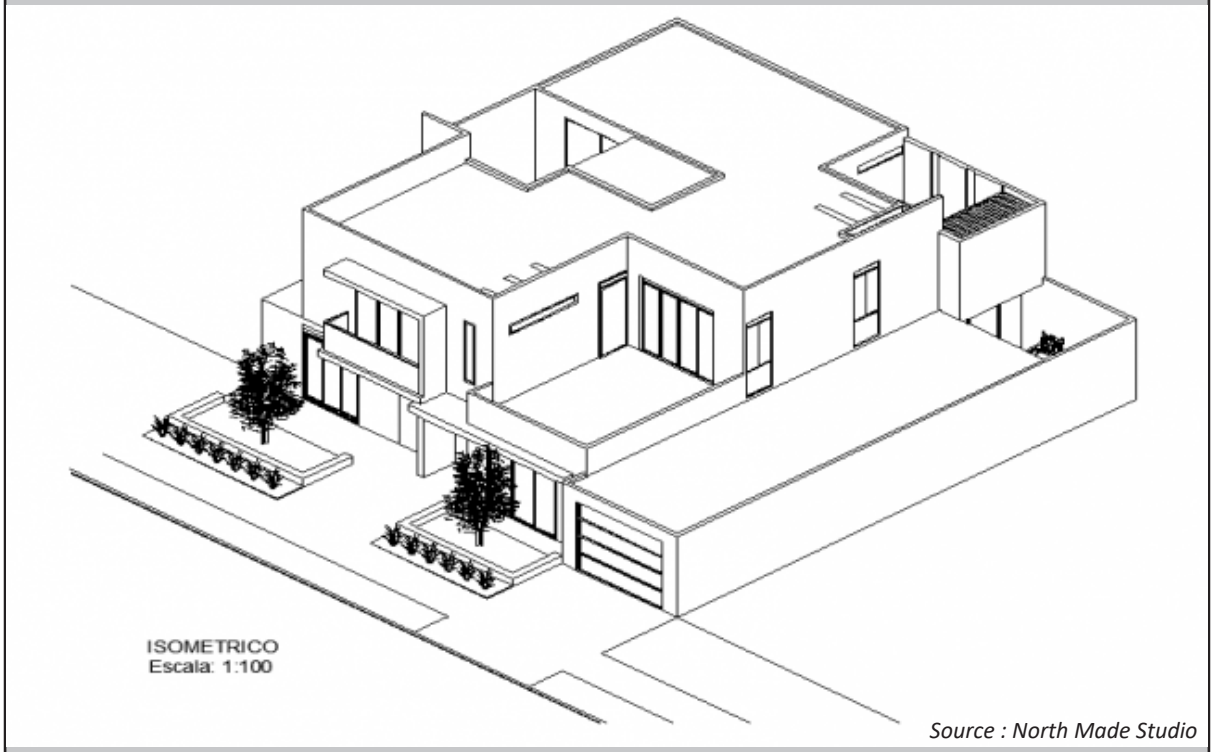


Source : North Made Studio

Analysis of Spatial configuration and functional efficiency of house layouts of various typologies in Ahmedabad

Analysis of Spatial configuration and functional efficiency of house layouts of various typologies in Ahmedabad

Bachelor of Architecture Research Thesis dissertation

June 2021

Submitted by

Priyanshi Shah

16BAR004

Institute of Architecture & Planning

Nirma University

Ahmedabad 382481

FINAL DRAFT

ORIGINALITY REPORT

13%	11%	6%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	eprints.usm.my Internet Source	5%
2	Submitted to Institute of Technology, Nirma University Student Paper	2%
3	thescipub.com Internet Source	1%
4	s3.amazonaws.com Internet Source	1%
5	Submitted to Higher Education Commission Pakistan Student Paper	<1%
6	Yasemin Ince Guney, Jean Wineman. "The Evolving Design of 20th-Century Apartments in Ankara", Environment and Planning B: Planning and Design, 2008 Publication	<1%
7	www.slideshare.net Internet Source	<1%
8	repository.up.ac.za Internet Source	<1%
9	Faris Ali Mustafa, Ahmad Sanusi Hassan. "Mosque layout design: An analytical study of mosque layouts in the early Ottoman period", Frontiers of Architectural Research, 2013 Publication	<1%
10	shura.shu.ac.uk Internet Source	<1%
11	www.researchgate.net Internet Source	<1%
12	Faris Ali Mustafa, Ahmad Sanusi Hassan. "Spatial-Functional Analysis of Kurdish Courtyard Houses in Erbil City", American Journal of Engineering and Applied Sciences, 2010 Publication	<1%
13	discovery.ucl.ac.uk Internet Source	<1%
14	www.emeraldinsight.com Internet Source	<1%
15	umpir.ump.edu.my Internet Source	<1%
16	digitalcollections.dordt.edu Internet Source	<1%

17	Submitted to London Metropolitan University Student Paper	<1 %
18	dx.doi.org Internet Source	<1 %
19	issuu.com Internet Source	<1 %
20	SIDDHARTHA RAYCHAUDHURI. "Colonialism, Indigenous Elites and the Transformation of Cities in the Non-Western World: Ahmedabad (Western India), 1890-1947", Modern Asian Studies, 2001 Publication	<1 %
21	en.wikipedia.org Internet Source	<1 %
22	Submitted to CEPT University Student Paper	<1 %
23	kclpure.kcl.ac.uk Internet Source	<1 %
24	www.scipedia.com Internet Source	<1 %
25	mafiadoc.com Internet Source	<1 %
26	www.11ssslisbon.pt Internet Source	<1 %
27	www.scribd.com Internet Source	<1 %
28	citeseerx.ist.psu.edu Internet Source	<1 %
29	docs.wixstatic.com Internet Source	<1 %
30	www.ukessays.com Internet Source	<1 %
31	banamid.org Internet Source	<1 %
32	journals.sagepub.com Internet Source	<1 %
33	Submitted to 8936 Student Paper	<1 %
34	Abir Bandyopadhyay, Arif N Merchant. "Space Syntax Analysis of Colonial Houses in India", Environment and Planning B: Planning and Design, 2016 Publication	<1 %
35	J. L. Nasar. "Book Reviews", Environment and Behavior, 05/01/1991 Publication	<1 %
36	books.bk.tudelft.nl Internet Source	<1 %
	orca.cf.ac.uk	

37	Internet Source	<1%
38	theses.ucalgary.ca Internet Source	<1%
39	Dalia Ali Rafeeq, Faris Ali Mustafa. "Evidence-based design: The role of inpatient typology in creating healing environment, hospitals in Erbil city as a case study", Ain Shams Engineering Journal, 2020 Publication	<1%
40	MUSTAFA, FARIS ALI. "Using space syntax analysis in detecting privacy: a comparative study of traditional and modern house layouts in Erbil city, Iraq", Asian Social Science, 2010. Publication	<1%
41	Ritu Bhatt. "Christopher Alexander's pattern language: an alternative exploration of space-making practices", The Journal of Architecture, 2010 Publication	<1%
42	Sam McKinstry. "Status building: Some reflections on the architectural history of Chartered Accountants' Hall, London, 1889–1893", Accounting, Organizations and Society, 1997 Publication	<1%
43	Deniz Erinsel Onder. "A new housing group for sub-residential area in Samarkand: a morphological comparison", Cities, 2002 Publication	<1%

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		

Institute of Architecture & Planning, Nirma University

Approval

The following study is hereby approved as a creditable work on the subject carried out and presented in the manner, sufficiently satisfactory to warrant its acceptance as a pre-requisite towards the degree of Bachelor of Architecture for which it has been submitted.

It is to be understood that by this approval, the undersigned does not endorse or approve the statements made, opinions expressed or conclusion drawn therein, but approves the study only for the purpose for which it has been submitted and satisfies him/her to the requirements laid down in the academic program.

Thesis Title : Analysis of Spatial configuration and functional efficiency of house layouts of various typologies in Ahmedabad

Student Name : Priyanshi Shah

Roll Number : 16bar004

Date:7th June, 2021

Prof. Ankit Kumar

Guide & Professor

Institute of Architecture & Planning, Nirma University, Ahmedabad

Prof. Vinay Shah

Prof. Supriya Pal

Prof. Purvi Jadav

Prof. Nishant Kansagara

Prof. Sujan Umaraniya

Thesis Committee,

Institute of Architecture & Planning, Nirma University, Ahmedabad

Prof. Utpal Sharma

Director,

Institute of Architecture & Planning, Nirma University, Ahmedabad

Declaration

I, **Priyanshi Shah**, **16bar004**, give an undertaking that this research thesis entitled "**Analysis of Spatial configuration and functional efficiency of house layouts of various typologies in Ahmedabad**" submitted by me, towards partial fulfilment for the Degree of Bachelor of Architecture at Institute of Architecture and Planning, Nirma University, Ahmedabad, contains no material that has been submitted or awarded for any degree or diploma in any university/school/institution to the best of my knowledge.

It is a primary work carried out by me and I give assurance that no attempt of plagiarism has been made. It contains no material that is previously published or written,
except where reference has been made. I understand that in the event of any similarity
found subsequently with any published work or any dissertation work elsewhere; I would be responsible.

This research thesis includes findings based on literature review, study of existing scientific papers, other research works, expert interviews, documentation, surveys, discussions and my own interpretations.

Date: 7thJune, 2021

Name : **Priyanshi Shah**

Roll number : **16bar004**

Institute of Architecture and Planning,

Nirma University, Ahmedabad

Acknowledgements

I want to thank the God for providing me the patience and inspiration which motivated me to accomplish my research work. I pay all my respect for granting me the continuous perseverance to accomplish one of the most enchanting work that I had to do.

I express my appreciation towards my biggest motivator and guide, Prof. Ankit Kumar for his constant support and encouragement during my work. His perception and comments in every stage of my work have helped me immensely. I am highly obligated to him for the time he has put in me to analyze each step I take towards completing my work and for his immense trust in me.

I am extremely grateful to all the facilities and professors at the Institute of Architecture at Nirma university for helped me grow as an individual.

Additionally, I pay my sincere thanks to those who participated in my process of research thesis. I am extremely thankful to Ar. Dilip Soni, Ar. Neel Ghiya and Mr. Rajiv Patel who have assisted me with priceless knowledge and provided me with the required drawings for my research.

I am out of words to thank my respected parents and grandmother who have poured their faith in me while I conduct my thesis. This thesis would honestly have been impossible without my father, who is a real estate developer, Mr. Manan Shah's contacts in the builder lobby and his real estate developers colleagues and friends. I am grateful for my mother who has provided me with affection and encouragement throughout my journey. I owe gratefulness to my sister, Harshini for constantly motivating me and accompanying me in the long working nights.

I owe special thanks to my dear friends who are like family, Anushka, Devarshi, Sohani, Maaz, Rahul, Archi, Vishrut and Saumil for bringing sunshine in the darkest of my days.

Lastly, I want to thank everyone who have contributed knowingly or unknowingly towards the success of my research thesis through their encouragement and motivation.

TABLE OF CONTENTS

Abstract

The purpose of this study is to look at how spatial configuration affects the functional effectiveness of different housing layouts in Ahmedabad.This city is UNESCO's first world heritage city in India, and has been chosen for this study because it has mixed types of traditional and contemporary architecture. The city's architecture has experienced the most progressive changes with the influence of western architecture.

The literature study comprises of three parts. The first, being the study of the relationship between spatial configuration and functional efficiency of the house layouts, and understanding the characteristics of spatial configuration and their impact on functional efficiency of a house layout based on the parameters of Space Syntax. The second, being a study of the house layouts of various typologies namely pol housing, row housing and bungalows in Ahmedabad city through a comparison based on the changes in their configurations. The analysis realizes modifications with time, considering the historical, political and social events that influence the design of the layouts and zoning of spaces and activities, etc.

The indicators of Space syntax that contributed in measuring functional efficiency are Mean Depth of space (MD), The real relative asymmetry of space (RRA), the Difference factor of space(H*), Space-Link ratio and Space-Type. They are analyzed using the Space Syntax theory by applying a software - A Graph which provides quantitative results. This is used to compare house layouts of each typology. The numerical results prove the impact that spatial configuration has on the functional efficiency of the house layouts. The typologies of row houses are realized to be the most functionally efficient after analysing using the methodology. The results supports the hypothesis that argues that spatial configuration affects the functional efficiency of a house layout.

CHAPTER 01 : INTRODUCTION

1.1 Aim

To study the spatial configuration and functional efficiency of house layouts of various typologies in Ahmedabad.

1.2 Objectives

- To understand the spatial configurations of various house layouts.
- To analyse the functional efficiency of the spatial configuration of various house layouts.
- To evaluate the level of functional efficiency of house layouts of various typologies.

1.3 Research hypothesis

The research hypothesis is to test the argument that spatial configuration affects the functional efficiency of house layouts of various typologies in Ahmedabad, India.

1.4 Research Questions

- What are the characteristics of spatial configuration affecting the functional efficiency of house layouts of various typologies?
- How the process of spatial configuration and functional efficiency is being affected over time?
- Are the pol house layouts efficient in terms of functionality?
- Are the row house layouts efficient in terms of functionality?
- Are the bungalow layouts efficient in terms of functionality?
- How can the theory of space syntax evaluate the spatial configuration affecting the functional efficiency of the house layouts?

1.5 Scope of this research

This research is to analyse the impact of spatial configuration on the functional efficiency of house layouts of various typologies in the city of Ahmedabad. Ahmedabad is UNESCO's first world heritage city in India, and has been chosen for this study because it has mixed types of traditional and contemporary architecture. This study uses the parameters of spatial configuration of house

layouts in terms of its functions.

1.6 Limitations of this research

This research is to the study of spatial configuration and functional efficiency of house layouts of residential buildings only. This study is limited to the functional efficiency of interior spaces of the houses.

This research does not involve study of apartments because the purpose of apartments is to provide compact living environment at low rates. Apartments are designed as per the user's functional requirements, and due to their compact form, there are less wastage spaces and are functionally most efficient.

The samples taken for this study are limited to 15, due to the time limitation at undergraduate level and due to the ongoing pandemic, corona virus spread across the world.

1.7 Research Framework

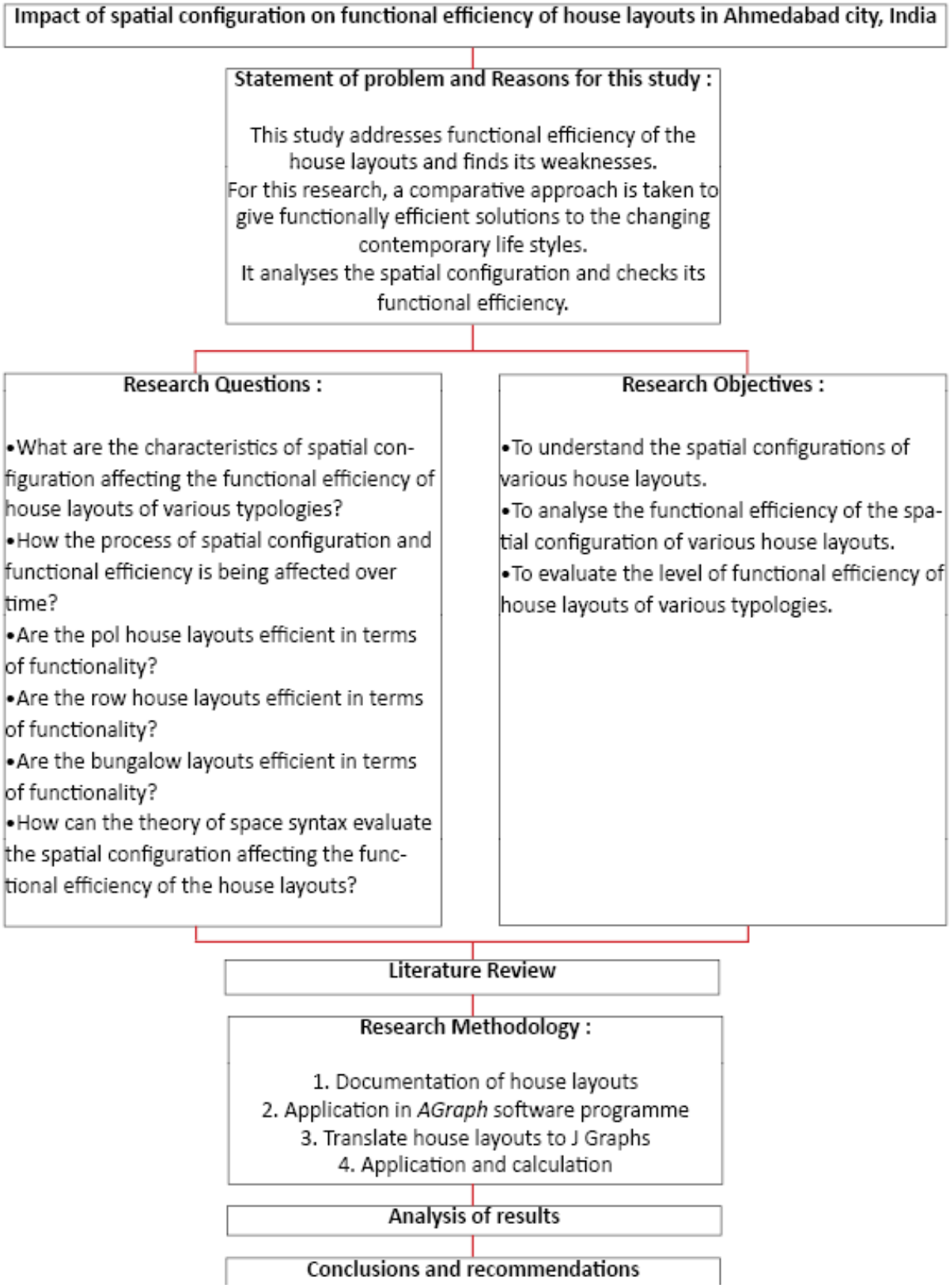


Figure 1.1 : Research framework
Source : by author

CHAPTER 02 : UNDERSTANDING SPATIAL CONFIGURATION AND FUNCTIONAL EFFICIENCY

2.1 Keywords

Architectural space, Interior spaces, Spatial configuration, Functional efficiency, Space Syntax

2.1.1 Architectural space

(G., 2003) states that space acts as a shelter for people's activities, along with its value of culture and lifestyles and social meaning of the society. The varied characteristics of societies are shown in the spatial forms of the spaces and its organization. Space can be organized by the rules that reflect the activities and goals of the people. (Rapoport, 1969) (Rapoport, 1977) (Rapoport, 1982)

2.1.2 Interior spaces

The physical elements define the space, but the interior spaces define its relationship, openness and characteristics. (Mzoori, 2004) The spaces can be categorized according to their relationship with the mass:

1. Open spaces outside the mass are corridors.
2. Interior spaces surrounded by mass within a building differ by degree of privacy.
3. Transitional spaces in between masses

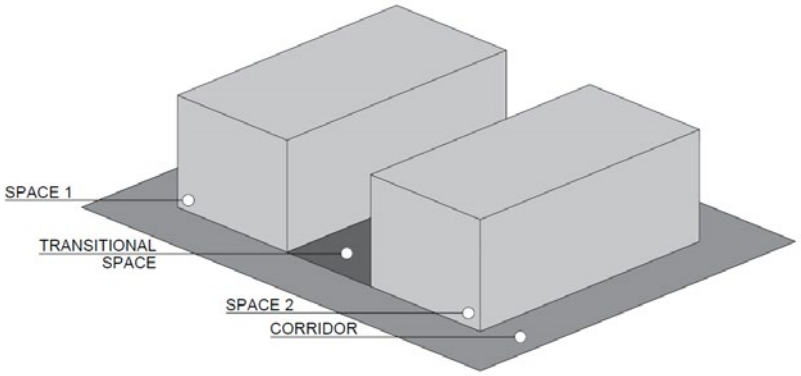


Fig 2.1 : Categorization of the spaces according to their relationship with the mass.
Source : by author

2.1.3 Spatial configuration

"The ordering of space is the purpose of house layout, not the physical object itself. In this

sense, buildings are not just objects, but transformations of space through objects. Therefore, configuration is a fundamental relation of form and space, which is appropriated in the processes, by which buildings are transformed from bodily objects to social and cultural objects" (Hanson H. &., 1988)

"Spatial configuration is compilation of house layout spaces as tangible and defined construction in a particular form, which leads to generate certain relations between inside and inside, and between inside and outside." (Nesbitt, 1965-1995) (Robinson, 2001)

"These relations are numerous and varied, either to be a functional relationship (visual - kinetic), which can be achieved through the element of physical contact (doors), or visual relationships, which can be identified through visual linkage." (Al-Beiruti, 1992)

"All of these relationships reflect the degree and type of social relation; through the assumption that the segregation degree of the space within house layout is an indicator of the degree of functionality and social efficiency, an indication to the type of use by resident and stranger (outsider), on the one hand." (Hanson H. &., 1988)

"On the other hand, spatial relationships within the house layout are the most obvious formula to identify the nature of that society and the behavior of its individuals,
because it reflects the way of thinking and lifestyle." (Hanson H. &., 1988) (Al-Beiruti, 1992)

2.1.4 Functional efficiency

The built spaces carry the impressions of the society by the way of organising the spaces for the functional needs. Functionality is the relationship between two spaces, their purposes, the distribution of people and services. (Aspinall, 1993)

The relationships between space and activities, flexibility, ways of circulation, safety, etc are some of the factors of functionality which are the main aspects of the design of a layout. These factors have to do with people's activities and organisation. (Nijaidi, 1985)

The plans that increase the depth of the house layout are not flexible in terms of functionality, where as in the layouts with less depth, there can be more number of functions and more functional efficiency. (Hanson H. &., 1988)

The availability of internal spaces for public and private usage, as well as the openness and proximity of partitions, can reveal the level of functional efficiency from house layouts. (Mzoori, 2004)

2.1.5 Space Syntax

"Space Syntax is a theory of space and a set of analytical, quantitative and descriptive tools for analysing the spatial formations of house layout as well as buildings, cities, and landscapes." (Hanson H. &., 1988) Space Syntax is used to analyse spatial formations of a house layout and to understand the relationship between humans and inhabited spaces. (G., 2003) (Osman, 1993)

The goal is to develop description strategies for arranging areas while recognising their social significance. Space syntax can predict how spatial patterns will work by establishing strategies for representation and analysis.

Briefly, space syntax identifies how social and cultural meanings are identified in spatial configurations and how they create social relations in a built environment. (Mzoori, 2004)

The two characteristics directly linked to functionality of house layouts are : Symmetry-Asymmetry and Distributedness-Non distributedness.

2.2 Spatial configuration in architecture

2.2.1 Spatial configuration vs Spatial arrangement

Spatial configuration is the allocation of a space, depending on the relative disposition of other spaces. It is the way things are arranged to achieve a result or a purpose.

Spatial arrangement is an act of arranging or placing spaces. It may or may not decipher a result.

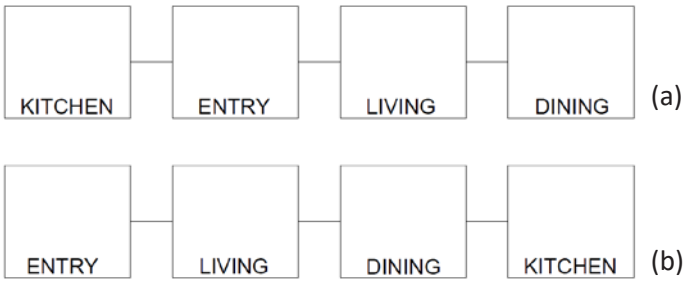


Figure 2.2 : Illustration 'a' shows that the spaces are arranged but they do not decipher a result functionally. Illustration 'b' shows that the spaces are configured as they decipher a result functionally.
Source : by author

2.2.2 Factors affecting the spatial configuration of a house layout

(Rapoport, House form and culture, 1969) in his study of "House form and culture" addressed the impact of social and cultural aspects in house layouts. He studied that the humans have varied views,

which are affected on their physical environments.

The space organizations, climate, location, materials are some of the secondary factors.

Rapoport (Rapoport, Human aspects of urban form, 1977) identified five cultural aspects affecting the organization of house layouts, called :

1. Basic needs and habits such as eating, sleeping, sitting, and their impact on organization of a layout.
2. Size of the family.
3. The extent of social interaction.
4. Status of women and their need of privacy.
5. The orientation of the building and their need of privacy.

2.3 Spatial configuration and functional efficiency

2.3.1 Spatial configuration and functional efficiency of spaces

Configuration is the relation between two spaces in a house layout. The relations between the spaces influence the nature of spatial configuration of a house layout. (Hanson H. &., 1988)

The location of the internal spaces affects the spatial relationships, which then affect the functional efficiency of the spaces. (Rapoport, The meaning of built environment, 1982)

A building achieves its function mainly from the layouts of the spaces. (Rapoport, The meaning of built environment, 1982) The functional relationships reflect the spatial configuration based on the property of segregation which measures the degree of the social-functional efficiency of a space. (Mzoori, 2004)

2.3.2 The spatial-functional relationships of a house layout

According to the studies of space syntax, there are two characteristics which analyse the functional efficiency, called Symmetry-Asymmetry and Distributedness-Non distributedness.

Symmetry-Asymmetry shows the depth of spaces in a layout in reference to the entrance space. If the layout has less depth, then the space is more symmetric. When the steps/depth increases, the segregation of spaces increases, and it shows that the layout is less functionally efficient.

Distributedness-Non distributedness shows the options of ways available to access all spaces in a lay-out. If there are more ways, then the distributedness increases and segregation decreases. (Hanson

H. &., 1988) (Hillier, Space is a machine : A configurational theory of architecture, 2007)

Figure 2.1 shows the relationships between the interior spaces and the main space (a). It shoes that the spaces 2, 3, 4, 5 and 6 are linked to the space a with the spatial depth level as 1. The spaces 7 and 8 are segregated as they are not linked to the main space. The spatial depth level is 2 steps.

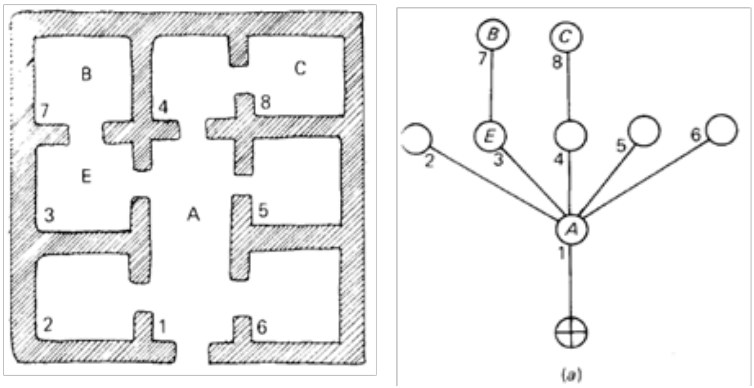
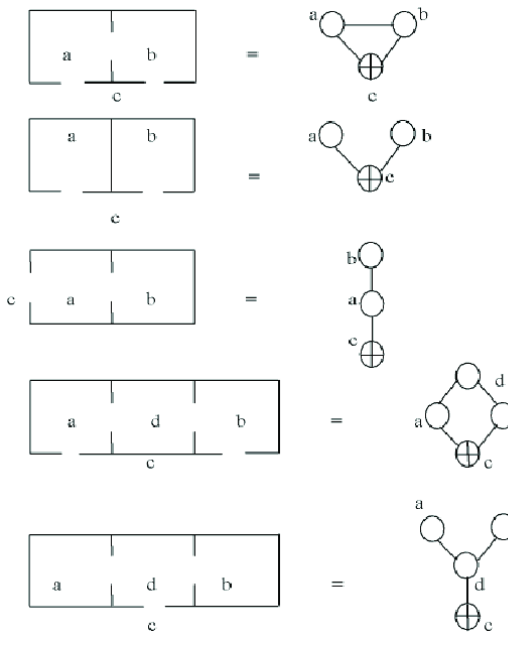


Figure 2.3 : Relationships between the interior spaces and the main space (a) in a house layout
Source : (Hanson H. &., 1988) (Hillier, Space is a machine : A configurational theory of architecture, 2007)

2.3.3 Illustration of syntactical characteristics of spatial configuration



A and B are Symmetrical and distributed wrt C

A and B are symmetrical and non-distributed wrt C

A and B are asymmetrical and non-distributed wrt C

A and B are symmetrical to C but D is asymetrical and non-distributed wrt C

D is non-distributed and asymmetric wrt A and B. A and B are symmetric wrt D and C

Figure 2.4 : Symmetry-Asymmetry and Distributedness-Non distributedness of spaces in a house layout
Source : (Hanson H. &., 1988) (Hillier, Space is a machine : A configurational theory of architecture, 2007)

Distributed relations : **Ringy** graphs

Non distributed relations : **Tree like** graphs

These graphs show spatial configurations, which are quite different. This difference is analysed using a Justified graph.

“This is a graph in which a particular space is selected as the ‘root’, and the spaces in the graph are then aligned above it in levels according to how many spaces one must pass through to arrive at each space from the root.” (Mzoori, 2004)

These graphs show the depth of each spacefrom the main space. A space at depth 1 from the root if it is directly linked to it, at depth 2 if there is an intervening space, at depth 3 if a minimum of 2 spaces must be passed through.

Thus, according to “Space Syntax”, the characteristics of various spatial configurations of house lay-outs can be measured and compared to each other, in order to clarify individual differences in spatial systems, and to discover their patterns, identify the changes and transformations that occurred in house layouts over time, which in turn affects the functional efficiency of the house, accordingly. (Hanson H. &., 1988)

CHAPTER 03 : RESEARCH METHODOLOGY

3.1 Space Syntax as a methodology

Space Syntax is a method for analyzing spatial configurations that was developed. It is used to graphically and quantitatively represent the layouts.

"The reasons for adopting this methodology in dealing with the syntactical characteristics of spatial configuration are as follows:

1. This methodology able to combine both physical and social indicators in interpreting the spatial-functional systems in order to identify their configurations in terms of differences and similarities. This paves the way to diagnose the strengths and weaknesses in the structures of house layouts functionally.
2. It adopts the syntactical characteristics of spatial configuration (such as Symmetry - Asymmetry, Distributedness – Nondistributedness) in interpreting the structures of different house layouts. This, in turn, facilitates the process of analysing, evaluating, and comparing these various systems.
3. Having the ability to assess, understand, describe, and modeling of numerous formal and spatial systems provides the research a fair amount of credibility and reality." (Mzoori, 2004)

3.2 The methodology :

Part One : The characteristics of spatial configuration namely Symmetry – Asymmetry and Distributedness – Non-distributedness will be found out, and how they affect the functionality of the house layouts.

Part Two : The numerical values of each variable of these characteristics will be found out through the indicators of measuring. These indicators involve these measurements :

- Integration degree of space – Real relative asymmetry – RRA
- Mean Depth of spatial system – MD
- Difference factor of space – H*
- Space-Link ratio – Type of graph formed (Ringy / Tree like)
- Space-type (Degree of spaceness)
- Every house layout has to be translated into a justified graph by a Gamma analysis method,

to be applied to the software A-Graph , then to be calculated and measured.

Part Three : To understand the impact of spatial configuration on the functional efficiency of house layouts. This requires interpretation, comparison and evaluation of similarities and differences of each house layouts. The results will produce conclusions and recommendations for house layouts in Ahmedabad.

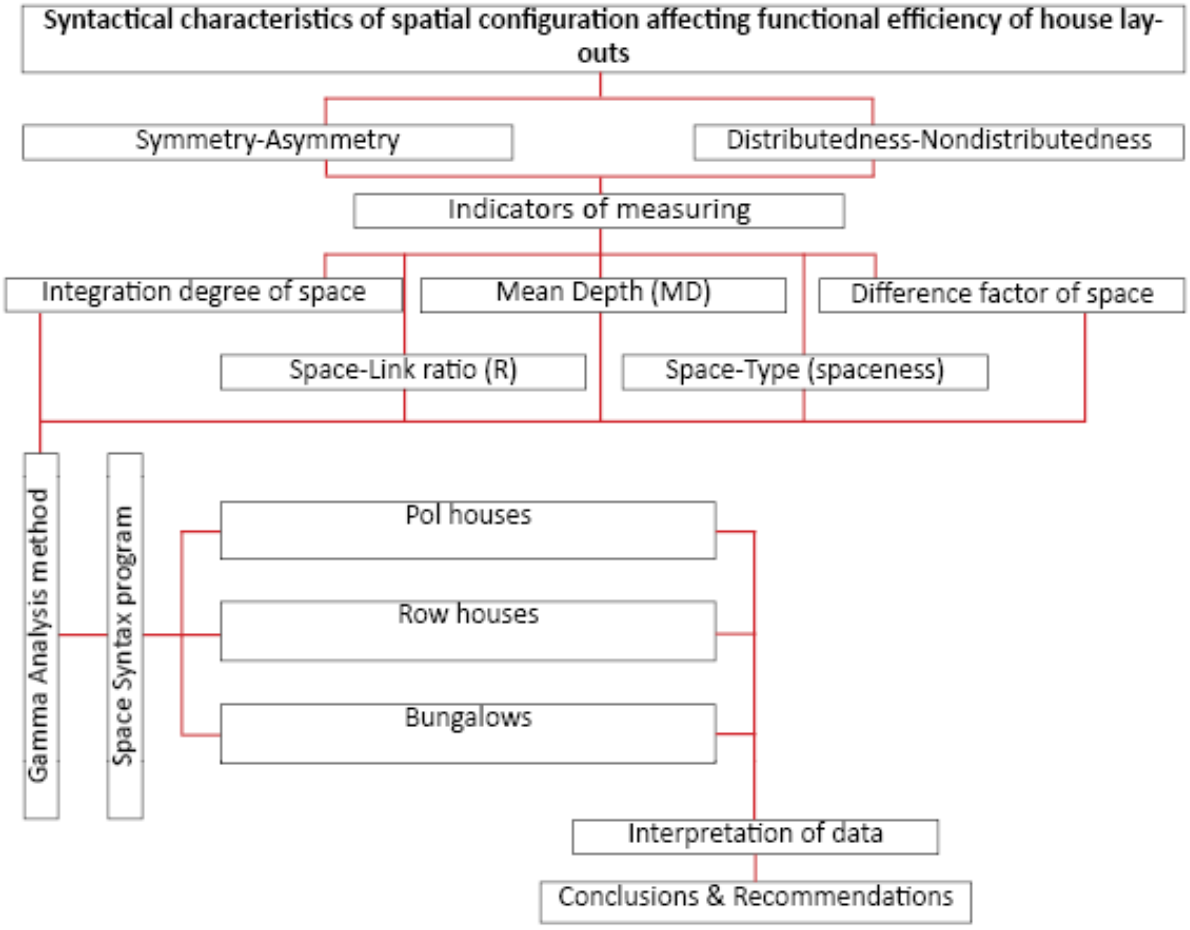


Fig 3.1 : Research Methodology
Source : by author

3.3 Indicators of measuring syntactical characteristics of spatial configuration

The following indicators can be used to measure and give numerical values to syntactic characteristics of spatial configurations such as (Symmetry – Asymmetry, and Distributedness – Non-distributedness), which affect the functional efficiency of the house:

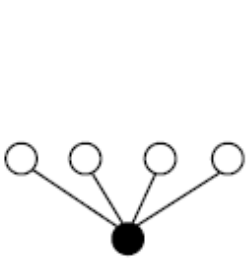
3.3.1 Indicator of Integration (Real Relative Asymmetry-RRA and Mean depth MD) :

“Integration degree of space is an indicator related to the property of (Symmetry - Asymmetry), it reflects the relative depth of space in relation to the rest of spaces in any spatial system.” (Hillier, 1993)
“The mean depth of a space from all other spaces in the configuration (house layout) is integration (RRA) which describes how permeable that particular space is. The low values mean higher integration and, the high values mean high segregation.” (Manum, 1999)
The integration of the spaces can be measured by these steps:

Firstly, calculate the mean depth of space :

1.Making a justified graph by setting the intended space at the bottom of the house layout as a primary space (root space) and aligning the other spaces above it in levels based on how many spaces must be passed through to get to each space from the root space. Each space in the structure is represented by a small circle, and the permeability between spaces is depicted by connecting lines.

2. The graph determines the depth of each space from the root space, where the depth of each space is determined by the number of spaces that must be traversed to get from the root space to each space in the system.
“The least depth can be achieved, when all spaces are directly connected to the original space (root space), while the most depth existing when all spaces are arranged in a linear sequence away from the original space. In the first case, the space will be symmetric in respect to the other spaces in the system, and will be asymmetric in the second case.” (Hanson H. &., 1988) (Hillier, 2007)



a - All spaces are directly connected to the root space

The overall depth of the space is minimum.

b - All spaces are stacked and not directly connected to the root space

The overall depth of the space is maximum.

Figure 3.2 : Symmetry-Asymmetry in Spatial relationships
Source : (al, 1987a)

- Accordingly, the mean depth of the space is calculated by :

$$M.D = \frac{\sum D}{K-1}$$

Where :

MD – Mean depth of space from root space

ΣD – total magnitude of depth for all spaces in system from root space

K – Total number of spaces in graph

Secondly, : Calculating the integration value of space (Relative Asymmetry – R.A.): this value expresses the relative depth of that space from all others in the graph through the following formula:

$$R.A = \frac{2(M.D-1)}{K-2}$$

Where :

RA – Relative asymmetry

MD – Mean depth of space

K – Total no of spaces in a graph

“The integration value of space (Relative Asymmetry - R.A.) thus expresses numerically a key aspect of the shape of justified graph from that space. Integration values (R.A.) vary between (0) for maxi-

mum integration, that is no depth (high-functional efficiency); and (1) for maximum segregation, that is maximum depth (low-functional efficiency)" (al, 1987a) (Onder, 2002) (Zako, 2006)
To quantify integration and depth, the external space of the house is used as a root space in relation to the remainder spaces in the spatial system. Depth from the root is the number of steps that separate a specific space from the front door. (Monteiro, 1997) (Toker, 2003)

Thirdly, calculate the Real Relative Asymmetry RRA :

The RRA illustrates the degree of depth/isolation of a node while comparing it with all other nodes, and also in comparison with a benchmark configuration. The results of RA vary between 0-1, but the RRA results are compared with a chosen configuration. (Mzoori, 2004)
RA values of spaces will show the distribution of integration. But if we compare systems with varied complexities and sizes, we have to eliminate the effect of various sizes on the levels.
"So, we need to compare the RA value to the RA value of the root of a 'diamond shaped' pattern. It means a justified map where there are k spaces at the mean depth level, k/2 at one level above and below, k/4 at two levels above and below, and so on until there is 1 space at the shallowest and deepest points. Then, find the D value of k of the system, then divide the value into the value obtained for each space." (Ostwald, 2011)

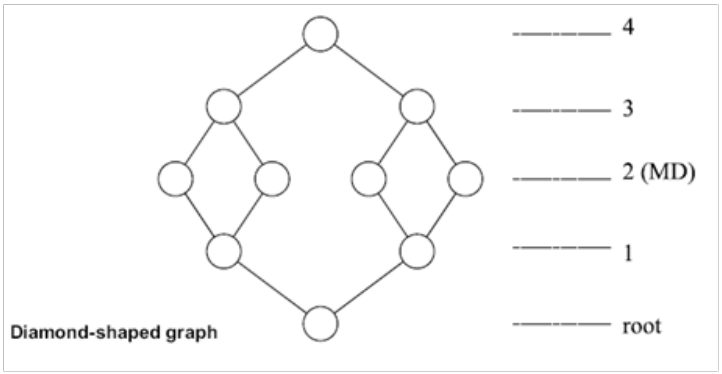


Figure 3.2 : Diamond spaced graph to calculate the integration of spaces in a layout
Source : (al, 1987a) (Hanson H. &., 1988) (al, 1987a)

Real relative asymmetry can be calculated using this formula :

$$R.R.A = \frac{R.A}{D_K}$$

Where,

RRA : Real relative asymmetry of space

RA : Real asymmetry of space

Dk : Real asymmetry of space from diamond-shaped graph

The value of RRA varies around the number 1; values of less than 1 refer to the integrated spaces and less segregation in the system, while the values that are more than 1 refer to the segregated spaces. (Shoul, 1993) (Sungur, 2001)

3.3.2 Difference factor of space H*

The degree of configurational differentiation is seen from this difference factor. “The degree of variance in integration values is considered as an indication of the strength or weakness of social relations related to spatial ordering, i.e. how much a space is interchangeable with others. The difference factor is used to quantify this difference as a proportion of the sum of integration values of spaces under consideration.” (Guney, 2005) (Bellal, 2007)

$$H = -\sum \left[\frac{a}{t}\ln\left(\frac{a}{t}\right)\right] + \left[\frac{b}{t}\ln\left(\frac{b}{t}\right)\right] + \left[\frac{c}{t}\ln\left(\frac{c}{t}\right)\right] \quad \text{..... (4.4)}$$

Where

H : Difference factor of three spaces

a, b, c : integration values of three spaces in a house layout

t : sum of Σ (a + b + c)

The H-formula shows a difference in integration in each layout, which may be a product of the differ-

ences in functions of the spaces. (Bustard, 1999)

“H can be ‘relativised’ between (Ln2) and (Ln3) to give a ‘relative difference factor’, (H*), whose values vary between 0 (maximum difference), and thus strong functional differentiation which refers to a real functional efficiency of space; and 1 (minimum difference), no difference and thus no functional differentiation; this indicates that there is no real difference in the values of integration and ; therefore there is no real functional efficiency of space.” (al, 1987a) (Guney, 2005)

The relative difference factor can be calculated by this formula :

$$H^* = \frac{H - \ln 2}{\ln 3 - \ln 2}$$

“Whereas low values for (H*) would indicate the existence of a ‘strong’ genotype; on the other hand, values close to 1 would be indicating ‘weak’ genotypes, that means no functional differentiation and weakness in the functional efficiency of space.” (Zako, 2006)

3.3.3 Indicator of Space-Link ratio ; the Ringiness degree of the spatial system :

To asses the distributedness-non distributedness of a layout, a ringiness measure is measured. Distributedness is defined as the existence of multiple non-intersecting paths from one point in a system to another.. The system is said to be non-distributed if there is only one path between any two points in the system; a tree-like structure. So, with every increase in the rings in the system, it can be deciphered that there are more rings in the structure, making it a ringy structure.

Figure 3.3 : Illustration shows a: tree-like structure , b: Ringy structure
Source : (Mzoori, 2004)

The degree of 'ringiness' of a spatial system, or the space-link ratio is used to determine the level of a spatial system's permeability.

"Its values vary around the number (1), where the values more than (1) refer to a high degree of 'ringiness' of a spatial system (ringy structures), and therefore its tendency to distributedness; this in turn refers to a high degree of flexibility (functional efficiency) in using the space enabling the user to change the layouts to adapt different circumstances, either by closing or opening doors. While the values <1 refers to that the spatial system takes the form of tree – like system, which makes it a system tends to lack distributedness, and in turn means the increase in the depth of spaces within the house layout" (Hanson H. &., 1988) (al, 1987a) (Hanson, 2003) (Bellal, 2007)

The Space – Link ratio calculated by this formula :

$$R = \frac{L + 1}{K}$$

Where,

R- Space – Link ratio of spaces

L - No. of lines of link between spaces

K – No. of spaces in system

3.3.4 Indicator of Space-Type (the degree of spaceness)

The space-type makes various categories of spaces, the ones which have an occupation and follows a function, and the others which are used as movement paths.

“According to Space Syntax terminology, there are four different topological types of space: a-type space which has one link; b-type space which has more than one connection and lies on a tree; c-type space which has more than one connection and lies on a ring; and d-type space with more than two connections and lies on at least two rings. In other words, a- and b-type spaces indicate tree-like graphs; whereas c and d types indicate ringy graphs” (Manum, 1999) (al, 1987a) (Hanson, 2003) (Guney, 2005) (Bellal, 2007)

In an a-type space, an occupation is present and does not give space for circulation.

In b-type and c-type spaces, movement and circulation are present and occupation might not be present.

In d-type spaces, the most choice of circulation is offered. (Mzoori, 2004)

- “To calculate the degree of a-ness of a house layout the number of a-type spaces is divided by the total number of spaces minus one.

$$\text{The degree of a-ness} = \frac{\text{NO. of (a-type spaces) in house layout}}{\text{total No.of spaces} - 1}$$

- The degree of b-ness is calculated by dividing the number of b-type spaces in a house layout by the total number of spaces minus two.

$$\text{The degree of b-ness} = \frac{\text{NO. of (b-type) spaces in house layout}}{\text{total No.of spaces} - 2}.$$

- The degree of c-ness and d-ness is calculated by dividing the number of c- or d type spaces by the total number of spaces in the layout as a whole.” (Mzoori, 2004)

$$\text{The degree of (c-/d-ness)} = \frac{\text{NO. of (c or d-type) spaces in house layout}}{\text{total No.of spaces}} \quad (4.9)$$

The figure 3.4 illustrates that :

a-type space : It is on a tree and it is a dead-end space, like space 7

b-type space : It is on a tree and has two connections, like space 6

c-type space : It is on a ring and has more than one connection, like the spaces 2, 3, 4, 5

d-type space : It is on a ring and has more than two connections, like the space 1 (Mzoori, 2004)

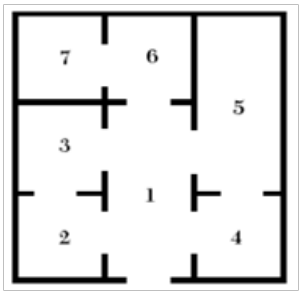


Figure 3.4 : Classification of spatial patterns in a house layout
Source : (Amorim L. , 1997) (Amorim, 2001)

3.4 Sampling methods:

The sampling methods were created with the aim of obtaining the most comprehensive source of data possible to address the research questions. The sampling can ensure the highest degree of representation to all types of house layouts in a society.

The sample size to represent house layouts are 15 (5 for each house typology), taking into consideration the time limitation and the spread of the pandemic, corona virus across the world.

CHAPTER 04 : AN OVERVIEW OF HOUSE LAYOUTS IN AHMEDABAD CITY, INDIA

4.1 Growth and evolution of Ahmedabad

Ahmedabad is a historic city in Gujarat, India, located in the western part of the country. It was established by Islamic conquests in India. Ahmed Shah established the city in 1411 AD.

The wealth and religious architecture of the Solanki kingdom awed new Muslim rulers. The new rulers were eager to develop their dominance and began construction projects in Ahmedabad. They created a Hindu architecture model.

The result was Ahmedabad's famous "sultanate architecture," which is regarded as a high point in world architectural heritage.

The architecture of Ahmedabad, a walled city on the Sabarmati River, was influenced by Hindu practises.

After a deal with the rulers of western India, the Poona Peshwas, Ahmedabad came under British rule in 1817. Ahmedabad came under British rule in 1817 after a treaty with the rulers of western India, the Poona Peshwas.

The British were interested in annexing Ahmedabad because of the enormous power that controlling the city bestows on its owner in the eyes of the world. Both the Mughal and Peshwa rulers had depopulated the district. When the British arrived, Ahmedabad's economy was focused on gold, silk, and cotton. By 1839, the opium trade to China had increased Ahmedabad's trade guilds, and the city was rapidly progressing.

In 1917, Mahatma Gandhi stayed in this town for 13 years to carry out his anti-colonial campaign, which aimed to conquer the entire colonized world.

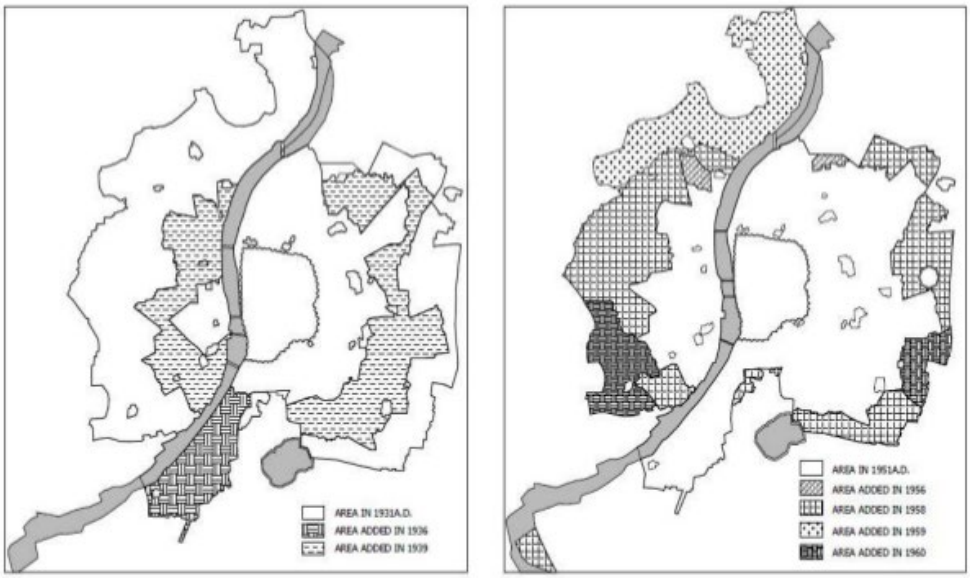


Figure 4.1 : Growth and evolution of Ahmedabad city
Source : (vikashsaini, 2014)

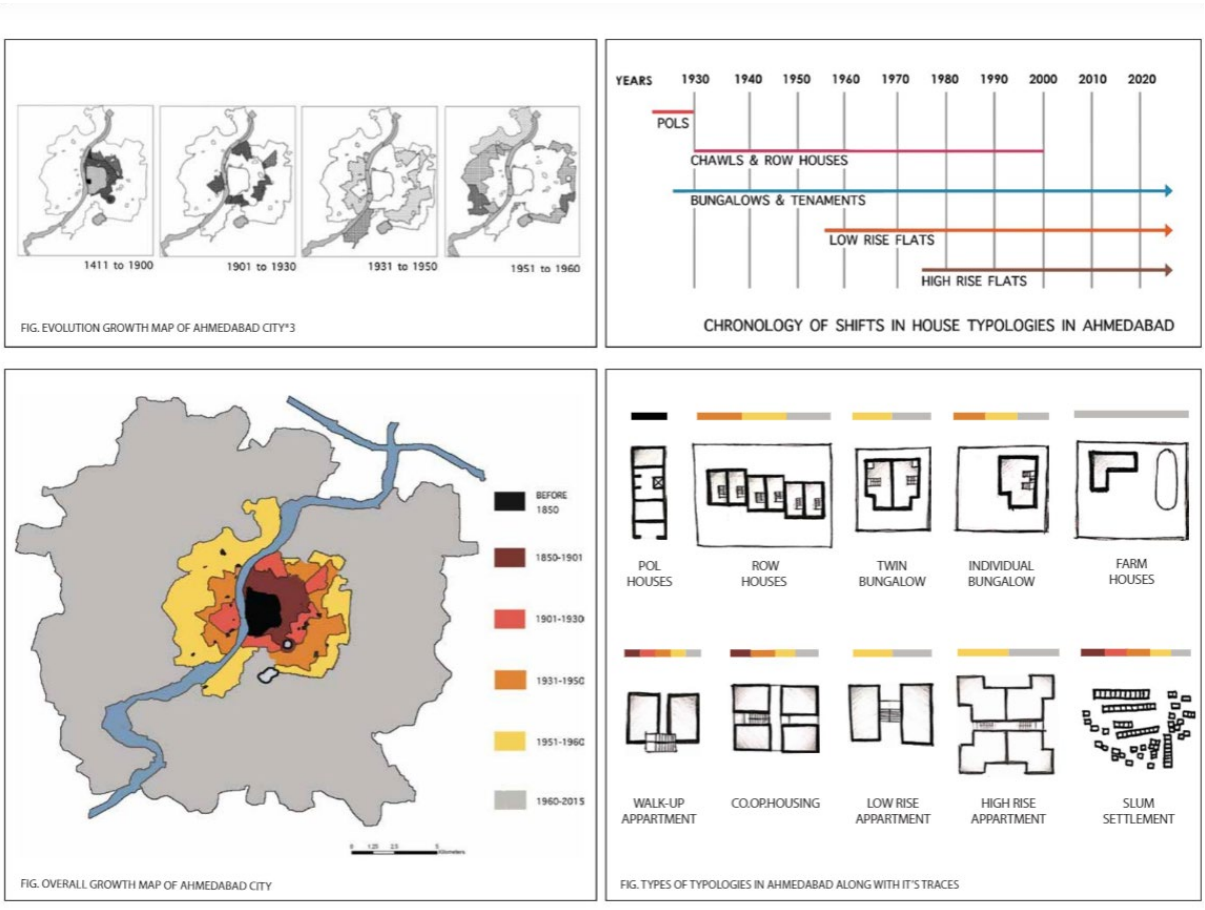


Figure 4.2 : History of housing typologies in Ahmedabad

4.2 House layouts in Ahmedabad city

The research addresses the relationship between spatial configuration and functional efficiency of house layouts in Ahmedabad. The study of house layouts will be done to clarify the same. For this purpose, various housing typologies that can be found in Ahmedabad, as follows :

- Pol houses
- Row houses
- Bungalows

Figure 4.3 : Pol houses

Figure 4.4 : Bungalows

Figure 4.5 : Row houses

4.2.1 Pol house layouts

In 1872, the city had 356 pols. A pol is a residential neighbourhood with clearly defined boundaries. A pol has a single entrance that leads to a main street, followed by secondary streets that lead to the cluster of houses. At the quadrangles, there are temples and mosques. The pol has a fixed border that runs through all of the houses, tying the families together and giving them a sense of belonging. Despite their proximity to public spaces, the pols configuration offered protection to the inhabitants.

People from the same caste occupied a group of pols.

Wooden facades, carved windows, balconies, otlas, khadkis, and chowks adorned the pol buildings. They have narrow and deep house types with an open courtyard and semi-open areas. The linear arrangement depicts the transition from public to semi private private spaces. (shah, 2015)

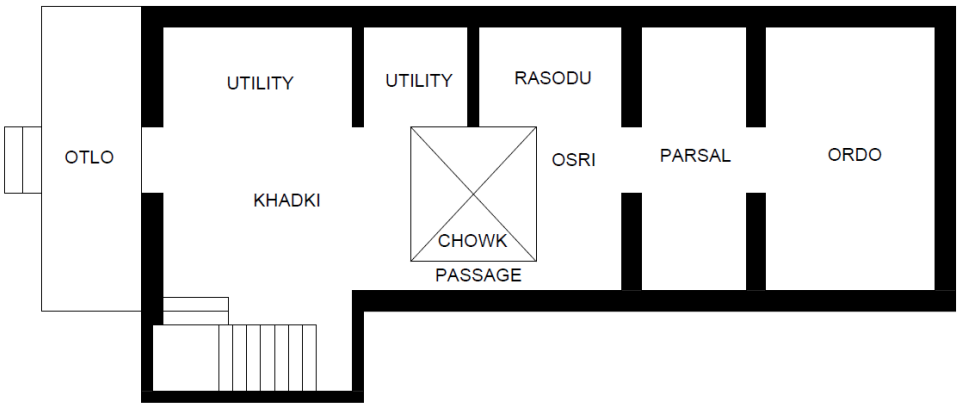


Figure 4.6 : Illustration of a typical pol house's spaces and its spatial configuration
Source : by author

The main elements of the pol houses are as follows :

4 Otla (veranda)

5 Khadki (living space)

6 Chowk (courtyard)

7 Osri (semi open space)

8 Parsal (family space)

9 Ordo (bedroom)

10 Rasodu (kitchen)

11 Utility areas

12 Passage

4.2.2 Row house layouts

In order to design housing, architects collaborated with builders to implement the idea of row housing near the city center for the price of an apartment. Row houses are a group of houses of identical designs that are lined up and separated by a common wall. Row houses, which are derived from the idea of pol houses, have inward-looking open space, territories, and common areas. They also have private open spaces in the front and back of the building.

A row house's layout is divided into three sections: the front yard, built-up space, and backyard. The house is mainly made up of three rooms, a kitchen, and a double-height living room with a view of the backyard. Spaces are adaptable and can be used according to the needs of the user.

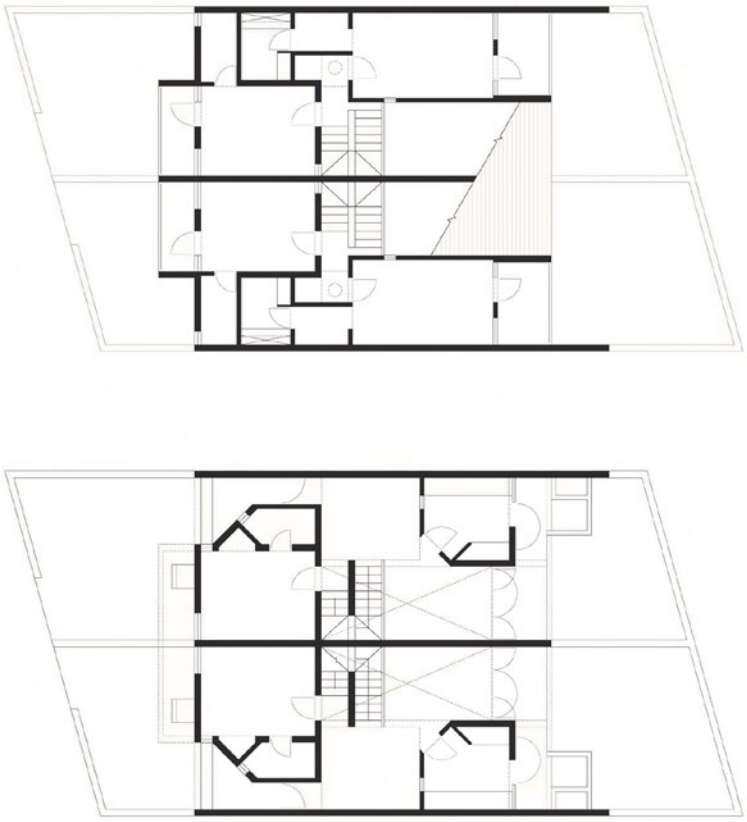


Fig 4.7 : Illustration of Shyamal row house designed by Architect Hasmukh Patel

Source : Architect Hasmukh Patel

4.2.3 Bungalows layouts

The concept of bungalows came in when the elite class started gaining their wealth and status and the city expanded towards the western part. They acquired private land to cater to their housing needs. A bungalow is a small to medium home which started to be built between 1900-1930. It has a private, relatively open, single story plan.

The elements of a bungalow include a front porch, overhangs and horizontal orientation. The bungalow's plan had flexibility in terms of the user's needs and it kept evolving catering to their lifestyles. The main entrance was guarded, leading to the reception area, the dining room, and finally the private bedrooms. Multiplicity in levels was also found where bedrooms and other amenities were arranged on the second floor.

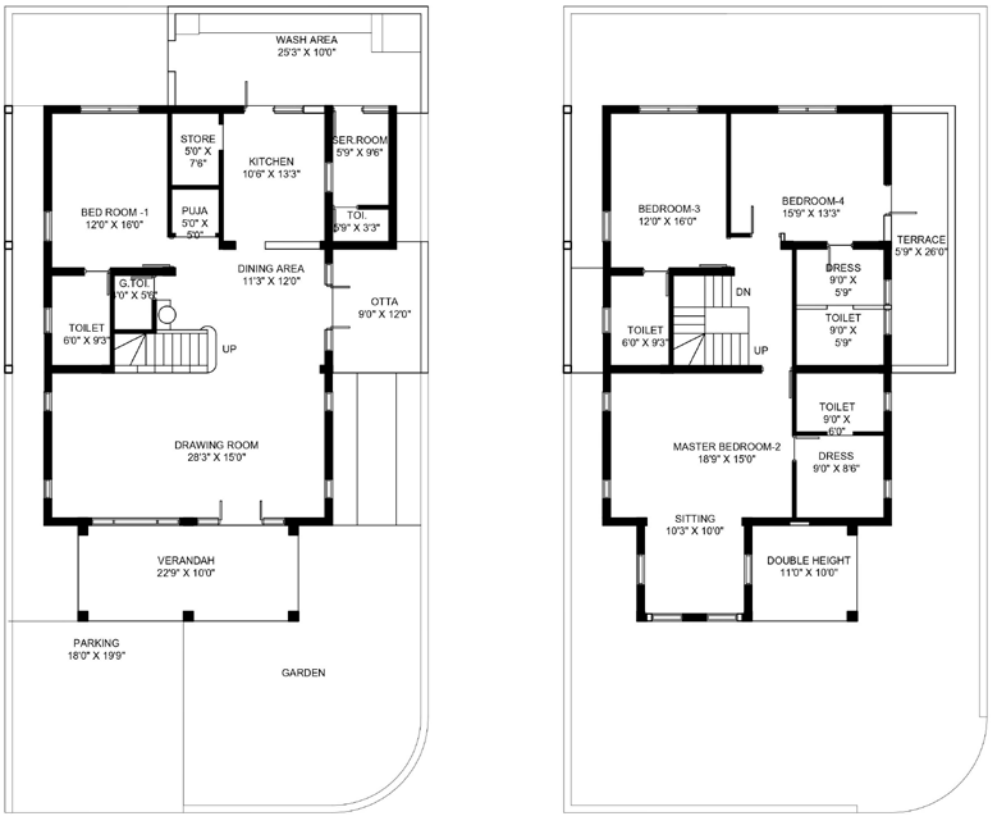


Figure 4.8 : Illustration of a typical bungalow in Vrindavan 7 designed by Architect Dilip Soni

Source : Architect Dilip Soni

CHAPTER 05 : CASE STUDIES, ANALYSIS AND DISCUSSION OF DATA

5.1 Case studies selection

The case studies were limited to the city Ahmedabad in India. The residences were selected were of varying time periods according to their typology to make a comparative analysis.

The cases selected were built between 1920 to 2020 and their built up areas were ranged between 100 to 300 sq m. This range was selected as it becomes a reasonable parameter to compare the houses. If the sizes of the houses are extremely fluctuating, they cannot be compared as if the sizes become more, the functionality decreases in terms of mean depth.

The approximate year of construction of pol houses case studies were of 1920s.

The approximate year of construction of row houses case studies were of 1970-1990

The approximate year of construction of bungalows case studies were of 1990-2020.

These time periods had the most number of cases of the typologies selected.

5.2 Case studies selected

5.2.1 Pol houses :

1. Atul Rana house (1920s)
2. Babukaka house (1920s)
3. Dodhia haveli (1920s)
4. Yellow house (1920s)
5. Modi house (1920s)

5.2.2 Row houses :

6. Jay Shefalli row houses (1974-78)
7. Shyamal row houses (1982)
8. Cosmoville row houses (1986)
9. Readers quarters, Gujarat University (1977)
10. Staff quarters, Gujarat Universty (1977)

5.2.3 Bungalows :

11. Padmakantbhai house (1992-95)

12. Chitrak Shah house (2013)

13. Kartikay Thakkar house (2010)

14. Vrindavan 7 bungalows (2013)

15. Vishnudhara bungalows (2017)

Figure 5.1 : Master plan of Ahmedabad showing the location of the selected case studies

Source : by author

5.3 Case studies of Pol houses

5.3.1 Name : Dodhia Haveli, Ahmedabad (1920s)

Built up area : 162 sq. m.

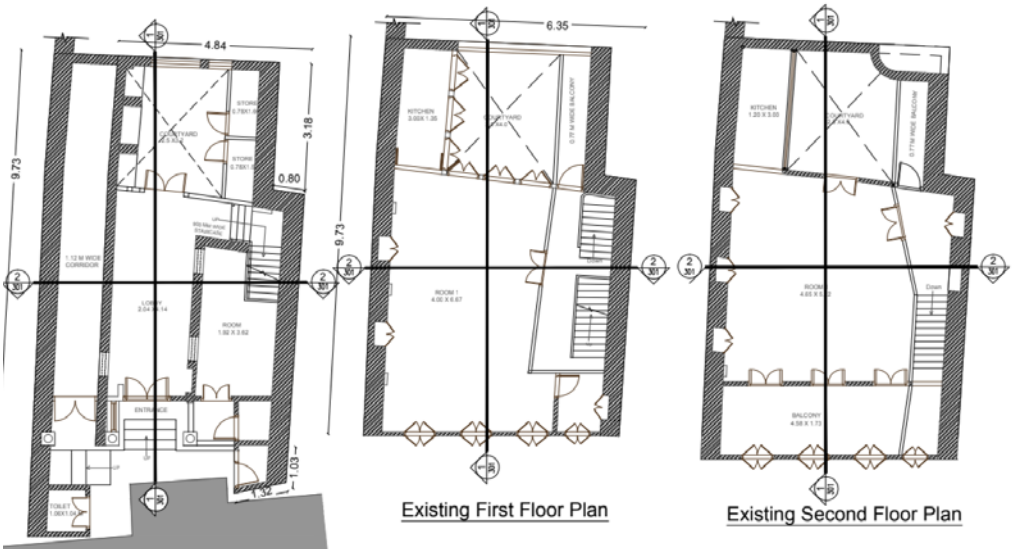


Figure 5.2 : Ground, first and second floor plan of Dodhia Haveli

Source : (Patel, 2021)

5.3.2 Name : Atul Rana house, Ahmedabad (1920s)

Built up area : 160 sq. m.

Figure 5.3 : Ground, first, second and third floor plan of Atul Rana house

Source : (Patel, 2021)

5.3.3 Name : Babukaka house, Ahmedabad

Built up area : 272 sq. m.

Figure 5.4 : Ground, first and second floor plan of Babukaka house

Source : (Patel, 2021)

5.3.5 Name : Yellow house, 2675 Khijda Sheri, Dhal ni pol, Khadia - II

Built up area : 195 sq. m.

Figure 5.5 : Ground, first, second and third floor plan of Babukaka house

Source : (Patel, 2021)

5.3.6 Name : Modi house,Haldarvalo Khacho (1920s)

Built up area : 263 sq. m.

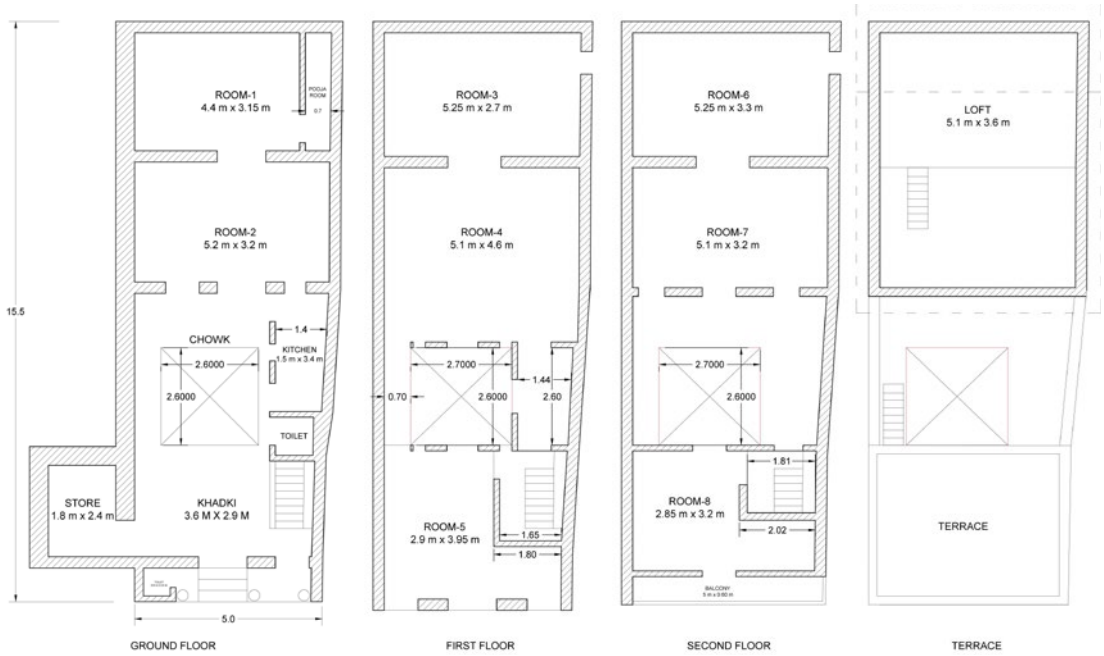


Figure 5.6 : Ground, first, second and third floor plan of Modi house

Source : (Patel, 2021)

5.4 Case studies of Row houses

5.4.1 Name : Jay Sheffali park, Ahmedabad (1974-78)

Architect : Kamal Mangaldas

Area : 188 sq. m

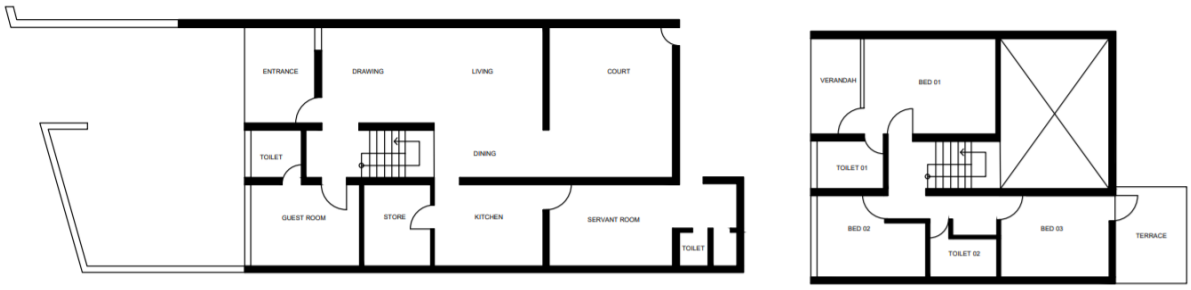


Figure 5.7 : Ground and first floor plan of Jay Sheffali row houses

Source : (mangaldas, 2021)

5.4.2 Name : Shyamal row houses, Ahmedabad (1982)

Architect : Hasmukh Patel

Built up area : 146 sq. m.

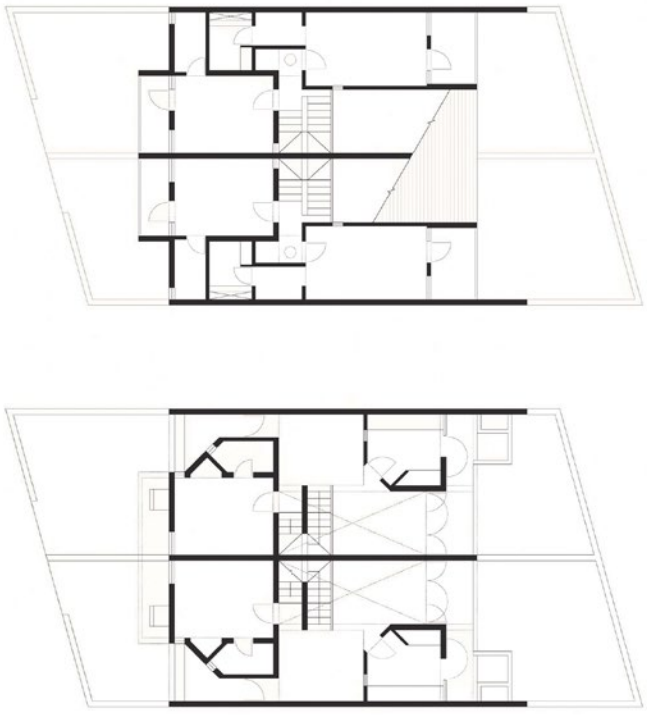


Figure 5.8 : Ground and first floor plan of Shyamal row houses

Source : (patel, 2021)

5.4.3 Name : Cosmoville, Ahmedabad

Architect : Abhikram architects

Built up area : 188 sq m.

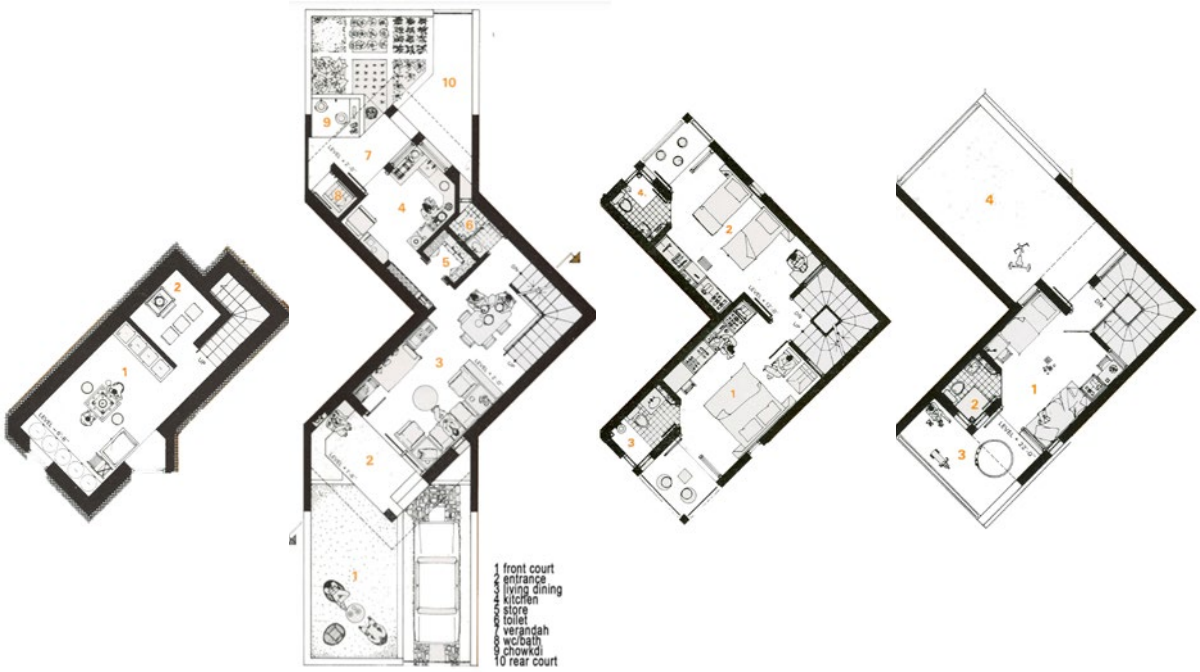


Figure 5.9 : Lower, Ground, First and second floor plans of Cosmoville row houses

Source : (architects, 2021)

5.4.4 Name : Readers quarters, Gujarat university, Ahmedabad

Architect : Hasmukh Patel architects

Built up area : 152 sq m.

Figure 5.10 : Ground and first floor plan of Readers quarters row houses

Source : (Patel, 2021)

5.4.5 Name : Staff quarters, Gujarat university, Ahmedabad

Architect : Hasmukh Patel architects

Built up area : 97 sq m.

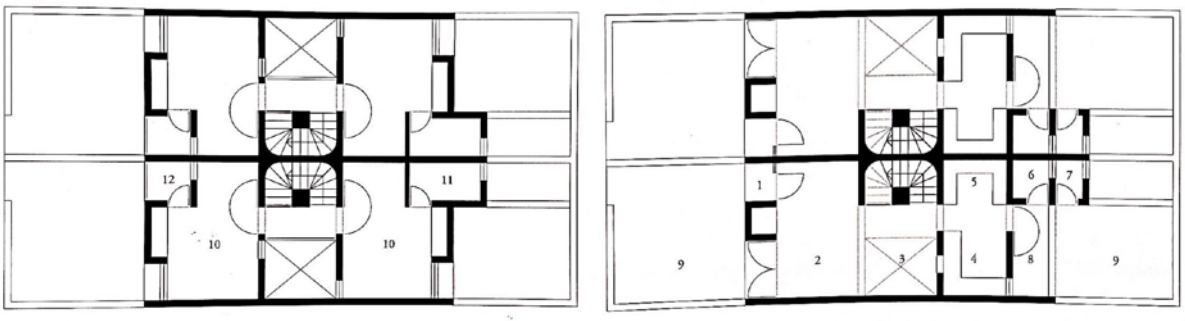


Figure 5.11 : Ground and first floor plan of Staff quarters row houses

Source : (Patel, 2021)

5.5 Case studies of Bungalows

5.5.1 Name : Padmakant Shah house, Ahmedabad (1992-95)

Architect : Kamal Mangaldas architects

Built up area : 255 sq. m.

Figure 5.12 : Ground and first floor plan of Padmakant Shah house

Source : (mangaldas, 2021)

5.5.2 Name : Chitrak Shah house, Ahmedabad (2010)

Architect : Dilip Soni architects

Built up area : 250. m.

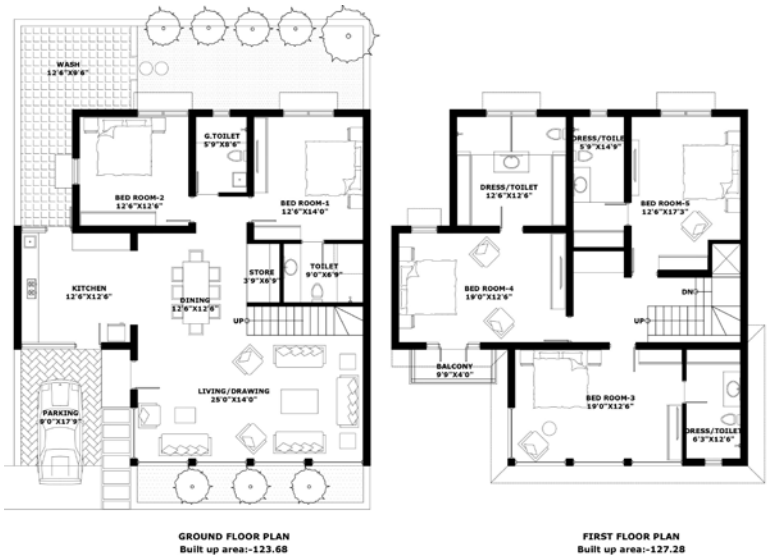


Figure 5.13: Ground and first floor plan of Chitrak Shah house

Source : (Soni, 2021)

5.5.3 Name : Vrundavan 07, Ahmedabad (2013)

Architect : Dilip Soni architects

Built up area : 283 sq. m.

Figure 5.14 : Ground and first floor plan of Vrundavan 7 bungalows

Source : (Soni, 2021)

5.5.4 Name : Kartikay Thakkar house, Ahmedabad (2013)

Architect : Dilip Soni architects

Built up area : 294 sq. m.

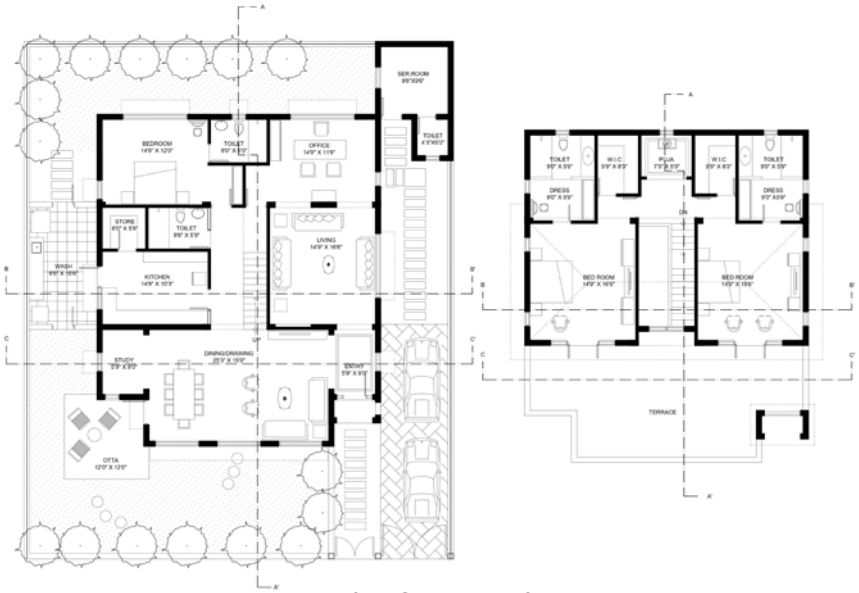


Figure 5.15: Ground and first floor plan of Kartikay Thakkar house

Source : (Soni, 2021)

5.5.5 Name : Vishnudhara bungalow, Ahmedabad

Architect : Dilip Soni architects

Built up area : 228 sq. m.

Figure 5.16 : Ground, first and second floor plan of Vishnudhara bungalows

Source : (Soni, 2021)

5.6 How the analysis was conducted

For the analysis of the data, a mathematical methodology was taken up in the form of formulas and equations. These methods provide results by applying the theory of Space syntax and the methodology as discussed earlier. To conduct the analysis, the samples of house layouts for all typologies are compared for each indicators of Space syntax that are studied.

5.7 Results

5.7.1 Results related to indicator of depth and integration

5.7.1.1 Results related to indicator of depth

For the key spaces in a house layout such as Kitchen, Receiving room, Bedroom, Living room and Toilet, the analysis related to the spatial depth is done as follows.

Table 5.1 : Mean depth values of the key spaces in the house layouts of all typologies

Source : by author

Pol housing	**Dodhia haveli**	**Atul rana house**	**Babukaka house**	**Yellow house**	**Modi house**	**Average**
Kitchen	2.76	2.90	3.10	2.18	3.35	**2.86**
Entrance	3.15	2.70	4.21	1.90	2.94	**2.98**
Bedroom	3.23	3.30	3.10	3.36	3.23	**3.24**
Living room	2.46	2.00	3.36	2.18	2.11	**2.42**
Toilet	4.07	3.60	4.31	4.27	3.88	**4.03**

Row housing	**Jay Shefalli**	**Shyamal Row**	**Cosmoville**	**Readers GU**	**Staff GU**	**Average**
Kitchen	2.61	2.21	3.57	2.37	1.92	**2.53**
Entrance	1.16	3.00	3.30	3.56	3.30	**2.86**
Bedroom	3.00	2.14	3.92	2.37	2.53	**2.79**
Living room	2.72	2.07	3.57	2.62	2.46	**2.68**
Toilet	3.94	3.07	3.73	2.12	1.92	**2.95**

Bungalows	Padmakant Shah	Chitrak Shah	Kartikay Thakkar	Vrindavan 7	Vishnud-hara	Average
Kitchen	2.84	2.80	2.56	2.92	2.85	**2.79**
Entrance	2.05	3.90	3.16	3.32	2.33	**2.94**
Bedroom	3.21	3.00	2.80	2.57	2.38	**2.79**
Living room	2.36	2.45	3.43	2.50	2.42	**2.63**
Toilet	3.00	3.00	3.23	2.60	2.38	**2.84**

a. Kitchen : For the indicator of mean depth by using –Graph, the analysis of Kitchen for all house typologies is as follows :

Pol houses - 2.86

Row houses - 2.53

Bungalows – 2.79

This indicates that the depth decreased from pol houses to row houses, but it increased in bungalow layouts.

b. Entrance : For the indicator of mean depth by using –Graph, the analysis of Entrance area for all house typologies is as follows :

Pol houses - 2.98

Row houses - 2.86

Bungalows – 2.94

This indicates that the depth decreased from pol houses to row houses, but it increased in bungalow layouts.

c. Bedroom : For the indicator of mean depth by using –Graph, the analysis of Bedroom for all house typologies is as follows :

Pol houses – 3.24

Row houses - 2.79

Bungalows – 2.79

This indicates that there is decreased spatial depth from pol houses to row houses and remained the same in bungalows.

d. Living room : For the indicator of mean depth by using –Graph, the analysis of Living room for all house typologies is as follows :

Pol houses – 2.42

Row houses - 2.68

Bungalows – 2.63

This indicates that the depth increased from pol houses to row houses, but it decreased in bungalow layouts.

e. Toilet : For the indicator of mean depth by using –Graph, the analysis of Toilet for all house typologies is as follows :

Pol houses – 4.03

Row houses - 2.95

Bungalows – 2.84

This indicates that there is decreased spatial depth from pol houses to bungalows.

Table 5.2 : Mean depth values of the overall house layouts of all typologies

Source : by author

Pol housing	**Dodhia haveli**	**Atul rana house**	**Babukaka house**	**Yellow house**	**Modi house**	**Average**
Overall depth	3.29	2.72	3.70	2.70	3.25	**3.13**

Row housing	Jay Shefalli	Shyamal Row	Cosmoville	Readers GU	Staff GU	Average
Overall depth	2.87	2.65	4.42	3.02	2.60	**3.11**

Bungalows	Padmakant Shah	Chitrak Shah	Kartikay Thakkar	Vrindavan 7	Vishnudhara	Average
Overall depth	3.28	3.25	3.14	3.38	3.01	**3.21**

This indicates that there is decrease in overall depth of the layout from pol houses to row houses, but it increases in bungalows.

Table 5.3 : Depth levels of the house layouts of all typologies

Source : by author

Pol housing	Dodhia haveli	Atul rana house	Babukaka house	Yellow house	Modi house	Average
Depth level	5	5	9	5	6	**6**

Row housing	Jay Shefalli	Shyamal Row	Cosmoville	Readers GU	Staff GU	Average
Overall depth	5	6	11	7	6	**7**

Bungalows	Padmakant Shah	Chitrak Shah	Kartikay Thakkar	Vrindavan 7	Vishnudhara	Average
Overall depth	6	7	7	9	7	**7.2**

This indicates that there is increase in the depth levels from pol houses to bungalows.

5.7.1.2 Results related to indicator of integration

From the results of A Graph, the indicator of integration degree is found out and is tabulated.

a. Kitchen : The mean integration value of kitchen for all the house typologies are as follows :

Pol houses – 1.11

Row houses – 0.74

Bungalows – 0.76

This indicates that the integration of kitchen decreases from pol houses to row houses, then increases slightly in bungalows. It is highest integrated in row house layouts (0.74) and least integrated in pol houses (1.11)

b. Entrance : The mean integration value of entrance for all the house typologies are as follows:

Pol houses – 1.15

Row houses – 0.71

Bungalows – 0.74

This indicates that the integration of entrance decreases from pol houses to row houses, then increases slightly in bungalows. It is highest integrated in row house layouts (0.71) and least integrated in pol houses (1.15)

c. Bedroom : The mean integration value of bedroom for all the house typologies are as follows :

Pol houses – 1.4

Row houses – 0.72

Bungalows – 0.76

This indicates that the integration of bedroom decreases from pol houses to row houses, then increases slightly in bungalows. It is highest integrated in row house layouts (0.72) and least integrat-

ed in pol houses (1.4)

d. Living room : The mean integration value of living room for all the house typologies are as follows :

Pol houses – 0.93

Row houses – 0.59

Bungalows – 0.6

This indicates that the integration of living room decreases from pol houses to row houses, then increases slightly in bungalows. It is highest integrated in row house layouts (0.59) and least integrated in pol houses (0.93)

e. Toilet : The mean integration value of toilet for all the house typologies are as follows :

Pol houses – 1.64

Row houses – 0.73

Bungalows – 0.75

This indicates that the integration of toilet decreases from pol houses to row houses, then increases slightly in bungalows. It is highest integrated in row house layouts (0.73) and least integrated in pol houses (1.64)

Table 5.4 : Mean values of Real relative asymmetry of the key spaces in the house layouts of all typologies

Source : by author

Pol housing	**Dodhia haveli**	**Atul rana house**	**Babukaka house**	**Yellow house**	**Modi house**	**Average**
Kitchen	1.08	1.42	1.02	0.81	1.22	**1.11**
Entrance	1.31	1.25	1.56	0.63	1.01	**1.15**
Bedroom	1.37	1.73	1.11	1.65	1.14	**1.4**
Living room	1.39	0.74	1.15	0.81	0.55	**0.93**
Toilet	1.91	1.93	1.6	1.26	1.52	**1.64**

Row housing	Jay Shefalli	Shyamal Row	Cosmoville	Readers GU	Staff GU	Average
Kitchen	0.90	0.69	0.83	0.74	0.56	**0.74**
Entrance	0.65	0.92	1.16	1.09	0.42	**0.71**
Bedroom	1.15	0.66	0.63	0.74	0.94	**0.72**
Living room	0.55	0.62	0.84	0.86	0.89	**0.59**
Toilet	1.01	0.90	0.61	0.61	0.56	**0.73**

Bungalows	Padmakant Shah	Chitrak Shah	Kartikay Thakkar	Vrindavan 7	Vishnudhara	Average
Kitchen	0.89	0.82	0.52	0.76	0.84	**0.76**
Entrance	0.49	1	0.68	0.92	0.61	**0.74**
Bedroom	1.07	0.95	0.57	0.59	0.61	**0.76**
Living room	0.67	0.68	0.42	0.59	0.65	**0.60**
Toilet	0.98	0.95	0.63	0.59	0.61	**0.75**

The analysis also shows mean integration values of overall house layouts for all the house typologies.

The results are as follows :

Pol houses – 1.29

Row houses – 0.95

Bungalows – 0.98

This indicates variation in integration values of all house typologies. Row houses are highest integrated and Pol houses are the least integrated.

Table 5.5 : Mean values of Real relative asymmetry of the overall house layouts of all typologies

Source : by author

Pol housing	Dodhia haveli	Atul rana house	Babukaka house	Yellow house	Modi house	Average
RRA	1.42	1.29	1.33	1.23	1.18	**1.29**

Row housing	Jay Shefalli	Shyamal Row	Cosmoville	Readers GU	Staff GU	Average
RRA	1.1	0.87	1.04	1.02	0.97	**0.95**

Bungalows	Padmakant Shah	Chitrak Shah	Kartikay Thakkar	Vrindavan 7	Vishnudhara	Average
RRA	1.11	1.05	0.89	0.92	0.93	**0.98**

As a result of the parameters of indicator of depth and integration, the row houses are the best in terms of functional efficiency.

5.7.2 Results related to indicator of difference factor (H*)

From the results of A Graph, the indicator of difference factor is found out and is tabulated.

The results indicate that the pol houses show the lowest difference factor (0.464) followed by row houses (0.638), then bungalows show the highest difference factor (0.766)

Table 5.6 : Values of difference factor of house layouts of all typologies

Source : by author

Pol housing	Dodhia haveli	Atul rana house	Babukaka house	Yellow house	Modi house	Average
H*	0.44	0.33	0.66	0.30	0.59	**0.464**

Row housing	Jay Shefalli	Shyamal Row	Cosmoville	Readers GU	Staff GU	Average
H*	0.81	0.51	0.83	0.58	0.46	**0.638**

Bungalows	Padmakant Shah	Chitrak Shah	Kartikay Thakkar	Vrindavan 7	Vishnudhara	Average
H*	0.69	0.72	0.82	0.87	0.73	**0.766**

Even though the indicator of difference factor provided the result of pol houses layouts being the least differentiated, followed by row houses ; the house layouts of row houses are the most functionally efficient according to this research.

5.7.3 Results related to indicator of Space-Link ratio

According to the justified graphs made for the house layouts of pol housing, 80% of the houses had "ringy" structures. The space-link ratio for pol houses is 1.156. This shows that the layouts were predominantly "ringy" but with the least number of rings as compared to row housing and bungalows layouts. But they were somewhat distributed in general.

According to the justified graphs made for the house layouts of row housing, 100% of the houses had "ringy" structures. The space-link ratio for pol houses is 1.416. This shows that the layouts were "ringy" with the most number of rings. They were distributed and more functional in general.

According to the justified graphs made for the house layouts of bungalows, 100% of the houses had "ringy" structures. The space-link ratio for pol houses is 1.392. This shows that the layouts were "ringy" with lesser number of rings as compared to row houses. They were distributed and functional in general.

Table 5.7 : Values of the mean of space-link ratio of overall house layouts of all typologies

Source : by author

Pol housing	**Dodhia haveli**	**Atul rana house**	**Babukaka house**	**Yellow house**	**Modi house**	**Average**
Space-Link ratio (R)	1	1.15	1.14	1.16	1.33	**1.156**

Row housing	**Jay Shefalli**	**Shyamal Row**	**Cosmoville**	**Readers GU**	**Staff GU**	**Average**
Space-Link ratio (R)	1.79	1.73	1.41	1.12	1.03	**1.416**

Bungalows	**Padmakant Shah**	**Chitrak Shah**	**Kartikay Thakkar**	**Vrindavan 7**	**Vishnudhara**	**Average**
Space-Link ratio (R)	1.24	1.78	1.2	1.5	1.24	**1.392**

5.7.4 Results related to indicator of Space-Type

The analysis shows the degree of space-ness for the overall house layouts for Pol housing. The values in the table indicate that a type and b type of spaces are more significant than c and d type of spaces.
For row housing, the values in the table indicate that c and d type of spaces are more significant than a and b type of spaces.
For bungalows, the values in the table indicate that c and d type of spaces are more significant than a and b type of spaces.

Overall, it is seen that the Row houses have highest c and d type spaces

Table 5.8 : Values of the mean of space-type ratio of the overall house layouts of all typologies in detail.

Source : by author

Pol housing	**Dodhia haveli**	**Atul rana house**	**Babukaka house**	**Yellow house**	**Modi house**	**Average**
a-type spaces	0.38	0.5	0.32	0.18	0.35	**0.346**
b-type spaces	0.38	0.6	0.32	0.18	0.29	**0.354**
c-type spaces	0.30	0	0.42	0.45	0.29	**0.292**

Row housing	**Jay Shefalli**	**Shyamal Row**	**Cosmoville**	**Readers GU**	**Staff GU**	**Average**
a-type spaces	0.33	0.43	0.46	0.25	0.23	**0.340**
b-type spaces	0.33	0.14	0.35	0.17	0.15	**0.228**
c-type spaces	0.21	0.29	0.19	0.33	0.30	**0.264**

Bungalows	**Padmakant Shah**	**Chitrak Shah**	**Kartikay Thakkar**	**Vrindavan 7**	**Vishnudhara**	**Average**
a-type spaces	0.32	0.30	0.38	0.36	0.29	**0.330**
b-type spaces	0.21	0.20	0.23	0.29	0.24	**0.234**
c-type spaces	0.37	0.35	0.07	0.21	0.14	**0.228**

Table 5.9 : Values of the mean of space-type ratio of overall house layouts of all typologies.

Source : by author

Space type	Pol houses	Row houses	Bungalows
a-ness	0.346	0.34	0.33
b-ness	0.354	0.228	0.234
c-ness	0.292	0.264	0.228
d-ness	0.112	0.202	0.236

5.8 Discussion and interpretation of data

5.8.1 Discussion of the data of indicators of depth and integration

5.8.1.1 Discussion of the indicator of depth

The indicator of depth deals with efficiency of the functions. The low values suggest high integration and more importance and the high values suggest high segregation and less importance. The key spaces of the house layout (Kitchen, Entrance, Bedroom, Living room and Toilet)will be discussed and the results will be interpreted.

a. Kitchen : The least mean depth of the kitchen is in the row layouts, then bungalows, then pol houses. This means that kitchen is the most important in row houses and hence, we can use models of kitchen from bungalow layouts for maximum functional efficiency.

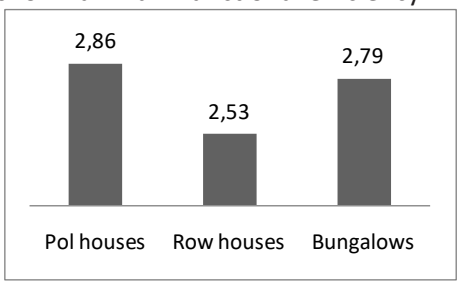


Figure 5.17 : MD values of kitchen in the house layouts for all house typologies

Source : by author

b. Entrance : The least mean depth of the entrance is in the row houses layouts, then bungalows, then pol houses. This means that entrance is the most important in row houses and hence, we can use models of kitchen from row houses layouts for maximum functional efficiency.

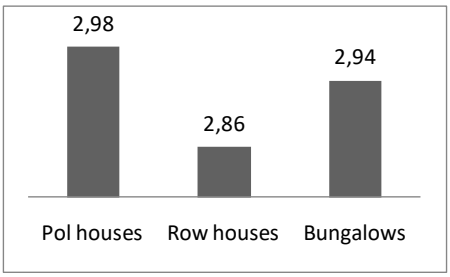


Figure 5.18 : MD values of entrance in the house layouts for all house typologies

Source : by author

c. Bedrooms : The least mean depth of the bedrooms is in the row house layouts, then bungalows, then pol houses. This means that bedroom is the most important in row houses and hence, we can use models of kitchen from row house layouts for maximum functional efficiency.

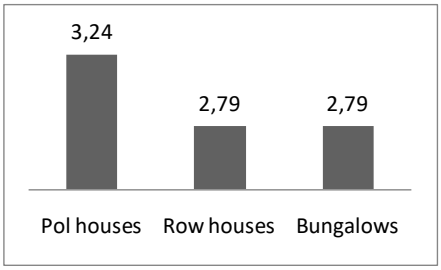


Figure 5.19 : MD values of bedroom in the house layouts for all house typologies

Source : by author

d. Living room : The least mean depth of the living room is in the pol house layouts, then bungalows, then row houses. This means that living room (court yard) is the most important in pol houses and hence, we can use models of living room from pol house layouts for maximum functional efficiency.

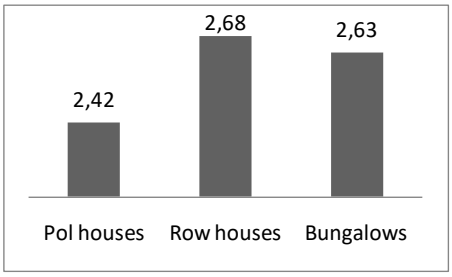


Figure 5.20 : MD values of living room in the house layouts for all house typologies

Source : by author

e. Toilet : The least mean depth of the toilet is in the bungalow layouts, then row houses, then pol houses. This means that toilet is the most important in bungalows and hence, we can use models of toilet from bungalow layouts for maximum functional efficiency.

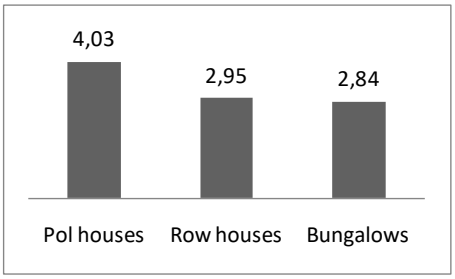


Figure 5.21 : MD values of toilet in the house layouts for all house typologies
Source : by author

From these above inferences, we can conclude that the house layouts of bungalows prove that they are the most functionally efficient, followed by row houses for the indicator of mean depth of the key spaces in the house (kitchen, entrance, bedroom, living room, toilet)

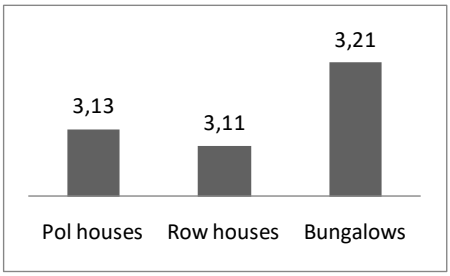


Figure 5.22 : MD values of overall house layouts of all house typologies

Source : by author

For the spatial depth of the house layouts, the row houses show more functionality, followed by the pol houses.

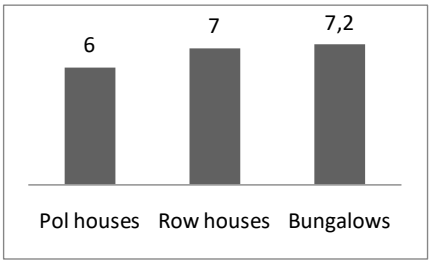


Figure 5.23 : Values of spatial depth level of overall house layouts of all house typologies

Source : by author

5.8.1.2 Discussion of the indicator of integration

The indicator of integration deals with efficiency of the functions. The low values suggest high integration and more importance and the high values suggest high segregation and less importance. The key spaces of the house layout (Kitchen, Entrance, Bedroom, Living room and Toilet) will be discussed and the results will be interpreted.

a. Kitchen : The most integrated kitchen is in the row house layouts, then bungalows, then pol houses. This means that kitchen is the most important in row houses and hence, we can use models of kitchen from row houses layouts for maximum functional efficiency.

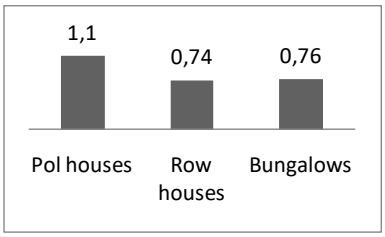


Figure 5.24 : Values of mean integration of kitchen in the house layouts for all house typologies

Source : by author

b. Entrance : The most integrated entrance is in the row houses layouts, then bungalows, then pol houses. This means that entrance is the most important in row houses and hence, we can use models of entrance from row houses layouts for maximum functional efficiency.

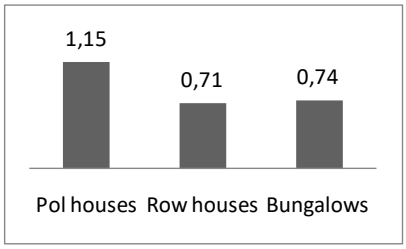


Figure 5.25 : Values of mean integration of entrance in the house layouts for all house typologies

Source : by author

c. Bedroom : The most integrated bedroom is in the row houses layouts, then bungalows, then pol houses. This means that bedroom is the most important in row houses and hence, we can use models of bedroom from row houses layouts for maximum functional efficiency.

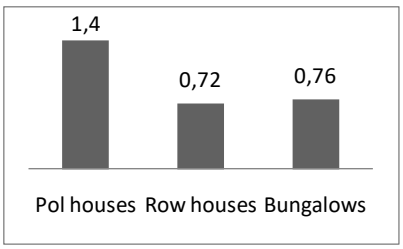


Figure 5.26 : Values of mean integration of bed room in the house layouts for all house typologies

Source : by author

d. Living room : The most integrated living room is in the row houses layouts, then bungalows, then pol houses. This means that living room is the most important in row houses and hence, we can use models of living room from row houses layouts for maximum functional efficiency.

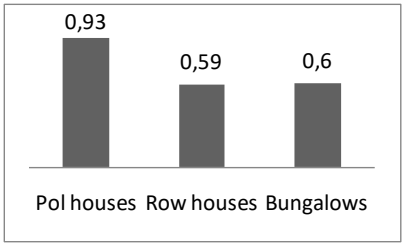


Figure 5.27 : Values of mean integration of living room in the house layouts for all house typologies

Source : by author

e. Toilet : The most integrated entrance is in the row houses layouts, then bungalowss, then pol houses. This means that entrance is the most important in row houses and hence, we can use models of toilet from row houses layouts for maximum functional efficiency.

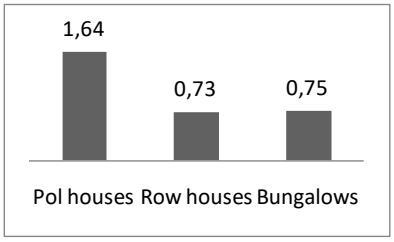


Figure 5.28 : Values of mean integration of toilet in the house layouts for all house typologies

Source : by author

From these above inferences, we can conclude that the house layouts of row houses prove that they are the most functionally efficient, followed by bungalows for the indicator of mean depth of the key spaces in the house (kitchen, entrance, bedroom, living room, toilet)

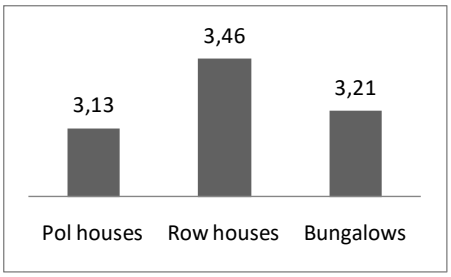


Figure 5.29 : Values of integration of overall house layouts of all typologies.

Source : by author

For the integration of the house layouts, the row houses show more functionality, followed by the bungalows.

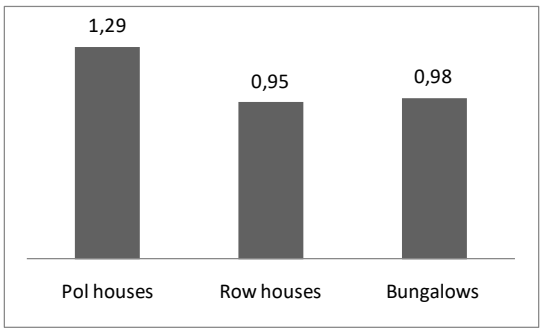


Figure 5.30 : Values of spatial depth level of overall house layouts of all house typologies

Source : by author

The analysis proves that the indicators of depth and integration provide similar results of the row house layouts being the most functionally efficient.

5.8.2 Discussion of the difference factor (H*)

The indicator of difference factor deals with differentiations in terms of house layouts. The low values which are near to 0 suggest high differentiation and high functional efficiency and the high values which are near 1 suggest low differentiation and low functional efficiency.
The analysis suggests that the pol houses have highest differentiation, followed by row houses, then bungalows. This means that the spaces are independent and non-interchangeable with other spaces, which provides high functional efficiency.

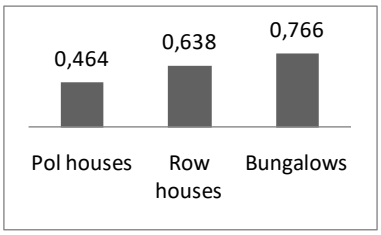


Figure 5.31 : Values of difference factor of overall house layouts of all house typologies.

Source : by author

5.8.3 Discussion of the indicator of Space-Link ratio

The indicator of space-link ratio deals with distributedness in terms of the structure of the house layouts. The values are close to 1, the ones more than 1 suggest more ringiness, distributedness, high flexibility and functional efficiency. The values which are less than 1 suggest a tree-like system, less distributedness, less flexibility and less functional efficiency.

The analysis suggests that the row houses are the most functionally efficient in terms of space-link ratio, followed by bungalows, then pol houses.

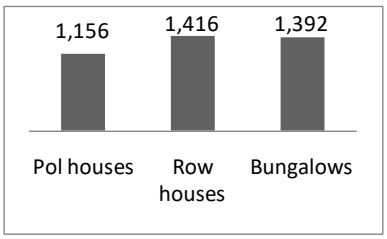


Figure 5.32 : Values of space-link ratio of overall house layouts of all house typologies.

Source : by author

5.8.4 Discussion of the indicator of Space-Type

The indicator of space-type deals with the proportion of a-ness, b-ness, c-ness and d-ness of the house layouts. The functional efficiency increases when the c-ness and d-ness of the layout increases, which suggests that the layout is ringy. It decreases with more amount of a-ness and b-ness of the layout, which suggests that the layout is tree-like.

The analysis suggests that the row houses are the most functionally efficient in terms of space-type, followed by bungalows, then pol houses.

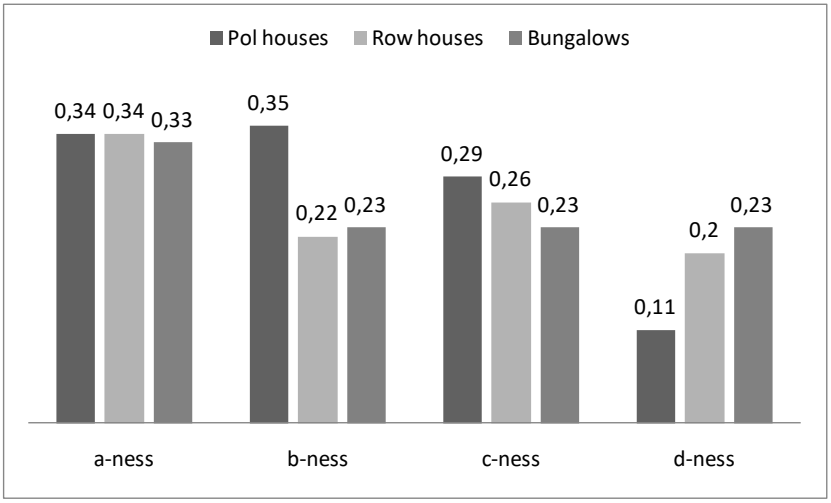


Figure 5.33 : Values of space-type of overall house layouts of all house typologies.

Source : by author

CHAPTER SIX : CONCLUSIONS

6.1 Summary

This research studies the spatial configuration and the functional efficiency of the house layouts in Ahmedabad. The design of the house layouts in Ahmedabad have been affected by many factors. The study has been done to accomplish the need of sustainable architecture by analysing the house layouts of various typologies in Ahmedabad, by specifically analysing the design of the house layouts in the terms of functionality. To measure the functional effficiency of the layouts, the spatial configuration has been studied. The parameters of Space syntax which aid in finding the functional efficiency have been taken into consideration, and if there are any modifications in the formations of the layouts, the functional efficiency might be weakened.

To analyse the functionality, the research questions have been brought up which will identify its various parameters. Hence, the house layouts of Ahmedabad have been divided according to various typologies namely, Pol houses, Row houses and Bungalows.

To plan out the study, a methodology has been picked up which will analyse the level of functional efficiency. By the use of a software called AGraph, the spatial configuration is studied, and it provides quantitative measurements to analyse its functional efficiency.

6.2 Research hypothesis validation

The research hypothesis was to test the assumption that spatial configuration affects the functional efficiency of house layouts of various typologies in Ahmedabad.

For the testing, these research questions were raised :

6.3 Conclusions

To solve the research question, the analysis of the results was done and conclusions were made, which supported the research hypothesis. The conclusions are :

6.3.1 Research question 1:

What are the characteristics of spatial configuration affecting the functional efficiency of house layouts of various typologies?

Answer of research question 1:

The modifications in house layouts in each period of time, starting from pol houses to row houses to bungalows proved that there are some factors and reasons which affect the same.

In chapter 5, the characteristics which affected spatial configuration were studied by the way of Space syntax's indicators and parameters. For the results of indicator of spatial depth for the key spaces in the house layout, the layouts of row houses came up to be the most functionally efficient as they had less spatial depth in terms of spatial configuration, while the bungalows had the most spatial depth, so they were less functional.

For the results of the indicator of integration, the layouts of row houses were the most integrated and the pol houses were the least integrated. So, it is proved that the spatial configuration affects the functional efficiency in terms of house layouts.

The layouts of row houses proved to be the most functionally efficient in terms of both spatial depth and integration.

6.3.2 Research question 2:

How the process of spatial configuration and functional efficiency is being affected over time?

Answer of research question 2:

One of the main reasons that spatial configuration in architecture is affected is due to time. With time and advancements, certain factors such as social, political, economical, etc. are affected on the spatial configuration of the house layouts of various typologies. In Ahmedabad, the Pol housing was built, then after certain modifications due to advancement, money and western influences, the concept of row houses as a community came up. With time and growing economical conditions of the people, the requirement of individual houses arose, which resulted in the development of the bungalows.

From the parameters of space syntax, the functionality of the various layouts are studied on the basis of various parameters. The parameter of space-type ratio was conducted on the layouts. The row houses were again, the most functionally efficient, followed by bungalow layouts with a very slight difference in results, as it had more number of c-type and d-type spaces ; and less number of a-type and b-type spaces. This proves that the spatial configuration which affects the functionality of the layouts is changing with time and modifications.

6.3.3 Research question 3:

Are the pol house layouts inefficient in terms of functionality?

Answer of research question 3:

Pol houses were amongst the first in the city of Ahmedabad. After modifications in the house forms due to technological advances, western influences, social factors, political factors and the rising economy, the row houses were developed, followed by bungalows. By analysing the spatial structures with the indicators of Space syntax, some functional disorders in the layouts of pol houses are realized.

Studying the indicator of the mean depth, it is realized that the pol house layouts have more spatial depth in their structures as compared to the row house layouts. This results in functional inefficiencies. By measuring the indicator of integration, it is realized that the pol house layouts are the least integrated as compared to row houses and bungalow layouts. This proves that the spatial structure is less integrated and less important, hence it is less functional.

Studying the indicator of the difference factor of space, it is realized that the pol houses have the most degree of difference in the values of integration ; which means that the spaces in a pol house are not interchangeable with others. This proves that there is a strong social factor in the ordering of the spaces.

Studying the space-link ratio, it is realized that the pol house layouts are less ringy in nature, hence they are not 100% distributed. This proves that there are less number of routes to go from one space to another which increases the segregation and decreases the functional efficiency.

Studying the space-type, it is realized that pol houses have more a-type and b-type of spaces in their layout, which proves that there is less number of ways to circulate around the layout.

The results of the indicators prove that there is clearly a weakness in the functionality of the house and might not be very functionally efficient.

6.3.4 Research question 4:

Are the row house layouts efficient in terms of functionality?

Answer of research question 4:

The row houses developed after the pol houses in Ahmedabad as a result of modifications due to technological advances, western influences, social factors, political factors and the rising economy.

Studying the indicator of the mean depth, it is realized that the row house layouts have less spatial

depth in their structures as compared to the other house layouts. This results in functional efficiency. By measuring the indicator of integration, it is realized that the row house layouts are the most integrated as compared to pol houses and bungalow layouts. This proves that the spatial structure is more integrated and more important, hence it is more functional.

Studying the indicator of the difference factor of space, it is realized that the row houses have moderate degree of difference in the values of integration ; which means that the spaces in a row house are less interchangeable with others. This proves that there is a strong social factor in the ordering of the spaces.

Studying the space-link ratio, it is realized that the row house layouts are ringy in nature, hence they are very distributed. This proves that there are more number of routes to go from one space to another which increases the integration and increases the functional efficiency.

Studying the space-type, it is realized that row houses have more c-type and d-type of spaces in their layout, which proves that there is more number of ways to circulate around the layout.

The results of the indicators prove that there is clearly strength in the functionality of the house and might be very functionally efficient.

6.3.5 Research question 5:

Are the bungalow layouts inefficient in terms of functionality?

Answer of research question 5:

The bungalows developed after the row houses in Ahmedabad as a result of modifications due to technological advances, western influences, social factors, political factors and the rising economy.

Studying the indicator of the mean depth, it is realized that the bungalow layouts have the most spatial depth in their structures as compared to the other layouts. This results in functional inefficiencies. By measuring the indicator of integration, it is realized that the bungalow layouts are less integrated as compared to row houses. This proves that the spatial structure is less integrated and less important, hence it is less functional.

Studying the indicator of the difference factor of space, it is realized that the bungalows have the most degree of difference in the values of integration ; which means that the spaces in a bungalow are not interchangeable with others. This proves that there is a weak social factor in the ordering of the spaces.

Studying the space-link ratio, it is realized that the bungalow layouts are lesser ringy in nature as

compared to row houses, hence they are not 100% distributed. This proves that there are less number of routes to go from one space to another which increases the segregation and decreases the functional efficiency.

Studying the space-type, it is realized that bungalows have less number of c-type and d-type spaces as compared to row houses, which proves that there is less number of ways to circulate around the layout.

The results of the indicators prove that there is clearly a weakness in the functionality of the house and might not be very functionally efficient.

6.3.6 Research question 6:

How can the theory of space syntax evaluate the spatial configuration affecting the functional efficiency of the house layouts?

Answer of research question 6:

The theory and parameters of space syntax is used to analyse the spatial configuration and functional efficiency of the house layouts in Ahmedabad.

For the purpose of this research, each space in each layout has been considered as independent with some function. Taking each space, it is connected with all the other spaces in one house layout. Each space will have its own function and effectiveness in evaluating functional efficiency of the layout as a whole. The indicators of Space syntax are applied to test the functionality of the layouts, such as :

1. Mean depth and Integration of space :

The mean depth of the spaces shows the depth and isolation of a space in a house layout. The integration of a space shows how connected and integrated a space is with all the other spaces in a house layout. By knowing the results of each space using this indicator, we can judge the functional efficiency of a house layout.

2. Difference factor of a space :

The layouts which have high differentiation of spaces are more efficient and show the level of functional efficiency of the system. It proves that the space is interchangeable with other spaces because it has its own function and value.

3. Space-link ratio:

The indicator of space-link ratio deals with distributedness in terms of the structure of the house layouts. It shows the ringiness of the house layout which proves the interconnection of the spaces. If the house layout is more ringy and less tree-like, the house layout is more functionally efficient.

4. Space-type :

The indicator of space-type deals with the proportion of a-ness, b-ness, c-ness and d-ness of the house layouts. The functional efficiency increases when the c-ness and d-ness of the layout increases, which suggests that the layout is ringy. It decreases with more amount of a-ness and b-ness of the layout, which suggests that the layout is tree-like.

For all the indicators, the results are showing that the row houses are most functionally efficient in terms of spatial configuration.

BIBLIOGRAPHY

al, H. e. (1987a). Ideas are in things: An application of the space syntax methods to discovering house genotypes.

Al-Beiruti. (1992). Architectural evolution of house in Baghdad during 20th centurywith. Baghdad, Iraq: Unpublished PHD Thesis.

Amorim. (2001). Houses of Recife: from diachrony to synchrony. Atlanta.

Amorim, L. (1997). The sector's paradigm: Understanding modern functionalism and its effects in configuring domestic space. London.

architects, A. (2021, 03 05). Cosmoville. Ahmedabad, Gujarat, India.

Aspinall, P. (1993). Aspects of spatial experience and structure. London.

Bellal. (2007). Spatial interface between inhabitants and visitors in M'zab houses. Istanbul.

Bustard. (1999). Space, evolution, and function in the houses of Chaco Canyon.

Desai, B. P. (2016). Readers quarters gujarat university. In B. P. Desai, The architecture of Hasmukh C Patel : Selected projects 1963-2003 (p. 394). Ahmedabad: Mapin publishing.

G., D. P. (2003). Spatial analysis of different home environments in the city of Trabzon, Turkey. London.

Guney. (2005). Spatial types in Ankara apartments. Netherlands.

Hanson. (2003). Decoding Homes and Houses. Cambridge.

Hanson, H. &. (1988). the social logic of space. Cambridge.

Hillier. (1993). A Partial Account of the Ascent from Building as Cultural Transmission to Architecture as Theoretical Concretion. Rizzoli International Publications.

Hillier. (2007). Space is a machine : A configurational theory of architecture. London: Space syntax .

Mangaldas, K. (n.d.). Google chrome. Retrieved 03 02, 2021, from Kamal Mangaldas architects: https://kamalmangaldas.net/type/housing

Manum. (1999). Spatial themes among the traditional houses of Turkey. Brasilia.

Monteiro. (1997). Activity analysis in houses of Recife, Brazil. . Lodnon.

Mzoori, F. A. (2004). Spatial configuration and functional efficiency of house layouts. Erbil: Lambert.

Nesbitt, K. (1965-1995). Theorizing a new agenda for architecture: An anthology of architectural theory. New york: Princeton Architectural Press.

Nijaidi, A. (1985). Flexibility in the design of a building. Oxford.

Onder. (2002). A new housing group for sub-residential area in Samarkand: A morphological comparison.

Osman, K. M. (1993). The Space Syntax Methodology: Fits and Misfits.

Ostwald, M. (2011). The mathematics of spatial configuration : Revisiting, Revising and critiquing justified plan graph theory. New south wales, Australia.

Patel, R. (2021, 02 25). Pol houses. (P. Shah, Interviewer)

Rapoport, A. (1969). House form and culture. New Jersey: Englewood cliffs.

Rapoport, A. (1977). Human aspects of urban form. Oxford.

Rapoport, A. (1982). The meaning of the built environment : A nonverbal communication approach. Sage: Tucson.

Robinson, J. W. (2001). Institutional Space, Domestic Space, and Power Relations:. Atlanta: Proceedings of the third International Space Syntax Symposium.

shah, R. (2015). issuu.

Shoul. (1993). The Spatial Arrangements of Ordinary English Houses.

Sungur. (2001). Analysis of Effect of Housing Morphology on User Satisfaction. Istanbul.

Toker, T. a. (2003). Family structure and spatial configuration in Turkish house form in Anatolia from late nineteenth century to late twentieth century. London.

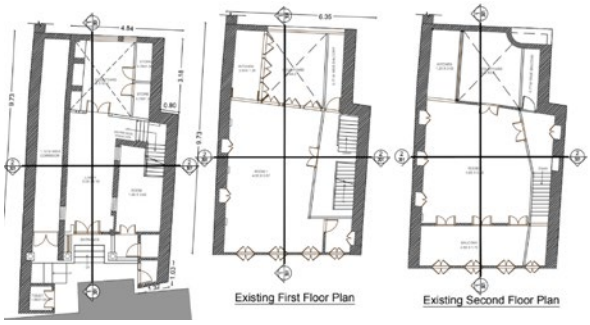
vikashsaini. (2014, 4 10). slide share. Retrieved 5 17, 2021, from Slide share: https://www.slideshare.net/vikashsaini78/ahmedabad-33357196

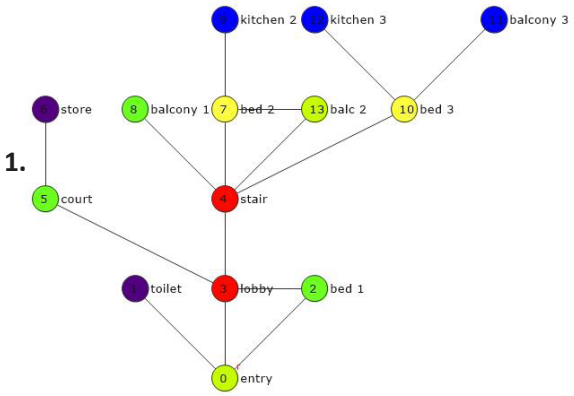
Zako. (2006). The power of the veil: Gender inequality in the domestic setting of traditional courtyard houses. UK.

APPENDIX – A

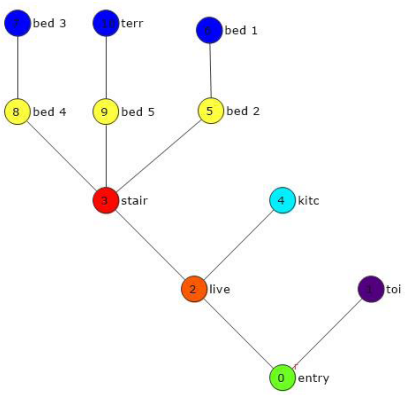
Justified graphs of pol house layouts (5 graphs)

1.

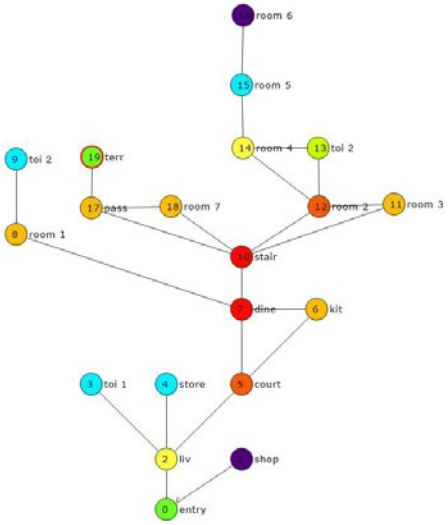




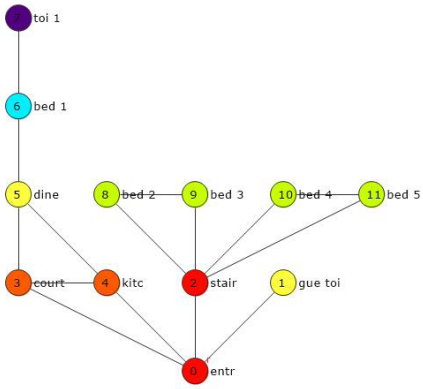
2. Name : Atul Rana house



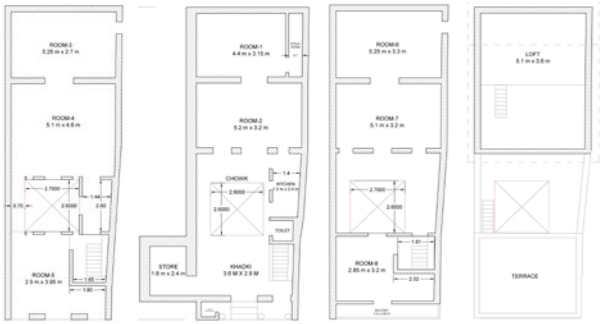
3. Name : Babukaka house

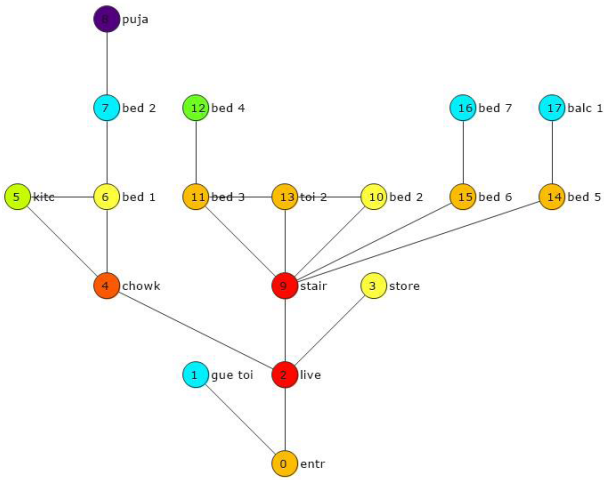


4. Name : Yellow house



5. Name : Modi house

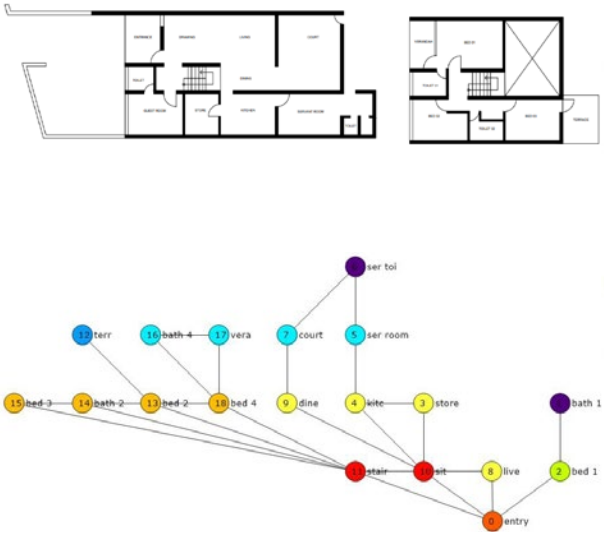




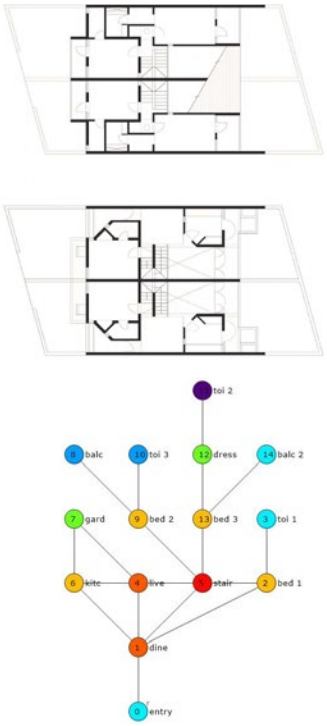
APPENDIX – B

Justified graphs of row house layouts (5 graphs)

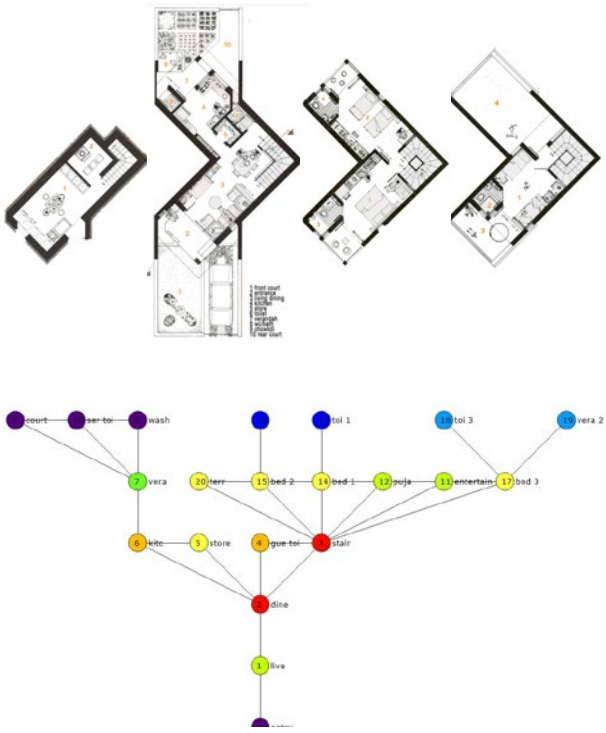
1. Name : Jay Sheffali row houses



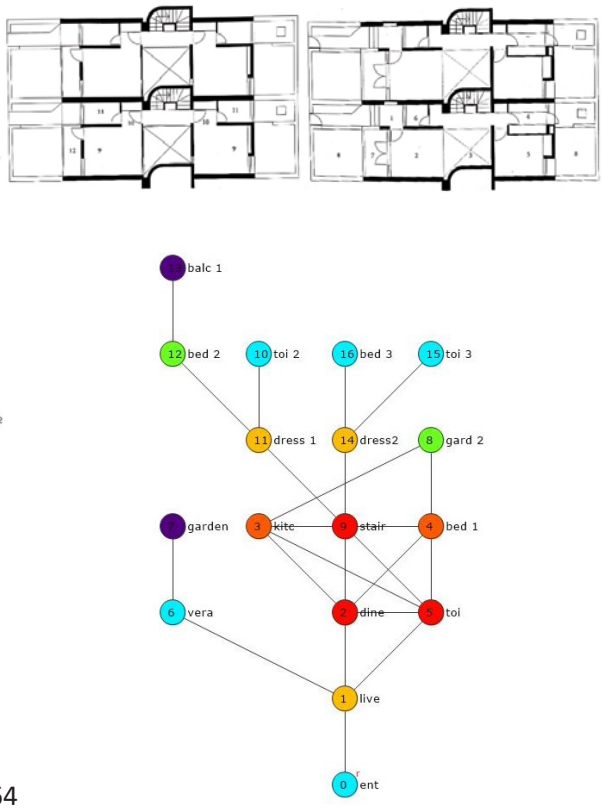
2. Name : Shyamal row houses



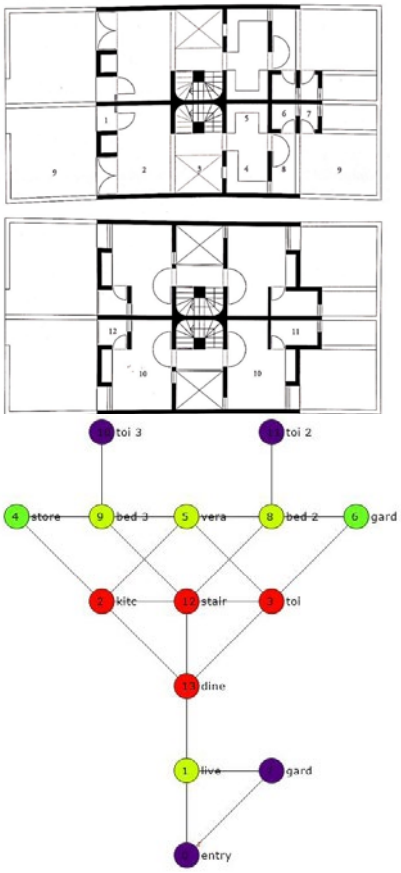
3. Name : Cosmoville row houses



4. Name : Readers quarters, GU



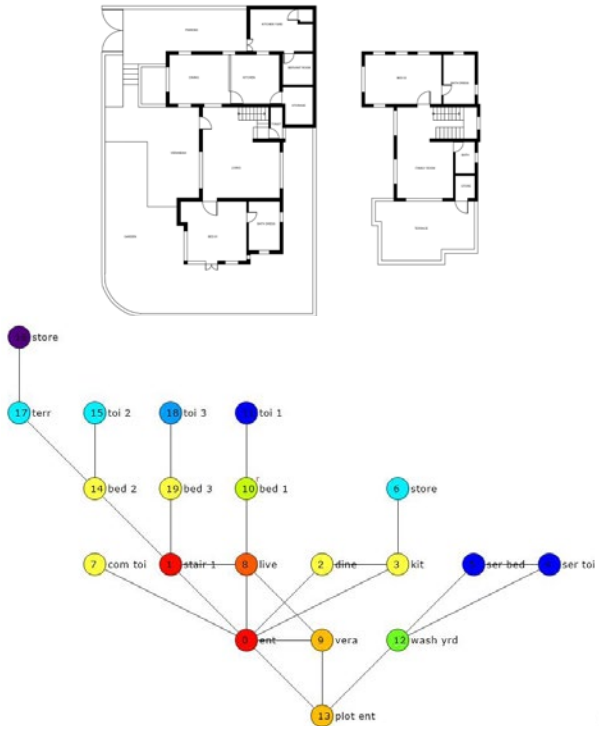
5. Name : Staff quarters, GU



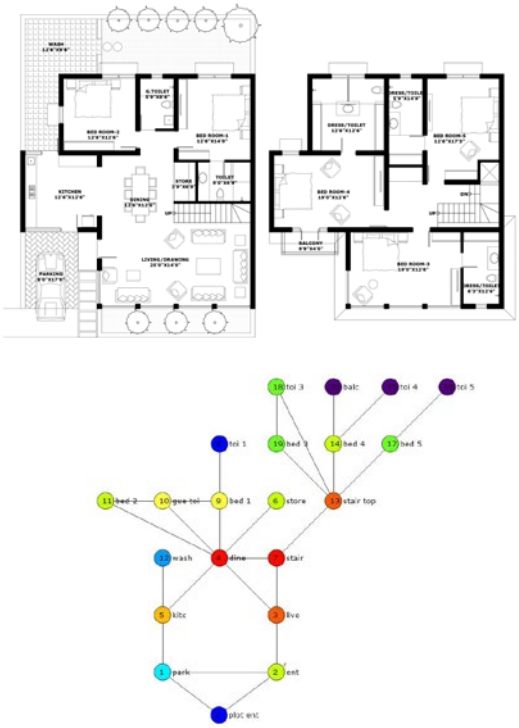
APPENDIX – C

Justified graphs of bungalow layouts (5 graphs)

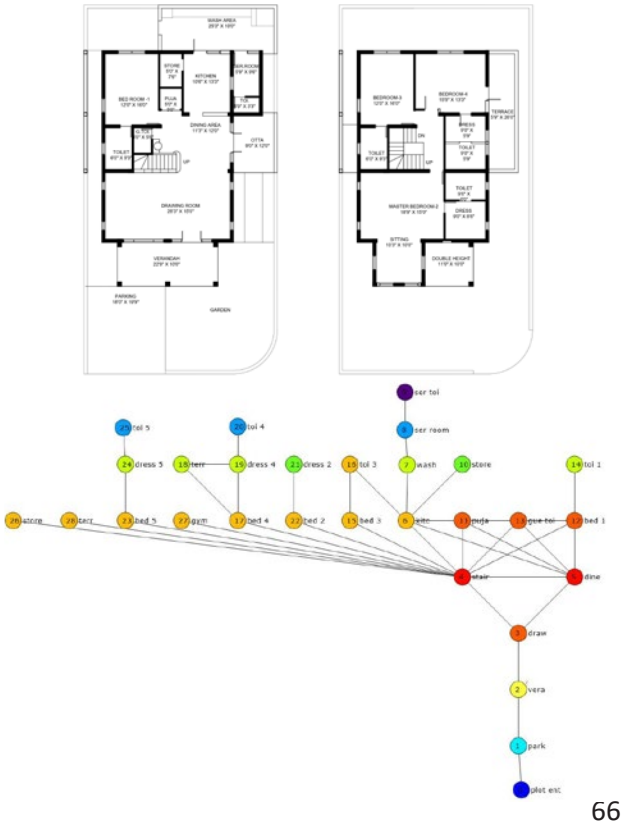
1. Name : Padmakant Shah house



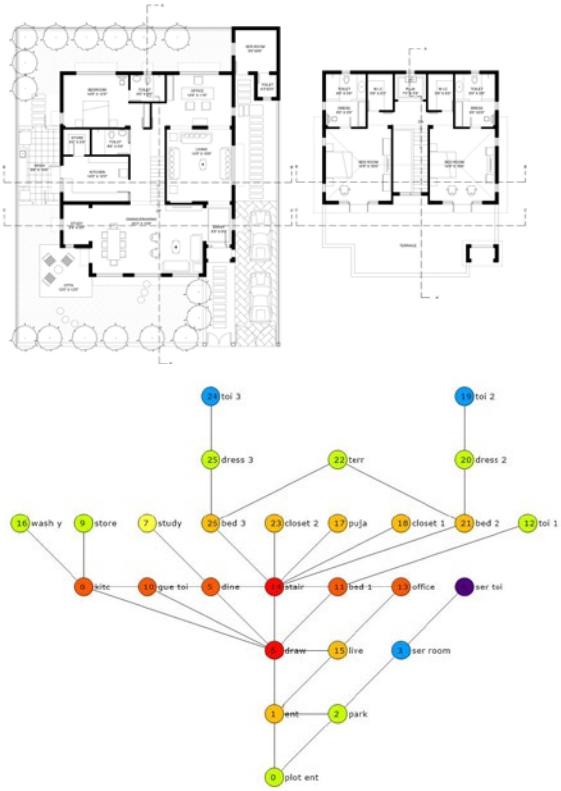
2. Name : Chitrak Shah house



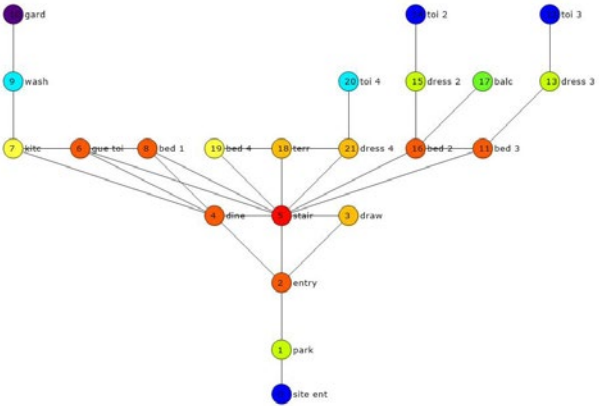
3. Name : Vrindavan 7 houses



4. Name : Kartikay Thakkar house



5. Name : Vishnudhara bungalows



APPENDIX D

Calculations of A Graph software for pol house layouts

1. Dodhia haveli

		TDn	MDn	RA	i	CV
0	**entry**	41	3,15	0,35	2,78	1,75
1	**toilet**	53	4,07	0,51	1,95	0,33
2	**bed 1**	42	3,23	0,37	2,68	0,58
3	**lobby**	32	2,46	0,24	4,10	1,66
4	**stair**	30	2,30	0,21	4,58	1,75
5	**court**	42	3,23	0,37	2,68	1,25
6	**store**	54	4,15	0,52	1,90	0,50
7	**bed 2**	32	2,46	0,24	4,10	0,58
8	**balcony 1**	42	3,23	0,37	2,68	0,33
9	**kitchen 2**	36	2,76	0,29	3,39	2,33
10	**bed 3**	45	3,46	0,41	2,43	1,75
11	**balcony 3**	46	3,53	0,42	2,36	0,58
12	**kitchen 3**	57	4,38	0,56	1,77	0,33
13	**balcony 2**	48	3,69	0,44	2,22	0,25
	Min	30,00	2,30	0,21	1,77	0,25
	Mean	**42,85**	**3,29**	**0,38**	**2,83**	**1,00**
	Max	57,00	4,38	0,56	4,58	2,33

2. Name : Atul Rana house

		TDn	MDn	RA	i	CV
0	**entry**	27	2,70	0,37	2,64	1,33
1	**toi**	36	3,60	0,57	1,73	0,50
2	**live**	20	2,00	0,22	4,50	1,75
3	**stair**	17	1,70	0,15	6,42	1,83
4	**kitc**	29	2,90	0,42	2,36	0,33
5	**bed 2**	24	2,40	0,31	3,21	1,25
6	**bed 1**	33	3,30	0,51	1,95	0,50
7	**bed 3**	33	3,30	0,51	1,95	0,50
8	**bed 4**	24	2,40	0,31	3,21	1,25
9	**bed 5**	24	2,40	0,31	3,21	1,25
10	**terr**	33	3,30	0,51	1,95	0,50
	Min	17,00	1,70	0,15	1,73	0,33
	Mean	**27,27**	**2,72**	**0,38**	**3,01**	**1,00**
	Max	36,00	3,60	0,57	6,42	1,83

3. Name : Babukaka house

		TDn	MDn	RA	i	CV
0	**entry**	80	4,21	0,35	2,80	1,25
1	**shop**	98	5,15	0,46	2,16	0,50
2	**liv**	64	3,36	0,26	3,80	2,83
3	**toi 1**	82	4,31	0,36	2,71	0,25
4	**store**	82	4,31	0,36	2,71	0,25
5	**court**	54	2,84	0,20	4,88	1,00
6	**kit**	59	3,10	0,23	4,27	0,58
7	**dine**	47	2,47	0,16	6,10	1,53
8	**room 1**	63	3,31	0,25	3,88	1,25
9	**toi 2**	81	4,26	0,36	2,75	0,50
10	**stair**	47	2,47	0,16	6,10	1,83
11	**room 3**	60	3,15	0,23	4,17	0,45
12	**room 2**	56	2,94	0,21	4,62	1,53
13	**toi 2**	71	3,73	0,30	3,28	0,58
14	**pass 2**	69	3,63	0,29	3,42	1,25
15	**room 5**	85	4,47	0,38	2,59	1,33
16	**room 6**	103	5,42	0,49	2,03	0,50
17	**pass**	62	3,26	0,25	3,97	1,70
18	**room 7**	63	3,31	0,25	3,88	0,53
19	**terr**	80	4,21	0,35	2,80	0,33
	Min	47,00	2,47	0,16	2,03	0,25
	Mean	**70,30**	**3,70**	**0,30**	**3,65**	**1,00**
	Max	10	5,42	0,49	6,10	2,83

4. Name : Yellow house

		TDn	MDn	RA	i	CV
0	**entr**	21	1,90	0,18	5,50	1,86
1	**gue toi**	31	2,81	0,36	2,75	0,25
2	**stair**	23	2,09	0,21	4,58	2,25
3	**court**	24	2,18	0,23	4,23	0,91
4	**kitc**	24	2,18	0,23	4,23	0,91
5	**dine**	29	2,63	0,32	3,05	1,16
6	**bed 1**	37	3,36	0,47	2,11	1,33
7	**toi 1**	47	4,27	0,65	1,52	0,50
8	**bed 2**	32	2,90	0,38	2,61	0,70
9	**bed 3**	32	2,90	0,38	2,61	0,70
10	**bed 4**	32	2,90	0,38	2,61	0,70
11	**bed 5**	32	2,90	0,38	2,61	0,70
	Min	21,00	1,90	0,18	1,52	0,25
	Mean	**30,33**	**2,75**	**0,35**	**3,20**	**1,00**
	Max	47,00	4,27	0,65	5,50	2,25

5. Name : Modi house

		TDn	MDn	RA	i	CV
0	**entr**	50	2,94	0,24	4,12	1,25
1	**gue toi**	66	3,88	0,36	2,77	0,50
2	**live**	36	2,11	0,13	7,15	2,00
3	**store**	52	3,05	0,25	3,88	0,25
4	**chowk**	44	2,58	0,19	5,03	1,08
5	**kitc**	57	3,35	0,29	3,40	0,66
6	**bed 1**	55	3,23	0,27	3,57	1,33
7	**bed 2**	69	4,05	0,38	2,61	1,33
8	**puja**	85	5,00	0,50	2,00	0,50
9	**stair**	36	2,11	0,13	7,15	2,41
10	**bed 2**	51	3,00	0,25	4,00	0,50
11	**bed 3**	49	2,88	0,23	4,25	1,50
12	**bed 4**	65	3,82	0,35	2,83	0,33
13	**toi 2**	49	2,88	0,23	4,25	1,00
14	**bed 5**	50	2,94	0,24	4,12	1,16
15	**bed 6**	50	2,94	0,24	4,12	1,16
16	**bed 7**	66	3,88	0,36	2,77	0,50
17	**balc 1**	66	3,88	0,36	2,77	0,50
	Min	36,00	2,11	0,13	2,00	0,25
	Mean	**55,33**	**3,25**	**0,28**	**3,93**	**1,00**
	Max	85,00	5,00	0,50	7,15	2,41

APPENDIX E

Calculations of A Graph software for row house layouts

1. Jay Sheffali row houses

		TDn	MDn	RA	i	CV
0	ent	134	5,58	0,39	2,50	0,50
1	park	111	4,62	0,31	3,17	1,33
2	foyer	90	3,75	0,23	4,18	1,00
3	sit	74	3,08	0,18	5,52	1,41
4	live	83	3,45	0,21	4,67	0,58
5	dine	94	3,91	0,25	3,94	1,33
6	court	112	4,66	0,31	3,13	0,66
7	stair	76	3,16	0,18	5,30	0,83
8	bath	124	5,16	0,36	2,76	0,50
9	gue room	101	4,20	0,27	3,58	1,25
10	store	134	5,58	0,39	2,50	0,33
11	kitc	111	4,62	0,31	3,17	1,83
12	ser room	129	5,37	0,38	2,62	0,66
13	court 2	129	5,37	0,38	2,62	2,00
14	ser toi	152	6,33	0,46	2,15	0,33
15	pass	80	3,33	0,20	4,92	1,41
16	room 1	112	4,66	0,31	3,13	2,20
17	vera 1	135	5,62	0,40	2,48	0,33
18	bath 1	135	5,62	0,40	2,48	0,33
19	room 2	99	4,12	0,27	3,68	0,53
20	bath 2	116	4,83	0,33	3,00	0,20
21	room 3	114	4,75	0,32	3,06	1,20
22	terr	137	5,70	0,40	2,44	0,50
23	pass 2	93	3,87	0,25	4,00	2,66
24	stair 2	83	3,45	0,21	4,67	1,03

2. Name : Shyamal row houses

		TDn	MDn	RA	i	CV
0	entry	42	3,00	0,30	3,25	0,20
1	dine	29	2,07	0,16	6,06	1,86
2	bed 1	30	2,14	0,17	5,68	1,56
3	toi 1	43	3,07	0,31	3,13	0,25
4	live	29	2,07	0,16	6,06	1,36
5	stair	23	1,64	0,09	10,11	1,56
6	kitc	31	2,21	0,18	5,35	1,06
7	gard	41	2,92	0,29	3,37	0,45
8	balc	45	3,21	0,34	2,93	0,33
9	bed 2	32	2,28	0,19	5,05	2,16
10	toi 3	45	3,21	0,34	2,93	0,33
11	toi 2	54	3,85	0,43	2,27	0,50
12	dress	41	2,92	0,29	3,37	1,33
13	bed 3	30	2,14	0,17	5,68	1,66
14	balc 2	43	3.07	0.31	3.13	0.33

3. Name : Cosmoville row houses

		TDn	MDn	RA	i	CV
0	plot entr	181	6,96	0,47	2,09	0,50
1	park	156	6,00	0,40	2,50	1,50
2	front court	133	5,11	0,32	3,03	1,00
3	entry	112	4,30	0,26	3,77	1,00
4	living	93	3,57	0,20	4,85	0,75
5	dine	76	2,92	0,15	6,50	1,70
6	kitc	93	3,57	0,20	4,85	0,50
7	store	86	3,30	0,18	5,41	0,45
8	gue toi	97	3,73	0,21	4,57	0,20
9	vera	112	4,30	0,26	3,77	3,50
10	ser toi	137	5,26	0,34	2,92	0,25
11	chowkdi	137	5,26	0,34	2,92	0,25
12	rear court	137	5,26	0,34	2,92	0,25
13	stair 2	72	2,76	0,14	7,06	2,33
14	bed 1	102	3,92	0,23	4,27	1,25
15	bed 2	102	3,92	0,23	4,27	1,25
16	toi 2	127	4,88	0,31	3,21	0,50
17	toi 1	127	4,88	0,31	3,21	0,50
18	stair 1	93	3,57	0,20	4,85	2,20
19	puja	118	4,53	0,28	3,53	0,33
20	entertin	118	4,53	0,28	3,53	0,33
21	stair 3	79	3,03	0,16	6,13	1,53
22	stair 4	96	3,69	0,21	4,64	1,58
23	bed 3	117	4,50	0,28	3,57	2,33
24	terr	121	4,65	0,29	3,42	0,33
25	toi 3	142	5,46	0,35	2,80	0,33

4. Name : Readers quarters GU

		TDn	MDn	RA	i	CV
0	ent	57	3,56	0,34	2,92	0,25
1	live	42	2,62	0,21	4,61	1,90
2	dine	34	2,12	0,15	6,66	1,11
3	kitc	38	2,37	0,18	5,45	1,06
4	bed 1	38	2,37	0,18	5,45	1,06
5	toi	34	2,12	0,15	6,66	1,11
6	vera	55	3,43	0,32	3,07	1,25
7	garden	70	4,37	0,45	2,22	0,50
8	gard 2	51	3,18	0,29	3,42	0,50
9	stair	31	1,93	0,12	8,00	1,56
10	toi 2	55	3,43	0,32	3,07	0,33
11	dress 1	40	2,50	0,20	5,00	1,66
12	bed 2	53	3,31	0,30	3,24	1,33
13	balc 1	68	4,25	0,43	2,30	0,50
14	dress2	42	2,62	0,21	4,61	2,16
15	toi 3	57	3.56	0.34	2.92	0.33

5. Name : Staff quarters GU

		TDn	MDn	RA	i	CV
0	entry	43	3,30	0,38	2,60	0,83
1	live	32	2,46	0,24	4,10	1,25
2	kitc	25	1,92	0,15	6,50	1,40
3	toi	25	1,92	0,15	6,50	1,40
4	store	35	2,69	0,28	3,54	0,45
5	vera	33	2,53	0,25	3,90	1,40
6	gard	35	2,69	0,28	3,54	0,45
7	gard	43	3,30	0,38	2,60	0,83
8	bed 2	33	2,53	0,25	3,90	1,20
9	bed 3	33	2,53	0,25	3,90	1,20
10	toi 3	45	3,46	0,41	2,43	0,50
11	toi 2	45	3,46	0,41	2,43	0,50
12	stair	23	1,76	0,12	7,80	1,65
13	dine	24	1,84	0,14	7,09	0,93
	Min	23,00	1,76	0,12	2,43	0,45
	Mean	**33,85**	**2,60**	**0,26**	**4,34**	**1,00**
	Max	45,00	3,46	0,41	7,80	1,65

APPENDIX F

Calculations of A Graph software for bungalow layouts

1. Padmakant Shah house

		TDn	MDn	RA	i	CV
0	ent	39	2,05	0,11	8,55	3,00
1	stair 1	42	2,21	0,13	7.43	1,22
2	dine	55	2,89	0,21	4,75	0,47
3	kit	54	2,84	0,20	4,88	1,64
4	ser toi	81	4,26	0,36	2,75	0,83
5	ser bed	81	4,26	0,36	2,75	0,83
6	store	72	3,78	0,30	3,22	0,33
7	com toi	57	3,00	0,22	4,50	0,14
8	live	45	2,36	0,15	6,57	1,22
9	vera	50	2,63	0,18	5,51	0,72
10	bed 1	61	3,21	0,24	4,07	1,25
11	toi 1	79	4,15	0,35	2,85	0,50
12	wash yrd	64	3,36	0,26	3,80	1,33
13	plot ent	50	2,63	0,18	5,51	0,80
14	bed 2	54	2,84	0,20	4,88	1,75
15	toi 2	72	3,78	0,30	3,22	0,33
16	store	88	4,63	0,40	2,47	0,50
17	terr	70	3,68	0,29	3,35	1,33
18	toi 3	76	4,00	0,33	3,00	0,50
19	bed 3	58	3,05	0,22	4,38	1,25
	Min	39,00	2,05	0,11	2,47	0,14
	Mean	**62,40**	**3,28**	**0,25**	**4,42**	**1,00**
	Max	88,00	4,63	0,40	8,55	3,00

2. Name : Chitrak Shah house

		TDn	MDn	RA	i	CV
0	plot ent	78	3,90	0,30	3,27	0,66
1	park	70	3,50	0,26	3,80	1,16
2	ent	62	3,10	0,22	4,52	1,16
3	live	49	2,45	0,15	6,55	0,80
4	dine	44	2,20	0,12	7,91	3,16
5	kitc	56	2,80	0,18	5,27	1,47
6	store	63	3,15	0,22	4,41	0,14
7	stair	44	2,20	0,12	7,91	0,67
8	toi 1	79	3,95	0,31	3,22	0,33
9	bed 1	60	3,00	0,21	4,75	1,47
10	gue toi	60	3,00	0,21	4,75	0,97
11	bed 2	62	3,10	0,22	4,52	0,47
12	wash	75	3,75	0,28	3,45	0,33
13	stair top	49	2,45	0,15	6,55	2,16
14	bed 4	64	3,20	0,23	4,31	2,20
15	toi 4	83	4,15	0,33	3,01	0,33
16	toi 5	85	4,25	0,34	2,92	0,50
17	bed 5	66	3,30	0,24	4,13	1,20
18	toi 3	67	3,35	0,24	4,04	0,70
19	bed 3	67	3,35	0,24	4,04	0,70
20	balc	83	4,15	0,33	3,01	0,33
	Min	44,00	2,20	0,12	2,92	0,14
	Mean	**65,04**	**3,25**	**0,23**	**4,59**	**1,00**
	Max	85,00	4,25	0,34	7,91	3,16

3. Name : Vrindavan 7 houses

		TDn	MDn	RA	i	CV
0	plot ent	145	5,17	0,30	3,23	0,50
1	park	118	4,21	0,23	4,20	1,50
2	vera	93	3,32	0,17	5,81	0,83
3	draw	70	2,50	0,11	9,00	0,74
4	stair	55	1,96	0,07	14,00	6,48
5	dine	64	2,28	0,09	10,50	1,31
6	kitc	82	2,92	0,14	7,00	1,86
7	wash	105	3,75	0,20	4,90	0,75
8	ser room	130	4,64	0,26	3,70	1,50
9	ser toi	157	5,60	0,34	2,93	0,50
10	store	109	3,89	0,21	4,66	0,25
11	puja	68	2,42	0,10	9,45	0,94
12	bed 1	72	2,57	0,11	8,59	1,69
13	gue toi	73	2,60	0,11	8,40	0,64
14	toi 1	99	3,53	0,18	5,32	0,20
15	bed 3	81	2,89	0,14	7,13	0,57
16	toi 3	81	2,89	0,14	7,13	0,57
17	bed 4	76	2,71	0,12	7,87	0,91
18	terr	101	3,60	0,19	5,17	0,66
19	dress 4	100	3,57	0,19	5,25	1,83
20	toi 4	127	4,53	0,26	3,81	0,33
21	dress 2	107	3,82	0,20	4,78	0,50
22	bed 2	80	2,85	0,13	7,26	1,07
23	bed 5	78	2,78	0,13	7,56	0,57
24	dress 5	103	3,67	0,19	5,04	1,50
25	toi 5	130	4,64	0,26	3,70	0,50
26	store	82	2,92	0,14	7,00	0,07
27	gym	82	2,92	0,14	7,00	0,07
28	terr	82	2,92	0,14	7,00	0,07
	Min	55,00	1,96	0,07	2,93	0,07
	Mean	**94,82**	**3,38**	**0,17**	**6,46**	**1,00**
	Max	15	5,60	0,34	14,00	6,48

4. Name : Kartikay Thakkar house

		TDn	MDn	RA	i	CV
0	plot ent	113	3,76	0,19	5,24	0,95
1	park	111	3,70	0,18	5,37	1,50
2	entry	95	3,16	0,14	6,69	1,09
3	draw	78	2,60	0,11	9,06	1,25
4	dine	91	3,03	0,14	7,13	2,05
5	study	120	4,00	0,20	4,83	0,14
6	entry	109	3,63	0,18	5,50	0,84
7	office	84	2,80	0,12	8,05	1,31
8	toi 1	113	3,76	0,19	5,24	0,16
9	bed 1	84	2,80	0,12	8,05	1,81
10	store	106	3,53	0,17	5,72	0,12
11	gue toi	97	3,23	0,15	6,49	0,74
12	kitc	77	2,56	0,10	9,25	2,26
13	stair	74	2,46	0,10	9,88	0,76
14	ser room	138	4,60	0,24	4,02	1,20
15	ser toi	167	5,56	0,31	3,17	0,50
16	wash	95	3,16	0,14	6,69	0,82
17	live	103	3,43	0,16	5,95	0,41
18	stair top	79	2,63	0,11	8,87	3,36
19	puja	108	3,60	0,17	5,57	0,16
20	closet 1	108	3,60	0,17	5,57	0,16
21	toi 1	156	5,20	0,28	3,45	0,50
22	dress 1	127	4,23	0,22	4,48	1,33
23	bed 1	100	3,33	0,16	6,21	1,16
24	vera 1	125	4,16	0,21	4,57	0,83
25	bed 2	100	3,33	0,16	6,21	1,00
26	vera 2	123	4,10	0,21	4,67	1,33
27	dress 2	127	4,23	0,22	4,48	1,33
28	toi 2	156	5,20	0,28	3,45	0,50
29	closet 2	104	3,46	0,17	5,87	0,50
30	terr	144	4,80	0,26	3,81	0,83
	Min	74,00	2,46	0,10	3,17	0,12
	Mean	**110,06**	**3,66**	**0,18**	**5,92**	**1,00**
	Max	16	5,56	0,31	9,88	3,36

5. Name : Vishnudhara houses

		TDn	MDn	RA	i	CV
0	site ent	87	4,14	0,31	3,18	0,50
1	park	67	3,19	0,21	4,56	1,25
2	entry	49	2,33	0,13	7,50	1,10
3	draw	51	2,42	0,14	7,00	0,51
4	dine	46	2,19	0,11	8,40	1,43
5	stair	38	1,80	0,08	12,35	3,00
6	gue toi	50	2,38	0,13	7,24	0,76
7	kitc	60	2,85	0,18	5,38	1,16
8	bed 1	50	2,38	0,13	7,24	0,76
9	wash	78	3,71	0,27	3,68	1,25
10	gard	98	4,66	0,36	2,72	0,50
11	bed 3	50	2,38	0,13	7,24	0,85
12	toi 3	88	4,19	0,31	3,13	0,50
13	dress 3	68	3,23	0,22	4,46	1,33
14	toi 2	87	4,14	0,31	3,18	0,50
15	dress 2	67	3,19	0,21	4,56	1,25
16	bed 2	49	2,33	0,13	7,50	1,93
17	balc	69	3,28	0,22	4,37	0,25
18	terr	55	2,61	0,16	6,17	0,93
19	bed 4	57	2,71	0,17	5,83	0,43
20	toi 4	75	3,57	0,25	3,88	0,33
21	dress 4	55	2,61	0,16	6,17	1,43
	Min	38,00	1,80	0,08	2,72	0,25
	Mean	**63,36**	**3,01**	**0,20**	**5,71**	**1,00**
	Max	98,00	4,66	0,36	12,35	3,00