A Sub-Systems Approach
to
Small Lot Single-Family Housing

by
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Master of Science in Architecture Studies.

ABSTRACT

The trends and preferences explored in this work indicate that the "American Dream" of a single-family detached house is still the preferred housing model.
In-order to achieve this goal most home buyers will have to accept a transformed version of this model in the form of small lot housing. The housing industry on the other hand, must be very creative and innovative to incorporate the housing trends and preferences into designs that are both affordable and still recognizable as the all American single-family detached house.

The breakdown of a dwelling into Sub-Systems (Shell/Infill) that is explored in this work introduces a hierarchy of Sub-Systems that is based on the concept of control and variety. In American society it is the aspect of variety rather than control that is stressed as the dominant factor.

In today's technology and design approach it is often only the furniture that is easily adaptable to user needs. All other Sub-Systems once installed, are difficult to change or to separate.
The Shell/Infill Sub-Systems concept as applied in this work makes it possible for the house to be much more adaptable.

The implementation of the Sub-Systems concept would allow the developer/builder to provide the variety and diversity the market expects on a customized bases. It would also make it possible to respond to shifts in demographic and housing demands.

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Introduction.

INTRODUCTION

Today fewer and fewer Americans of low to moderate income can afford to own a home of their own. Despite this affordability crisis the most popular house type for Americans is the single-family detached house embodied in the "American Dream". This image of the single family detached house is fundamentally interwoven with the American society and by no means arbitrary, as so aptly stated by Clark (1986) in "The American Family Home";

"The design, layout, and style of the house were invested with a moral purpose. Single-family houses were designed not only to strengthen the family but also to fulfill a symbolic function...
The constant promotion of the American family home ideal by countless advice manuals, plan books, and housing magazines has served to set a standard for middle-class aspirations and expectations.
A properly designed single-family house would protect and strengthen the family, shoring up the foundations of society and instilling the proper virtues needed to preserve the republic."

The subject of this thesis focuses on the provision of single-family housing in America by the private sector. The recognized popularity and success in which it is able to provide both responsive and flexible housing makes it an ideal case study. From this case study I hope to draw conclusions that can be applied to a broader spectrum of housing needs both in America and abroad.

Over the last couple of decades many different attempts at creating affordable housing solutions have been made. These range from the ill fated Operation Breakthrough to cluster
Introduction.

housing. The small lot housing concept is one, increasingly popular, approach used to bridge the affordability gap. The first goal of this study is to determine what demographic trends and housing preferences underly today’s small lot housing market. The small lot house type will then be analyzed so as to evaluate how these housing preferences and expectations can be transferred to a new house typology.

The second goal will be to focus on a "Sub-Systems" approach to housing design so as to understand the organization and spatial implications of new technological innovations upon the design of small lot single family American houses. The concept of Sub-Systems for housing implies the development and the organization of "catalogs" of coordinated elements, sub-assemblies, and components for a wide range of variation. The research will concentrate on analyzing housing that conventional home builders and manufactured home industry supply to the market, so as to determine how it can be adapted to a Sub-Systems approach.

The third goal of this research is to analyze popular, high-density single-family detached house design types, to understand the designs as systems and sub-systems that can be arranged in numerous ways to satisfy both the demands of the market place and the need of the industry to become more automated, more price competitive and more in tune with today’s demands. A design methodology that will satisfy both the "stick-built" and the prefabricated/manufactured housing industry.

The fourth goal is to analysis the small lot house using the Shell/Infill concept in order to develop a set of design guidelines and principals that can be used to develop market and context specific design primers by:
- Builders to market their developments.
- Architects to plan a development
Introduction.

- Housing manufacturers to develop capacity studies for their modules.

This rational, and systematic approach will have the added benefit of being able to be transferred into CAD/CAM which can, in turn, be used for cost take-offs and production drawings.

Systems and sub-systems distinguished for the purpose of this thesis are those usually referred to as Shell/Infill systems. Usually a "Shell" would be the roof walls and floors. An "Infill" system would be a sub-assembly that forms a unit such as a kitchen or bathroom.

Furthermore for the purpose of this thesis the typical house that is analyzed is a single family detached house (with a capacity for at least two bedrooms) set on a zero-lot-line configuration, within a cluster of similar homes as part of a Planned Unit Development (PUD). This house type was selected because it is one of the few "affordable" single family detached house types available today. This type has proven to be popular, marketable, and capable of being used in medium to high-density residential neighborhoods.

This thesis is a contribution to a growing body of work at MIT based on Thematic Design principals that are devoted to the systematic analysis of the built environment to:

- Help us understand the underlying principals that lend structure to that environment.
- Make the computer an ever more useful tool to the design professional.

The hypothesis sustaining this work is that the adoption of a Sub-Systems approach, as applied to small lot single-family detached housing, can introduce a flexible design methodology that can benefit both the developer/builder and the home-owner.
Study Organization:

The study is composed of four parts and a conclusion:

1. **Normative Housing Factors.**
   The first chapter explores the current state of housing demographics, trends and preferences in America. Recent demographic studies and surveys done by the industry are used to determine current demographic shifts and trends in the housing market. The most important design and marketing trends in small lot housing are analyzed for house types, space layouts and feature preferences.

2. **Small Lot (ZLL) Housing Factors.**
   The second chapter investigates the criteria and principals that underlie small lot detached housing.

3. **The Concept of Sub-Systems (Shell/Infill).**
   The third chapter describes the fundamentals of the Sub-Systems approach as applied to small lot housing.

4. **Small Lot Housing Analysis.**
   The fourth chapter analysis small lot detached housing in-terms of Sub-Systems principals. The small lot house topology will be analyzed using Sub-Systems principals and control rules so as to extract a common set of design guides and principles. These design guides and principles can then be used to generate variations from a base design model that have more than just image value. Service distribution requirements are analyzed to develop control guides and principles for the distribution of services. These design guides and principals facilitate the adaptable and flexible Shell/Infill sub-systems.

5. **Shell/Infill and (SL) Housing Application.**
   As a result of this research, conclusions will be drawn regarding housing issues on the national level for both the public sector and the private sector. Future reform and research issues will be suggested.
1. NORMATIVE HOUSING FACTORS.

1.1 Housing Demographics.

1.2 Housing Trends and Preferences.
   1.21 Housing Demand Factors.
   1.22 Planning and Regulatory Factors.
   1.23 External Factors.
   1.24 Internal Factors.

1.3 Housing Economics.
   1.31 Home Ownership Affordability.
   1.32 Cost Reduction Factors.
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NORMATIVE HOUSING FACTORS

The economic swings and changing demographics of the past decade have altered the way we form households. However, regardless of family status and income, most Americans still share a common dream, "The American Dream" of owning a single family home. Americans tend to think of home ownership as a right, not a privilege, but for most lower to moderate income families, affordable housing remains a dream. The "American Dream" can be defined as a single family detached home surrounded by trees and grass in either country or suburb. Despite the strong cultural identity with the family home, Americans rarely stay in a house for more than 5 years. It is not only a need but also a symbol.

The trends and preferences explored in this section indicate that the "American Dream" of a single-family detached house is still the preferred housing model. The analysis also indicate that in order to achieve this goal most home buyers will have to accept a transformed version of this model in the form of small lot housing. The housing industry on the other hand is going to have to be very creative and innovative to incorporate current housing trends and preferences into designs that are both affordable and still recognizable as the all American single-family detached house.

Traditionally the American Dream has evoked an image of certain patterns of housing demand, based on the typical American nuclear family. Most people leave their parents' households when in their early twenties and rent an apartment. They become homeowners in their late twenties and early thirties and then move up into larger and more expensive houses during their late thirties and early forties.
Chapter 1.

In some cases, as homeowners become elderly they give up their large houses for smaller homes or become renters again.

These traditional housing patterns and demands are changing significantly due to changing social patterns, demographics, and economics. Today, for example, there are a growing number of working women, large populations of elderly people and a continuing increase in single-person households. (Apgar, 1985)

In social, political, economic, and architectural terms, such demographic data evidences the need to acknowledge a growing variety of housing types. New housing will have to adapt to these many definitions.

Traditionally detached houses did not have garden fences or walls (See Figure 1.1), but now the fence may well express the territoriality and the need for privacy. The nature of territorial symbols in relation to problems of overpopulation, and crowding has become an important factor. Historically fences have not been popular, but there has been a considerable increase in fence sales which may well be due to an identification of fences with privacy - thereby making the fence a status symbol.

Figure 1.1
Chapter 1.

Prospective home buyers who reflect this social change are no longer satisfied with the traditional "bedroom suburb" but instead want detached homes with reduced maintenance and convenient social amenities. To make housing both affordable and available for this population different kind of political lobbying, financial reform, and new zoning laws, will have to take place.

Ultimately the building industry will have to adopt a new design attitude in order to provide house design methods that are innovative and adaptable to these diverse housing demands.

This study explores some possible innovations.
The following three sections focus on attitudes and conditions that are shaping the market.
The section on demographics (1.1) looks at how the profile of the American family has changed.
The second section on trends and preferences (1.2) surveys current consumer opinions.
The third section in this chapter on economics (1.3) analysis economic factors that govern the cost of housing.
1.1 HOUSING DEMOGRAPHICS.

According to the Joint Center For Housing Studies (The Housing Outlook 1980-1990), the housing sector is effected by demographic changes through population and household growth as well as through changes in life style and housing consumption.

The study found that today, young adults have delayed marriage, and couples have chosen to have fewer children, later in life. The reasons why married-couples have fewer children are:
1. Young couples are waiting longer to have children.
2. Young parents are having fewer children because of the freedom of choice offered by modern birth control methods, and because of a shift towards less child-orientated lifestyles.
3. The parents of the baby-boom generation are increasingly in the "empty nest" life cycle stage. These "empty nest" households reduce the average size of all married-couple households the longer they continue. Children are present for a smaller part of the life span of a married-couple.

The housing demand for starting families will be spread out more slowly over the rest of the century. This is in contrast to that of the previous baby-boom generation. (See Figure 1.2)

<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(In Thousands)</td>
</tr>
<tr>
<td>All Ages</td>
</tr>
<tr>
<td>Under 15</td>
</tr>
<tr>
<td>15 to 24</td>
</tr>
<tr>
<td>25 to 34</td>
</tr>
<tr>
<td>35 to 44</td>
</tr>
<tr>
<td>45 to 54</td>
</tr>
<tr>
<td>55 to 64</td>
</tr>
<tr>
<td>65 &amp; older</td>
</tr>
</tbody>
</table>

Source: Figure 1 URBAN LAND – Nov 1987 pp. 8

Figure 1.2
Chapter 1.

The study points out that the oldest members of the baby-boom are reaching middle age with established families, thus strengthening the demand for detached single-family housing.

Increase of Households.
The JCHS study found that the distribution of household types in 1980 reaffirmed the trend that the number of husband-wife households increased only 10.5% over the 1970's, while the number of single-person households grew 63.5%, which is a substantial increase over the last decade. It is estimated that by 1990 the number of households containing unattached individuals - those who have never been married, who are divorced, or who are widowed - will nearly equal the number of households with married couples.

Figure 1.3
The Joint Center study found that the causes for the increase in numbers of households, can be separated into three components:

1. **The age structure factor;**
   This factor shows the effects of simple aging of the population. As the baby-boom and baby-bust generations move into the household formation stage, and as longevity among the elderly improves, housing demand increases. In the 1970's this factor accounted for almost 63% of the total increase in households.

2. **The migration factor;**
   Migration accounts for 17% of the national household growth. The sizable increase of immigrants from abroad has contributed significantly to this factor. Regional analysis shows important population movement around the country that cause geographic variation in growth rates (Apgar 1985). The 1970's witnessed the movement of population from larger metropolitan areas to smaller cities, towns, and rural areas. For the first time in 150 years, housing in the rural counties expanded more rapidly than in urban counties.

---

**Figure 1.4**

U.S. MIGRATION TRENDS
Home Location

<table>
<thead>
<tr>
<th>Single-family Detached</th>
<th>Single-family Attached</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close-in Suburbs (27.0%)</td>
<td>Close-in Suburbs (41.8%)</td>
</tr>
<tr>
<td>Central City &amp; Other (4.7%)</td>
<td>Central City &amp; Other (4.7%)</td>
</tr>
<tr>
<td>Outlying Suburbs (41.3%)</td>
<td>Rural (5.8%)</td>
</tr>
<tr>
<td>Rural (27.1%)</td>
<td>Outlying Suburbs (35.4%)</td>
</tr>
</tbody>
</table>

Source: Professional Builder - Dec 1987 pp. 110
3. The household formation factor;
   The number of households formed by a given population also depends on how the population distributes itself among various family types.

The demographic profile outlined by the Joint Center's study is substantiated by a recent survey done by BUILDER magazine's Home Buyers Survey (July 1987). This survey shows the profiles of three buyer groups; singles, couples, and families.

The survey indicates that most single family home buyers are Baby Boomers in their peak earning years (median age of 36). All groups prefer single-family detached homes as opposed to attached homes by a 94.3%. (Fig. 1.5).

Of the buyers, 78% already own a home, although renters make a significant portion of the market, especially in the lower price range.

Nationwide statistics however do not necessarily reflect local realities. Housing markets are segmented by income, family size, and race. Supply changes in one segment have no impact on supply in another - an increase in Houston does not ease the crisis in New York. Moreover, costs in New York are 30% greater than in Alabama, and costs in Manhattan are 30% greater than in the four "outer" New York boroughs. Therefore affordability is relative.

<table>
<thead>
<tr>
<th>HOUSING TYPE PREFERENCES.</th>
<th>ALL MARKETS</th>
<th>SINGLES</th>
<th>COUPLES</th>
<th>FAMILIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Currently Homeowners</td>
<td>77.5</td>
<td>64.1</td>
<td>69.7</td>
<td>85.1</td>
</tr>
<tr>
<td>Home Type Owned</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-family Detached</td>
<td>82.1</td>
<td>69.6</td>
<td>74.9</td>
<td>87.9</td>
</tr>
<tr>
<td>Townhouse</td>
<td>12.7</td>
<td>22.6</td>
<td>18.9</td>
<td>9.7</td>
</tr>
<tr>
<td>Mid-rise Condominium</td>
<td>2.4</td>
<td>10.7</td>
<td>4.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Garden (Patio) Home</td>
<td>2.0</td>
<td>8.0</td>
<td>2.5</td>
<td>1.4</td>
</tr>
<tr>
<td>High-rise Condominium</td>
<td>0.7</td>
<td>1.2</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Prefer Single-family to Attached</td>
<td>94.3</td>
<td>77.6</td>
<td>93.7</td>
<td>96.4</td>
</tr>
</tbody>
</table>

Source: Builder – Jul 1987 pp. 81

Figure 1.5
1.2 HOUSING TRENDS AND PREFERENCES.

The difference between the popular mass produced houses and the architect designed house can help us gain an insight into the needs, values, and desires of people. It is the tract house rather than the architect designed house that needs to be discussed here. An understanding of the values it represents might help explain its success. These roadside and tract buildings represent certain values that are lacking in the architect designed buildings, and which tell us something about life-styles, thus explaining their acceptance and commercial success. Even though people no longer build their own houses, the houses they buy reflect popular values and goals more closely than do those of the design subculture - and these houses constitute the bulk of the built environment.

There is still the old search, started by Ebenezer Howard with the Garden City movement, for the ideal environment of which the house is merely one physical component. The recent tendency in the United States to design housing estates and "new towns" around recreational facilities is a striking reflection of an old idea in a new guise. Within the middle-class culture, dwelling forms change to accommodate people outside the "standard family" through new types of popular housing.

This era is one of reduced physical and building material constraints. Man can do much more than was possible in the past. The result is the problem of excessive choice, the difficulty of selecting or finding constraints, which arose naturally in the past and which are necessary for the creation of meaningful house form, is no longer a problem.
Chapter 1.

This great freedom of choice, and the fact that the house form can now be in the domain of fashion, suggests the importance of social-cultural factors. Therein may lie the great lesson of vernacular building for today, namely, the value of constraints to establish generalized, "loose" frameworks where the interplay of the constant and interchangeable aspects of man can find expression. (Rapoport 1969).

1.21 Housing Demand Factors.

The increased demand for single-family detached homes during the 1970-1980's in the face of rising costs and high interest rates can be attributed to the following factors:

1. Americans suddenly became more aware of the value of home ownership as a hedge against inflation.

2. A single-family home is viewed as a popular concept of security.

3. Buyers were able to cash in on the high equity they held in an older house and trade up to a more comfortable feature filled model.

4. Movement to the suburbs and to the countryside opened up new areas of land; which in turn promoted single-family home ownership and the American Dream ideal.

5. Working wives brought in added income that made higher priced single-family homes affordable.

6. Builders developed a host of new designs, styles, and amenities that made single-family living more desirable.

7. Builders employed new concepts for designing subdivisions enabling them to provide single-family detached and attached units in Planned Unit Developments along with duplexes, townhouses in zero lot line arrangements.

8. To meet higher cost and energy saving requirements, many new, single-family houses were built smaller but used more sophisticated design to create the illusion of more space.
The most important reasons for the popular preference of single-family detached homes are security, privacy, investment potential and the need to conform to social norms.

**HOUSING PREFERENCES**
Reasons to Buy Single-family

<table>
<thead>
<tr>
<th></th>
<th>ALL MARKETS</th>
<th>SINGLES</th>
<th>COUPLES</th>
<th>FAMILIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>More Privacy</td>
<td>87.0%</td>
<td>85.6%</td>
<td>87.3%</td>
<td>87.0%</td>
</tr>
<tr>
<td>Private Yard</td>
<td>84.0%</td>
<td>77.9%</td>
<td>81.7%</td>
<td>86.0%</td>
</tr>
<tr>
<td>No Common Walls</td>
<td>82.2%</td>
<td>83.9%</td>
<td>81.3%</td>
<td>82.8%</td>
</tr>
<tr>
<td>Larger Home</td>
<td>70.8%</td>
<td>57.5%</td>
<td>66.1%</td>
<td>75.4%</td>
</tr>
<tr>
<td>Better Investment</td>
<td>65.0%</td>
<td>68.4%</td>
<td>67.1%</td>
<td>63.7%</td>
</tr>
<tr>
<td>More Traditional</td>
<td>56.4%</td>
<td>44.3%</td>
<td>55.4%</td>
<td>58.7%</td>
</tr>
</tbody>
</table>

Source: Builder – Jul 1987 pp. 81

**Figure 1.6**

**1.22 PLANNING and REGULATORY FACTORS.**

The attitudes of lending agencies, tax policies, and government regulation of all sorts, such as building and health/safety codes and zoning, are all important determinants of building form and development design.

Zoning that limits the possibility of having non-family members rent part of the single-family house poses a hardship. Some ordinances prohibit more than three unmarried persons from living together; other ordinances also make it impossible to rent a bedroom to a student or older person in exchange for childcare.

With the high cost of living and the increased difficulty for first time buyers to enter the house market more families will want to adapt part of their house as an office or to be able to rent out a "granny apartment". Innovative local subdivision regulation and or zoning ordinances can free the developer from highly specific requirements on such planning and zoning matters as lot sizes and street widths. The developer in return promises to treat the land more imaginatively.
1.23 External Factors.

There are several other factors that govern house design in today's emerging markets. The popular housing magazines are a good source in determining the current housing trends and preferences. For the purpose of this research surveys from three prominent magazines were used, namely that of The Atlantic Monthly (Sep 1984), Builder (Jul 1987), and Professional Builder (Dec 1987).

Architectural Design Style.
House builders/designers and architects are reverting more and more to traditional and classical styles (The Atlantic Monthly Sep 1984). Colonial and contemporary houses are equally popular, though singles mostly prefer contemporary styles. (See Figure 1.7)

![ARCHITECTURAL DESIGN STYLE](image)

<table>
<thead>
<tr>
<th>Style</th>
<th>Consumers prefer (%)</th>
<th>Best-selling models (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>35.8</td>
<td>43.2</td>
</tr>
<tr>
<td>Contemporary</td>
<td>24.9</td>
<td>25.5</td>
</tr>
<tr>
<td>Colonial</td>
<td>18.3</td>
<td>18.5</td>
</tr>
<tr>
<td>Victorian</td>
<td>6.2</td>
<td>4.4</td>
</tr>
<tr>
<td>Spanish</td>
<td>4.8</td>
<td>7.7</td>
</tr>
<tr>
<td>Tudor</td>
<td>3.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Other</td>
<td>6.6</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Source: Professional Builder – Dec 1987 pp. 119

Figure 1.7

Futhermore the following features are prevalent in current designs for single-family detached homes:
1. The front porch is back, if only for appearance sake.
2. Builders and designers use visually complex, traditional forms to convey status. An elaborate house seems bigger, more lavish and more expensive.
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3. Innovations are incorporated into the house design in an unobtrusive way especially if the innovation is brought about by scarcity or conservation. The developers choose to innovate and then to disguise the innovation to create an atmosphere of pleasant familiarity.

4. The conventional is preferred; there is an unshakable belief that anything that looks unconventional will be regarded as inferior.

Lot Size and Configuration.

With increasing lot prices the configuration of the lot has become an important factor governing the lot size, house type and location.

The ideal is still a large lot (half-acre or more) but this is fast becoming prohibitive in many areas. (See Figure 1.8)

<table>
<thead>
<tr>
<th>LOT SIZE/CONFIGURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detached homes (%)</td>
</tr>
<tr>
<td>Half acre or more</td>
</tr>
<tr>
<td>Narrow frontage / deep rear yard</td>
</tr>
<tr>
<td>Minimum yard with private court</td>
</tr>
<tr>
<td>Narrow frontage / deepfront yard</td>
</tr>
<tr>
<td>No private yard / common open space</td>
</tr>
</tbody>
</table>

Source: Professional Builder - Dec 1987 pp. 119

Figure 1.8

Space Configuration.

The components that makeup the single-family detached house, (the number of stories, basement, and garage components,) are largely determined by regional factors;

1. Number of Stories; Although 40.6% of all consumers prefer a single-level home, 60.6% of New Englanders prefer a two story home. (Professional Builder - Dec 1987 pp. 119).
2. Most consumers (69%) prefer a basement, although more than half of the builders do not provide a basement in their models. Preference for a full basement is again strongest in New England (97%).

3. About two-thirds of all buyers want a two-car garage and an automatic garage opener.

<table>
<thead>
<tr>
<th>GARAGE LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attached, In Rear Driveway on side</td>
</tr>
<tr>
<td>Attached to home as Part Of Front Elevation</td>
</tr>
<tr>
<td>Detached, In Rear Driveway On Side</td>
</tr>
<tr>
<td>Detached, In Front Of Home</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attached, In Rear Driveway on side</th>
<th>Attached to home as Part Of Front Elevation</th>
<th>Detached, In Rear Driveway On Side</th>
<th>Detached, In Front Of Home</th>
</tr>
</thead>
<tbody>
<tr>
<td>49.3%</td>
<td>32.3%</td>
<td>16.8%</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

Source: Builder – Jul 1987 pp. 83

Figure 1.9

1.24 Internal Factors.

The single-family detached house plan is primarily a reflection of behavioral patterns. However there are several internal factors, such as Western society’s attitude to privacy or new approaches to bathroom and kitchen design, that govern trends and preferences in the "ideal" house of today.

Space Layout.
Attitudes about privacy are culturally shaped, and have great impact on house form. This may be why the "open plan" so beloved of the architect, has never really been accepted by the public.
Today, according to the Builder (Jul 1987) survey:
1. Most buyers prefer the living room and dining room to face the front yard, and the kitchen, family room and bedrooms to face the back yard.
2. Most consumers prefer a three bedroom home.
3. The location of the master bedroom on the first or second level is dependent on regional demographics. Amongst retirees it is found that 80.7% want their master bedroom on the first level. Of move-up buyers 51.8% prefer the second level.

Bathroom Amenities.
Attitudes in the United States towards the bathroom are also largely culturally derived. The form of the bathroom is the result of attitudes about the body, relaxation, privacy, and so on. The same fundamental problems of hygiene have always existed, but the importance attached to them, and the forms used, have been very different, depending on the beliefs, fears, and values rather than utilitarian considerations. The choice between tub and shower is largely a matter of attitude and image. Two bathrooms are preferred by 40.5% of consumers. Amenities such as a private bath, walk-in closets and separation from other bedroom areas are the most important elements of the master suite.

<table>
<thead>
<tr>
<th>BATHROOM AMENITIES</th>
<th>All Consumers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private bath</td>
<td>80.1</td>
</tr>
<tr>
<td>Walk-in closet</td>
<td>79.1</td>
</tr>
<tr>
<td>Separation from other bedrooms</td>
<td>58.9</td>
</tr>
<tr>
<td>Dressing/makeup area</td>
<td>35.2</td>
</tr>
<tr>
<td>Sitting area</td>
<td>18.9</td>
</tr>
<tr>
<td>Mirrored doors</td>
<td>17.6</td>
</tr>
<tr>
<td>Balcony or patio</td>
<td>17.2</td>
</tr>
<tr>
<td>Fireplace</td>
<td>9.7</td>
</tr>
<tr>
<td>None</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Source: Professional Builder – Dec 1987 pp. 119

Figure 1.10
Chapter 1.

Kitchen Arrangement.
Patterns of formality or informality in dinning still play an important role in molding childhood attitudes, and to that extent the house is still a mechanism for shaping character. Thus cultural patterns strongly influence eating area requirements in the house. The breakfast nook or eating area in the kitchen is preferred by most consumers, in addition to a full dining room.

<table>
<thead>
<tr>
<th></th>
<th>Consumers prefer (%)</th>
<th>Builders offer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eating area + full dinning room</td>
<td>48.5</td>
<td>48.1</td>
</tr>
<tr>
<td>Combined kitchen/family room</td>
<td>18.0</td>
<td>12.3</td>
</tr>
<tr>
<td>Area for small table</td>
<td>11.5</td>
<td>10.0</td>
</tr>
<tr>
<td>Full dining area</td>
<td>8.5</td>
<td>10.2</td>
</tr>
<tr>
<td>Countertop only with stools</td>
<td>7.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Food preparation area only</td>
<td>6.0</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Source: Professional Builder – Dec 1987 pp. 120

Figure 1.11

Service features.
The emergence of "intelligent/smart house" features although, currently limited only to the high end market, have evoked much interest among consumers. (Fig.1.12)

<table>
<thead>
<tr>
<th></th>
<th>Want</th>
<th>Don't want</th>
<th>Average will pay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security/safety</td>
<td>69.0</td>
<td>31.0</td>
<td>$748</td>
</tr>
<tr>
<td>Energy Management</td>
<td>66.7</td>
<td>33.3</td>
<td>$761</td>
</tr>
<tr>
<td>Entertainment</td>
<td>43.7</td>
<td>56.4</td>
<td>$853</td>
</tr>
<tr>
<td>Communications</td>
<td>37.8</td>
<td>62.3</td>
<td>$342</td>
</tr>
<tr>
<td>Service/Data</td>
<td>12.7</td>
<td>87.3</td>
<td>$258</td>
</tr>
</tbody>
</table>

Source: Professional Builder – Dec 1987 pp. 123

Figure 1.12
Chapter 1.

With these centralized electronic systems many different functions in the home can be monitored and controlled. Security and energy management are the most important features, especially in demographic areas where the elderly population rate security as an important need.
1.3 HOUSING ECONOMICS.

For many Americans today owning a single family detached house, on a large lot, is an impossible dream. The cost of money, land, and construction, have made the conventional single-family house affordable only to the affluent.

1.31 Home Ownership Affordability.

The "affordability crisis" can be attributed to five factors that have played a major role in raising the cost of home ownership:

1. The rising cost of available land and infrastructure development.
2. Changes in the mortgage market and higher interest rates resulting from Federal Reserve Bank monetary policies, coupled with rising federal deficits and deregulation of the savings and loan industry.
3. Inflation in home prices in the expectations of future gains through appreciation.
4. Movement of the baby-boom generation into the prime home buying stage.
5. Impact fees as a result of declining Federal support for municipal services, and having to comply with government regulations.

Increased mortgage rates and higher utility rates, together with the high prices resulting from the economic boom of the late 1970's and the lower expected gains from subsequent housing price inflation, have left potential home buyers with few options.
Chapter 1.

Those households that did not make the transition to home ownership, and new households that are entering the market for the first time, are facing increasingly unfavorable conditions.

Younger and poorer households are now less likely to own their own home than they were five years ago. Those that have been able to purchase houses are much more likely to have selected condominium ownership or a mobile home than a traditional single-family home. Households that were able to afford the traditional single-family detached home are more likely to have selected a smaller unit with fewer amenities.

1.32 The Cost Reduction Factors.

Several methods are used to cut costs; by downsizing the house, by using manufactured construction, or through the use of the compact site plan with varying results and acceptance.

Downsizing.
This notion holds that the smaller, "smarter" house will be cheaper to build, heat, and maintain, and is better suited to today's smaller households. Three ways to shrink the standard single-family detached house, according to a HUD pamphlet titled "Designing Affordable Housing" by Steven Winter are;
1. Decrease the number of rooms.
2. Reduce the dimensions of rooms.
3. Change the relationship of rooms.
This approach however is handicapped by rigid limits set by consumers, and an unwillingness to accept downsizing.

Manufactured Housing.
Today's building industry already relies heavily on prefabricated components and sub-assemblies, from factory-made window and door assemblies, prefabricated roof trusses and wall panels, to packaged kitchens and bathrooms.
Chapter 1.

The U.S. Office of Technology Assessment concerned with the state of the industry and foreign competition proposes four main areas of reform to aid the industry:

1. A uniform national building code to replace the present fragmented system of regional and local codes.
2. New fiscal interventions to help stabilize the demand for housing, such as interest reductions for housing loans to lower-income buyers or tax-exempt mortgage bonds.
3. A national quality-control and labeling system, so that consumers can distinguish between good and bad quality.
4. Building research promoted and funded by the Federal government.

Although these sweeping proposals, if implemented, may bring down the cost of housing these reductions have little to do with affordability. With only less than half the cost of housing taken up by the unit itself it is land costs, financing, infrastructure development and taxes that are the real problems. (See Figure 1.13)

The Compact Site Plan.

Land and infrastructure development costs are major cost components of a home (An acre of land in Irvine California can sell for as high as $500,000).

![DEVELOPMENT COST BREAKDOWN]

<table>
<thead>
<tr>
<th></th>
<th>Detached-home Builders</th>
<th>Attached-home Builders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Land</td>
<td>18.9</td>
<td>18.3</td>
</tr>
<tr>
<td>Land Improvements</td>
<td>7.9</td>
<td>7.8</td>
</tr>
<tr>
<td>Financing</td>
<td>4.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Labor</td>
<td>18.7</td>
<td>19.2</td>
</tr>
<tr>
<td>Materials</td>
<td>27.8</td>
<td>24.1</td>
</tr>
<tr>
<td>Overhead</td>
<td>5.8</td>
<td>6.3</td>
</tr>
<tr>
<td>Marketing/Sales</td>
<td>4.3</td>
<td>4.9</td>
</tr>
<tr>
<td>Advertising</td>
<td>1.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Profit</td>
<td>10.3</td>
<td>9.5</td>
</tr>
<tr>
<td>Other</td>
<td>1.3</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Source: Professional Builder – Dec 1987 pp. 117

Figure 1.13
It is in the area of land-use and development that the most opportunity for cost reduction lies. Figures 1.13 and 1.15 both reflect the fact that land and infrastructure development costs are major cost components.

The finished lot costs and financing has more than doubled over the last forty years where most other costs have either been reduced or kept constant. (See Figure 1.14)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor &amp; Mats.</td>
<td>69</td>
<td>55</td>
<td>56</td>
<td>48</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>Finished Lot</td>
<td>11</td>
<td>21</td>
<td>19</td>
<td>25</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Ohd. &amp; Profit</td>
<td>15</td>
<td>13</td>
<td>18</td>
<td>12</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Financing, etc.</td>
<td>5</td>
<td>11</td>
<td>7</td>
<td>15</td>
<td>12</td>
<td>15</td>
</tr>
</tbody>
</table>


Figure 1.14

Land costs can be reduced by developing smaller lots at higher densities provided local development standards and regulations governing density, have been adjusted to ensure that the advantages of single family detached housing are maintained.

Over the last decade a number of local governments have tried to remedy the factors contributing to the high costs of traditional zoning regulations. With the need for affordable new single-family housing, many land use ordinances have been revised, to promote affordable housing development by including cluster zoning provisions. (See Figure 1.6)
Some of the changes are;

1. Communities encourage the provision of affordable single-family detached housing primarily by reducing lot area, frontage, coverage, and setback requirements.

   **Lot Area:** Minimum lot sizes permitted range from 3,600 to 5,000 square feet. (The standard average finished residential lot size is 12,800 square feet.) In PUD's, dramatic reductions are achieved (Below 3,000 square feet).

   **Frontage:** Lot frontage requirements range between 30 and 60 feet. Some communities set no minimum requirement but rely on site plan review to determine appropriate frontage, especially under PUD developments.

   **Setbacks:** Where land use standards are revised "zero lot line" provisions are possible. Under this concept, one side yard is reduced to zero to allow the dwelling to be located on the side lot line.

2. Depending on their perception of local market preferences, developers of affordable housing often exceed the minimum requirements.

3. Planners and developer find it necessary to adjust building and site designs as lot area, frontage, and setbacks were reduced, by;
   - Implementing zero lot line planning.
   - Integrating indoor and outdoor areas for more efficient use of the small lot.
   - Varying the exterior design and siting of buildings to improve the streetscape.

4. As lots become smaller the main trade-off involves parking, open space, and the privacy of the individual units.

   **Parking:** When frontage is reduced below 50 feet the front setback has to be 20 - 25 feet in order to accommodate off-street parking. Some communities encourage alleys so parking can be placed at the rear of the lot.

   **Open Space:** Common open space becomes important when the lot size is below 4,000 square feet.
Chapter 1.

Privacy: Small-lot development requires landscaping, fences or walls to ensure privacy between dwellings and to minimize the impact of street traffic.

5. The key factor to these new regulations is flexibility to deal with different planning and development situations.

6. The acceptance of small-lot development depends on a project’s compatibility with the existing residential development and the willingness of the developer to share the cost of public facilities that might be required.

Potential Cost Reduction.
The two oil crises resulted in the upgrading and streamlining of construction methods and costs, so any major new cost reduction in building construction methods seems unlikely.

Many of the large developer/builders are now offering only standardized pattern book designs. This avoids architects fees and ensures that the building cost is a known and proven factor.
The manufactured housing industry especially prefers the standard pattern book approach. In both cases individual customizing is either not accommodated or priced prohibitively.

<table>
<thead>
<tr>
<th>POTENTIAL AREAS FOR REDUCING HOUSE COSTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relax land-use restrictions</td>
</tr>
<tr>
<td>Improve building techniques</td>
</tr>
<tr>
<td>Increase density</td>
</tr>
<tr>
<td>Reduced labor costs</td>
</tr>
<tr>
<td>Innovative financing</td>
</tr>
<tr>
<td>Downsize units</td>
</tr>
<tr>
<td>Decrease construction time</td>
</tr>
</tbody>
</table>

Source: Professional Builder – Dec 1987 pp. 117

Figure 1.15
Some of the smaller developer/builder companies provide customization of its designs or even total customer specification for extra cost. These services tend to be the exception rather than the rule.

The survey in figure 1.16 indicates the most potential areas for reducing housing costs are through relaxed land-use, improved building technique, and increased density. This thesis will focus especially on these areas.

<table>
<thead>
<tr>
<th>POTENTIAL DEVELOPMENT COST REDUCTION</th>
<th>Detached-home Builders ( % )</th>
<th>Attached-home Builders ( % )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard designs</td>
<td>51.4</td>
<td>48.9</td>
</tr>
<tr>
<td>Smaller lots</td>
<td>53.0</td>
<td>39.1</td>
</tr>
<tr>
<td>Design expandable homes</td>
<td>32.0</td>
<td>23.4</td>
</tr>
<tr>
<td>Build smaller homes</td>
<td>31.3</td>
<td>14.1</td>
</tr>
<tr>
<td>Build attached units</td>
<td>15.7</td>
<td>68.8</td>
</tr>
<tr>
<td>Erect prefab homes</td>
<td>11.9</td>
<td>17.2</td>
</tr>
</tbody>
</table>

Source: Professional Builder – Dec 1987 pp. 117

Figure 1.16

Consumers desires and the reality of what they can afford often do not match. The maximum monthly mortgage payment people can afford often does not fit the home they want. Consequently the compromises that consumers are willing to make range from affordable financing (adjustable-rate loans or buydowns) to excepting an increase in amenities for a smaller-size lot.

Although many different conclusions can be drawn from the preceding analysis this study will use Small Lot Housing as a basis for further research. Small Lot Housing offers most of the potential cost reduction features outlined above and yet is still recognizable as fitting the American Dream.
2. SMALL LOT (ZLL) HOUSING FACTORS.

2.1 Background To Small Lot Housing.

2.2 Small Lot Marketing Factors.

2.3 Small Lot (ZLL) Development Factors.
   2.31 Site Planning and Lot Layout.
   2.32 Street Design.
   2.33 Climatic Orientation.

2.4 External Small Lot House Design Factors.
   2.41 Small Lot Easement Factors.
   2.42 Small Lot Configurations.
   2.43 Small Lot House Types.

2.5 Internal Small Lot House Design Factors.
   2.51 Space Configuration.
   2.52 Space Planning.
   2.53 Volume and Space.
   2.54 Circulation.
Chapter 2.

SMALL LOT (ZLL) HOUSING FACTORS.

Cost saving measures in residential construction have long been a focal point of the building industry. This has led to very cost effective and efficient structures and there is little room left for significant further reductions in this area.

The attention of the housing industry has consequently turned to land planning as the area with the most potential for cost savings and innovation.

The cost savings that can be achieved with small lot detached housing are then generally utilized in one of two ways:

1. By passing the savings on to the unit and thereby reducing the overall unit cost.
2. By applying the savings to design features and options thereby giving more value.

The small lot detached housing concept has developed over the last thirty years and has produced several versions of the small lot configuration. It is expected that innovation in small lot planning will be very active over the next decade. New solutions that do not have some of the disadvantages of existing types will encourage further innovation.

With small lot planning the design of the cluster (neighborhood), the lot, and the house are all integrated. As the elements are closely related to each other the design needs careful consideration. The design criteria and principles that underlie small lot house plans are explored in this section in-order to establish a framework for further analysis of this housing form.
2.1 BACKGROUND TO SMALL LOT HOUSING.

The detached single family house located on a lot large enough to provide privacy from its neighbors has become increasingly unobtainable over the last couple of decades.

As developers responded to economic pressures by providing narrower and narrower lots, the use of side yard space became limited and reduced privacy between units. The introduction of the small lot concept in the form of the zero lot line (ZLL) house made it possible to retain the American dream house image while reestablishing unit privacy. This was done by shifting the unit to one of the side property lines and utilizing intensively all of the yard space. (See Figure 2.1)

**Figure 2.1**

**AMERICAN LOT/HOUSE TREND**

Present American showcase (vestigial renaissance)

Future American-trend home
Total use of site as living space. Privacy regained. Indoor-outdoor integration. Natural elements introduced. Compact home-garden units grouped amid open park and recreation areas which preserve natural-landscape features.

Source: Simonds - LANDSCAPE ARCHITECTURE, 1983.
With the introduction of a backyard wall/fence the transformation of the house, from an external orientation to that of an internal orientation, was completed. The small lot ZLL house type has a lot in common with the ancient patio, atrium and court-yard house that has been in use all over the world for centuries. Although this house type is widely accepted in most parts of the world its introduction into the Untied States at first met with limited success. Post War housing efforts however, saw the successful introduction of ZLL designs into countries like Denmark, Sweden, England, and Canada. The ZLL concept in the U.S.A. had its roots in the 1930 Radburn innovations, that pioneered the use of cul-de-sacs and loop roads of feeder roads and the legislation and regulations that made this form of medium density housing possible.

THE EVOLUTION OF SMALL LOT DEVELOPMENTS

![Diagram](image)

Source: Jensen — ZERO LOT LINE HOUSING, 1982.

Figure 2.2
Chapter 2.

However, it was the cluster housing and the planned unit development (PUD) concepts of the 1960's that contributed most to the evolution of this house type. Clustering is aimed at grouping dwellings closer together in order to preserve open space.

The ZLL approach was devised to more efficiently utilize smaller lots resulting from clustering.

Small lots that made use of a zero lot line have been in use in the U.S. since the 1960's, when ZLL homes were first introduced in Southern California. The ZLL approach seeks to keep the most important characteristics of conventional single-family detached housing on reduced lots.

Since the first ZLL housing was built in the mid 1960's, at least three different regulatory approaches have been used to permit ZLL developments;
1. ZLL development in planned unit or cluster developments.
2. In separate medium density residential zoning districts with zero lot line provisions.
3. As exceptions (infill) in existing districts.

Developers have been trying to provide buyers with what they want on smaller and smaller pieces of ground. The original zero-lot-line plan has been refined over and over to achieve densities approaching or equal to attached housing, while still maintaining single family privacy on lots as small as 3,000 square feet.
2.2 SMALL LOT MARKET FACTORS.

In ZLL developments, market analysis plays a key role in setting guidelines for the character, scope, and timing of a project. ZLL housing can improve the stability and quality of neighborhoods by providing more affordable housing for a wider range of incomes. This is likely to contribute to the popularity and acceptability of ZLL housing in the future.

The acceptability of ZLL housing in various markets can be divided into three identifiable market stages;

1. **Stage 1** - is made up of small markets where there have been no previous experience with this housing concept. For this market it is necessary to determine whether a significant share of potential home buyers have been priced out of the conventional housing market. The public awareness of ZLL housing should also be evaluated.

2. **Stage 2** - exists in those cities (such as Denver and Chicago) where the population has had a fair amount of experience with ZLL housing. This stage involves the analysis of the total available demand, and where new desirable location opportunities are.

3. **Stage 3** - represents markets (California, Florida) where ZLL housing is considered standard, and now makes up a major component of the total new housing construction (40-50%). Because of its general acceptance this market includes the middle and upper-income brackets, virtually all age groups, and households with or without children.

To justify the development of ZLL projects the following needs have to be satisfied;

1. The development of better and more competitive residential environments in all price ranges.
2. The increase of density and reduction of costs.
3. Making the small house and its lot more attractive.
4. Providing detached units and making high land values work.
5. Meeting specialized market demand for a compact single-family house in specific regions.
6. Maximizing lot usability and reducing outside maintenance.
7. Making more efficient use of individual lots.

For ZLL developments, as for other types of housing, two basic markets exist;
1. The **Shelter Market** in which ZLL housing comprises the lowest priced single family detached housing available.
2. The **Specialty or Life Style Market** where prices are comparable to competitive housing types but the chief attraction is the distinction of having security, low maintenance, unique design and possibly increased recreational opportunities. (See Figure 2.3)

<table>
<thead>
<tr>
<th>SMALL LOT (ZLL) MARKETS</th>
<th>SHELTER MARKET</th>
<th>SPECIALTY MARKET</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONCEPT</strong></td>
<td>Starter House – lowest priced detached unit, probably a &quot;temporary&quot; home.</td>
<td>Lifestyle preference over other equal or lower priced units – lower maintenance, higher security, and common amenities.</td>
</tr>
<tr>
<td><strong>TYPICAL MARKET</strong></td>
<td>Low-to middle-income singles and young families.</td>
<td>Middle – to upper-income professionals, empty nesters, retirees, ect.</td>
</tr>
<tr>
<td><strong>TYPICAL DENSITIES</strong></td>
<td>5 – 9 Units per acre.</td>
<td>3 – 8 Units per acre.</td>
</tr>
<tr>
<td><strong>DEVELOPMENT FEATURES</strong></td>
<td>An affordable detached unit – usually avoiding open space, homeowners' associations, ect.</td>
<td>Quality lifestyle units, with common theme/amenities (lake, tennis, etc.)</td>
</tr>
<tr>
<td><strong>MARKETING CONCERNS</strong></td>
<td>Reassurance about value appreciation potentials.</td>
<td>A better product for the target market than competitors.</td>
</tr>
<tr>
<td><strong>DESIGN CONCERNS</strong></td>
<td>Minimization of building mass impacts on project appeal – maximum facade, detailing, and landscaping with limited budget.</td>
<td>Proper mix of lot sizes, unit sizes, features, common amenities, and development image for maximum appeal to target market.</td>
</tr>
</tbody>
</table>


Figure 2.3
2.3 SMALL LOT (ZLL) DEVELOPMENT FACTORS.

Small lot (ZLL) housing development introduces new design constraints and characteristics that need special attention. To avoid the appearance of overcrowding and monotony a number of important lot layout and building siting principles for ZLL housing have to be considered.

2.31 Site Planning and Lot Layout.

Site planning considerations for a small lot project, although similar to the standard subdivision, take on more importance because of the relatively high density involved.

Figure 2.4

Source: Jensen - ZERO LOT LINE HOUSING, 1982.
Due to the density involved:
- The lot size should be in proportion to the house size.
- The site must be able to accommodate the specific high-density concept. Hilly terrain with slopes greater than 3 to 4 percent is unsuitable.
- Land planning and unit design must be integrated concurrently.

2.32 Street Design.

The introduction of a hierarchy of streets, based on traffic flow patterns and a logical layout are essential to a ZLL development. A mix of different types of streets, cul-de-sacs, motor courts, and loop roads off collector roads is most successful. The fewer houses on a street, the narrower it can be without interrupting traffic flow. Extensive comparative studies have been done on the street width and hierarchy of streets to substantiate this principle (Land Design/Research 1976). ZLL housing should only front on short cul-de-sacs or loop roads, to avoid long monotonous streets. Ideally, collector roads should not have any houses fronting on them, and therefore no on-street parking. They can thus be reduced in width. With ZLL development special attention should be given to street widths, driveways, and garage locations.

Figure 2.5
2.33 Climatic Orientation.

The small lot house is usually placed to one side of the lot so siting considerations are more important than for conventional single-family housing. Because the ZLL house has one blank wall this usually implies a directional window orientation. Most windows can therefore be consolidated on one side of the ZLL house. This is ideal for passive solar gain, provided the windows are oriented correctly. By orienting lots so that the zero lot line faces to the north and the area that will be used for outdoor activities faces to the south, maximum use of outdoor areas is gained. This is not always possible, of course, so layouts that position the house and outdoor areas in alternative orientations need to be developed as well.

Figure 2.6
2.4 EXTERNAL SMALL LOT HOUSE DESIGN FACTORS.

There are three factors that effect the external elements of small lot house design, easements, lot configurations, and house types. Each of these factors are closely related to one another.

2.41 ZERO LOT EASEMENT FACTORS.

Easements for utilities and other uses in ZLL development have to be carefully planned. Due to the restricted size of ZLL lots, easement constraints need to be considered in the design process.

Drainage Easements.

Drainage easements can occur in two basic locations:
1. **Between lots**, for the purpose of allowing runoff. These drainage easements between lots can range form 5 to 15 feet and can be incorporated into pedestrian walkways.
2. **On each lot**, to allow the run-off from adjacent roofs and private yards to exit the yard. Easements on lots range from 3 to 10 feet in width.

![DRAINAGE EASEMENTS](image)


Figure 2.7
Maintenance/Access/Use Easements.

Provision must be made for maintenance or access where a homeowner may need to have the right to access an adjacent property to service the side of his/her building. These easements on lots range from 3 to 10 feet in width. An alternative to having an easement on an adjacent lot, is to set the dwelling unit back 3 to 8 feet from the lot line to provide access on each lot. The adjacent lot is then given use of this area through an easement on the setback area.

Utility Easements.

Due to the small size of ZLL lots most major easements are planned to occur either in public or common areas.

These easements occur in the same way as in conventional development with emphasis on the following options;
1. All utilities located on the front of the unit.
2. All utilities located in the rear of the unit.
3. All utilities located in the side yard of the unit.
Chapter 2.

Building Setbacks.

Setbacks vary considerably depending on the planning and architectural program, but the setbacks from the street are the most important in terms of safety and aesthetics. (See Figure 2.9)

![Diagram of Zero Lot Line Building Setbacks]

**Figure 2.9**

**View Preservation Easements.**

These easements, typically applied to the whole project, occur in horizontal and vertical planes relating to structure and landscaping. View corridors between buildings and controls placed on architectural height and landscaping are ways to preserve this option.
Landscaping Easements.

Landscape easements allow the use of certain areas such as building setbacks and/or right-of-ways for landscaping. In some instances these areas are also used for off-street parking, thus allowing the unit's front setback to be reduced.

Figure 2.10

Solar Easements.

Most financial institutions require lenders to ensure permanent, legal, access rights to direct sun-light. Careful design attention is needed to assure that building heights, roof planes, and landscape elements do not exclude the sun.

Figure 2.11
2.42 SMALL LOT CONFIGURATIONS.

Since the original, rectangular zero-lot-line plan was developed many derivations have been used to achieve higher densities and improved site features.

Presently three basic ZLL configurations can be identified:
1. The original rectangular zero lot line configuration.
2. The z-lot configuration.
3. The wide-shallow configuration.

Each of these is explored and evaluated in more detail on the following pages because the lot configuration is an integral part of the unit design.

Figure 2.12
Chapter 2.

The Rectangular Zero-Lot-Line Configuration.

Characteristics:
- The typical zero-lot-line lot has a rectangular shape with a narrow street frontage and long side lot lines.
- The house is located on one of the long side lot lines with a blank wall that faces the neighboring house.
- The house opens up to the side courtyard, which provides the unit’s major outdoor space.

![ZLL LOT VARIATIONS:](image)

<table>
<thead>
<tr>
<th>Narrow Rectangular Lot</th>
<th>Lot Characteristics.</th>
</tr>
</thead>
<tbody>
<tr>
<td>o Street Front Width: 30-45’</td>
<td>o Lot Size: 30-45’x 100’</td>
</tr>
<tr>
<td>o Lot Area: 3000-4500 Square Feet</td>
<td>o Orientation: Perpendicular to street.</td>
</tr>
<tr>
<td>o Density: 6-8 Units/Acre</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wide Rectangular Lot</th>
<th>Lot Characteristics.</th>
</tr>
</thead>
<tbody>
<tr>
<td>o Street Front Width: 45-60’</td>
<td>o Lot Size: 45-60’x 100’</td>
</tr>
<tr>
<td>o Lot Area: 4500-6000 Square Feet</td>
<td>o Orientation: Perpendicular to street.</td>
</tr>
<tr>
<td>o Density: 4-6 Units/Acre</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2.13

Advantages:
- Can have high density of up to nine units per acre.
- Narrow street frontage means more houses can be built along a street, reducing per unit utility cost.
Plans offer privacy and the same main features of the conventional single family detached house.

**Drawbacks:**

- Units are usually entered at side of the house because of courtyard orientation and garage position.
- The side entry results in the first view inside to be short and dark, because of blank back wall.
- Because lots are narrow the garage occupies a large portion of the street frontage.
- Space in zero-lot-line houses are at a premium so garages often are used for purposes other than storing cars. Cars are kept in driveway or street. The narrow lots, however, result in short curb lengths from one driveway to the next.
- The outdoor area of the ZLL lot is often covered, up to 70%, with impervious materials, such as driveway, pool decks, patios, and walk ways. This make the consideration of run-off water a serious design problem.
- The long narrow L shaped yard of the zero-lot-line house generally limits its usability and aesthetic appeal.
Chapter 2.

The Staggered/Z-Lot Configuration.

Characteristics:
- The Z-Lot configuration achieves a Z-shaped lot through the use of side yard easements.
- On the street front the lot uses a 5 feet wide zone from its neighbor to create a 10 foot entry court in addition to the garage across the width of the lot.
- On the back the lot "borrows" another 5 feet from the opposite adjoining yard to create a larger usable rear patio area.
- The Z-Lot house configuration typically touches on both side lot lines.

Figure 2.14
Advantages:

- The Z-Lot configuration overcomes a major drawback of the zero-lot-line plan, that of the long windowless wall. This plan makes it possible to have windows on all four sides of the house.
- It is possible to enter these units from the front, which enhances the detached image.
- The entry view can utilize the high impact view that stretches diagonally from the front door through the living area and out the rear windows to the outdoor living space, giving the tightly spaced house a larger feeling.
- The street elevation looks better than standard ZLL plans, because garage doors are balanced by front court yards.
- Z-Lot angled at 30-40 degrees to the street is a further refinement. This has the effect of presenting a front view with two elevations - front and side, that creates the impression of a wider house.
- The angling of lots also creates deep pockets in the site for landscaping, an important element in high density housing.
- The angled plan is well suited to sites with good views such as a golf course or lake. The living area at the rear of the house can be orientated to these amenities at an angle creating a view greater than actual lot width.

Drawbacks:

- The increased street elevation adds to construction costs because both elevations must be well detailed.
- The increased street frontage also increases the infrastructure development costs.
- While the angled lots add variety they also make the house look more attached than detached.
- The concept of the angled Z-Lot with all its zigs and zags is difficult to explain to prospective buyers.
Chapter 2.

The Wide Shallow Lot Configuration.

Characteristics:
- Similar to a zero-lot-line plan except the lot is turned 90 degrees, so that its long edge faces the street, and its dimensions tend to be closer to a square.
- The wide front of the house faces the street, with an entry and windows in addition to the garage door.
- The two story plan is best suited for wide-shallow lots because it is difficult to get a big enough footprint on these lots for a single story house.
- Densities for this type of configuration is as high as eight units per acre.

Figure 2.15
Chapter 2.

- Outdoor living spaces are usually located in the rear yard.
- Lots are separated by a 6 foot privacy fence.
- Wide-shallow lots are at least 65 feet deep.
- Second story bedrooms are oriented to the front of house.

**Advantages:**
- The wide street frontage allows a broad front elevation that looks similar to a traditional single-family detached house.
- The entry and windows of the front facade draws attention away from the garage, giving the house greater curb appeal.
- The wider street dimension also allows more curb length per unit which increases the amount of street parking available.
- Wide-shallow lots look like small versions of traditional single family lots so the concept is easily understood by municipalities and buyers.

**Drawbacks:**
- The broad front elevation increases building costs because of additional need for design treatment and detail.
- Rear elevations also require careful design because of close proximity to other units for window placements.
- Privacy for back yard is a design problem with double story units and narrow yard width.
- The wider street frontage increases infrastructure development costs.
- The wide-shallow floor plan offers fewer opportunities for variations than does the ZLL and Z-Lot configurations.
Chapter 2.

2.43 Small Lot House Types.

As the shape of the ZLL lot underwent a change and refinement process so have the house types associated with it.

Three clear house types have evolved that suit different configurations, densities, and demographics;
1. Conventional Style Detached House (Front and back orientation).
2. The Patio House Type.
3. The Atrium/Garden Court House Type.

Each of these is explored and evaluated in more detail on the following pages.

Figure 2.16
Chapter 2.

Conventional Style Detached House.

Characteristics:
- Similar to conventional detached house in that it has two main facades, one facade facing the street, and one facade that faces the back yard.
- They can be single or double story configurations.
- The orientation of this house type is usually towards the street. Light and air can be utilized on back elevation and perhaps one side elevation.
- The house plan and footprint tends to be compact.

CONVENTIONAL DETACHED HOUSE VARIATIONS:
Single Story

Double Story

Source: Professional Builder – House Plans Series.
Chapter 2.

Advantages:
- Easily identifiable house type with a historic reference and style.
- It is possible to have light and orientation of living spaces from two opposing sides.
- The broad street elevation with the entrance and windows help balance the garage doors.
- The garage tends to be incorporated into the house so its massing is not so prominent as in ZLL housing.

Drawbacks:
- On the zero-lot this house type requires a wide lot frontage which results in low densities; 2 to 4 units per acre.
- In its conventional style this house type is ill suited for the privacy demands that zero-lot development require.
- The floor plan of this house type offers fewer opportunities for variation of its massing and its roof lines.
- On compact small lots this house type necessitates double story arrangements in order to provide the floor space.
Chapter 2.

Patio House Type.

Characteristics:
- The patio house is a linear configuration stretching the length of the lot with either:
  - **Single orientation** where the elevation and all the living spaces are oriented towards the side yard.
  - **Double orientation** with one elevation facing the side yard and the other elevation facing the back yard.
  - **Triple orientation** with one portion of the house facing an entry court and the rest of the house facing in the opposite direction with a double orientation.
- The patio house can have single or double story configurations.

Source: Professional Builder - House Plans Series.

Figure 2.18
Core and service utilities are typically located along the blank side wall.
The garage is located in the front and typically dominates the front facade.

Advantages:
- The linear configuration makes it possible to have very narrow lots (30 feet) that have high densities of 7-9 units per acre.
- Being predominantly one sided the units can be orientated to make use of passive solar energy.

Drawbacks:
- The street facade tends to be dominated by garage doors and utilities.
- The roof-line has to be elaborate in-order to give the house a presence.
Atrium/Garden Court House Type.

Characteristics:

- The Atrium/Garden court house is also a linear configuration stretching the length of the lot with either:
  - **Single orientation** where the elevation and all the living spaces are oriented towards the side yard.
  - **Double orientation** with one elevation facing the side yard and the other elevation facing the back yard.
  - **Triple orientation** with one portion of the house facing an entry court and the rest of the house facing in the opposite direction with a double orientation.

- An Atrium/Garden court is introduced along the ZLL wall. This allows the living spaces along the lot line wall.

![ATRIUM/GARDEN COURT HOUSE VARIATIONS:
Single Story](image)

![Double Story](image)

Source: Professional Builder - House Plans Series.

Figure 2.19
Chapter 2.

The unit has a double orientation with one elevation facing the side yard and the other elevation facing the back yard.
The Garden Court house can have single or double story configurations.
Core and service utilities are typically located along the blank side wall.
The garage is located in the front and typically dominates the front facade.

Advantages:
The linear configuration makes very narrow lots possible (30 feet) that have high densities of 7-9 units per acre.
Being predominantly one sided the units can be orientated to make use of passive solar energy, as well as introduce light into the back areas through the atrium/court.

Drawbacks:
The street facade tends to be dominated by garage doors.
Atriums and enclosed courts can be very expensive additions.
Water drainage presents a special problem for atriums and enclosed courts.

Conclusion.

From this lot and house type analysis no clear type or combination is better than the other. At the moment the Z-Lot/Staggered configurations with patio type houses are favored by developer/builders in moderate priced developments. But, as outlined in the preceding analysis, each type has advantages that given certain circumstances would be more suited to a specific market and specific economic constraints. From this can be deduced that it would be very useful to develop a design methodology that can provide a means to generate house and lot types from some common starting point.
2.5 INTERNAL SMALL LOT HOUSE DESIGN FACTORS.

2.51 Space Configurations.

The interior systems of a basic house type can be made up of a range of variations of interior systems. For example:
1. Room sizes, location and adjacencies can vary within the same basic design.
2. The service systems can vary greatly for the same house type. For example, heating systems can vary between an electrical heat pump with ducted air distribution, or a water distribution system.

Despite this differentiation between houses, a certain amount of conformity exists. This is because houses share a context, a site, a number of regulatory constraints, a building process, a repertoire of materials, and socio-cultural factors.

Thus:
1. Different houses can have the same kitchen layout.
2. Different houses may have the same wiring and heating.
3. Different houses may have the same construction strategy, materials, roofing, siding, and windows.
2.52 Space Planning.

Space types within dwellings units can be categorized into primary and secondary spaces. 

**Primary Spaces** - require natural light and ventilation. These spaces, such as living rooms, dinning rooms, bedrooms and family rooms, are arranged to face private outdoor spaces or towards open streetspace for light, ventilation, and views.

**Secondary Spaces** - do not require natural light or ventilation. Their location in a small lot house can be along the blank lot line wall. Spaces that are typically located in this zone include bathrooms, storage space, utility rooms, stairs and in some instances kitchens. These spaces are artificially lit and ventilated.

---

**SPACE PLANNING PRINCIPLES**

**Patio Type House Plan**
with one living space along ZLL wall.

**Atrium/Garden-Court House Plan**
with two living space along ZLL wall.

---

Patio House Section. Space Use Section. Atrium House Section. Space Use Section.

**PRIMARY SPACES:**
Require natural light and ventilation.

**SECONDARY SPACES:**
Do not require light and ventilation.

---

Figure 2.20
Primary and secondary spaces can be enhanced through the use of courts, atriums, and skylights. All introduce natural light and plantings that can add an extra dimension to the space fronting it.

2.53 Volume and Space.

Efficient and effective space planning in small lot housing hinges on trade-offs between indoor spaces and trade-offs between indoor and outdoor space. Dramatic spacial impacts can be achieved using these trade-offs as a design principle.

Volume and space design are techniques used to make living spaces appear more generous than they really are. This can be achieved by:

- Creating double volume space and open stairway/balconies in double story units.
- Creating cathedral ceilings through the use of scissors trusses and ceilings that follow the roof line.
- Using dormer and bay windows and transoms and rounded windows on top of major windows as means to extend space and add light.
- Locating plant shelves above high closets, service areas and walls, can make spaces appear more generous.

Figure 2.21
2.54 Circulation.
The most important parts of a house's circulation system are the entry space and the staircase (if it has one). In the small lot house these two elements present particularly difficult design problems. Because of their linear shape many small lot houses have side entrances in the middle third of the house. This results in a short entrance space with a dark view towards the blank lot line wall. The concept of "entry" impact advocates the use of through-views to internal public spaces and focusing attention on key features such as fireplaces, large windows, dramatic stairways and vaulted ceilings. Circulation should be kept as efficient as possible by combining circulation spaces with public spaces such as the living room and the dinning room.

Source: Professional Builder – House Plans Series.

Figure 2.22
Chapter 2.

Conclusion.

Small lot housing is only one concept for providing affordable single-family detached housing. The housing approach adopted for a development depends on the particulars of the specific site and on local market conditions. Small lot housing project are usually unsuitable for sloping sites and difficult terrain.

For very specific limited markets, like senior-housing, high densities of 10 to 12 units per acre can be achieved. The more acceptable densities are, however, six to eight units per acre without serious compromise in livability and appearance.

Small lot housing has proved that refinements in site planning and unit design can make it possible to achieve greater densities without sacrificing privacy and livability. For this housing type to gain more general acceptance it will be necessary to advocate the merits of small lot housing to local planning and zoning officials as well as cynical community residents. Without their acceptance of the small lot housing concept, affordability in areas with high land costs will remain un-achievable.
3. THE CONCEPT OF SUB-SYSTEMS (SHELL/INFILL).

3.1 The Need For Division of Sub-Systems.

3.2 The Division of Sub-Systems.

3.3 The Site Element.

3.4 The Shell Element.

3.5 The Infill Element.

3.6 The Housing Industry and Sub-Systems.
THE CONCEPT OF SUB-SYSTEMS (SHELL/INFILL).

The concept of housing sub-systems, also known as Support/-Infill or Shell/Infill systems, has been developed over the last 20 years by N. John Habraken in such works as *Supports: An Alternative to Mass Housing* (1964), *Transformation of the Site* (1983) and *The Appearance of the Form* (1985). Through the work of a Dutch group, Stichting Architectten Research (SAR), theoretical studies and practical projects have been carried out in Holland and elsewhere based on the original concepts and ideas of Habraken.

Habraken’s work seeks to re-establish the link between dwellers and dwellings; this concept recognizes the individual dweller as an integral player in the decision making and production process that results in the built form of the house. The concept offered by Habraken establishes a framework for residents to have a greater say in the design process. The basis for this concept is the organization of dwellings into Supports/Shells and Detachable Units/Infills thereby creating two spheres of control. The Support/Infill concept is therefor not merely a technical or functional solution, but also introduces a method that makes sharing control possible. The sphere that is represented by the community (developer, manufacturer, and builder), might control decisions regarding the Site and Shell. The sphere that is represented by the household, might control decisions about the Infill. The exact delineation of these two spheres of control, the community vis-a-vis the household, varies depending on the development and building process and socio-cultural factors in each context. The aim of this concept is to establish a framework in which responsibilities and control can be distributed in the act of creating and forming dwellings or homes.
The breakdown of a dwelling into Sub-Systems (Shell/Infill) that is explored in this work, constitutes one of the ways to introduce a hierarchy of Sub-Systems that is based on the concept of control and variety.

In the American society it is the aspect of variety rather than control that is stressed as the dominant factor.

To illustrate the Sub-Systems concept in this chapter a demonstration small lot house type will be used as a bases for the analysis. The house type consist of a typical linear configuration with three bedrooms in a double story plan.

Figure 3.1
3.1 The Need For Division of Sub-Systems.

The provision of housing in the U.S. is predominantly in the hands of the large housing developers/builders. Because cluster and small lot ZLL housing requires that the site planning and design/build be done as an integral part of the project development, only big housing developers/builders are able to execute them. This results in the entire development process - land acquisition, development, building, and marketing the project, being in the control of one group.

The large developers/builders who produce the bulk of residential projects deliver a commodity on a mass scale, in other words, mass housing. Consequently sophisticated consumer surveys and market analysis are often used by developers/builders to determine general and regional housing trends and preferences, but they have no easy way in which to offer this consumer input on a customized bases in their products.

Standardized Small Lot House Design Approach.

As indicated in chapter 1, one of the principle ways that the developer/builders feel they can reduce housing costs is by using standardized designs. This means that individual or customized designs are strongly discouraged. Individual or customized designs are perceived as being uneconomical.

The use of planbooks or catalogues of standard house types is widely practiced. Clark (1986) traces the important role that plan books and housing magazines have played in setting housing trends as well as providing designs for developer/builders. (See Figure 3.2) The desire to standardize seems to persist when housing on a mass scale is involved. Although these houses are very responsive to current housing preferences and trends the idea of a customized house being made available on a mass scale has been difficult to achieve.
This figure is an example page out of a plan book published by Professional Builder magazine. The example illustrates a design for a specific market appeal.

**PLANBOOK EXAMPLE PLAN: Traditional Value Appeal**

The high impact entry of this 1724-square-foot plan, with a vaulted living area and a balcony above demands attention. The family/breakfast area has a fireplace and a wet bar. The kitchen between the family/breakfast area and the dining room has a view of the backyard deck and easily serves either room. Upstairs, the master bedroom has a large walk-in closet, double-bowel vanity and compartmentalized bath.

The basic shape of the plan is simple to build which lowers finished price.

Order plan JDB-1234-6510. Use Plan Price Schedule A on order form.

Source: Professional Builder - House Plan Series.

Figure 3.2
Chapter 3.

Small Lot Design Variation.

The design of the typical small lot single family detached house varies depending on current style, technology and organization.
In this context the problem appears to be the need to devise more effective ways to organize the variety that the market expects.

In a typical cluster of ZLL lots this variety can operate in various ways.
The same basic house type may be built on several different lot types, with variation introduced in the building facade, roof lines, window placements, and detailing. (See Figure 3.3)
Chapter 3.

Customized Small Lot House Design Approach.

The implementation of the Sub-Systems concept would allow the developer/builder to provide the variety and diversity the market expects on a customized basis. It would also make it possible to respond to shifts in demographic and housing demands if an adaptable housing process was used.

In the context of ZLL house design in U.S.A. the Shell/Infill concept can and should be used by developers because; providing customized design options will give developer/builders the ability to cater for a more diverse market. The Sub-Systems (Shell/Infill) concept once understood lends itself to be implemented into computer-aided design and manufacturing. Both of the above notions are practiced successfully in Japan. (Open House Vol. 12 No. 2 1987)
3.2 The Division of Sub-Systems.

The concept of Sub-Systems involves the use of discrete systems which together form three larger groups of assemblies: the Site, the Shell and the Infill. These three assemblies are not fixed configurations, or designs, but should be seen as three logistical groups of assemblies which, with associated assembly rules, make a house. This method can be used to generate any number of designs and variations. These three larger groups of assemblies, the Site, the Shell, and the Infill contain the Sub-Systems that comprise the house. (See Figures 3.5 and 3.6)

![Diagram of Division of Site Sub-Systems](image)

**Figure 3.5**
Chapter 3.

Every major Sub-System consists of several lower-order Sub-Systems that provide the variety. As the Sub-Systems vary and are customized, so will the final design vary.

Figure 3.6
Hierarchy Of Sub-Systems.

Once houses are seen as Assemblies and Sub-Systems it is easy to introduce a new distinction in the way we think of houses. The distinction (or grouping) is a technical one with definite organizational consequences and implications. This design approach of Habraken is based on an open systems method where the house is composed of many Sub-Systems that relate to one another in a hierarchical way. In this approach Sub-Systems are ranked in such a way that each system can only be built or installed after the systems higher in rank have been deployed first. The deployment of each Sub-System creates, in turn, the context for the next Sub-System to be deployed. The house design process, using this design methodology, can be seen as a "path" down a tree structure; (See Figures 3.7 and 3.8)

Figure 3.7
Chapter 3.

Every main Sub-Assembly, such as the Shell Primary Structure, has several choices of Sub-Systems that underlie it.
Service And Installation Distribution.

Given a certain Site configuration, different house types for the Shell Assembly exist (See chapter 2). When a Shell Assembly is selected different components for the facade can be chosen. The Sub-Systems approach makes for a variety of designs that can be produced and designed efficiently. This systematic way of working also makes future adaptation to user preferences easier to achieve. The Infill Sub-Systems can therefore change while the Shell Assembly remains constant. The Site/Shell/Infill service distribution can be understood as three separate but connected groups of technical systems, which can be, but need not be, organized and controlled separately in their design construction use and change. The Site, Shell and Infill Assemblies have many of the same building services.

Figure 3.9
Chapter 3.

The service distribution system has a fixed part which provides services to distribution points or distribution trunks. The flexible part provides services that can be adapted.

**SHELL/INFILL SERVICE DISTRIBUTION VARIATIONS.**

Shell Service Distribution Variations Using Trunk Ducts.

- Site/Shell/Infill Service Elements.
- Fixed Shell Service Trunk.
- Flexible Infill Service Distribution.
- Shell Service Distribution With A Looped Trunk Duct.
- Shell Service Distribution With A Branched Trunk Duct.

Site Service Distribution Variations And Shell Service Ducts.

- Shell Service Distribution With A Corner Service Duct.
- Shell Service Distribution With Central Service Duct.
- Shell Service Distribution With Two Service Ducts.

Figure 3.10
The separation is therefore not simply a technical separation but also a separation allowing a hierarchy of design decision, construction and organization. Thus a builder might choose to build the same Shell Core Assembly and let the market decide on the position of the kitchen or other spacial Sub-Systems in the house. (See Figure 3.11)
3.3 The Site Assembly.

The Site Assembly constitutes the determination of the site through a series of factors that govern the site planning. The Site is a completed phase of the site development. Decisions must still be made about house type, number of stories, garage size.

Site Assembly Characteristics:

1. The Site determinants once established are permanent.
2. Landscape covenants require regular maintenance and upkeep of outdoor spaces.
3. The site determinants are governed by local conventions, climate, regulations and streetscape.
4. The Site configuration can accommodate a certain number of alternative building types. The Site shape has the capacity to "hold" several variations of a selected house type.
5. The determinants of the Site are governed by;
   Lot Shape;
   This factor is complex because it interconnects with decisions about density and dwelling type as well as directly affecting the efficiency of the layout.
   Area;
   The lot area determines the density of the cluster and effects the building bulk of the site.
   Frontage;
   The lot width has a direct effect upon building type. For example; Narrow frontage of a lot may result in the use of narrow frontage dwelling types like the Patio House type.
Chapter 3.

The Site Assembly factors normally are determined before the consideration of house design. In chapter 2 its was shown that the planning of both site and house type planning for small lot developments need to occur concurrently. With the Shell/Infill concept this process can be made to be to work both ways. In other words the site can be determined first and the Shell Assembly can be adapted to it or vise versa. This approach will be more fully explored in chapter 4.

Figure 3.12
3.4 The Shell Assembly.

The Shell Assembly comprises all the sub-systems that form the external envelope. The Shell Assembly is a completed phase of construction but it does not yet comprise a dwelling. Decisions must still be made about where to place the various functional areas (the Infill) within the Shell.

The Characteristics of the Shell Assembly:

1. The Shell sub-systems are usually very durable because they are exposed to the external environment and generally have a 50 to 100 year life expectancy.
2. Low maintenance and upkeep is a critical factor so as to prolong life expectancy and minimize replacement costs and labor.
3. The Shell design is rooted in local conventions, climate, regulations and streetscape.
4. The Shell design must have the capacity to accommodate several "lower order/level" functional spaces, such as bathrooms, kitchen, living, dinning room, and bedrooms, in order to make the house livable.
5. Some sub-systems can either be part of the Shell Assembly or they can be part of Infill Assembly. For Example; Bathrooms can either be part of the Shell as a fixed sub-system or part of the Infill as an interchangeable sub-system. Other sub-systems that can either be part of the Shell or the Infill Assembly are;
   1. Facade components - windows, doors, bays, porches, and sun-rooms.
   2. Roof components - dormers, pergolas, awnings.
   3. Service cores - service stacks, bath rooms.
Chapter 3.

Shell Primary Structure.

The Shell primary structure is one of the main Sub-Systems assemblies that make up the core of the design. This Sub-System consists minimally of the following elements:
- Foundation.
- Outer structural walls.
- Columns.
- Floors.

The Shell primary structure is also responsible for distributing part of the services and installation elements, from the site connections to distribution nodes, within the design.

Figure 3.13
Chapter 3.

Shell Roof Structure.

The Shell roof structure is constrained by the primary structure underlying it. But for any one Shell primary structure several different roof configurations can be used. This Sub-System consists minimally of the following elements:
- Roof structure and membrane.
- Drainage system.
- Dormers, awnings and pergolas.

The Shell roof structure can have a control sub-division within itself if desired. In other words elements like dormers, awnings and pergolas can either be part of this Sub-System or it can be a add-on option which makes it an Infill element.

Figure 3.14
Chapter 3.

Shell Vertical Circulation.

The Shell vertical circulation is constrained by the position and opening size in the Shell primary structure underlying it. But for any one Shell primary structure several different stair configurations can be made. This Sub-System consists minimally of the following elements:

- Stairs.
- Floor openings.

The Shell vertical circulation can also have a control subdivision within itself if desired. For various stairs, different parts of the floor opening can be closed.

Figure 3.15
Chapter 3.

Shell/Infill Facade Elements.

The Shell/Infill facade elements are constraint by fixed openings in the Shell primary structure. The facade elements are detached from the primary structure so that for any one opening a wide choice of facade elements exist. This Sub-System consists minimally of the following elements: Windows, bay-windows, doors, and porch elements. The facade elements can also have several control sub-divisions if desired. Facade elements can be part of the primary structure, in which case they will be chosen before the plan configuration is known. Facade elements can be chosen when the plan is made, in which case the openings in the primary structure is adapted. Facade element frames can be fixed leaving only the panel/mullion components as variables. (See Fig. 3.19)

THE SHELL/INFILL FACADE ELEMENTS.

Assembly Of All SHELL Higher Sub-Systems. Assembly Of Facade Elements. Facade Elements SHELL/ INFILL Components.

Dormer and Skylight Elements.

Window Elements.

Door Elements.

Porch Elements.

Figure 3.16
3.5 The Infill Assembly.

The Infill Assembly consists of:
1. Infill wall Sub-System.
2. Infill fixture Sub-System.
3. Infill finishing Sub-System.
4. Infill furniture Sub-System.
These Sub-Systems, when combined with the Shell Assembly, make a house that can be lived in.

The Characteristics of the Infill Assembly:

1. Infill sub-systems usually have a shorter life span than Shell sub-systems because of changing needs, tastes, and the updating of fixtures. They are relatively independent of the external environment.
2. Maintenance and upkeep are also more frequent than Shell sub-systems.
3. Infill sub-systems are generally not regulated by local codes.
4. Infill sub-systems are often packaged as assemblies that incorporate Infill walls, fixtures, and finishes that can generate a wide range of configurations.

The Sub-Systems approach lends itself to the desirability of having available various Infill System Catalogs. From these catalogs builders and owners could order packages containing the elements which are needed to finish the Shell that they want to build.

Another purpose of these catalogs would be to offer a wide variation of assembly possibilities. Specific assemblies of Infill packages could be organized for each Shell, but each Infill package could be different.
Infill Wall Systems.

The Infill wall systems are constrained by the Shell primary structure surrounding it. For any one Shell primary structure several different internal wall layouts can be made. This Sub-System consists minimally of the following elements:
- Internal wall assemblies.
- Cupboards and storage systems.

The Infill wall systems can have a control sub-division that can facilitate owner choice and manipulation. Wall systems can be detachable to facilitate the adaption of space layout. Wall systems can be fixed but allow variable cupboard and storage systems. Internal distribution of services and installation networks are linked to the Infill wall systems.

Figure 3.17
Chapter 3.

Infill Fixture Systems.

The Infill fixture systems are constrained by the internal wall layout and service distribution. Fixtures can be chosen or replaced from a wide range of product lines. This Sub-System consists minimally of the following elements;

- Sanitary fixtures.
- Kitchen and laundry equipment.

The Infill Fixture Systems can be chosen by the owner. The adaptability of future installations and changes of fixtures and their location are constrained by the flexibility of the services and installation networks that support it.

Figure 3.18
Chapter 3.

Infill Finishes Systems.

The Infill Finishes are constrained by the sub-assembly they are attached to. The choices of finishes are only limited to the ranges offered by manufacturers.

This Sub-System consists minimally of the following elements;

- Finishes to build structure (Siding, roofing, flooring).
- Finishes to surfaces (Painting, carpeting).
- Finishes to products (Color schemes).

The Infill Finishes systems can have a control sub-division that facilitate the owner to have a say over all the finishes, partial, or none at all.

Figure 3.19
Infill Furniture Systems.

The Infill Furniture is constrained by the internal space layouts and size. For any one internal space configuration, a wide range of furniture product lines are available. This Sub-System consists minimally of the following elements:
- Household furniture.
- Cupboard and storage systems.
- Electrical equipment.

The Infill Furniture system is usually in the control of the owner. The choice of furniture and its location within a design is subject to the constraints of the design and its ability to accommodate it.

Figure 3.20
3.6 The Housing Industry and Sub-Systems.

For the Shell/Infill concept to work various sectors of the building industry need to cooperate in establishing a base on which to implement the Shell/Infill concept. There are no significant technical changes necessary to accomplish this as most of the aspects that comprise the Shell/Infill concept are already in place in one form or another. What is important is a change in the traditional perception in the provision of housing.

Flexible Control Over Housing Process.

In today's housing market it is often only the furniture and internal finishes that are easily adaptable to user needs. All other Sub-Systems once installed, are difficult to change. The Sub-Systems concept makes it possible for Infill Sub-Systems to be much more adaptable. This includes the service distribution systems that are connected to the Infill Sub-Systems. The house owners can with this approach extend their control to include the Infill Sub-Systems (See Figure 3.21).

The Shell Sub-Systems, that make up the more permanent Shell Assembly can be distinguished from the Infill Sub-Systems which are less permanent and more flexible. Decisions have to be made about how much of each system belongs to one of the three elements (Site/Shell/Infill). This implies a communication process and a decision-making process to enable the three larger sets of elements and their sub-systems to come together efficiently to make a house. This communication process involves the developer, architect, product manufacturers, contractors, code officials etc., and as has been discussed, the future owner.
Chapter 3.

This approach will allow the developer/builders to provide:

1. Designs that can easily be expanded to allow home owners to adjust or extend their houses to their living patterns.

2. Efficiency and flexibility in planning spaces. For example, a kitchen can be placed in different positions in the same location in a number of different houses of the same type within a Development.

3. Market Research for determining Shell/Infill preferences and then to build them into different Shells in the project, thereby providing different functional area distribution, different layouts and varied equipment.

4. Customized design for prospective home owners by providing interactive computer aided design capability.

Figure 3.21
Design/Build "Packaging" Alternatives.

The difference between the control that the developer/builder and the home owner exerts over the design will vary depending on various scenarios on how the development is "packaged". The "packaging" of the house will depend on the philosophy of the developer/builder, manufacturing community and market demand.

Different scenarios that can be used to produce a house are;
1. Traditional situation where a developer/builder offers the whole house speculatively to the homebuyer except for the furniture. (See Scenario 1 in Figure 3.22)
2. The homebuyer obtains the Shell from a speculative Shell contractor as is, and selects the Infill from an Infill contractor's catalogue. The Infill is then installed by the Infill contractor. (See Scenario 2 in Figure 3.22)
3. Developer/Builder provides the Shell construction speculatively (either standardized or with some customization), the developer/builder also facilitates the Infill contract with the homebuyers choices. (See Scenario 3 in Fig. 3.22)
4. A Local builder puts together a house with products from Shell manufacturing companies customized to homebuyers needs and Infill from Infill companies to the homebuyers specification. (See Scenario 4 in Figure 3.22)
5. The Homebuyer builds a customized Shell construction and completes the house with Infill packages selected from catalogues. The Infill packages are then installed by a specialist Infill installer. (See Scenario 5 in Fig. 3.22)

These scenarios may have many permutations and combinations. The division will generally be between variety and choice for the builder, versus variety and choice for the homebuyer. The implication is two separate but coordinated spheres of responsibility - one for the Shell and one for the Infill. (Kendal 1986)
### Design/Build Construction/"Packaging" Alternatives.

<table>
<thead>
<tr>
<th>Shell Assembly</th>
<th>Shell/Infill</th>
<th>Infill Assembly</th>
<th>Infill/Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell Primary Structure</td>
<td>Shell Vertical Circulation</td>
<td>Infill Wall Systems</td>
<td>Infill Furniture Systems</td>
</tr>
<tr>
<td>Shell Roof Structure</td>
<td>Shell/Infill Facade Elements</td>
<td>Infill Fixture Systems</td>
<td></td>
</tr>
<tr>
<td>Infill Wall</td>
<td>Infill Finishes Systems</td>
<td>Infill Finishes Systems</td>
<td></td>
</tr>
<tr>
<td>Infill Fixture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infill Furniture</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3.22**

**Implications Of Shell/Infill On The Housing Sector.**

The manufacturing industry which has lately been relatively successful with component, panel and modular products can play a key role in coordinating and providing Shell and Infill "packages" to the market.

The coordination of the various elements and sub-assemblies from different manufacturers into coherent packages will be a key factor. Some new technical, regulatory, and organizational initiatives will be required. Several manufacturing companies already advertise the ability to panelize custom designs.
Chapter 3.

Some companies specializes in providing customized components such as wall, floor, and roof elements.

The division of the house into two groups of assemblies, the Shell and Infill, and all the Sub-Systems that make up those groups provides the ability to combine the Sub-Systems in many ways to make different houses. This can have renewed possibilities for the local, the regional, and the national housing sector. This would be much more positive than the current conflict between large and small developers/builders, national corporations and local companies. (Kendal 1986).

With the Shell/Infill concept it is possible to have the production of Shells and Infill packages on a local level. Whereas on a regional scale companies could make elements for Shells that are then locally constructed. Elements for Infill packages on the other hand can be produced nationally.

The manufacturing industry relies to a great extent on the local architect, contractor, builder, and sub-contractors to provide the coordination on a local level to complete the house. This is an important fact as local expertise play a vital role in the transfer and acceptance of this technology.
4. SMALL LOT HOUSING ANALYSIS.

4.1 Shell Core Arrangement Analysis.
   4.11 Shell Shape/Footprint.
   4.12 Shell Volume And Space.
   4.13 Shell Garage Size And Location.
   4.14 Shell Entrance Circulation.
   4.15 Shell Architectural Style.
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4.2 Shell Analysis.
   4.21 Shell Service Distribution System.
   4.22 Shell Primary Wall System.
   4.23 Shell Roof System.
   4.24 Shell Internal Systems.
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4.3 Infill Analysis.
   4.31 Infill Service Distribution Systems.
   4.32 Infill Wall Systems.
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4.4 Site Arrangement Analysis.
   4.41 Site Shape Principles.
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   4.43 Site Easement Principles.
   4.44 Site Service Distribution Principles
   4.45 Site Landscape Principles.
SMALL LOT HOUSING ANALYSIS.

Historically most single-family detached housing developments have been developed in two major phases:

**Phase One** - consisted of the site planning to accommodate lots, houses, and services on the site. Lot sizes were largely determined through a density objective or the maximum density that local zoning laws would permit.

**Phase Two** - involved the design of house types or the selection of house designs from plan books that would fit the lot constraints.

With the advent of small lot housing this approach is still very much the norm today. This practice of over stressing strict density objectives can however compromise a project's livability and ultimately its salability.

Today many developers are siting in-appropriately large houses on increasingly smaller lots. With small lot housing the developer needs to consider density in relation to consumer expectations and to avoid project objectives that are driven by density numbers.

The fact that land planning and house design, in small lot developments, must be integrated and carried out concurrently has already been established in the previous chapters.

An alternative approach to the traditional density-site-house design process would be to determine a **core house** based on the size that fits the target market for which the planning is being done. The appropriate lot size and shape can then be determined from the size and context of the core house.

Plan Books in use today already practice part of this concept in that they publish house designs in certain floor sizes and for specific market profiles. These plans omit any site or lot reference and information. (Refer to Figure 3.2.)

A Developer/Builder should be able to choose a house type that fits the specific site layouts and market needs.
Chapter 4.

The core house concept is explored in this chapter by applying the Sub-Systems method to small lot housing design principles.

---

### THE CORE HOUSE CONCEPT.

**Shell Core Arrangement.**

- Shell Shape
- Shell Volume
- Shell Garage
- Shell Entrance
- Shell Arch.
- Shell Capacity

**Specific Shell Core Configuration**

- Vertical Extension
- Linear Extension
- Side Extension

**Shell Assembly.**

- Shell Primary Structure
- Shell Roof Structure
- Shell Vertical Circulation
- Shell/Infill Facade Elements

**Specific Shell Assembly Configuration**

**Infill Assembly.**

- Infill Wall Systems
- Infill Fixture Systems
- Infill Finishes Systems
- Infill Furniture Systems

**Specific Infill Assembly Configuration**

**Site Assembly.**

- ZLL Lot Configuration
- 2-Lot/Slotted Configuration
- Wide Shallow Lot Configuration
- Other Lot Type Configuration

---

Figure 4.1
4.1 Shell Core Arrangement Analysis.

The Shell Core design approach takes as its input the house size, demographics and preferences of a target market. For example single-family detached housing for elderly people would differ greatly from that for families with children in both house size and context as well as lot size and density.

Once the profile of the house size and context have been established, the Shell Core Arrangement can be developed using the following design principles;
1. Shell Shape/Footprint Principles.
2. Shell Volume and Space Principles.
3. Shell Garage Size and Location Principles

The Shell Core house represents a base model determined by the Shell Core Arrangement principles for a particular size and market type. Variation of this Shell Core can be generated from the base model through the use of the following Shell Extension principles.
2. Linear Extension Principle.

For any variation of the Shell Core Arrangement further variation can be generated within the constraints set by this arrangement through numerous Shell/Infill options, add-on's and alternatives.
Once the Shell Core Arrangement has been established, the appropriate lot size and shape can be determined to fit the constraints set by the Shell Core Arrangement.
Chapter 4.

Shell Core Arrangement.

This phase can be likened to the traditional planning phase of developing the design program. The difference is that the Shell Core Arrangement represents a base model that has the ability to accommodate a range of external variations as well as the ability to accommodate a series of internal spacial arrangements and configurations. The value of this approach is that it is flexible and can be manipulated easily, especially if this method is applied to computer aided design technique.

Figure 4.2
4.11 Shell Shape/Footprint.

The shape of the Shell footprint has a great influence on the lot size and configuration. The Shell type also influences the minimum lot width and lot depth;

**Compact Shell Shape** - This will have to use additional second story floor space to make-up the desired floor area.

**Rectangular Shell Shape** - This will result in wider lots with lower densities but with more available outdoor space.

**Narrow Shell Shape** - This will result in lot shapes that are primarily long and narrow with high densities but limited outdoor space. Zoning and dimensional coordination used in this work are based on Habraken's supports concept. In Appendix A is a zoning analysis based on a series of popular small lot (ZLL) houses from several plan books and magazines.

---

**Figure 4.3**

---

**SHELL SHAPE/FOOTPRINT.**

**SHELL SHAPES OF SAME SIZE.**

**AREA**

1445 Sq. Ft.

**RECTANGULAR SHELL SHAPE.**

Size Range 1175 - 1445 Sq. Ft.

**COMPACT SHELL SHAPE.**

Size Range 675 - 875 Sq. Ft.

**NARROW SHELL SHAPE.**

Size Range 1175 - 1445 Sq. Ft.
4.12 Shell Volume and Space.

Shell Volume and Space principles involve the choice of the number of stories, as well as internal space configuration for the Shell Core Arrangement. There are the following options;

**Single Story Option;** Best suited for small lot house types because it affords privacy and good solar access.

**Double Story Option;** Provides double volume space opportunities, but needs careful design of window placement and massing.

**Basement Option;** Can be added to any type to provide utility and unfinished living space.

The top diagrams in figure 4.04 illustrate the single and double story options combined with the basement option. The bottom diagrams in the figure illustrate volume and space distribution within a particular Shell configuration.

**SHELL SPACE VOLUME OPTIONS.**

<table>
<thead>
<tr>
<th>SINGLE STORY OPTION ONLY</th>
<th>DOUBLE STORY OPTION ONLY</th>
<th>SINGLE STORY WITH BASEMENT</th>
<th>DOUBLE STORY WITH BASEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most suited for ZIL but limits density.</td>
<td>Given high density but needs careful design.</td>
<td>Can add useful space although not common choice.</td>
<td>Very popular option in cold North West region.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SINGLE STORY VOLUME</th>
<th>SINGLE STORY EXTENDED VOLUME</th>
<th>DOUBLE STORY VOLUME</th>
<th>DOUBLE STORY EXTENDED VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space can vary to full unit width.</td>
<td>Extensions gives ideal opportunity for volume</td>
<td>Double volume very effective over living areas</td>
<td>Extension can give volume without double story bulk.</td>
</tr>
</tbody>
</table>

Figure 4.4
4.13 Shell Garage Size And Location.

In some developments garage options range from a single garage to triple garages.

**Single Garage Option;** This option allows some street frontage for the home itself without increasing the lot width.

**Single Garage/Car-Port Option;** Although this configuration takes the same space as a double garage, the house can have a recessed street frontage.

**Double Garage Option;** This is the most popular option, although the garage tends to dominate the facade on a narrow lot configurations.

**Garage Location;**

The garage location can vary a great deal allowing different entrance options and driveway configurations.

Entrance Principles; Because the garage location often forces the front door entry to the side the negative aspect of facing the back zero lot line wall needs to be offset. By using entry focal points such as fireplaces, double volume space, and thru-views across living spaces to outdoor areas beyond, the entry can be made positive and spacious.

Shell Entrance Options;
The Shell entrance options depend on the Shell shape and the Shell garage option selected.

Side Entry Option; This is used with narrow Shell Core Arrangements with either a side yard, or a ZLL wall entry approach.

Front Entry Option; This option is used for Shell Core Arrangements that have street frontage.

Figure 4.6
Chapter 4.

4.15 Shell Architectural Style.

The density and nature of small lot projects require that an integrating architectural theme or style be developed. This theme should be in keeping with the local market and climatic conditions. Architectural styles can vary from the traditional historic and regional styles to crisp contemporary. New England salt box, Midwest farm house, and California mission are an example of regional styles of architecture. Continuity in the styles of buildings within a project promotes a sense of community. This continuity of theme however must be varied by divisions within the style to avoid monotony. For example a New England theme can include the New England salt box, the Boston Townhouse, and the Nantucket seaport.

Figure 4.7
4.16 Shell Capacity.

The Shell Core Arrangement must have the capacity to accommodate a wide range of internal space configurations and variations.

The capacity range that should be accommodated will be determined from the Shell Core market profile which would include the following options.

Bedroom Arrangements;
Bathroom Arrangements;
Kitchen/Eating Nook Arrangements;
Dinning Room Arrangements;
Living Room Arrangements;
Den/Family Room Arrangements;

Figure 4.8
Chapter 4.

4.17 Shell Core Variations.

Once the Shell Core Arrangement has been established this base model can be transformed, through extension rules, to generate a range of variants which have quite different site configuration and density implications. The importance of this approach is that the same basic design principles, building techniques and cost structure can be used to generate a wide range of different designs.

Figure 4.9
Chapter 4.

Vertical Extension Variation.

The Vertical Extension principle takes a Shell Core Arrangement of a certain floor size range on one floor level and distributes this arrangement over two floor levels with the same overall floor size range. The Shell Core footprint can be dramatically reduced with this rule. A Shell Core Arrangement on one floor level will probably have a long narrow ZLL lot. Whereas a Shell Core Arrangement on two floor levels can be accommodated on either a ZLL lot or a Wide-Shallow lot. The Vertical Extension principle can also be used where further expansion of the base model might be needed in the future.

Figure 4.10
Chapter 4.

Linear Extension Variation.

The Linear Extension principle takes a Shell Core Arrangement and extends it linearly within the floor size range of the base model. This extension can further vary in width, thus introducing the possibility of atrium/court spaces that can give additional building frontage with windows.

When this principle is coupled with a side shift of the garage space an alternative front entrance can be introduced into the design.

This principle, however, is constrained by the overall length of the Shell and the fact that the longer the Shell the less back-yard space will be available.

Figure 4.11
Side Extension Variation.

The Side Extension Principle takes the Shell Core Arrangement and extends the base model sideways, within established floor size constraints, into new arrangements. This principle can be combined with "side-moves" and/or "side-flips" of portions of the Shell Core Arrangement to introduce variations that have different orientations and frontages. Because this principle extends the width of the base model the overall width and street frontage will be effected.

Figure 4.12
4.2 Shell Analysis.

The Shell Assembly is made up of the following sub-systems;
1. Shell service distribution system.
2. Shell primary wall system.
3. Shell roof system.
4. Shell internal system.
5. Shell/Infill facade elements.

Shell Sub-Systems;
The Shell Assembly sub-systems themselves translate into different systems of choice in generating the house design.

Figure 4.13
4.21 Shell Service Distribution System.

The Shell service distribution system brings sewer, water, electrical and other services from the site connection into the Shell. These services are ducted to strategically located distribution points. The Shell service distribution system is usually a fixed system that is not easily adaptable.

Distribution Ducts.
The concept of introducing distribution ducts revolves around the notion of having flexible arrangements by means of the layering of services. The distribution duct will carry the main trunk service and installation distribution from which flexible distribution can be made.
4.22 Shell Primary Wall System.

The primary wall system makes up the structure of the house. The nature of this construction is the choice of the builder. Typically there are three systems that can be used;

1. Stick/Component Build Construction.
   The traditional stick-built method is the most widely used form of residential construction today. This is largely due to its flexibility and versatility and the fact that it is not a capital intensive system. Recent surveys indicate an industry-wide shift from stick to a combination of stick and component building. These factory-assembled components include roof trusses, wall panels, floor trusses and pre-hung doors and windows assemblies.

![Diagram of Stick/Component Shell Sub-System](image-url)
2. Panelized Construction.

This is the most popular and versatile form of manufactured housing. The panels are 8 feet high by whatever width the design requires (20'-30'). They are manufactured in a factory and shipped to the site as a package. Exterior wall panels include insulation, sheathing and exterior siding. There is the option for the windows and doors to be installed in the factory.

This form of construction requires some light weight equipment to erect the panels, but is probably not out of the reach of a small developer/builder.

Figure 4.16
3. Modular/Sectional Construction.

This is the most radical and comprehensive form of prefabrication housing. This form of construction is usually shipped in several volumetric units that have been entirely completed in the factory.

Site assembly is minimal but does require heavy duty cranes and equipment to handle the placement of the units.

This form of construction imposes quite rigid constraints on the design of the Shell Core Arrangement. In most cases there are very little cost advantage over normal stick-built construction. Its biggest advantage is speed of erection and product quality.

Figure 4.17
4.23 Shell Roof System.

The Shell Roof System is classified as a sub-system because, for a given Shell primary wall arrangement, different roof systems can be designed. The roof profile plays an important role in the Shell assembly as it is the major form giver both externally and internally.

1. External Roof Profiles.

Varying the external roof profiles with different gables, angles, extensions, and hips creates differentiation that is very important in high density housing.

Figure 4.18
2. **Internal Roof Profiles.**

Internal use of volume and vertical space to create spacious interior spaces plays an important role in the design of units especially where space is at a premium. The primary way of achieving a feeling of spaciousness is through the use of cathedral ceilings. This entails the design of scissors trusses and ceilings that follow the roof line.

![SHELL INTERNAL ROOF PROFILES.](image)

**Cathedral Ceiling Profile.**

**Sloping Ceiling Profile.**

Figure 4.19
3. **Roof Dormers/Sky Lights.**

Roof dormers and sky lights are a crucial design element because they provide light and air to spaces that are located along the ZLL wall and do not open on to outdoor living areas. Design options that can be used are:
- **Side Sky-Lights** - Located in the roof next to ZLL wall areas.
- **Roof Dormers** - Located in the main roof or in side extensions.
4.24 Shell Internal System.

The Shell Internal System includes floors, stairs, and distribution ducts for services and installations.

**Floor Systems.**
In a double story house, floor elements are left out to create double volume spaces over living areas. Attic floors should allow future expansion. The floor system is one of the prime elements that will accommodate distribution ducts for services and installations.

**Stair Systems.**
The stair design and location plays an important role in how flexible the two space areas it connects can be. The structural system should allow for the possibility of several locations for stairs.

---

**THE SHELL INTERNAL SYSTEMS.**

Assembly Of All SHELL Higher Sub-Systems. Assembly Of Internal Floor and Stair Elements. Internal Systems SHELL Components.

**Floor Systems.**

Service Zone Distribution. Floor Openings In This Zone.

**Distribution Systems.**

Distribution Duct

**Stair Systems.**

Figure 4.21
4.25 Shell/Infill Facade Elements.

Facade Systems can either belong to the Shell or Infill assemblies. In some instances the Shell assembly will determine the constraints imposed on the Infill systems, through fixed openings. In other instances Infill assemblies will determine the constraints imposed on the Shell systems, through predetermined opening sizes.

**Specific Shell Openings** - In this case different facade elements of the same size can be alternated but the opening size can not be adjusted.

**Adaptable Shell Openings** - In this case facade elements of different sizes can be accommodated by making up the difference through infill panels.

Figure 4.22
4.3 Infill Analysis.

The Infill Assembly is made up of the following sub-systems;
1. Infill service distribution systems.
2. Infill wall systems.
3. Infill fixtures systems.
4. Infill finishing systems.
5. Infill furniture systems.

Infill Sub-Systems
The Infill Assembly Sub-Systems provide different systems from which to select an internal house design.
Chapter 4.

4.31 Infill Service Distribution Systems.

The Infill service distribution system connects equipment and fixtures to the Shell duct distribution system. The Infill service distribution can either be part of various Infill sub-systems or it can be distributed independently through the Shell Internal Assembly.

The Infill service distribution is highly adaptable in order to accommodate the flexible configuration of spaces within the Shell Core Arrangement.

The concept of adaptable service distribution systems will become more important as new technological systems, such as the Smart House concept, become a reality.

Figure 4.24
4.32 Infill Wall Systems.

The Infill wall systems depend on the degree of flexibility that is required of the Infill system itself. This flexibility can exist on a design level only, or it can extend to totally demountable Infill systems. Infill wall systems that can be used are;


**Adaptable Infill Wall Systems** - Demountable wall systems that can be changed to form new space configurations.

**Storage Wall Systems** - Adaptable storage/wall units that form permanent infill divisions.

**Storage Systems** - Adaptable storage units that can be installed in a wide range of wall openings and storage openings.

**Figure 4.25**
4.33 Infill Fixture Systems.

Infill Fixture Systems include equipment, appliances and fixtures that can be periodically replaced and upgraded. To accommodate planned replacement and adaptability the fixtures can be installed through a "harness" system that allows the fixtures to be clipped onto it as well as connected to whatever services it needs.
4.4 Site Arrangement Analysis.

The Site Assembly is made up of the following principles;
1. Site shape principles.
2. Site orientation principles.
3. Site easement principles.
4. Site service Distribution principles
5. Site landscape principles.

Site Assembly Options
The Site Assembly Principles provide different options for creating the Site design.

![Site Assembly Options Diagram]

Figure 4.27
Chapter 4.

4.41 Site Shape Principles.

Once the Shell Core Arrangement has been established the appropriate Site shape can be chosen. This choice depends on careful market analysis to determine the profile of the community that the development will serve. The Site shape choice relates to either higher density and less land cost or to lower densities and higher land cost.

As seen in chapter 2 there are advantages and disadvantages to each of the Site shape types, but for the right market profile and demographics most of the disadvantages will be negated for each of the Site shapes.

Figure 4.28
Each of the Site Shapes can itself have many variations. For example, the Z-Lot/Staggered configuration can either be perpendicular or angled to the street (See Figure 4.29).

**Figure 4.29**
Chapter 4.

4.42 Site Orientation Principles.

The Shell Core base model (and its transformations) uses orientation principles in order to determine the unit's best site orientation. The four main orientation configurations are:

**West/East Orientation** - The long side yard elevation faces south and backyard faces east. Adaptable to most base models.

**East/West Orientation** - The long side yard elevation faces south and backyard faces west. Adaptable to most base models.

**South/North Orientation** - The long side elevation faces east and backyard faces south. Adaptable to most base models.

**North/South Orientation** - The long side elevation faces west and backyard faces north. Not suitable for most base models. Special types should be developed for this orientation.

Figure 4.30
4.43 Site Easement Factors.

The Shell Core base model (and its transformations) uses easement options in order to determine the unit's site setback and service easements.

The main easement configurations are:

**Building Setback** - The minimum front setback of 18 feet governs the ability to provide off-street parking. This setback can be reduced if the difference can be made up with a landscape easement on the street frontage.

**Service, Maintenance/Access/Use Easements** - The service and maintenance/access/use easement often can be combined into one and the same easement.

![SITE EASEMENT OPTIONS](image-url)
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4.44 Site Service Distribution Principles.

The Site service distribution system brings utility services from the public to a point where it connects with the Shell service distribution point. Due to the use of service easements, the service distribution system often occurs in service ducts or service ribbons that contain all the needed service lines.
4.45 Site Landscape Principles.

The Shell Core base model (and its transformations) use landscape principles in order to determine the units specific site use and landscaping. The main landscape elements are:
- **Patios** - paved surfaces that needs careful drainage.
- **Decks** - where there is a level change between house and lot.
- **Planting Beds** - along perimeter walls and special spots.
- **Pools/Jacuzzis** - in luxury units.

Figure 4.33
5. SHELL/INFILL AND (SL) HOUSING APPLICATION.

5.1 Social Reform Versus Market Driven Reform.

5.2 Regulatory Reform Versus Community Norms.

5.3 Further Research on Shell/Infill and (SL) Housing.

5.4 Summary.
SHELL/INFILL AND (SL) HOUSING APPLICATION.

Housing in America today has become a political issue. It is an issue that is fraught with conflicts and dilemmas. Government agencies, builders, manufacturers, and political organizations represent various interest groups with disparate political views and goals. Each group proposes solutions, claiming that it represents the shared interests of all. But there are too many different groups demanding better housing, with too many different needs. More than ever, American housing, like American society and American families, must be characterized by diversity. This political arena has historically been divided into the public sector and the private sector.
5.1 SOCIAL REFORM VERSUS MARKET DRIVEN REFORM.

America is in the midst of a deep and long-term housing crises. Its signs and signals have been protracted, diffuse, and at times camouflaged. For various sub-populations, such as those with very low incomes, female-headed households, and minorities, the housing crises takes on larger proportions: a higher incidence of poor physical conditions and overcrowding and a lack of available units, in addition to severe cost burdens. At another level, for a large and growing segment of middle-income consumers, owners and renters alike, securing decent, affordable housing is becoming problematic. At a third level, there are serious and increasing problems for some major institutional actors in the housing picture, most notably credit providers, the real estate industry, and government. There are two schools of thought on how to deal with the "affordablity crises" in housing namely that based on socialist reform and that based on market driven reform.

SOCIALIST REFORM.
The socialist view holds that the American dream of owning one's home, aided and abetted by an income tax system that subsidizes home ownership, is in fact the root of the problem. Social reformers see that housing - a necessity of life - is treated not as a social good but as a source of private profit, as a commodity. They therefore believe that the root cause of the problem is the fact that housing in our society is produced, financed, owned, operated, and sold in ways designed to serve the interests of private capital. Proponents of this reform believe that decent, affordable housing is a right that all Americans should have, and, like all rights, its acceptance in society will come about only through political struggle.
They further believe that the current housing dilemmas cannot be solved by new financing or more efficient housing prototypes, although both of these are necessary. The displacement of the poor, the unavailability of rental property, the high cost of land and financing, the wasteful energy expenditures, the stigma of public housing, are not isolated problems to be remedied by piecemeal government action or private enterprise. At issue are basic changes in how Americans live, as well as where they live. This reform speculates that like earlier junctures in American housing, today’s situation encompasses redefinitions of family life, class relations, and political power. This view advocates for a change in our approach to housing by introducing communal and cooperative housing, or combined live/work arrangements. This view draws heavily on the experience of Socialist nations. In the provocative "Critical Perspectives on Housing" several authors propose far reaching social reform models on how to deal with the housing crisis. However we have yet to reach the point at which our current dilemmas elicit the kind of engaged, idealistic response of previous generations of Americans, who consistently saw housing as a social, political, and cultural device for change. For many people today, the need to make "necessary sacrifices" leads to bitterness and resentment.

MARKET DRIVEN REFORM.
The second view holds that the owner-occupied, single-family detached house is the standard by which all housing options are judged. This market driven model defines the affordability problem as a gap between income and cost. This gap can only be bridged by one of two ways - increased income or reduced costs.

A massive government-funded commitment to build and subsidize housing would be one way to address the current prohibitive cost of housing and, as during the depression of the 1930’s, help alleviate high unemployment. But this is unlikely, given the present political climate.
What is more probable is that the various organizations and lobbying groups now focusing on housing issues will effect reforms on their own, only some of those in conjunction with the government.

The real changes in housing during the coming decade will involve new ways to use, buy, and sell the kinds of housing that already exist, as well as incentives to encourage builders to provide affordable shelter for diverse groups of people. They cannot continue to build for the "traditional" American family, and they will have to regard low-income housing as an opportunity rather than a threat. Builders will have to plan houses for living situations they might not approve of, houses that will accommodate working mothers or single parents, for instance. The industry, will have to engage in a different kind of political lobbying, working for financial reforms and new zoning laws. For decades, the real-estate lobby campaigned against public housing and for government support of suburban homeownership. Now builders will have to ally themselves with people whose values are different from their own.
5.2 REGULATORY REFORM VERSUS COMMUNITY NORMS.

In cities and the suburbs, smaller dwellings, clustered closer together and featuring energy-conserving systems, are an inevitable new model for the American home. Whatever their physical form and social makeup, every kind of suburban development will need political attention and economic investment in the decades to come.

In existing suburbs, as in the newer developments, changes in zoning laws are essential. Not only does exclusionary zoning still restrict poor and ethnic minorities from moving to most suburbs, but other ordinances restrict the freedom of the middle-class and the working-class who do live there. They make commuting time longer for everyone by separating residential and work areas. Most established suburbs insist upon a physical discontinuity between home and work, "home occupations" are therefore not allowed.

Zoning that limits the possibility of having non-family members rent or occupy part of a single-family house poses another hardship. Such ordinances prohibit more than three unmarried persons from living together; they also make it impossible to rent a bedroom to a student or older person in exchange for watching over the children.

Suburban houses do not have to be used as they were originally intended to be used. Both Wright (1983) and Hayden (1984) expound on the need to redefine the R1 single-family residential zoning ordinance to facilitate accessory apartments, single parent co-habitation as a significant means of providing affordable living that follows the traditional image.

Small Lot Housing ordinances could be an ideal environment to implement these changes, because most communities have to re-
write, or create new regulation for small lot housing. The Shell/Infill concept further provide the flexible bases the makes adaptable housing needs possible.

However regulatory reform will not succeed without a change in the way communities perceive and view community norms. At present the majority of use violations are reported by one owner against another, and usually concern work being done in the home, which is seen as a threat to property values and to stable family life. Clearly, such policies restrict the options for both women and men who want to engage in a productive job while they remain at home with their children. This community resistance also manifests when new developments, in the form of infill-projects and neighborhood extensions, that rely on the goodwill of the community for approval, are proposed.
5.3 FURTHER RESEARCH ON SHELL/INFILL AND SMALL LOT HOUSING.

Because Small Lot Housing and especially Shell/Infill are such new concepts, further research in these areas will be required to both further develop and promote the concept. Suggested further research areas are:

**Small Lot Housing Research Topics.**

The successful acceptance of Small Lot Housing on a national level will depend on further research to define;

1. Zoning and regulatory laws that can serve as a model and guide for the implementation at State level.
2. The legal implications of Small Lot planning to developer-builders and consumers.
3. Federal and State role and guidelines in providing "affordable" housing.
4. Marketing methods to promote the Small Lot Housing concept and ways to make its acceptance possible in existing communities.

**Shell/Infill Research Topics.**

The successful application of Shell/Infill concept to Small Lot Housing will require further in-depth research in several areas in-order to develop feasible market models. This research reinforces recommendations made by Kendal (1986) for further research areas;

1. To study regulatory implications for the Shell/Infill concept. The effect of significant changes and new regulations need to be evaluated with regards to Shell/Infill concept. (For example Article 780 - Closed-Loop and
programmed power distribution regulation that makes the Smart House technology possible.)

2. To develop a methodology for the coordination of independent Shell/Infill producers. Agreements have to be established for the interfacing of different systems for both Shell and Infill assemblies.

3. Develop Infill systems and assembly catalogues on both a national and regional level. Some Infill systems will consist of the assembly of existing products and materials. Other Infill systems will require the development of new technical solutions and systems.

4. Some new building products geared for specific interfacing systems used in the Shell/Infill concept will be necessary. The area of service distribution for both Shell and Infill indicates an obvious area.

5. The legal aspect of implementing the Shell/Infill concept will have to be studied. This will affect the control levels and communication between manufacturer, builder, and homeowner.

6. The marketing and educational effort will have to be undertaken to promote the Shell/Infill concept to the production industry, builders, and to consumers.
5.4 SUMMARY.

This Shell/Infill concept analysis, as applied to small lot housing development in America, reveals that the housing industry of the private sector has both positive and negative traits.

Positive Facts;
The housing industry has developed sophisticated market research techniques in order to be in touch with housing preferences, trends, and shifting demographics.
The industry also offers a remarkable range of varied designs, product choices and styles.
The market is relatively competitive and efficient in that it is made-up of a wide range of companies from small localized construction firms to large national corporations.

Negative Facts;
Because the industry is profit motivated it will not be motivated to extend its cost cutting endeavors beyond the point where it cannot make a profit. This unfortunately excludes it from providing much needed "affordable housing" for the market section below the average mean. Federal and State programs can however provide incentives and the means to "make-up" the difference between the affordability line and the production cost through land grants, development concessions and other financial aid programs.

The Small Lot Housing concept coupled with Shell\Infill technique provides an exciting means to provide housing that is high density and still based on the single-family detached principle. But before any proposal that promotes alternative "affordable housing" can be accepted on a meaningful national scale, the image of what constitute the American house will
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have to be altered. As pointed out by Clark (1986) the image of the American single-family detached home has by and large been the result of a century of promotion by advice manuals, plan books, and housing magazines. It is this conception and image that first and foremost will need to be altered, through the same promotion media, to prepare the American people for the inevitable change that housing will have to undergo to deal with the dynamic and varied needs of the 1980’s and 1990’s.
REFERENCES AND RESOURCES

BOOK BIBLIOGRAPHY:


- Bases for general housing demographics, trends, statistics and analysis.


- Bases for historical technological information.

- Bases for support design principals.

- Bases for thematic design principals.

- Bases for thematic design principals.

- Bases for thematic design principals.


Bases for base case analysis of the Zero Lot Line house type.


Examples of base case house type.


Bases for base case analysis of the Zero Lot Line house type.


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MAGAZINE BIBLIOGRAPHY:


UNPUBLISHED WORKS:


COMPUTER RESOURCES USED.

Computer Hardware Used For Producing This Work.

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Two hard disk drives and 2 MB of RAM.
EGA Color Screen.
Kurta graphics tablet.
IBM Pro-printer.
HP Laserjet Series II printer.

Computer Software Used For Producing This Work.

1. TEXT.
   Wordperfect 4.1 Wordperfect Corporation.
   Glyphix Font Manager For Wordperfect. SWFTE Int.
   Glyphix Basic Font Pack. SWFTE Int.

2. GRAPHS.
   Graphwriter. Lotus Development.
   Freelance. Lotus Development.

3. GRAPHICS.
   Drawbase 5.0. SKOK Systems Inc.
   LaserPlotter. Insight Development Corporation.
APPENDIX A: ZONING AND SPACE STUDIES.

This zoning and functional analysis was done on a wide selection of small lot housing house plans taken from popular housing magazines. The analysis is based on the SAR zoning and margins, functional analysis theory of Habraken.

For the purpose of this analysis the functional spaces in a house are divided into the following groups;
General Purpose Spaces - Living room and Family room/Den.
Special Purpose Spaces - Bedrooms and Study.
Service Spaces - Bathrooms, Kitchen and Utility areas.

The selected sample house plans were examined for the above listed functional spaces. From this analysis, generic layouts and space sizes was extracted. Finally a combination of bathroom and closet space analysis was done to develop sub-assemblies that can be added to make up a possible range of different bathroom/closet space layouts.

This functional analysis forms the bases in determining the zones and margins that can be used to generate the Shell Core Arrangement.
FUNCTIONAL ANALYSIS OF GENERAL PURPOSE SPACES IN SMALL LOT HOUSING.
LIVING ROOM AND DEN CONFIGURATIONS.

Figure A-01
FUNCTIONAL ANALYSIS OF SPECIAL PURPOSE SPACES IN SMALL LOT HOUSING.
DINING ROOM AND BREAKFAST NOOK CONFIGURATIONS.

Figure A-02
FUNCTIONAL ANALYSIS OF SPECIAL PURPOSE SPACES IN SMALL LOT HOUSING.
BEDROOM AND STUDY CONFIGURATIONS.

Figure A-03
FUNCTIONAL ANALYSIS OF SERVICE SPACES IN SMALL LOT HOUSING.
KITCHEN CONFIGURATIONS.

Figure A-04
FUNCTIONAL ANALYSIS OF SERVICE SPACES IN SMALL LOT HOUSING.
BATHROOM AND UTILITY CONFIGURATIONS.

Figure A-05
FUNCTIONAL ANALYSIS OF SERVICE SPACES IN SMALL LOT HOUSING.
STORAGE AND CLOSET CONFIGURATIONS.

Figure A-06
FUNCTIONAL ANALYSIS OF SERVICE ASSEMBLIES IN SMALL LOT HOUSING.
BATHROOM, UTILITY AND STORAGE/CLOSET CONFIGURATIONS.

Figure A-07