

A High volume builder who produces over one thousand homes per year is more compatible to use supply chain and sophisticated project management tools. Their step of industrialization requires integration of business and project management tools, the development of design for production management and modeling tools, and extension of the information management systems to field construction personnel and practices.

A Production builder who is producing large-scale components like wall panels, modular housing, etc. is making more extensive use of industrial processes. They have considerable supply chain influence and employ Just-in-time methods for inventory control. They will be using materials requirements planning (MRP) and take benefits from the application of design for manufacture and assembly techniques (DFMA). Production builders are the closest to implementing enterprise resource planning (ERP) systems with the development

of production modeling and field construction information tools (O' Brien et al, 2000). The main objective of the ERP system is to provide seamless, real time information to all employees who need it, throughout the entire organization (or enterprise). The ERP system extends the idea of a central database to all areas within an organization (Meredith and Shafer, 1999). In this "Information Age", the construction industry is a perfect example of information management, where the success lies below managing and controlling information quickly and accurately.

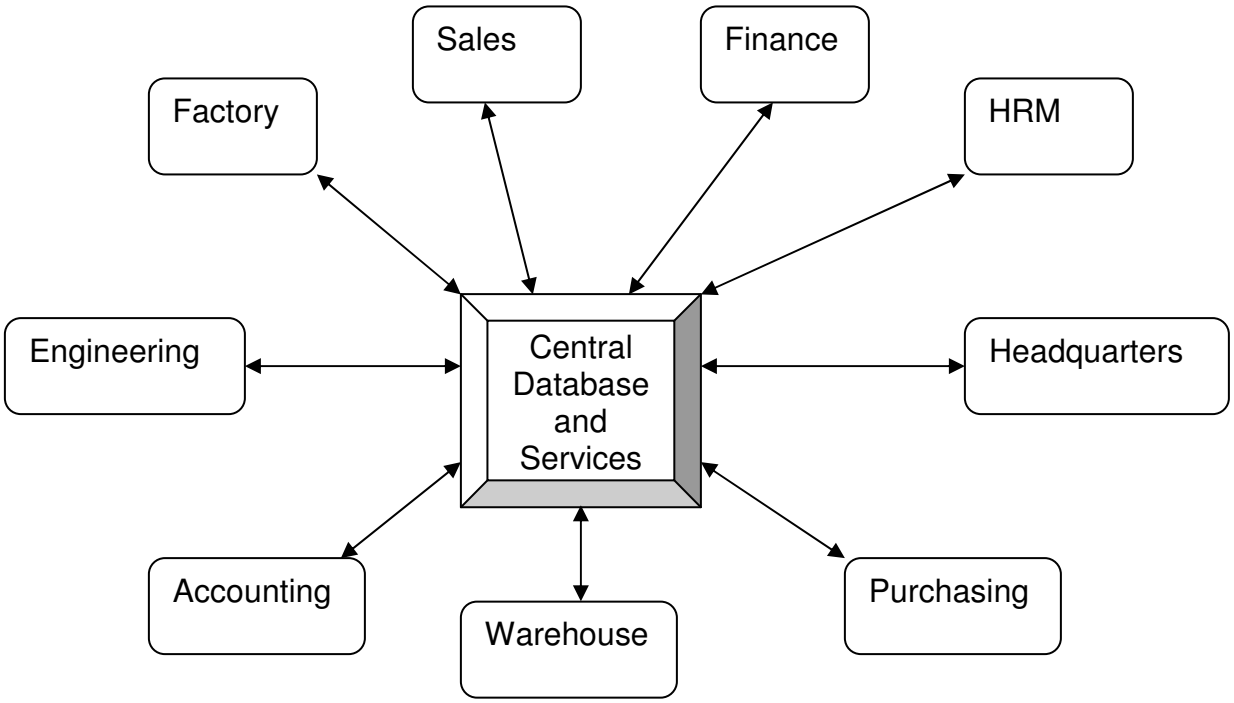

Figure 5: Typical ERP system

Source: Meredith and Shafer 1999

Advancement in information technology and other advancements have made technology the key enabler to supply chain management. The key factors for industrializing the residential construction site are enterprise-wide business

support systems, process and production management tools and assembly industrialization techniques. The supply chain management is the key to implement all major key success factors. Productivity in the housing industry lags behind other industries because of non-linkages of aspects of product design, production and sales to perform. Linking of all these aspects is the essence of systems integration, which lacks greatly in the housing industry, because housing treats each major building system independently and unconnected. The advantage of this system integration is reduction of developmental costs. Absence of system integration is largely a product of reduced design resources and the system of discrete trade subcontractors who are unable to coordinate in the design stage (O' Brien et al, 2000).

Information integration should become the "umbrella strategy" to act as a backbone to the housing industry. It is understood to support industrial design, production, and operation methods in similarity to the general manufacturing industry with the help of techniques such as JIT (just-in-time), MRP (Materials Requirement Planning), MRPII (Manufacturing Resource Planning), ERP (Enterprise Resource Planning), and DFMA (Design for Manufacture and Assembly). MRP, MRPII and ERP systems attempt to control raw material, finished product, and work in progress inventory. It also helps in managing increasing complex product designs and decreasing product to market cycle times (O' Brien et al, 2000). On account of housing development, conditions of integration fall into five primary areas of influence: (O' Brien et al, 2000).

1) Information Integration as one collective data source for many pieces of information and accessible to all the homebuilders.
2) Physical Integration for making the many parts fit together as one.
3) Performance Integration for making the many systems performs as one.
4) Production Integration as conducting the many processes as one, and
5) Operations Integration as operating the many subsystems as one.

VI – FLEXIBILITY

Flexibility is another important criterion that is required to be considered part of the proposed system to satisfy the needs of elderly persons. As the needs of households vary from individual to individual, the open building system would be a key strategy to adopt for the varying needs of elderly persons.

Open building has developed out of vernacular building traditions. Because most vernacular building types experienced a wide range of uses in their life span, builders learned long ago to make an infill level distinct, changeable, and less enduring. In traditional Japanese building, they used demountable sliding screens and removable tatanic floors between structural posts. There was a prevailing building system of putting first the façade, roof and fenestration's in Dutch Canal houses and then arranging rooms behind the windows (Habraken, 1998).

During the era and following the 20th century's world wars, mass housing spread throughout capitalist and socialist societies. The basic building block of urban fabric, an urban house lot, was replaced by coarse grained, multi story

housing block containing hundreds of rigidly uniform dwellings. By the late 1950's, mass housing sites worldwide started witnessing socially destructive effects from such dramatic coarsening of the urban fabric, centralization of control and attendant loss of individual freedom, participation and responsibility in the built environment. In the subsequent years, mass housing has proved inflexible as incapable to adjust with the change in social, economic and technical structure. Lot of concrete mass housing projects has become obsolete or uninhabitable. With such consequences in action, open building concept emerged as a residential infill system. The key Open Building Concepts emerged as follows (Kendall and Teicher, 2000):

Levels: Levels are defined as a certain grouping of physical parts and spaces that can be observed to jointly transform in an orderly and recurring way. In essence, they form spontaneously at points where boundaries of construction, social organization and territory coincide. Levels define both the environmental professions and their fields of operation – urban planning (tissue), architecture (base building), interior design (infill), and furnishings.

Supports: It is defined as a finished building, ready to be occupied by variable infill. It is a permanent, shared part of the building that provides service space for occupancy. The typical support elements include building structure and other building components. The support elements are dominated by local architectural styles, climate and building codes, and other local conditions. A support is not a skeleton but is rather enabling architecture. The support is a physical setting that offers space and possibility for building up of dwellings with as few constraints as

possible while requiring little work. From a community perspective, when the support is complete to be occupied, it requires infill.

Infill: An infill system is a carefully pre-packaged, integrated set of products, custom prefabricated off-site for a given dwelling and installed as a whole. Also, site made partition walls are infill elements if the resident has control over their positioning. However, if the dwelling lease prohibits moving any element, it remains part of the support, despite the technical ease of moving it. Thus, infill elements are also defined by social as well as technical criteria.

Unbundled decision-making: The decision makers and physical parts of the building have increased due to increasing size of the projects. Professionals have often ignored environmental and building trends, and advocated integration of many separate decisions into one “bundle”. With distinct bundles of technology and logistics in different buildings, production capacity can be effective by developing each ‘technology bundle’ or level’s possibilities for optimal production.

Capacity: Capacity analysis is founded on two ideas for open building practice- (1) designing form as an open-ended and dynamic fabric; and 2) designing space or form (at multiple scales) with built in capacity to accommodate more than one “program of functions” over time.

Sustainability: Re-usable components have linked open building and sustainability. Further, the concept allows the builder or end user to develop technical interfaces to ‘plug and play’ with products made by different companies. This makes open building infill move towards design and manufacture for assembly and disassembly.

The importance of the key components of the open building system is with the manufactured part of housing. The integration of open building system facilitates flexibility during the planning face, which helps in achieving barrier free circulation. The concepts of open building system also help in development of the structural system that is discussed in detail in the next chapter.

VII – AESTHETICS

With the present manufacturing housing system prevailing in the industry, there is lot of non-acceptance of the system because of the monotonous character of houses built. This is all because of the low value of architectural aesthetics. To encounter that, the research is concentrated on to suggest an innovative system that could produce multiple permutations and combinations of the structural concept. Moreover, the suggested methodology should have that flexible nature in order to generate possible alternatives of independent housing as required out of the basic structural concept and building as a unique house. In order to incorporate that flexibility in the system, the lessons have been adopted from manufacturing systems.

The production flexibilities should have the relevant structure such as mix flexibility, process flexibility, routing flexibility and machine flexibility, which comes under flexible manufacturing systems (Browne, 1984; Singh & Talavage, 1991; Singh, 1994). The following interpretation is from a practical understanding of manufacturing science and flexible manufacturing (Singh, 2001). For the building system proposed, mix flexibility will be for architectural flexibility. As the

production plant will be manufacturing side units of different sizes in order to fix to the central core, it will help in creating architectural variety to the cityscape without reducing manufacturing speeds (Armacost, 1992). Process flexibility helps in conserving resources and machines by designing them such that they are capable of executing multiple tasks of different types for different products (Black, 1994). Routing flexibility helps route a part of manufacturing to another station, if one or the other stations are busy. So, with an optimal design aimed at manufacturing housing units, the routing problem can be minimized because demand is virtually high, resulting in planned production and peak resource utilization (Gerwin and Kolodny, 1992). The machine flexibility is directly related for factors of high volume of production such as machine quality, reliability, and lack of breakdown. With the development of technological quality machines and computer-programmed production, the problem of machine reliability is diminishing day by day (Black, 1991). The concept of the building system proposed is concentrated for mass production. The production is related to the flexibility of the system, which is closely related with lean and agile production (Roos, 1995).

Part of the aesthetics is the consideration of user-friendly windows for the elderly persons. For example, these windows are casement and awning windows that are recommended to be part of the proposed system. Casement and awning windows are typically the most comfortable in comparison to single-double hung and sliding windows. They are the easiest for most people. They are operated by turning a hand crank located at the window sill within easy reach.

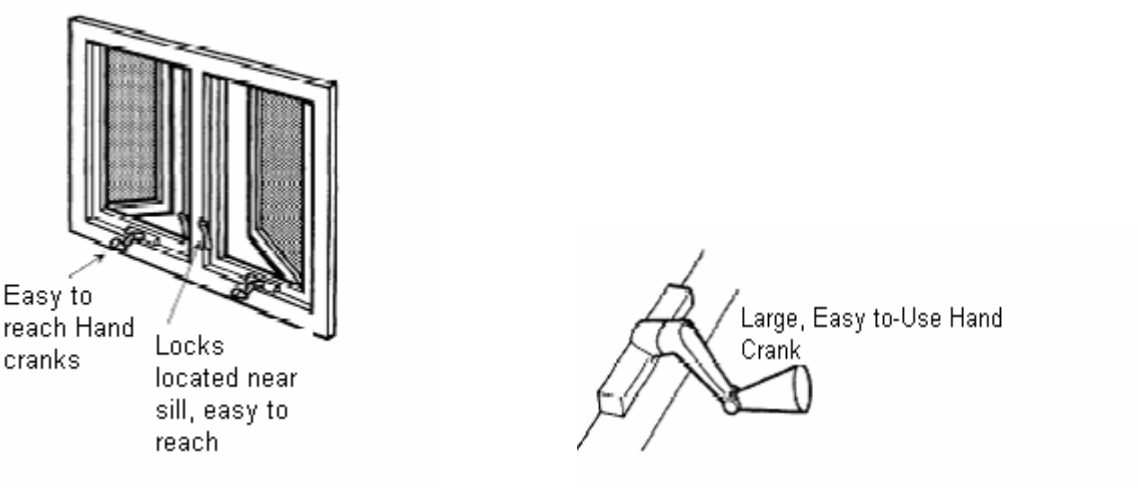

Figure 6: Casement window and view of hand crank

Source: NAHB Research Center, 1996.

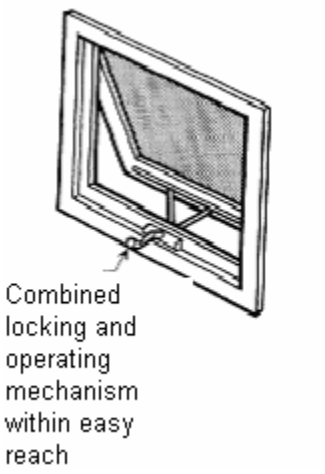

Figure 7: Awning window

Source: NAHB Research Center, 1996.

DISCUSSIONS AND RECOMMENDATIONS

Based on the importance of research, the literature review establishes three important pillars for conducting the research. These pillars are identified as follows:

1) Senior's Housing Demand,
2) Aging in place, and
3) Home needs special features.

These definitions of the pillars for research provide a path to move forward that further generates the aims and objectives for the research as:

> *A Building System that should meet the senior's housing demand adhering to the concept of aging-in-place with the house equipped with special features*.

Based on the problem definition of the research, it has been identified on the basis of literature review that the factors, which could solve the housing demand and at the same time cater to the needs of the elderly persons, should be as follows:

1) Housing that could cater to the need of Elderly persons,
2) Housing that could be mass produced, and
3) Housing that could be flexible enough to meet the requirement of each and every individuals and fulfilling it to the required satisfaction.

But in this particular scenario, the needs, flexibility and mass production becomes the basic backbone, which I discovered in order to define the

building system. The graphical development of research is represented as follows:

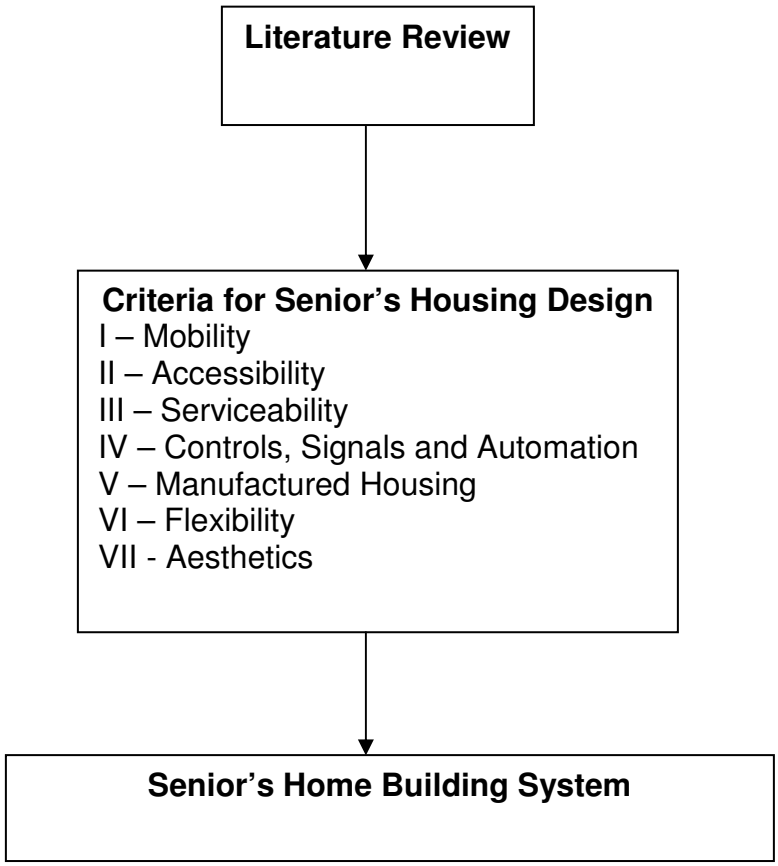

Figure 8: Developmental structure of research

Further emphasis is on latest construction techniques to support the mass production. The concentration of incorporating latest construction techniques will help in developing a building system that would make the housing more industrialized and easy manufacturing. The industrialized manufactured housing that is developed in various permutations and combinations will lead to variety in urban fabric. The cost analysis and other feasibility analysis have been recommended for future research.

CHAPTER V

DEVELOPMENT OF THE BUILDING SYSTEM

INTRODUCTION

The first step of the Baby Boomer generation, which began in 2001, has put tremendous pressure on the housing industry of the United States in terms of housing demands for elderly persons. This immediate need developed an interest to investigate and research, in order to develop a building system. The system would cater to the needs of the elderly persons, as well as suit individuals of all generations.

Also, figure 9 supports the ideological development of the building system that shows an importance of needs for the elderly people. The modifications already done in disabled elderly households also support this ideology.

	Number (000's)	Share (%)
Total Households with disabled Elderly People	5,028	100.0
Home has:		
Any home modification	2,258	44.9
Ramps	484	9.6
Elevators or stair-lifts	267	5.3
Extra handrails or grab bars	1,454	28.9
Extra wide doors or hallways	491	9.8

Door handles instead of knobs	306	6.1
Push bars on doors	108	2.1
Modified wall sockets or light switches	167	3.3
Modified sink faucets or cabinets	185	3.7
Bathroom designed for easier accessibility such as for wheelchair use	503	10.0
Kitchen designed for easier accessibility such as for wheelchair use	378	7.5
Raised lettering or Braille	57	1.1
Specially equipped telephone	376	7.5
Flashing lights	71	1.4
Any other modification	53	1.0
Someone in the household has:		
Any help or assistive device	3,100	61.6
Help of another person with their limitation	1,943	38.6
A cane, walker or crutches	2,352	46.8
Wheelchair	833	16.6
Motorized or electric cart	94	1.9
Any other device	213	4.2

Figure 9: Households with disabled elderly people of age 65 or over

Source: Louie, J., 1999

Precisely, the figure highlights the following points:

- Almost 45 percent of households have at least one of the home modifications
- Almost 29 percent of all elderly have extra handrails and grab bars
- Almost 10 percent of all elderly have extra wide doors or hallways
- Almost 9 percent of all elderly have ramps
- Almost 60 percent have either the help of another person or an assistive device
- Almost 39 percent receive personal assistance and almost 47 percent have a cane, walker, or crutches

Other findings also suggest that 50 percent or more of households with mobility impaired elderly members do not have any of the modifications required necessary or highly useful. According to the American Housing Survey in 1995 and tabulated by the Joint Center for Housing Studies at Harvard University, it clearly identifies that the 1.1 million disabled elderly household's lives in multi-family structures. The households form a small share of 22 percent of the total population with a disabled elderly member. The greater chunk of this population, which is over 70 percent, live in single-family homes, and almost a quarter of their units were built before 1940 (Louie, J., 1999). Also, there has been established a consistency with reports that elderly people wish to age in place (American Association of Retired Persons, 1996). Therefore, the concentration of the research is emphasized on the concept of developing a building system, to build an independent house that should cater to the needs of an elderly people.

Also, the strategies and various components of the building system could be implemented in any kind of development universally.

Furthermore, based on the portion of AHS data made available for analysis, certain important points are as follows (Louie, J., 1999):

- About 638,000 households with disabled elderly individuals (and without non-elderly disabled people) express the need for the ramp in the unit, but less than 50 percent of the households actually have a ramp.
- About 111,000 households with disabled elderly express a need for push bars on doors, but over 80 percent do not have them.
- About 95,000 households express a need for modified sink faucets or cabinets, but almost 74 percent do not have them.

The literature review, development of criteria and above-mentioned problems validates the requirement of a building system. The complete building system is envisioned as a set of formed linkages from one step to another in a hierarchical order. These natural formed linkages are a result of in depth study about the needs of the elderly people and the immediate housing problem faced by the United States. Initially, the criterion is developed as a backbone to the building system and is identified as follows:

1) Mobility
2) Accessibility
3) Serviceability
4) Controls, Signals and Automation
5) Manufactured Housing

6) Flexibility
7) Aesthetics

The birth of the above-mentioned criterion is supported by the results of many researchers in the field of senior's housing. The first four criterions have movement as their integral part of definition, which is already pre-defined in the previous chapter. On the other hand, the remaining three criterions are inter-related with the production process. In totality, the criterion gets divided in two set of hierarchical order. The first complete set of criterion is related to user participation and satisfaction. The second set of criterion gets related to the production process in terms of flexibility and mass production. Overall, the criterion grows into forming as components of building system, and is as follows:

1) User participation and satisfaction
2) Adaptability and mass production
3) Mobility
4) Accessibility
5) Serviceability
6) Controls, Signals and Automation
7) Manufactured Housing
8) Flexibility
9) Aesthetics

The discussion and recommendations further goes on in defining the relationship and identifying further sub components of the building system. All components have proven interrelationship with each other, in terms of facilitating

construction and providing comfort for the elderly person in the overall building of the house.

“User participation and satisfaction” is the most important and primary component of the building system that should guarantee user satisfaction. Also, it is in relationship to its secondary component “Adaptability and Mass Production”, meaning as the user satisfaction gets connected to provide adaptability and mass production. Adaptability means that the user should have the flexibility to determine the size of the dwelling that suits the requirement accordingly. Mass production means that this developed system could manufacture senior houses to as many users as possible in an affordable way.

Another hierarchy of components is defined as sub-components to the main components. The first component is the Mobility that has a direct relationship with user satisfaction. It is also an integral part of adaptability and mass production, as it is affects the production planning process on account of architectural planning. Further, mass production is related to manufactured housing, and adaptability is another term that grows from ease of mobility. Mobility as a function resonates with aesthetics on architectural principles of “form follows function”. The second component is accessibility that has mobility as an integral part of its definition. Accessibility means widening of doors and openings, leading to “barrier free circulation”. The third component is serviceability that also has mobility in its base definition, but is limited to areas providing services such as kitchen areas, bathrooms and laundry areas. The fourth component is controls, signals and automation which also has a

relationship with mobility as thro' mobility, these services are accessible. The fifth component is manufactured housing, which has a already defined relationship with above mentioned components. Manufactured housing is an integral factor with flexibility in terms of the building system proposed, which would result a kind of flexibility. That flexibility will govern the built up area depending upon the requirement of the individual. Flexibility is further defined as part of structural concept for the building system. Also, flexibility is in terms of usage of varying sizes of panel's in house construction and further in using the cam-nut and cam-screw technique for fixing of panels. The technique is a proven research in effective mass produced housing. The cam-nut and cam-screw technique becomes part of the component, as an effective proven method of mass production. These main components of the building system get developed further into sub-components that are described in the subsequent chapter, and the details are provided in the final detailed model of the building system.

THE FIRST HIERARCHY

Based on the literature review and continued research, the first hierarchy of components of the building system can be defined as:

1) User Participation and Satisfaction, and
2) Adaptability and mass production.

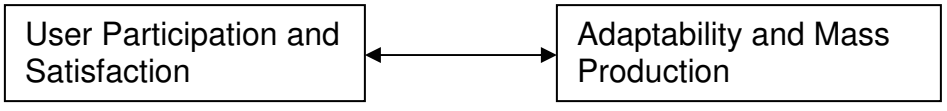

Figure 10: First Hierarchy of The Building System

The first component of the proposed building system, User Participation and Satisfaction, is the key enabler of the system that should support and satisfy all the needs of elderly persons. Also, the system acts as a universal requirement for all generations of the society, in order to avoid future remodeling. Generally, house builders have more concern in regard to cost other than understanding its value. In speculative housing development, the house-selling price is derived from what the markets will bear and is based on cost of land and production with expected profits. In contrast, producers in other consumer industry are forced to reduce production cost below selling prices to achieve profitability. The manufacturers also have to concentrate on innovative products for differentiating themselves from other producers. The speculative homebuilders, however, usually build the stock before the consumers are found. Nevertheless, the research shows that more than 83 percent of the homebuyers liked to be offered their choices over the initial design of homes (Naim et al. 1999). Other sectors of the construction industry have sought to capture customer requirements more effectively (Anumba et al. 1996, Dulami et al. 1996), house builders have made little efforts in this direction (Naim et al. 1999).

Despite these generic problems, there have been numerous attempts to introduce lessons of lean production in the home building industries of all countries. Business process modelings has been a forerunner to the elimination of non-value added activities and supply chain management programmes, which are designed to lead to time compression and reduced total costs (Evans et al. 1997, Melles and Welling 1996, Horman et al. 1997, Birke 1998). The proposed

system is a step towards mass production, but in a leagile (LEAn+aGILE) manner. The whole building unit is decomposed into four elements: foundation, central core, attached units and the roof. Thus, a house can be defined as a system consisting of different elements and components that needs assembly to create a whole. A house is in comparison to a personal computer for changing concept of mass production to agile one in terms of right hard disk size, screen size, processor size, and so on, in order to meet the particular customer needs. Learning from the other industry partners, the house building industry requires a proper integration of different players for the supply chain (Naim et al. 1999). The building system proposed is a step towards re-engineering the supply chain. The re-engineering can only be achieved by delivering standardized components up to a decoupling point and then assembling the relevant components to deliver the customized product. Overall, the above reasoning leads to the following proposition:

> *Proposition 1: Re-engineering the supply chain by delivery of standardized components manufactured in accordance with the elderly needs will meet the senior's housing demand and facilitate a universal development of the housing sector as a common algorithm for all generations.*

Secondly, mass housing and adaptability go hand in hand; if there is adaptability in construction, it will result in mass production. For mass housing to

be attractive, it has to have architectural flexibility. The flexibility will help in making each dwelling to be of different design avoiding architectural monotony and will be equivalent to product variety (Bessant, 1991; Barlow, 1998). Four factors attract the consumers for purchasing manufactured homes (Burkhart et al, 1996):

1) Most affordable housing alternative,
2) Completion is faster,
3) Easy maintenance, and
4) Living in a manufactured home provides more flexibility and freedom especially if the home is located in a manufactured housing community.

The strategy for the proposed building system is emphasized to develop houses of unique architectural character. The complete building structure will consist of main components as follows: The pre-manufactured middle area, built with concrete or steel components, as the main central core. Surrounding the central core, the building units will be attached using large concrete panels using cam-nut and cam-screw jointing methods. The building system has been designed to follow the resource-planning system in two aspects: firstly, to develop the information flow between independent demand of home sales and dependent demand items (BOM-Bill of materials). The resource planning system will help in detailed take offs, material ordering and scheduling processing based on customer needs. Secondly, it will help in enabling increased communication

between entire units (O' Brien et al, 2000). The principle of resource planning system will facilitates in detailed cost prior to manufacturing.

Flexibility is one of the key aspects of lean manufacturing. Lean construction has developed concepts from lean manufacturing to achieve low cost and fast erection of housing units. Flexibility could be defined in three modes – manufacturing, architectural, and erection flexibility. To obtain high erection speeds on the job site, lean production will be a fundamental benefit to the progress at site (Singh, 2001).

The flexibility measurement is related to the ability of a production system. Construction is also a production system, which processes a variety of different parts using various workstations and resources (Groover, 1987; Singh et al, 1996). The above discussion leads to the following proposition:

Proposition 2: Manufacturing of the central core with independent attached units will facilitate flexibility in the mass production for senior's housing.

THE SECOND HIERARCHY AND THE SUB HIERARCHIES

The second hierarchy of the components for the building system is represented as follows:

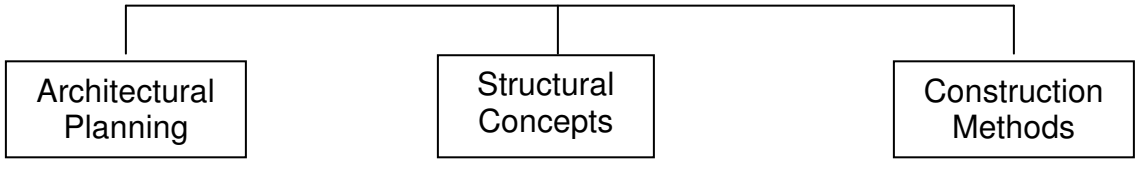

Figure 11: Second Hierarchy of The Building System

ARCHITECTURAL PLANNING

The architectural planning starts from the design of the architectural layout. The planning needs to be comprised of mobility issues in external and internal spaces. Mobility issues are directly related with ease of movement.

A porch / patio or stoop area size 5 feet by 5 feet is recommended to allow a person using a walker, cane or wheelchair room to maneuver while opening the entrance door (NAHB, 1996).

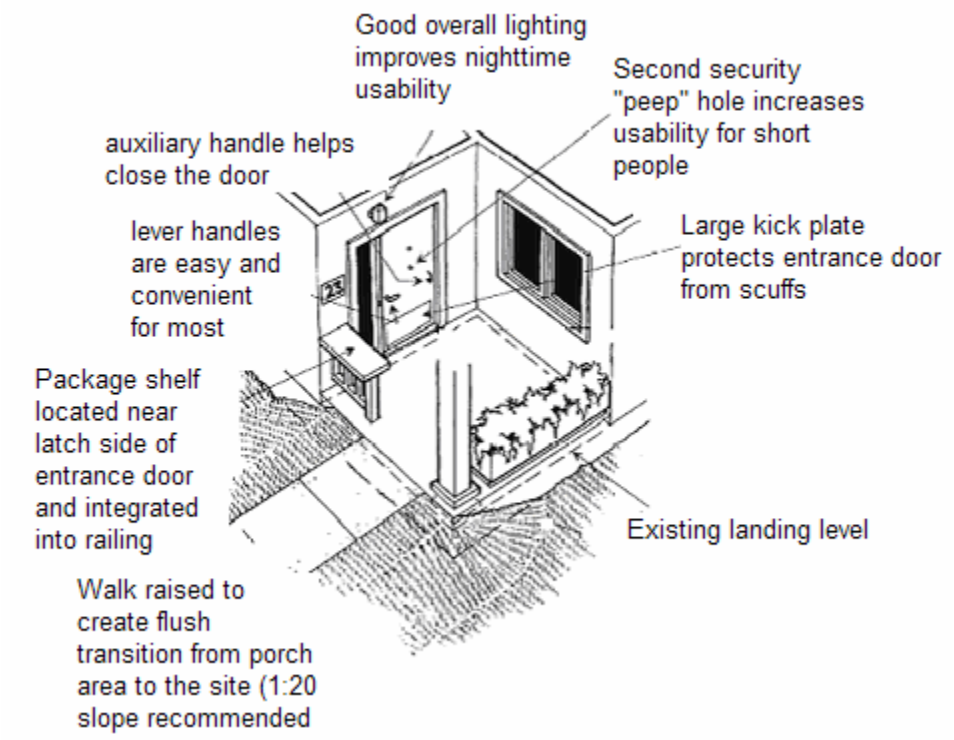

Figure 12: Entrance details

Source: NAHB Research Center, 1996.

The difference in level between the interior and exterior is recommended to be within ½" or less. Also, porch/stoop landings could be in almost level with the interior floor, but there is increased risk of water infiltration at the door. To avoid this, common water proofing techniques could be taken such as providing

positive slope away from the building; provision of continuous metal or plastic bars in flashing at perimeter of floor system; caulking at all exposed joints using appropriate joints and under thresholds; and adding of positive interlocking weather stripping, and providing drain and weep holes (NAHB, 1996).

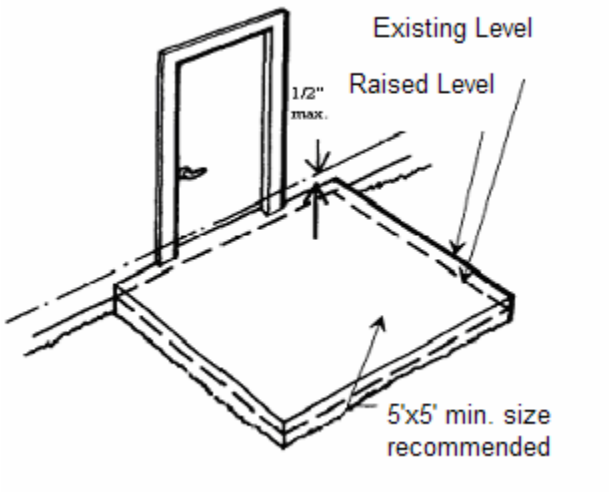

Figure 13: Raised Porch

Source: NAHB Research Center, 1996.

The walks leading to porches / patios could be sloped and flushed with the landing. The walk slope is recommended to be 1:20 as handrails are comfortable on slopes between 1:20 and 1:12 (the absolute maximum) (NAHB, 1996).

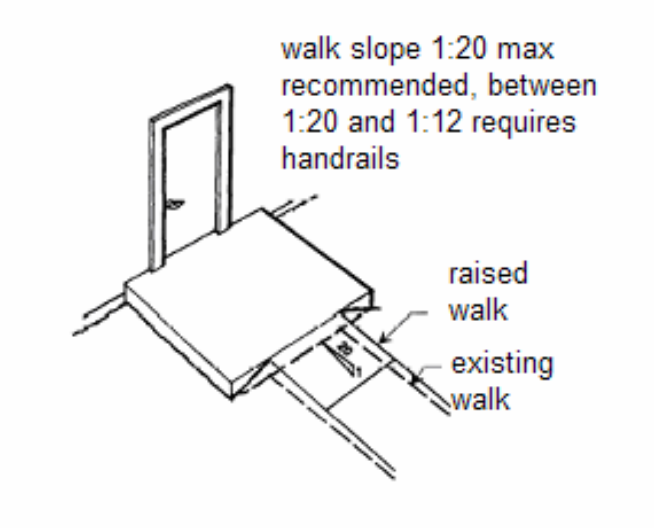

Figure 14: Raised Walk

Source: NAHB Research Center, 1996.

The steps are recommended to have curved or sloped nosing and eliminated sharp edges. Risers should be equally spaced to enable the body's natural rhythm to continue throughout the climb or descent. The treads and risers should be of consistent size to ensure maximum safety and ease of use. The railings should be sturdy in nature and rail extensions should be provided to ensure stability and assistance for people with balance or mobility limitations (NAHB, 1996).

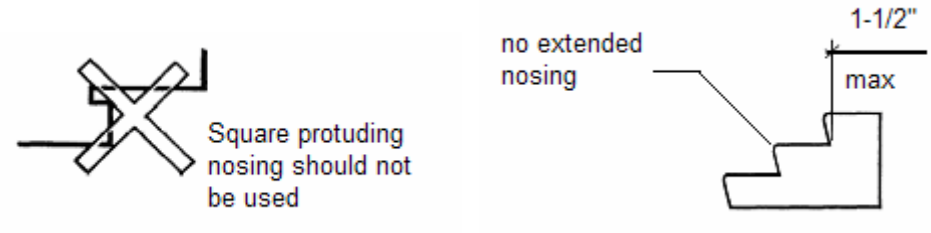

Figure 15: Design for Tread and Nosing

Source: NAHB Research Center, 1996.

The Center for Universal Design also recommends features like adding a chair lift to stairs; replacing steps with ramps; widening doorways or adding offset hinges; lowering cabinets; installing more elevated toilets; adding grab bars to the bath tub or toilet; and installing alerting devices for the hearing or visually impaired (Louie, J., 1999).

No immediate or unprotected drop off is recommended, instead a definition of edges is required in the form of railings, benches, planters, or curbs. Other general recommendations are as follows (NAHB, 1996):

- The signage recommended of bigger in size and contrast in nature. The mounting height is suggested to be 60 inches above the floor and on the latch side of the entrance door.
- The doorbell is recommended at a mounting height of 36 inches to 48 inches and it should be a high contrast activation button.
- An intercom box is recommended to be 48 inches maximum above the floor with contrasting features.
- A doorway should not have a clear opening less than 32 inches.
- Installation of a temporary ramp or platform lift.
- Installation of abrasive strips on steps and wood bevels under extended nosing of stair treads.
- Installation of awning for weather protection.
- Connection of doorbell (wireless) to interior light or a knocker light at the door.
- Installation of an intercom system with video display.

Another important issue as part of mobility is the surfaces. Access aisles are recommended next to the parking space for a person to transfer from a car to a wheelchair, or maneuver off a van lift. A paved strip is suggested to facilitate a secure arrival and departure spot for those with poor balance or mobility.

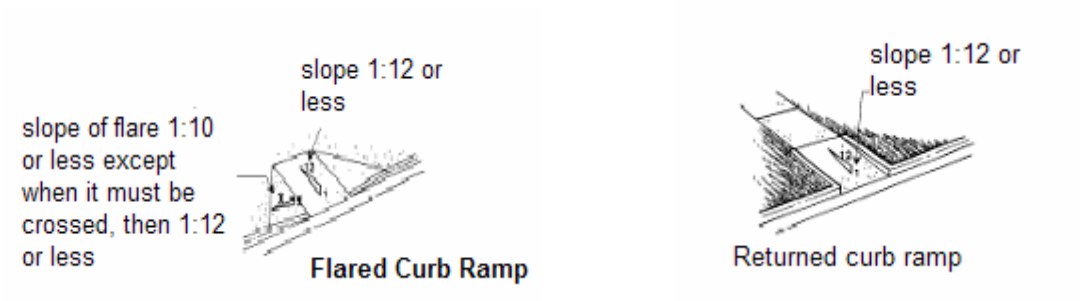

Figure 16: Details of Curb Ramps

Source: NAHB Research Center, 1996.

A broom finish walkway is recommended for good traction of wheel chairs. An uneven walkway or path with spaces larger than ½ inches between even surfaces is inappropriate for people with walking disabilities. Grills and grates are recommended not to have more than ½ inch openings in the direction of travel. Openings perpendicular to the direction of travel can be greater than ½ inch. Any vertical change in levels should not be greater than ¼ inch (NAHB, 1996).

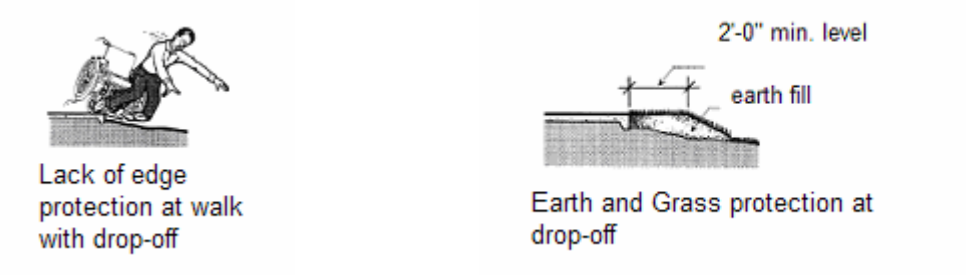

Figure 17: Importance of Edges

Source: NAHB Research Center, 1996.

The objects alongside the walks that are below 27 inches are detectable by people who are visually impaired and use detection canes. So, objects between 27 inches and 80 inches above the walking surface should not protrude more than 4 inches onto walks to avoid any accidents (NAHB, 1996).

Interior surfaces are recommended to be stable, firm and slip resistant. The “non skid” floor surface helps create enough friction to keep shoe heels and wheels of mobility devices in position. If there is carpet, it needs to be dense and tightly woven to avoid impeding wheelchairs and canes. For concrete exposed flooring, broom finish improves traction. Abrupt changes in floor levels are not recommended for elderly people with visual impairments and those using canes, or other mobility devices (NAHB, 1996).

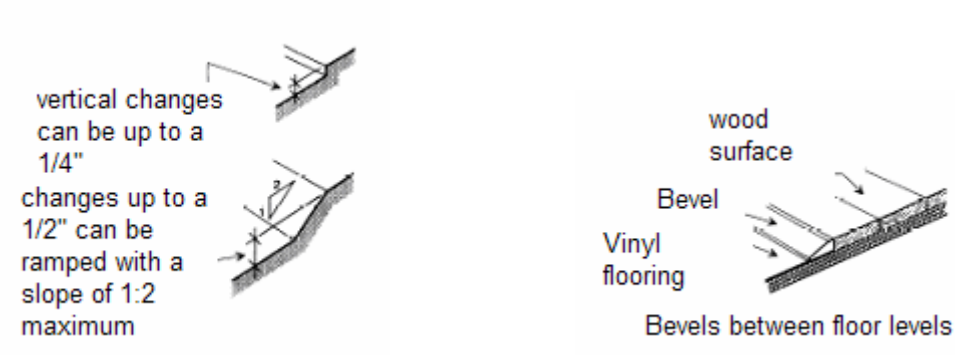

Figure 18: General recommendations for levels

Source: NAHB Research Center, 1996.

The surface material of steps and finishes is an important mode for taking care of elderly persons. Treads and risers of contrasting colors are helpful for people with vision impairments. Also needed is the uniform size of the treads and risers to maintain the body’s natural rhythm. Rounded nosing or risers angled

with a back slope are recommended for non-disruptive movement and to eliminate the lip created by a nosing (NAHB, 1996).

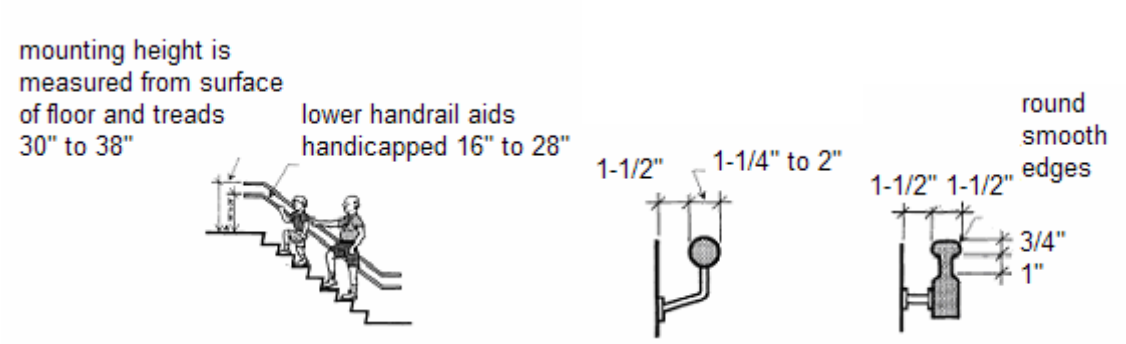

Figure 19: General recommendations for shape and height of handrails

Source: NAHB Research Center, 1996.

For stair's, it is recommended to provide handrails on both sides for user choice and flexibility. The extensions to the handrails at the top and bottom of the stairs provide added support and guidance for persons with balance or mobility limitations, or visual impairments (NAHB, 1996). The above reasoning leads to the following proposition:

> *Proposition 3: Incorporating mobility features (such as offset hinges, height of cabinets, positioning of grab bars and so on) for manufacturing of building components will fulfill the needs of elderly persons in the development of senior's housing.*

Secondly, the issues related to accessibility comprises of doors and internal closets. For doors, a clear opening of a minimum 32 inches is recommended at all locations. It can be easily provided by swing away hinges,

which swing completely off the opening. The swinging of doors should not to be in the way of other doors, furniture, or an easily accessed path in the home. A five-inch handle is required as enough leverage to open the door by an elbow or fist (NAHB, 1996).

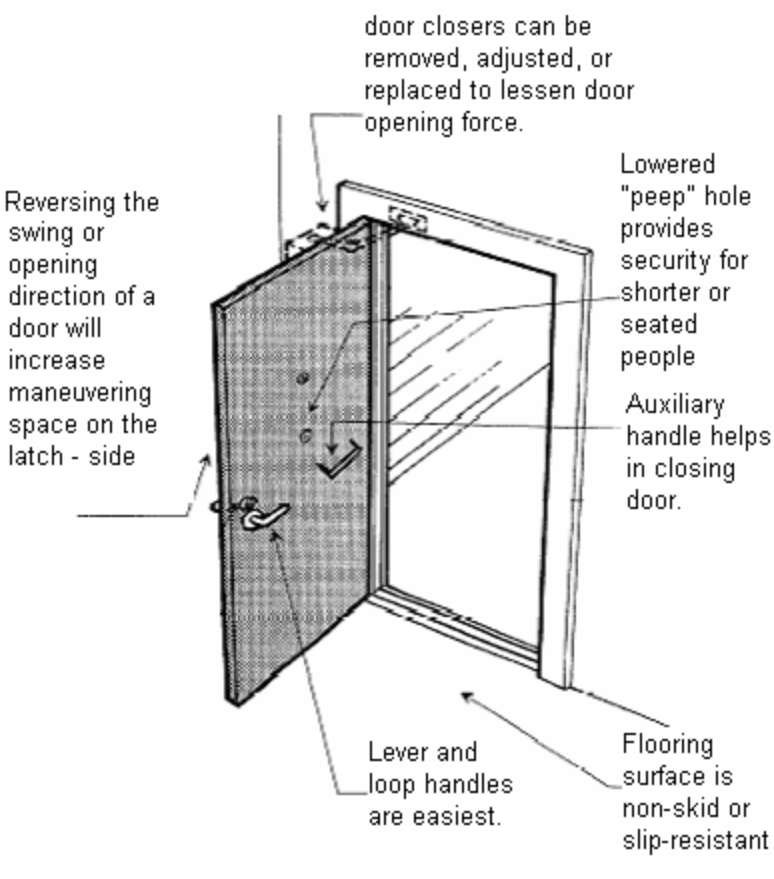

Figure 20: General recommendation for doors

Source: NAHB Research Center, 1996.

For a screen, glass or panels, it is recommended to provide at least 12 inches of solid material at the bottom to avoid damages by wheelchairs or sharp edges. A lever and loop handle are easiest to use by hand. Door thresholds are recommended to be a maximum ½ inch and avoided, if possible. Dual peepholes

are recommended in order to accommodate every household. Door closures can be adjusted to require a minimum amount of force needed for opening (NAHB, 1996).

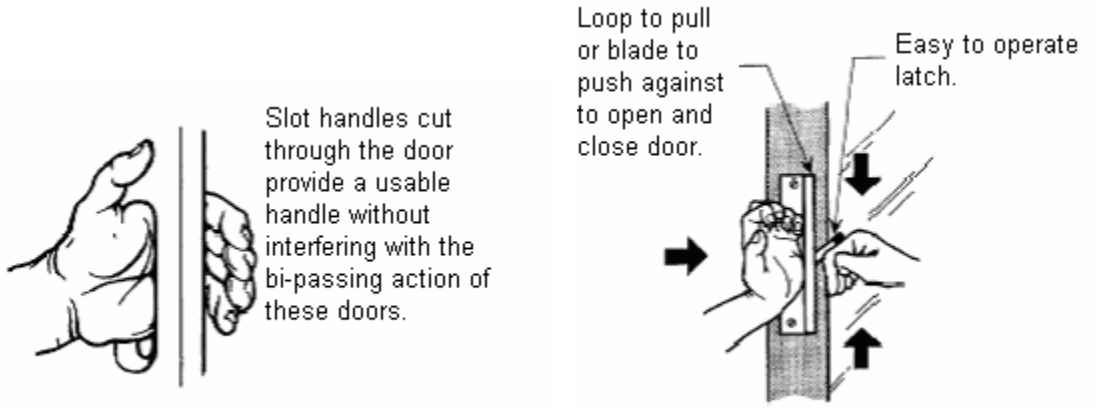

Figure 21: General recommendations of handles

Source: NAHB Research Center, 1996.

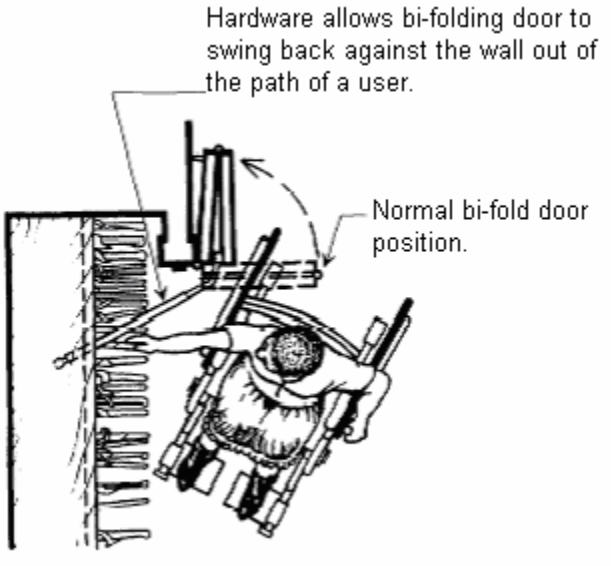

Figure 22: Recommendations of a door for a cloth closet

Source: NAHB Research Center, 1996.

Also, other organizations recommend replacing drawer knobs with loop handles; replacing knob faucets with levers; installing adjustable closet poles and shelves; or adding seat lifts in showers or tubs (Adaptive Environments Center, 1996).

For the cloth closets, the recommended way to access closets is by a low hanging rod or adjustable hanging rod. If the rod height is adjustable, users can set it to the most convenient height for themselves. A shelf is recommended to be mounted ranging a height of 20 inches to a maximum 44 inches from the floor. This is preferable for persons who have difficulty stooping, reaching, or bending. Also, adjustable shelves provide the greater degree of flexibility (NAHB, 1996).

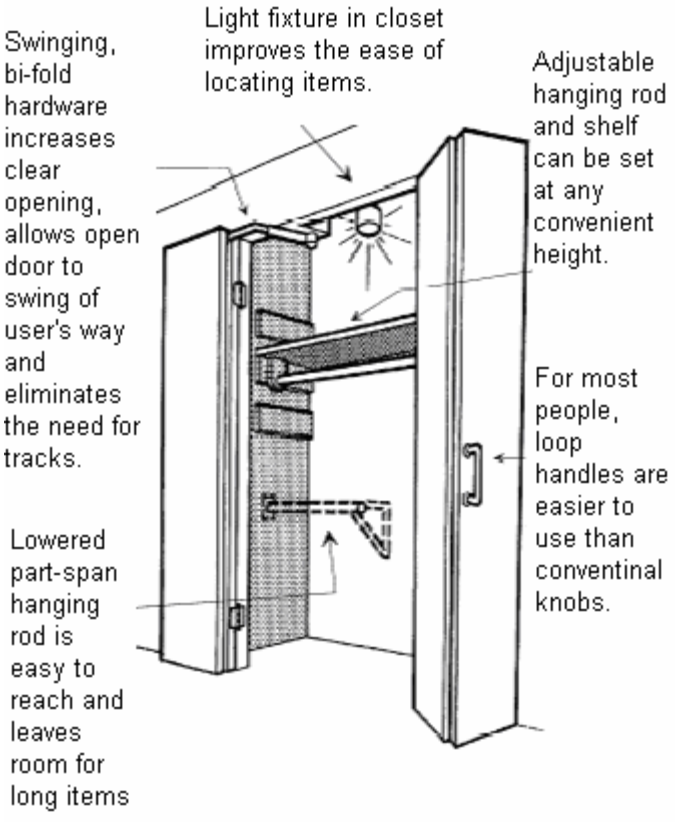

Figure 23: General recommendations for a closet

Source: NAHB Research Center, 1996.

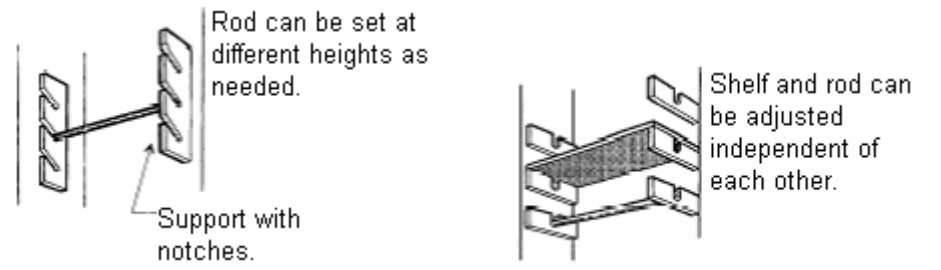

Figure 24: Adjustable shelves and hanging rod alternatives

Source: NAHB Research Center, 1996.

The light levels inside the closet are of utmost importance as generally the closets are internally located. A well-lit closet is advantageous for everybody and so for elderly persons. Also, provision for walk in closets is also recommended for persons who use mobility devices such as canes, walkers, or wheelchairs. For walk in closets, it needs widened doors, convenient hardware, and door swinging out or with no door (NAHB, 1996). The above reasoning leads to the following proposition:

> *Proposition 4: Incorporating accessibility features (such as swing away hinges, loop handles, lever faucets and so on) for manufacturing of building components will fulfill the needs of elderly persons in the development of senior's housing.*

Thirdly, the issues related to ease of maneuvering are in areas providing services. It includes areas such as kitchens, bathrooms and laundry areas.

Kitchens should have different height counters with comfortably accessed storage for people with reaching, stooping, kneeling, and/or lifting limitations. Faucet handles are best with single lever or asymmetrical models that do not require any gripping or twisting. A shallow basin with drain at the rear of the bowl is easier for people with limited reach and seated individuals (NAHB, 1996).

A drainpipe to the sink with a “tub bend” moves the pipe and the trap to the rear and provides a clear knee space. The ranges are recommended with front mounted controls as accessible for people, and eliminate the needs for reaching across bumpers. The staggered burners are recommended for cook tops to avoid reaching across one burner to use another. The cook tops are recommended to be flushed because of easy sliding of heavy pots and skillets. The countertops and cook tops are recommended to be mounted at a height of 32 inches above the floor to facilitate accessibility to all persons. Adjustable countertops are another option to install for ever changing needs in the household. Contrasting edges in countertops and adjacent walls help visually impaired persons to distinguish between surfaces (NAHB, 1996).

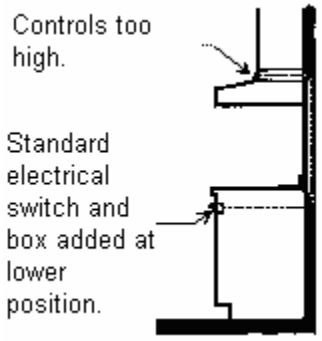

Figure 25: Auxiliary Controls

Source: NAHB Research Center, 1996.

Easy to operate switches are recommended as controls for the ventilation hood and are recommended to be located at a lower level as shown in figure 25.

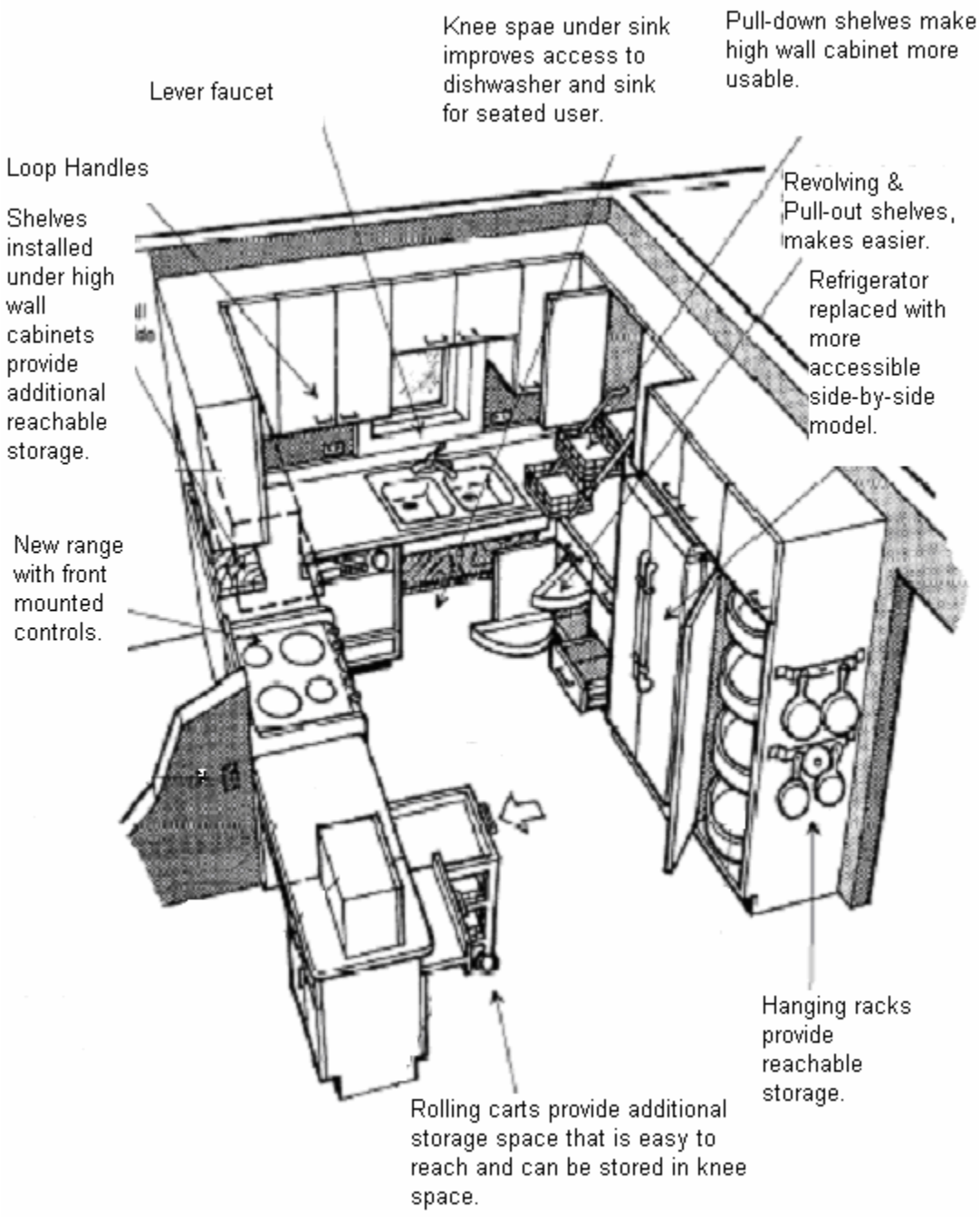

Figure 26: General recommendations for the Kitchen

Source: NAHB Research Center, 1996.

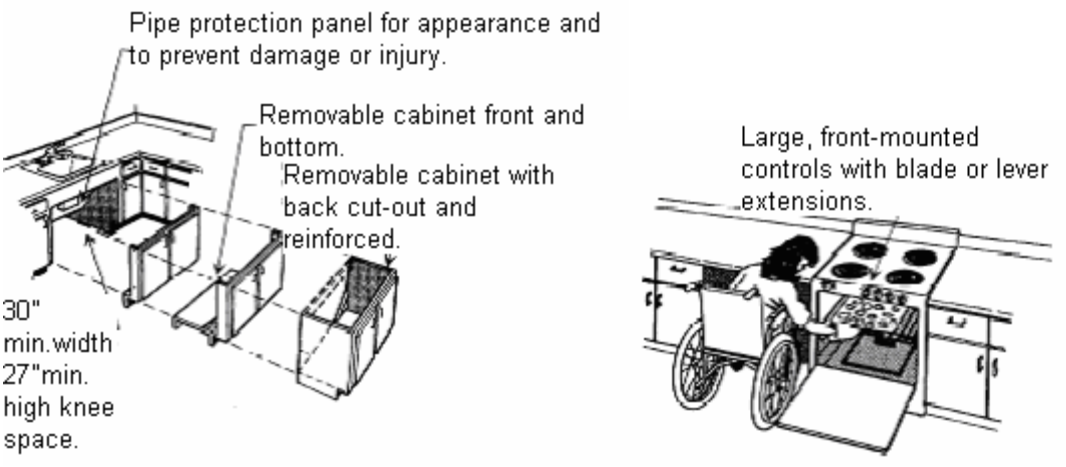

Figure 27: Important and optional Knee Spaces

Source: NAHB Research Center, 1996.

The suitable position for a refrigerator would be a place where the doors can be opened 180 degrees. The height of the freezer should not be more than 4 feet in order to provide pull out shelves and increased use of rear space. A model with the freezer underneath the fresh food space is a viable option for persons with bending and stooping problems. For the cabinets and drawers, use of loop handles is beneficial for elderly persons to avoid any twisting of the wrist or fine finger manipulation (NAHB, 1996).

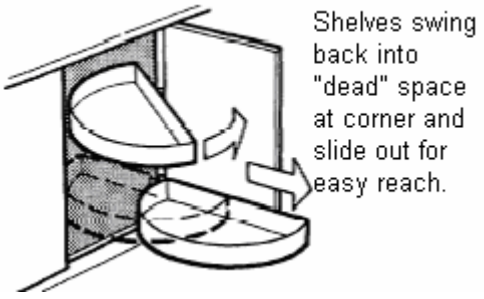

Figure 28: Rotating / Sliding Shelves

Source: NAHB Research Center, 1996.

The upper wall cabinets are recommended to be mounted at a height of 48 inches to be accessible by most people. Also, pull down shelves are suggested to be provided in cabinets to maximize usability for everyone (NAHB, 1996).

The other key issues are for the recommendations in a bathroom.

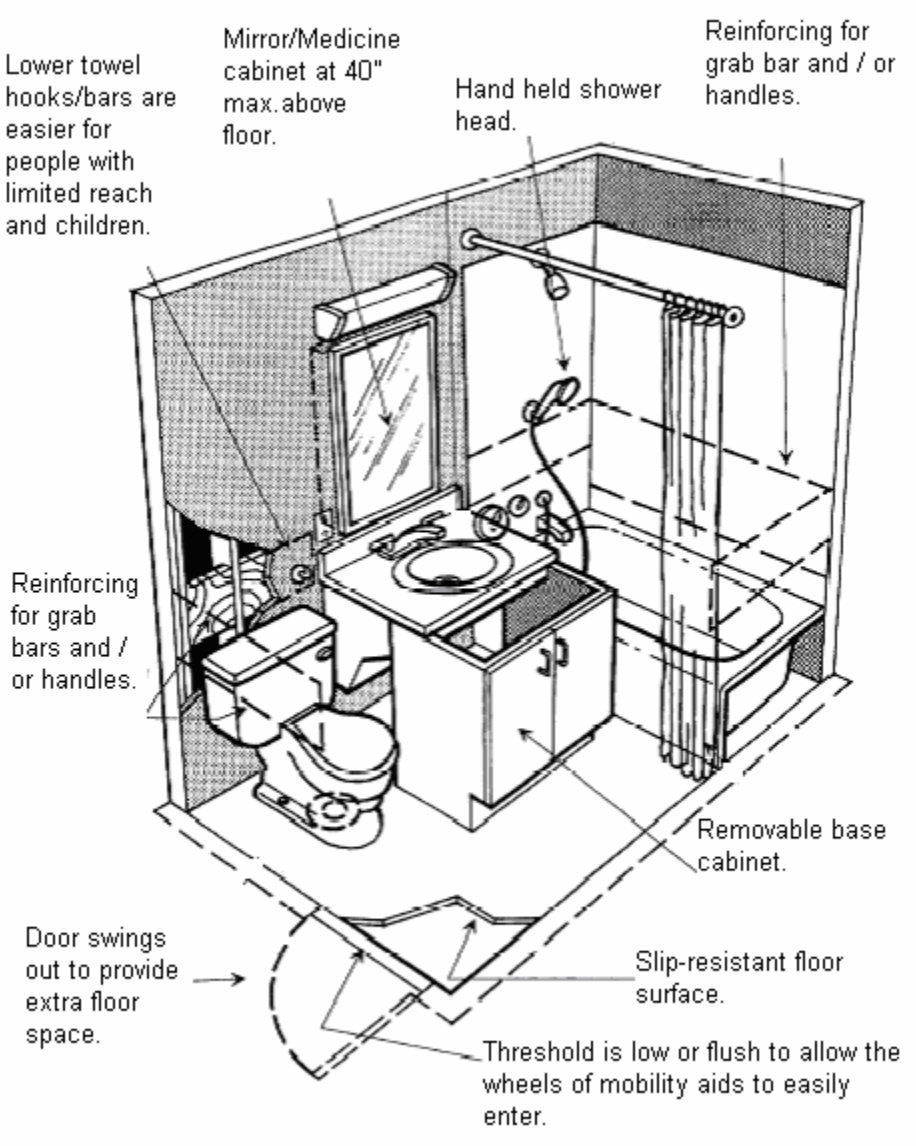

Figure 29: General recommendations for a bathroom

Source: NAHB Research Center, 1996.

As physical strength and agility diminishes for all persons and with time, many persons have difficulty with daily routines in the toilet. The problems includes sitting down, rising and maneuvering inside the toilet. And taking all those factors in consideration is a must for elderly persons (NAHB, 1996).

For the placement of the water closet, it is suggested to be provided at a distance of 18 inches from the wall in order to facilitate the provision of a grab bar mounted at the sidewall. Reinforcing behind w.c.'s or even the complete wall is always recommended for provision of grab bars at any required location. A thick seat or a spacer could be used to raise a toilet seat by 1-1/2 inches (NAHB, 1996).

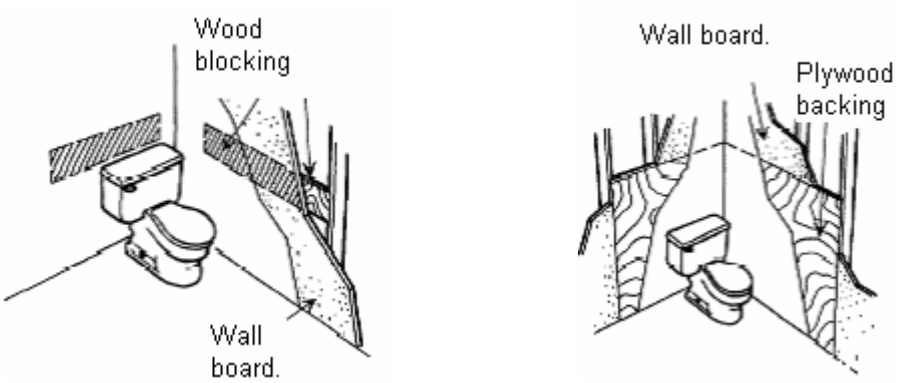

Figure 30: Bathroom wall reinforcements

Source: NAHB Research Center, 1996.

For the lavatory fixtures to be with adequate toe and knee spaces, it is recommended to have a front to back depth of at least 17 inches. The top of the rim should not he higher than 34 inches and bottom of the apron should not be lower than 29 inches above the floor (NAHB, 1996).

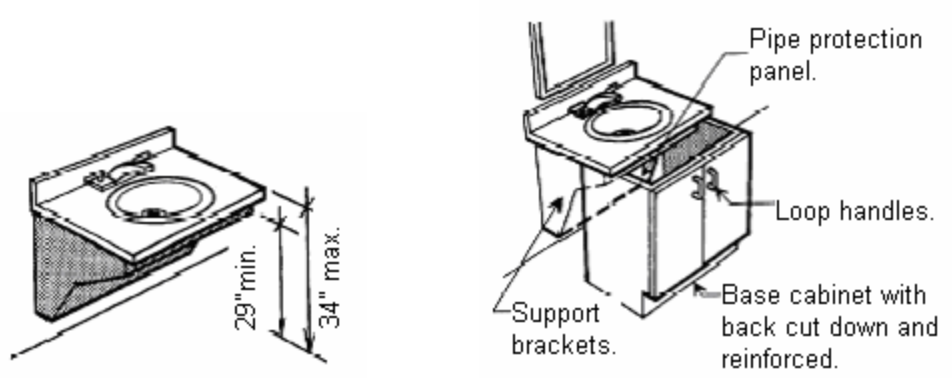

Figure 31: Other alternatives for lavatories

Source: NAHB Research Center, 1996.

Towel bars and hooks should be mounted in between and below 36 inches to 48 inches for accessibility to most people whether they are sitting or standing, or have difficulty reaching. The accessibility also applies in the same fashion to mirror mounting height, with its bottom varying from 36 inches to 40 inches. A bathtub is recommended with a built in removable seat with a self storing facility, or one that folding against the wall (NAHB, 1996).

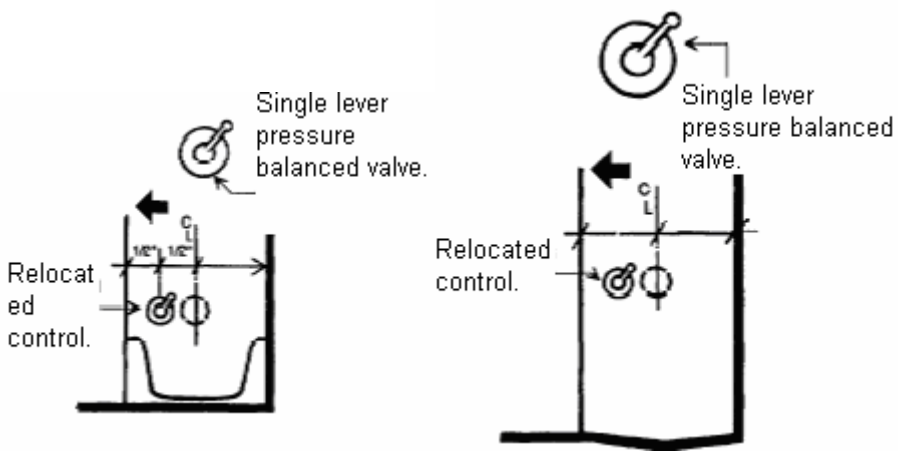

Figure 32: Offset control location for faucets

Source: NAHB Research Center, 1996.

A shower of size 3 feet by 3 feet is recommended that fit the needs of people with limited stamina, those with poor balance or unsure leg strength, and individuals who like to sit down while showering. The shower also needs to be equipped with an integral or folding “L” shaped seat, with a very low threshold. Persons who transfer by wheel chair into shower seats can also use it. If the shower needs to be accessed by a bathing wheelchair then at least one dimension of such a shower needs to be 60 inches ideally. A shower or a bathtub curtain is more advantageous than a door in terms of providing greater flexibility for locating seats and getting in-out of the bath space. If space permits, then trackless and combination of sliding or swinging doors can be used. For the shower head, a “T” diverter valve is recommended with an attachment of a hand held shower head. The hand held shower head will facilitate people who sit while bathing (NAHB, 1996).

Thirdly, the serviceability issues are for the laundry areas. Front mounted controls facilitate easy use by most people. The controls are accessible to seated people and individuals with limited reach. For elderly people who have bending problems, the washer and the dryer could be placed on a raised platform. Generally, utility sinks have deep basins that do not accommodate knee spaces for a seated individual. In order to facilitate a user in a seating position, a sink could be provided in a parallel position. Faucet handles are recommended with lever or asymmetrical handles that do not require gripping to operate (NAHB, 1996).

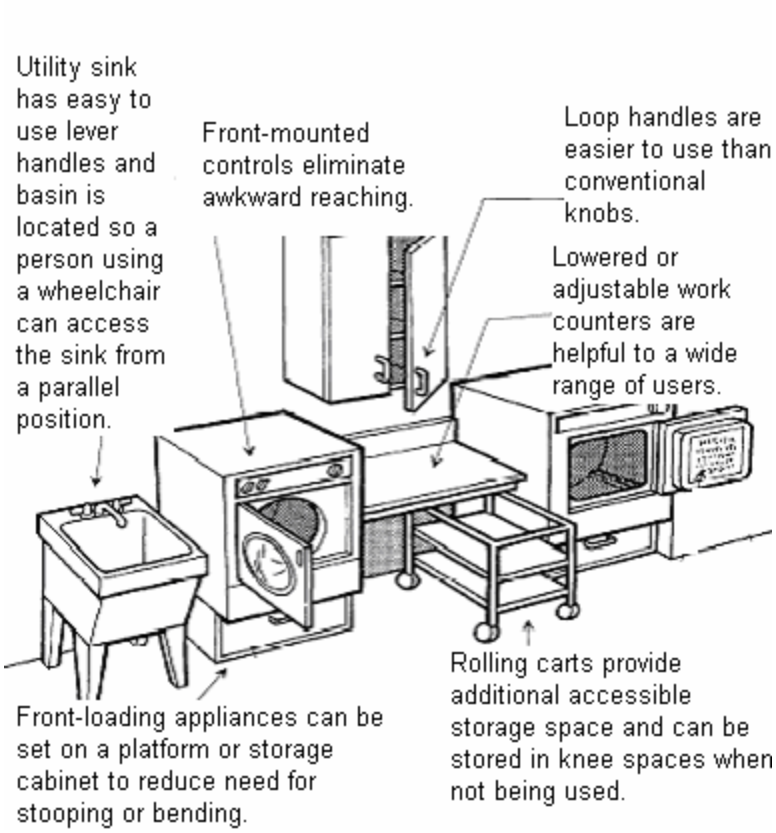

Figure 33: General Recommendations for a laundry area

Source: NAHB Research Center, 1996.

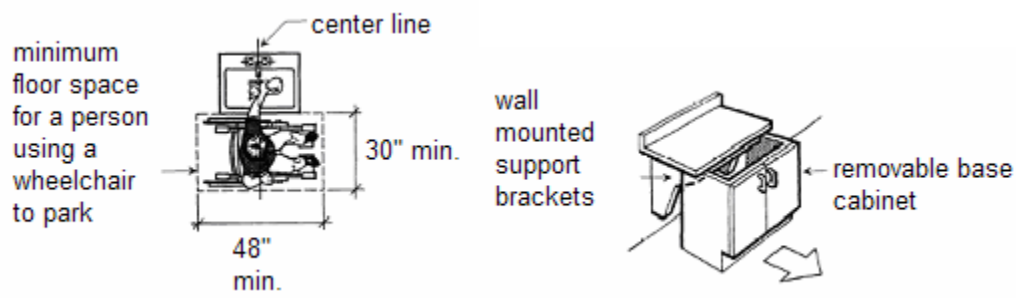

Figure 34: Other recommendations for knee spaces

Source: NAHB Research Center, 1996.

Wall mounted work counters are recommended to provide a leg space for a person while doing laundry. These could be provided as removable base

cabinet on rollers for more storage spaces (NAHB, 1996). The above reasoning leads to the following proposition:

> *Proposition 5: Incorporating serviceability features (such as for kitchens, bathrooms and laundry areas) for manufacturing of building components will fulfill the needs of elderly persons in the development of senior's housing.*

The other aspect of architectural planning is selection of controls, signals and automation. Controls, signals and automation are another important element of building system that facilitates easy and comfortable way for using service equipments. Light switches, toggle, rocker and touch sensitive switches are recommended to avoid tight pinching, gripping, twisting, or fine finger manipulation (NAHB, 1996).

Figure 35: Easy to use switches

Source: NAHB Research Center, 1996.

The mounting height for switches is recommended to be between 36 inches and 48 inches. The electrical outlet is recommended to be mounted not lower than 15 inches above the floor surface. At this height, it is easier for people

who have trouble bending and stooping. The switches and outlets installed over a counter or worktop should be mounted close to the surface to facilitate easy reach to seated persons and individuals using canes or walkers for support. The additional numbers of outlets are helpful to people with disabilities. Electrical outlets are also recommended to be near to the telephone jack for facilitating installation of not only the answering machines but also the TTY's and TDD's (text telephones). Text telephones help people with hearing and speech impairments to send and receive typed messages over telephone lines (NAHB, 1996).

Easy to use thermostats are recommended that emit clicking sound for every couple of degrees moved when setting temperature. They are helpful for people with limited hand dexterity or vision impairments. The thermostat also should be large, high contrasting and easy to read numbers with a mounting height of a maximum 48 inches above the floor surface (NAHB, 1996).

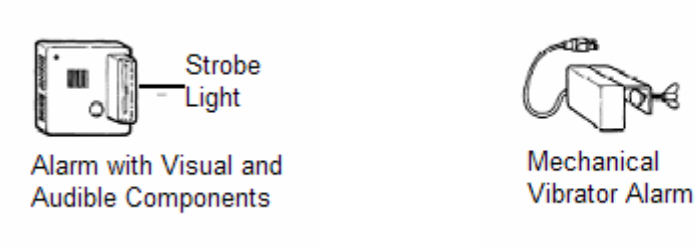

Figure 36: Options for controls

Source: NAHB Research Center, 1996.

New model smoke alarms with strobe lights are recommended. These alarms are good for the hearing impaired, but care is required for people who are sensitive to frequency of the flash from strobes that cause seizures. For people having hearing disabilities, auxiliary vibrating and strobe alarms are

recommended in sleeping rooms. These alarms are triggered by the sound of main fire alarms and typically plugged into standard electrical outlets (NAHB, 1996).

For installing a security system, control panels and key pads with large, high contrasting, easy to read instructions are recommended. Letters and numbers can also be raised to allow people with visual impairments to use the system. The installation height is recommended not to be higher than 48 inches above the floor surface (NAHB, 1996).

Home automation is another aspect of facilitating easy approach for the living of elderly persons. Simple remote control systems contain modules, which allow users to control lights and other appliances from a small keypad. There are three types of remote control systems: first, that send a signal through existing wiring; second, that is wireless and uses radio signals; and the third that requires additional wiring. “Total Environmental” control systems are also available that combine all the environmental controls, such as lighting and temperature. The connections are directed to one control panel or remote unit (NAHB, 1996). The above reasoning leads to the following proposition:

> *Proposition 6: Incorporating automation features (such as touch sensitive switches, alarm with strobe lights, remote control and so on) for manufacturing of building components will fulfill the needs of elderly persons in the development of senior’s housing.*

STRUCTURAL CONCEPT

The structural concept of the system is based on manufacturing the house in totality. The schematic diagram of the structural system proposed is shown in figure 37.

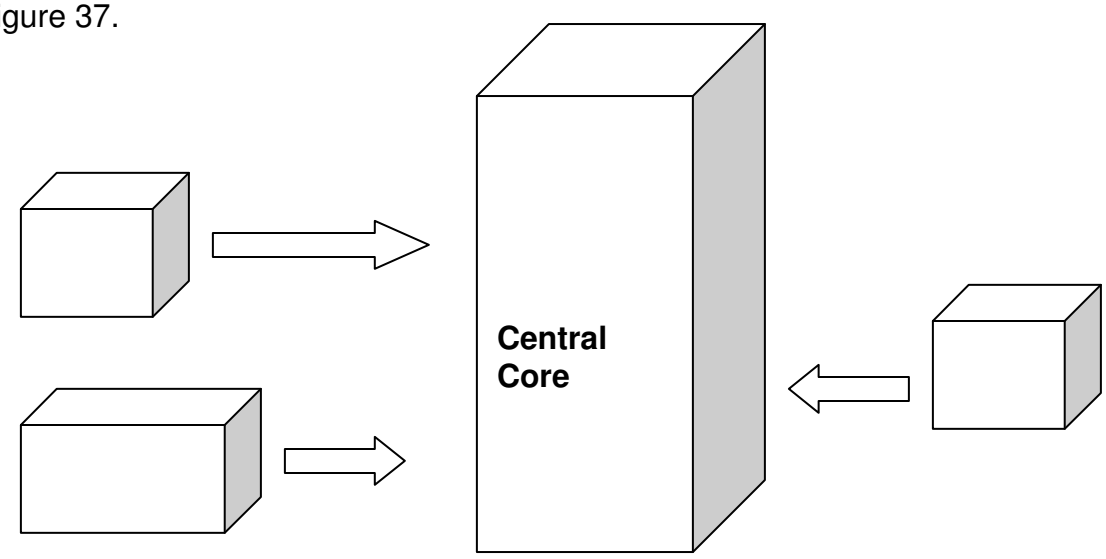

Figure 37: Schematic for the structural system

The concept of the structural system is based on concepts of open building system. There is grouping of physical parts and spaces in terms of levels. The structural concept is acting as a finished building ready to be occupied by variable infill. The prefabricated panels are the infill to the house. The nature of the manufactured house is of open-ended and dynamic fabric. Finally, the reusable of components links it with sustainability. The concept allows the builder or end user to develop technical interfaces to 'plug and play' with products made by different companies. This makes open building infill move towards design and manufacture for assembly and disassembly.

The central core and its attaching units will be pre-manufactured depending upon the requirement of the house. The central core will house the kitchenette, a

bathroom and all required in-house electro-mechanical services. The central core will have the flexibility in terms of its size and usability. The core will have the flexibility of building it from one to two storied or even more. The size and number of attachment units will vary from individual to individual in terms of their requirements. The central core will support the surrounding structure in all aspects of the structural equilibrium. For this kind of structural system, the house will itself be unique and aesthetically pleasing. All the houses built will be independent in architectural character but with the same backbone.

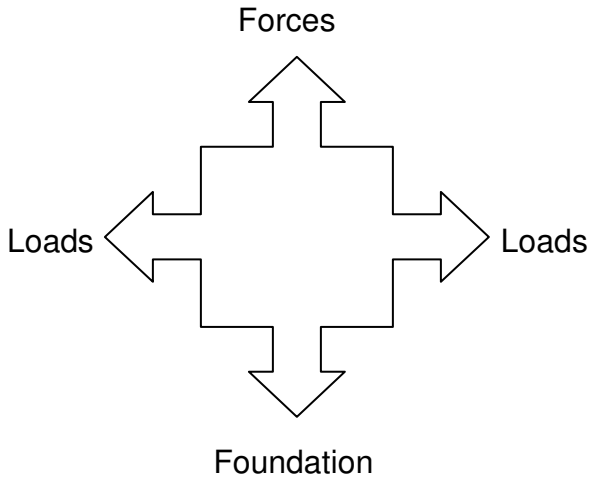

Figure 38: Schematic for the Central Core

Figure 38 shows the structural schematic of the central core. The figure depicts the importance of structural stability required for the central core. The central core will act as an anchor to the attached units and distribution of the loads will be calculated accordingly at the time of manufacturing. In the proposed structural system, manufacturing flexibility is in the pre-manufacturing of the central core that consists of a kitchenette, bath and other related electro-mechanical services. Around that central core, rooms and spaces will fit in

depending on the requirements. The height and functionality of central core will vary depending on the usability for one or two storey houses.

Overall, factory-built housing accounted for approximately one-third of all housing in the United States. The share of factory built housing as measured in 1998 is described as follows (Syal et al 2001):

1) Manufactured homes: 22.7 percent
2) Panelized homes: 6.3 percent
3) Modular: 3.4 percent
4) Precut: 3.3 percent

Also, comparison of cost makes the manufactured home more attractive than site built homes. The construction cost of a double-section 2,000 sqft manufactured home on private land is $47,277, as compared to a site built home with a cost of $77,140. Overhead and administration cost for a site built home is $29,380 in comparison to $14,644 for a manufactured home. The trends in Michigan are bending more towards manufactured homes as a popular option of housing (Syal et al, 2001). The proposed structural system goes in hand with the senior's housing design on two levels:

1) Architectural level
2) Manufacturing level, and

At the architectural level, the sub-components of architectural planning will act as a governing factor to the manufacturing of structural units and components. Architectural components will take care of the elderly needs for required openings, ramps and other necessary features.

At the manufacturing level, the structural system will help in building the house with the help of pre-manufactured building components. The process will be less labor intensive and the cost will be known before execution. The elderly persons will also have the opportunity to adjust their requirements with their budgets. The above proposal leads to the following proposition:

Proposition 7: Architectural planning and layout methodology for a factory built housing provides flexibility to users to build within their limited budget, and further enhances the design capability and manufacturing of the house.

CONSTRUCTION METHOD

The proposed construction system is of pre-cast panels of varied sizes depending upon the design and requirements of the individuals. All pre-cast panels will be manufactured in the factory. The sizes will vary depending upon initial requirement of the house. The methodology adopted is proposed by using cam-nut and cam-screw technique, which is researched and proven effective for mass-producing housing. The technique itself is proven flexible in terms of sizes for panels that will vary from unit to unit. The system design will further facilitate flexibility in terms of development of open spaces providing barrier free circulation, an important requirement for senior's housing design.

The construction system using cam-nut and cam-screw technique for joining concrete components facilitates repetition of work tasks that can be

undertaken by a single crew. The technique further reduces set up time between activities and enhancing process continuity (Meyers, 1998). The cam-nut and cam-screw are chosen because of efficient mechanical performance and faster assembly opportunities than other methods (Singh, 1998). Figure 37 shows the schematic of cam-nut and cam-screw at loose and tightened positions. It is being designed using finite element analysis (Singh and Yousefpour, 1998).

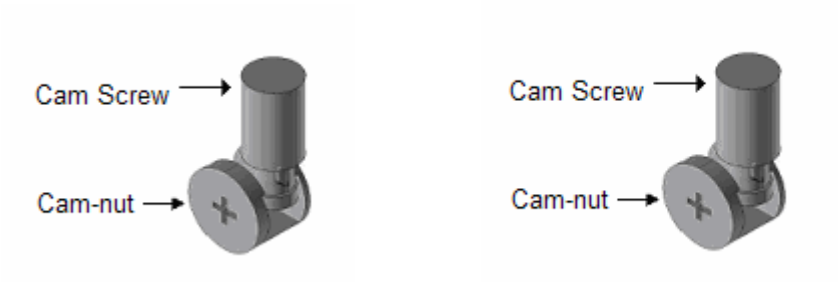

Figure 39: Detail of cam-nut and screw at loose and tightened positions

Source: Singh, A., 2001.

During pre-casting of elements, cam-nut will be embedded in the panel and cam screw will be attached to the side of adjoining panel. The joint will be designed in such a way that when two panels need to assemble at the site, cam-screw is inserted in the cavity inside the cam nut and the cam-nut is tightened using pneumatic or electrical power tools. The principle of cavity inside the cam-nut is designed in such a way that as the cam nut is tightened; it will pull the cam screw inside (Singh, 2001).

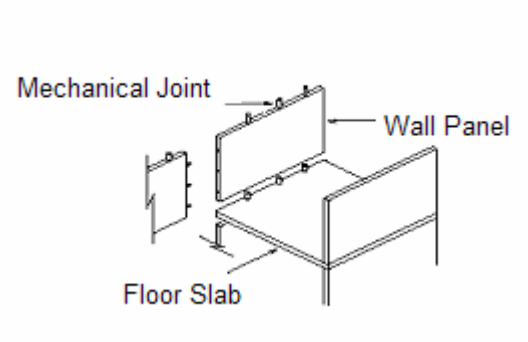

Figure 40: View for placement of panels and slabs

Source: Singh, A., 2001.

The cam screw and cam nut scheme is very appropriate for quick erection. The scheme is also capable of holding structural and natural loads. The erection speed using this system is estimated to be ten times faster than conventional methods, thereby facilitating lean production. The finishes will be minimized or eliminated at the manufacturing plant, thereby reducing site work and setting up time for erection. The repetitiveness in production will reduce the set up time and structured management at the manufacturing unit. The uniqueness of the system as the basic unit will be reducing set up time for new forms (Singh, 2001).

STRUCTURE OF THE FINAL MODEL

The final model of the proposed Building System is represented as follows:

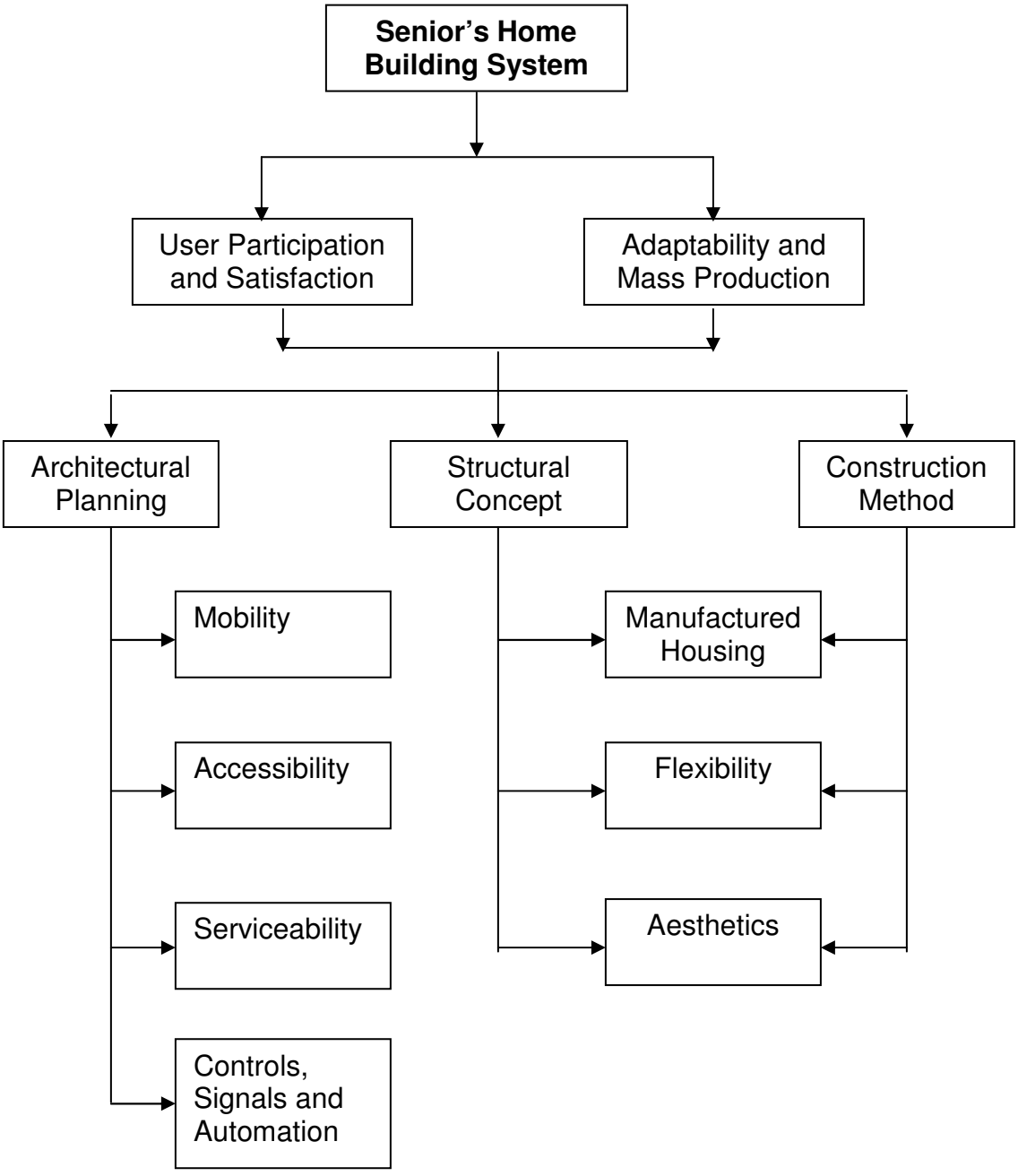

Figure 41: Model of the Senior's Home Building System

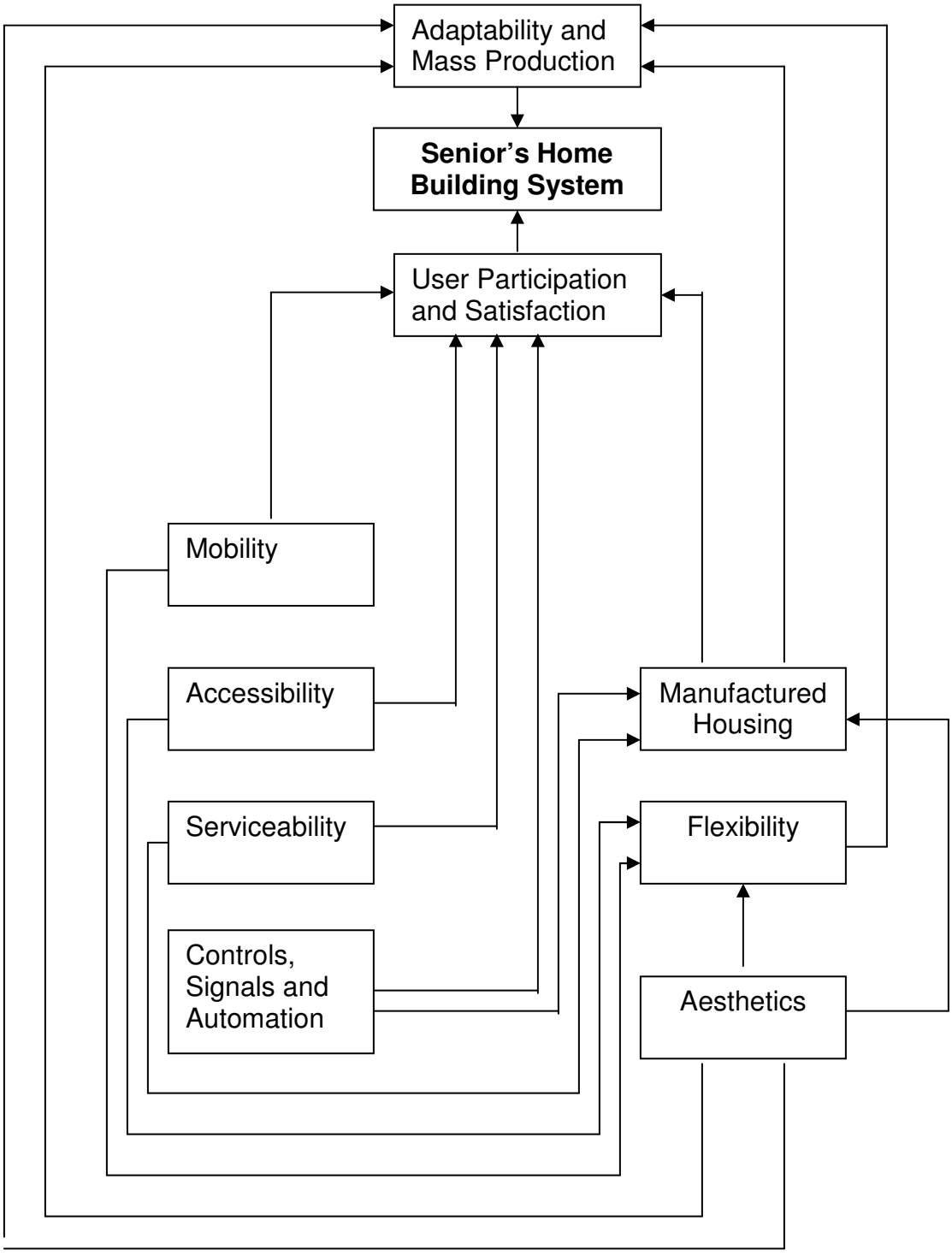

Figure 42: Reflective Linkages of the Design Criteria with Building System

The model developed above clearly identifies the linkages and relationship of the “user satisfaction and satisfaction” and “adaptability and mass production” with other sub-components of the building system. The various benefits of the proposed system are to build houses specifically for the needs of the elderly persons. Also, the emphasis is to facilitate a universal concept to suit the needs of all generations and will further help in minimizing remodeling of houses in the future.

Furthermore, benefits of the proposed system would be many briefing to be as follows (Singh, 2001): *Waste Reduction* – All the building components will be prefabricated; site activities will be reduced to a great extent and thereby reducing onsite wastage (Singh, 1999a). *Module of repetitive work* – The mode of construction will be limited in terms of construction elements, thereby relatively easier to standardize the repetitive work (Singh, 1998). *Unique custom product* – The building components will be a unique custom product and all the built homes will vary in architecture and design. *Minimized Resource Idleness and average waiting time* – Standardized repetition of building components will lead to organized and planned tasks to perform, thereby increasing resource utilization. The components will also help in reducing the time for the delivery of the finished products (Singh, 1999a). *Reducing Inventory* – All the requirements will be known in advance, so there will not be any requirements of storage of materials. *Minimized maintenance and operation cost* – With all the services centrally located, it will be easy to maintain and repair. The services will be in set module

of manufactured form and need to be replaced by other items in terms of failure or repair.

Finally, it is *Increased Production Rate*, which is obvious result of the proposed system as all the reasons, evidence and positive behavior of the above parameters proves it. With the assurance of high production rate, decrease in cost is made possible through economies in mass production (Regan, 2000).

The development of building system facilitates the production in any part of the United States, as it does not propose any restrictions on the building envelope. The building envelope could be decided depending upon the local climate. The system has second level of hierarchy as the supporting element to the concept that proposes it as a universal system:

1) Architectural planning do not imply any restrictions as it only caters to the requirement of the elderly people
2) Structural concept is a viable concept that do not impose any restriction on its usage in any location of the United States
3) Construction method using cam-nut and cam-screw technique facilitates the construction to be fast and less labor intensive

Integrating all these components of the building system is understood and based on soft system methodology as proposed by Peter Checkland and based on conventional 7 stage model:

1) The problem situation
2) The problem situation expressed
3) Root definition of relevant systems

4) Building conceptual models
5) Comparison of 4 with 2
6) Feasible and desirable changes
7) Action to improve the situation

ROOT DEFINITION: A house to be constructed for an elderly couple by manufacturing, in limits with the overall concept of the building system, in order to build a comfortable living environment.

C – 'Customers' – Householder

A – 'Actors' – Manufacturer

T – 'Transformation Process' – framing of requirement-building a house

W – 'Weltanschauung' – A flexible user's satisfaction house

O – 'Owner' – Householder

E – 'Environmental controls' – Elements outside the system which it takes as given

Figure 43: A root definition and CATWOE presentation of building system

Source: Checkland et al, 1990.

Root definition and CATWOE are the source of the purposeful holons known as "human activity systems". The modeling process carries out the transformation process in the lighted definitions of CATWOE elements. The root definition allows the schemata for proceeding further. The root definition helps to bridge the gap from definition to model. The main activity is to develop a prototype of the house and that will be surrounded by other activities that fit with CATWOE. The core activity is the manufacturing of the central core and

attaching units that is contingent upon procuring materials and deciding scope of the house. All the structuring is based on logical contingency. The aim is to express the main operation to bring about the transformation in a handful of activities. The core activity “manufacture central core and attaching units” will be contingent upon procuring materials, deciding requirements in the light of building system and taking a decision on the scope of the house. These considerations yield the first model from the root definition. The first model shows a general form for a monitoring and control subsystem. Furthermore, the logical analysis is considered on three different counts as follows:

1) Efficacy – for ‘does the means work?’
2) Efficiency – for ‘amount of output divided by amount of resources’
3) Effectiveness – for ‘is Transformation meeting the longer term aim?’

Depending on these ‘3 Es’ criteria of SSM, figure 42 shows a complete and defensible conceptual model from the root definition and inter-relation of all activities. The final model further facilitates the steps of Design for the Manufacture and Assembly of the House.

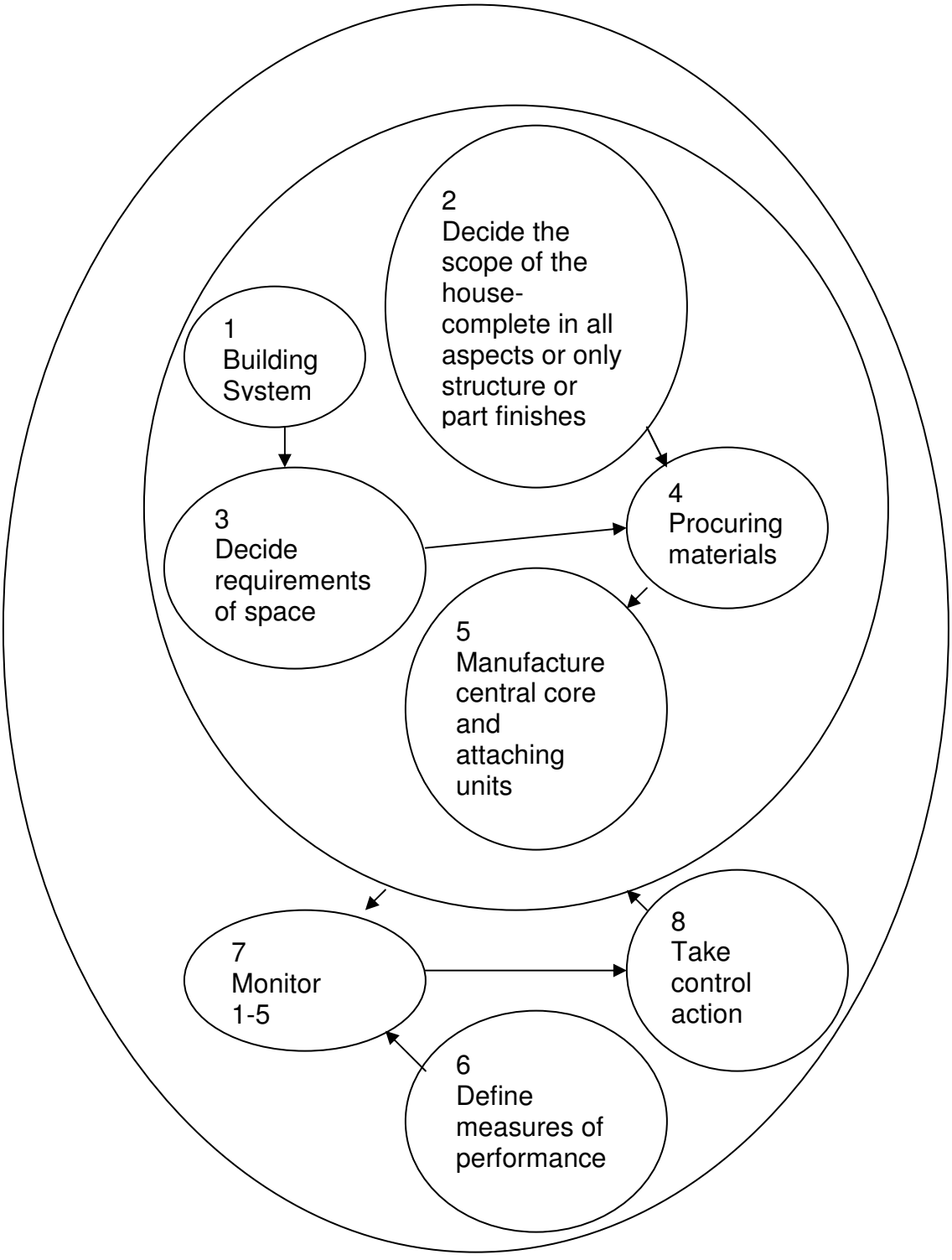

Figure 44: The first model from the root definition

Source: Checkland et al, 1990.

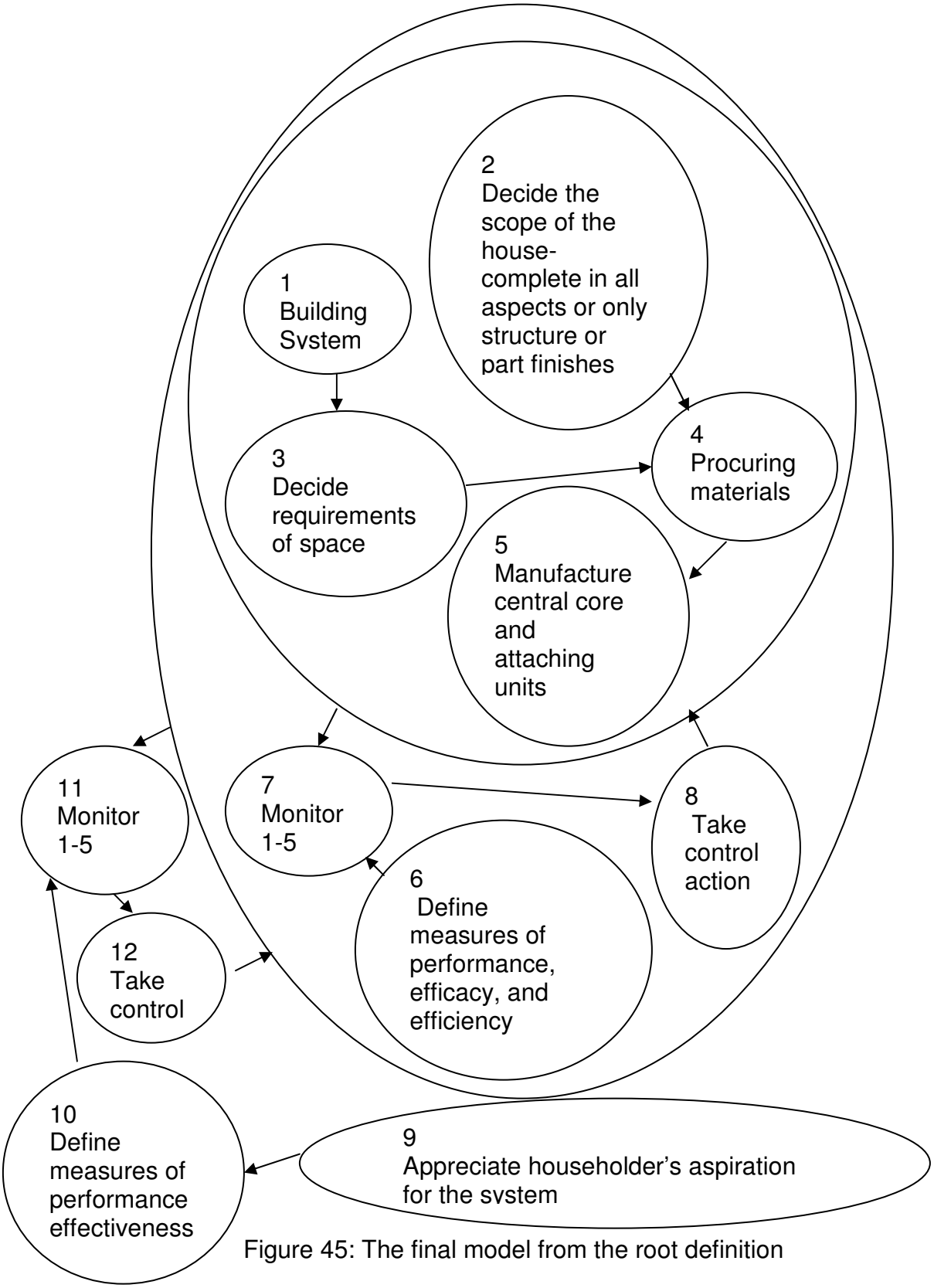

Figure 45: The final model from the root definition

Source: Checkland et al, 1990.

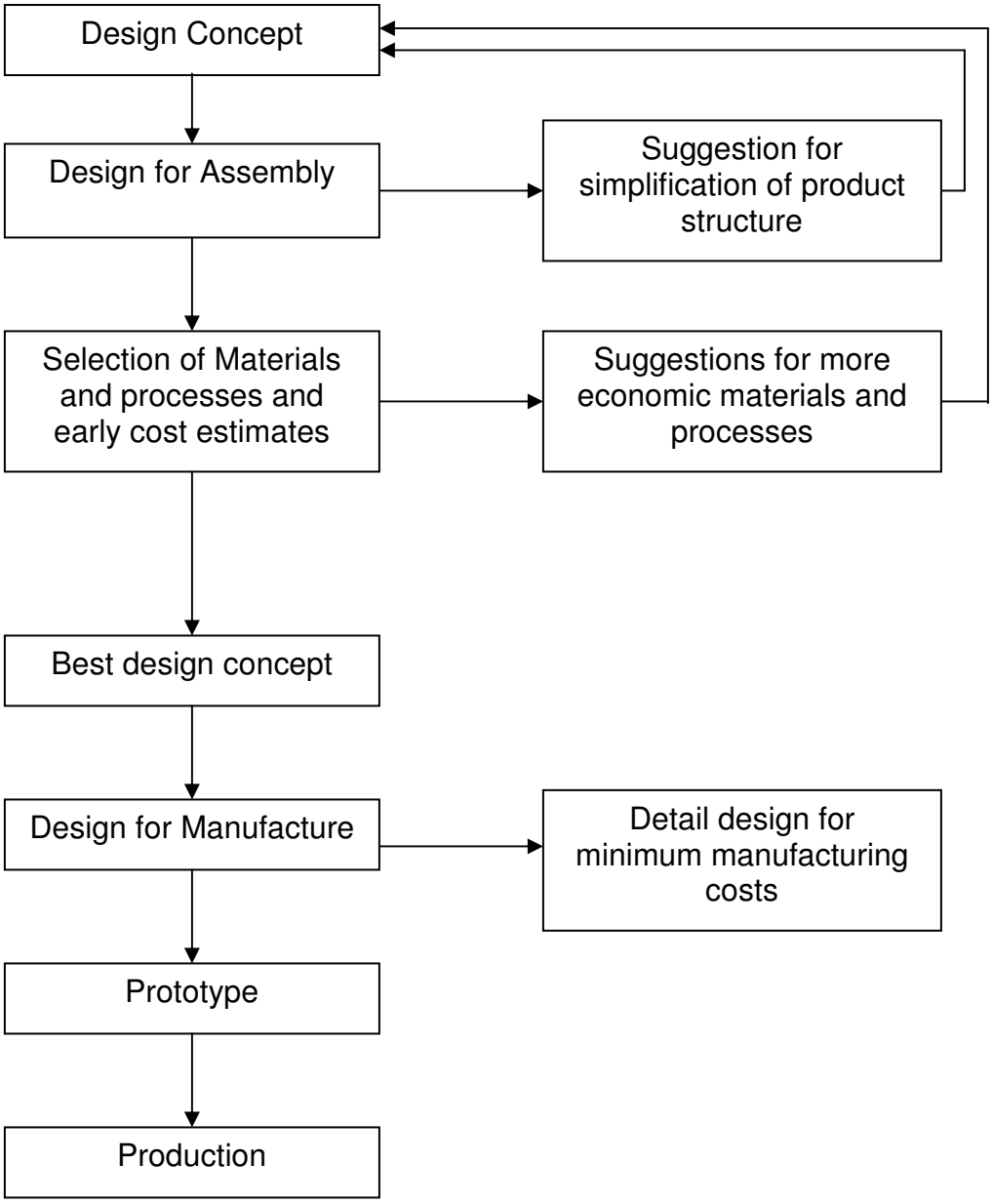

Figure 46: Typical steps in a Design for Manufacture and Assembly of the House

Source: U.S. Department of Housing and Urban Development, 2000

The proposed building system also acts as a source of “System Integration” to the housing industry. The system is a step towards linking product design,

production and sales to perform. This step is encouraged as housing industry treats major building system independently and unconnected. The conditions of integration fall primarily into five areas:

6) Information Integration: as one collective data source for many pieces of information and accessible to all the homebuilders.
7) Physical Integration: in terms of making the many parts fit together as one. The physical integration is based on the structural level where the central core needs a fit with the attaching units.
8) Performance Integration: is with making the proposed system performing as one unit.
9) Production Integration: as the proposed system conducting the many processes as one.
10) Operations Integration: as the proposed system operating the sub-systems of zoning, services and requirements under one umbrella of “Senior’s Home Building System”.

CONCLUSIONS AND FUTURE RESEARCH

The emphasis and conclusion of this research resulted in developing a concept of building system for elderly persons. The system proposed has the capabilities of mass-production to meet the immediate needs of the senior’s housing demand in the United States. The system has components that meet the requirements of the elderly people as part of their daily living. The system does have components to be used as a multi-generation building system as level of comforts is universal

for all the human beings. Further, it will result in reducing the proportionate cost of future remodeling of houses. Overall, the researches outline a model with propositions that need to be empirically tested as recommendations for future research. The main components of the proposed building system are described as follows:

1) The architectural planning in order to have a barrier free circulation and considering the entire needs of the elderly people,
2) Structural concept in order to have a simple system of home manufacturing, and
3) The construction method using large panels and joining with the cam-nut and cam-screw technique, as a fast erection method for mass-producing housing.

Further, the second level of components is described as mobility, accessibility, serviceability, controls, signals and automation, manufactured housing, flexibility and aesthetics. Finally, there are various sub-components to the second level of components, as described in definition of porch, doors, kitchen and laundry areas, and so on.

The system proposed is a straightforward design to standardize the use of machines at the plant and, thereby, produce a high volume of housing units. The system is based on concepts of lean production. The production system emphasize on reducing cycle times, increasing productivity, improving delivery, and enhancing customer satisfaction (Lean Concepts, 2001). Overall, the proposed building system in its entirety is a unique custom product. The design

in itself is conducive to simplified workflow (Landvater, 1993). As a whole, everyone is benefited eventually from a home of easy accessibility (Center for Universal Design, 1997).

The proposed building system, using cam-nut and cam-screw technique, with large concrete panels will allow for a planned and flexible design and production system. The production system includes the manufacture of large panels and site erection of panels and slabs (Singh, 2001). Improving continuously is a process in which lean principles can be applied to any construction process (Andery et al., 1998). With improvement and saving in time, material and money supports the lean production. Also, innovation contributes in the same fashion as improvement (Steudel and Desruelle, 1997). Mass manufacture is known to facilitate lean production, however, mass pre-fabrication has until now had the drawback of reduced product variety and reduced agility (Bessant, 1991; Baker, 1996; Burgess, 1994). With architectural flexibility supporting the building system, product variety is enhanced contributing directly to agile production (Singh, 2001). The future research is recommended as follows: empirical analysis of system components; detailing of the central core including all services; developing creative prototypes and analyzing several detailed models of a house; selection of appropriate construction materials and building envelope study; and the cost analysis.

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