

**ASSESSING THE IMPACT OF COURTYARD IN THE HOUSING  
TYPOLOGIES OF LOW RISE, MEDIUM DENSITY URBAN  
SETTLEMENTS**

Thesis Submitted for the Award of the Degree of

**DOCTOR OF PHILOSOPHY**

**In**

**Architecture**

**By**

**Richa Gupta**

**Registration Number: 41900383**

**Supervised By**

**Dr. Mahendra Joshi (25672)**

**Lovely School of Architecture & Design (Professor)**

**Lovely Professional University**



**L**OVELY  
**P**ROFESSIONAL  
**U**NIVERSITY

*Transforming Education Transforming India*

**LOVELY PROFESSIONAL UNIVERSITY, PUNJAB**

**2024**

## DECLARATION

I, hereby declared that the presented work in the thesis entitled “Assessing the Impact of Courtyard in the Housing Typologies of Low Rise, Medium Density Urban Settlements” in fulfilment of the degree of **Doctor of Philosophy (Ph. D.)** is an outcome of research work carried out by me under the supervision of Late. Dr. Mahender Joshi, working as a Professor at the Lovely School of Architecture & Design of Lovely Professional University, Punjab, India. In keeping with the general practice of reporting scientific observations, due acknowledgments have been made whenever the work described here has been based on the findings of other investigators. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

### **(Signature of Scholar)**

Name of the Scholar: Richa Gupta

Registration No.: 41900383

Department/School: Architecture

Lovely Professional University,

Punjab, India

## **CERTIFICATE**

This is to certify that the work reported in the Ph. D. thesis entitled “Assessing The Impact Of Courtyard In The Housing Typologies Of Low Rise, Medium Density Urban Settlements” submitted in fulfillment of the requirement for the reward of a degree of **Doctor of Philosophy (Ph.D.)** in the Lovely School of Architecture and Design, is a research work carried out by Richa Gupta, 41900383, is a bonafide record of his/her original work carried out under my supervision and that no part of the thesis has been submitted for any other degree, diploma or equivalent course.

**(Signature of Supervisor)**

Name of supervisor: Dr. Mahendra Joshi

Designation: Professor

Department/School: Architecture

University: LPU

**(Signature of Co-Supervisor)**

Name of Co-Supervisor: NA

Designation: NA

Department/School: NA

University: NA

## ABSTRACT

*The development of sustainable contemporary neighbourhoods across the world challenges everyone concerned to create housing that promotes social and cultural inclusion of inhabitants while also being environmentally sensitive. In India, the problem of urban expansion has pushed architects and urban designers to come up with housing solutions that encourage a balance between built-up areas and open areas that contribute to ecological sustainability.*

*The present study hypothesized that the courtyard typology are best suited solution in the Indian context and could be efficiently used in plotted development of medium size plot. Therefore keeping this in background, the major objective of the research is to explore the typological impact of courtyard houses in the present housing scenario. An archetypal and historical exploration of courtyard houses around the world provides a context for the research. Further Building bye-laws of five cities are studied in detail with reference to residential open spaces within a house. Various stakeholders like Architects builders, planners, and residents of different kind of houses are interviewed through questionnaires to understand the impact of a courtyard in low-rise residences. This research focuses on the utilization of Indian courtyards in a contemporary context and examines their viability under the specific lenses of building regulation and day lighting in houses.*

*The study blends qualitative and quantitative approaches to offer a practical solution to the research challenge that is both reflective and useful. The theoretical component integrated the exploration of archetypal and historical analysis of courtyard houses, design precedents, and Building regulation, along with specialized feedback from industry experts and the inhabitants.*

*The research analyses courtyard dwelling with various lenses of inquiry to conceptualize a sustainable neighbourhood in Lucknow*

*The simulation analysis was carried out by creating a housing prototype and comparing the results with reference to the daylight in the internal areas of dwellings using Ecotect software. The outcome of this intersection of theory and practice verified the possibility of the courtyard houses as a response to the precise requirement for spatial, liveable, and sustainable residential settlement in Lucknow, Uttar Pradesh.*

*Finally, broad guidelines have been provided at two levels, one at the courtyard level and the other at the building regulation level.*

*The study has been planned in six chapters. Chapter 1<sup>st</sup> summarizes the aims, objective, research questions, and scope of study to provide basic knowledge of the work. Chapter 2<sup>nd</sup> provides in depth review of the literature associated with courtyard houses and an overview of building regulation. Chapter 3<sup>rd</sup> deals with the research design and the methodology used to carry*



*out the research. Chapter 4<sup>th</sup> includes relevant case studies of traditional and contemporary houses; further bye-laws of five cities have been discussed to describe the relation between the typology and building regulation. Chapter 5<sup>th</sup> provide details analysis of survey finding and compile the result of modelling and simulation done for daylight parameters and the prototype design solutions have been provided toward s the end of the chapter. Chapter 6<sup>th</sup> concluded the study and provided the recommendation and scope for further research.*

**Keywords:** *Daylight, Bye-laws, Courtyard, Sustainability.*

## ACKNOWLEDGEMENTS

I would like to thank several persons and organizations.

First, I would like to extend my heartfelt appreciation to Professor Dr. Mahendra Joshi & Dr. Raminder Kaur, who supervised the completion of my Ph.D. thesis, for their detailed guidance and invaluable assistance during the whole process. Many thanks go to Shri. Vishal Jain, Chairman, IID, Lucknow chapter for their excellent technical help in the field of Architecture.

I also want to thank all the professors, research cells, admin staff, and colleagues at Lovely Professional University, Phagwara Punjab for all the support and assistance. My sincere thanks to Ar. Kratika Pandey and Ar. Ujjwal Gupta for their help and assistance in the data collection and compilation of the research.

Last but not the least, my sincere thanks to my family- my parents, my sisters, my husband, and my son without whose love and support this project would have been a dream.

To them, I say thanks for the generous and warm support during my long period of study.

Date: 21-06-24

# TABLE OF CONTENT

<i>Declaration</i>	<i>i</i>
<i>Certificate</i>	<i>ii</i>
<i>Abstract</i>	<i>iii</i>
<i>Acknowledgment</i>	<i>v</i>
<i>Table of Content</i>	<i>vi</i>
<i>List of Tables</i>	<i>ix</i>
<i>List of Figures</i>	<i>x</i>
<i>List of Appendices</i>	<i>xii</i>

## Chapter -1 Introduction

1.1 Introduction.....	1
1.2 Significance of Research.....	2
1.3 Research Gap Identification .....	5
1.3.1 Daylight as parameter.....	9
1.4 Research Hypothesis.....	11
1.5 Research Objectives.....	11
1.6 Scope And Limitations Of The Study.....	12

## Chapter -2 Literature review

2.1. Definition: Courtyard.....	13
2.2. Courtyard: Elements And Form.....	14
2.2.1. Shape.....	16
2.2.1. Orientation.....	16
2.2.2. Wall Enclosure.....	17
2.3. Historic Evolution of Courtyard in World.....	17
2.3.1. Ancient Civilization.....	17
2.3.2. Classic Civilization.....	18
2.3.3. Renaissance Civilization.....	18
2.3.4. Modern Civilization.....	18
2.4. Historic Context of Courtyard in India.....	11
2.5. Evolution Of Courtyard In India.....	18
2.5.1. Ancient Period.....	20
2.5.2. Vedic Period.....	22
2.5.3. Buddhist Period.....	28
2.5.4. Medieval Period.....	28
2.5.5. Colonial Period.....	30

2.5.6. Contemporary Period.....	31
2.6. Regional Variation In Courtyard Forms.....	33
2.6.1. Courtyards in Different Region Of India.....	33
2.7. Courtyard Impacts.....	40
2.7.1. Psycho-Social Impact.....	40
2.7.2. Climatic Impact.....	40
2.7.3. Religious Impact.....	41
2.7.4. Spatial Impact.....	41
2.7.5. Cultural Impact.....	41
2.8. Reasons for the disappearance of Courtyard.....	42
2.8.1. Transformation of Courtyard.....	42
2.8.2. Factors Affecting the Disappearance of Courtyard.....	42
2.9. Building Bye-laws: An Overview.....	43
2.9.1. Building Bye-laws In India.....	44
2.9.2. Challenges In Building Regulation.....	48

### **Chapter-3 Research Design**

3.1. Research Methodology.....	50
3.1.1. Data Collection.....	51
3.1.2. Sample Design.....	52
3.2. Lucknow: study Context.....	54
3.3. Procedure and Mile stone.....	57

### **Chapter -4 Case Studies**

4.1. Case studies; Courtyard Houses.....	59
4.1.1. Traditional Houses.....	59
4.1.2. Contemporary Houses.....	55
4.1.3. Spatial organization.....	76
4.2. Case studies; Building regulation.....	77
4.2.1. Amaravati: An Overview.....	77
4.2.2. Bhopal: An Overview.....	78
4.2.3. Chandigarh: An Overview.....	79
4.2.4. Jaipur : An Overview.....	80
4.2.5. Lucknow: An Overview.....	82
4.2.6. Concerns Of Lucknow Bye-laws.....	89
4.2.7. Impact of Plot Proportions on Compliance with Building Regulations.....	91
4.3. Inferences from Case study (Traditional and contemporary).....	95
4.4. Inferences from Case study (Building Regulation).....	96
4.5. Conclusion.....	97

### **Chapter-5 Result and Discussion**

5.1. Introduction.....	98
------------------------	----

5.2. Designing The Survey Questionnaire.....	99
5.2.1. User’s Perception Survey.....	100
5.2.2. Analysis of responses) .....	116
5.2.3. Statistical Analysis and hypothesis testing.....	118
5.2.4. Expert’s Survey.....	120
5.2.5. Inferences from Survey.....	124
5.3. Modelling and Simulation.....	125
5.3.1. Inferences from modelling and simulation.....	139
5.4. Design Intervention.....	141
5.4.1. Inferences from Design Intervention.....	144
5.5. Prototype Development .....	145
5.5.1. Inference from prototype development.....	148
5.6. Conclusion.....	150

**Chapter-6 Conclusion and Recommendation**

6.1. Background.....	151
6.2. Conclusion.....	152
6.3. Reccommendation.....	153
6.4. Research Contributions To Knowledge.....	155
6.5. Scope for further Research.....	155

*Bibliography*

*Appendices*

## LIST OF TABLES

Table 1 :Summary of Literature Review .....	7
Table 2: Classification of climatic zones in India )Source: ECB Ccode) .....	53
Table 3: Summary of research tools .....	57
Table 4: Comparision analysis of six case studies. ....	64
Table 5 :Summary of Courtyard Houses.....	74
Table 6: Calculated Proportion from case studies. ....	75
Table 7: Summarizing research paper for courtyard parameters. ....	75
Table 8 : Types of residential plot .....	79
Table 9: Summary of Jaipur Building bye-laws (Source: Rajasthan Building Bye Laws – 2020).....	81
Table 10 : Setback requirement with respect to road width .....	82
Table 11: Summary of building Bye-laws (Source: Building Bye-Laws Amended 2016, Lucknow).....	83
Table 12: Summary of Bye-laws of Five cities: Amaravati, Bhopal, Chandigarh, Jaipur, and Lucknow ...	84
Table 13: Comparison of Bye-laws for a Case example .....	87
Table 14 :Calculated ground coverage for different plot sizes and proportion .....	91
Table 15: Calculated ground coverage and F.A.R. for different plot sizes. ....	93
Table 16 : Compilation of Function related questions (Courtyard House) .....	103
Table 17: Compilation of Environment related questions (Courtyard House) .....	104
Table 18: Compilation of Religious and culture related questions (Courtyard House) .....	106
Table 19: Compilation of psychology/ preference related questions (Courtyard House) .....	107
Table 20; Compilation of Function related questions (Non courtyard H).....	109
Table 21: Compilation of Environment related questions (other type of House).....	110
Table 22: Compilation of Religious and cultural parameters (Non- courtyard House) .....	112
Table 23: Compilation of Environment related questions (other type of House).....	113
Table 24: Frequency of affirmative responses.....	116
Table 25: Architect/Planner statistics .....	120
Table 26: Summary of Shadow analysis of both layout.....	129
Table 27: Nomenclature of models.....	130
Table 28 :Parameters for Simulation .....	130
Table 29:Average Illumination of Fround floor setback model Summer.....	132
Table 30: :Average Illumination of Fround floor Courtyard model Summer .....	132
Table 31: Average illumination of Ground Floor .....	133
Table 32: Average illumination of Ground Floor .....	133
Table 33: Tabular summary of simulation finding for different models.....	135
Table 34: Summary of Lowest preforming model (Low illumination level) in terms of daylight .....	140
Table 35 : Comparison of parameters for existing house with modified house .....	143
Table 36: : Different plot proportion with different courtyard.....	145
Table 37: Different type of courtyard and their impact .....	146

## LIST OF FIGURE

Figure 1 Traditional and modern courtyard.....	14
Figure 2 Different type of transitional space .....	14
Figure 3 Attributes of courtyard .....	15
Figure 4 : Different shapes of courtyard .....	16
Figure 5:Courtyard Planning in Indus Valley Civilization .....	20
Figure 6 Observed house at Mohenjo-Daro, 6- central courtyard .....	21
Figure 7: Vaastu Mandala & Vaastu purush mandal .....	24
Figure 8:Various Type Of Amndal , .....	25
Figure 10:Manduka Vaastu Mandala And Parma Soyinka Vaastu Mandal, Source:(karani 2014).....	26
Figure 11:Sri Yantra, Source : (Huet, 2002). .....	27
Figure 12: Courtyard in Buddhist Monastery .....	28
Figure 13 Courtyard in Rajasthan Haveli.....	29
Figure 14: Indian Mosque Source.....	29
Figure 15 : Courtyard in Colonial Bungalow (A & B) .....	31
Figure 16: Nalukettu Courtyard, Kerala.....	31
Figure 17: Chettinad Courtyard, Tamil Nadu.....	31
Figure 18 : Three court Residence .....	33
Figure 19 : Courtyard in North Zone of India .....	34
Figure 20 : Courtyard Effect .....	34
Figure 21: Typical plan of Chettinad House .....	35
Figure 22 The Guttu Mane of Kodethur Guttu near Kinnigoli in Mangalore .....	36
Figure 23 : Cross Breeze Phenomenon in Courtyard House.....	37
Figure 24 : Nalukettu Courtyard Dwellings .....	37
Figure 25 : Courtyard Dwelling in Chhattisgarh .....	37
Figure 26: Typical Plan of Orissa Dwellings .....	38
Figure 27 : Typical plan of Kolkata House .....	38
Figure 28 : Typical courtyard of a pol house.....	39
Figure 29 : Passive cooling strategies used in Pol house .....	39
Figure 30 : Typical Floor plan of Haveli in Rajasthan.....	39
Figure 31 : Courtyard in Rajasthan Haveli.....	39
Figure 32 : Environmental impacts of Courtyard .....	40
Figure 33 : Brahmasthana as per vaastu shastra .....	41
Figure 34 : Research methodology framework .....	54
Figure 35: Geographical location and linkage.....	55
Figure 36 : Plan of House No-1 .....	61
Figure 37 : View from main entrance .....	61
Figure 38 Bird eye view of courtyard.....	61
Figure 39View from main entrance .....	61
Figure 40 Plan of house 2.....	61
Figure 41 View from inside the courtyard .....	61
Figure 42 Upward looking view of courtyard .....	62
Figure 43 Courtyard showing entrance of the house .....	62
Figure 44 Plan of house no 3 .....	62
Figure 45 View of courtyard from top. ....	62
Figure 46 : Plan of House No 4 .....	62
Figure 47 : Security grills at opening of the courtyard .....	62
Figure 48 : Views of courtyard.....	63
Figure 49 View from courtyard from entrance.....	63
Figure 50 : Plan of House No 5 .....	63
Figure 51 : Plan of house No-6.....	63
Figure 52 : View of courtyard from Top.....	63

Figure 53: Plan and View of House No 7, .....	66
Figure 54: Plan and section of House No 8 Source:www.buildofy.com.....	67
Figure 55 :Plan and section view of House No 9 .....	68
Figure 56 : Plan and Section View of House no-10.....	69
Figure 57: Plan and View of House No 11 .....	70
Figure 58: Plan and Section of House No 12 .....	71
Figure 59 : Plan and Section of House No 13 .....	72
Figure 60 :Plan and section oF House No:14 .....	73
Figure 61 Illustrating ground coverage for different plot proportion and sizes (Lucknow) .....	93
Figure 62 Graphical representation of relation of GC and Plot Proportion (Lucknow).....	94
Figure 63 Graphical representation of potential space for the courtyard in different plot sizes. ....	94
Figure 64 : Gender statistics .....	100
Figure 65: Age statistics .....	100
Figure 66 Family type statistics .....	101
Figure 67 Religion statistics .....	101
Figure 68 : House type statistics .....	101
Figure 69 Type of open space .....	101
Figure 70: Compilation of group-1 Result .....	108
Figure 71 Compilation of Group,-2 Results .....	115
Figure 72 : Comparision of both groups response .....	117
Figure 73 : Respondent general information .....	120
Figure 74: Plot size preference .....	121
Figure 75 : plot proportion preference .....	121
Figure 76 : Influence of plot ratio.....	121
Figure 77 : Influence of culture on court typology .....	122
Figure 78 : Impact of building Bye-laws .....	122
Figure 79 : Impact of building parameters .....	122
Figure 80 : Graph for reason of disappearance of courtyard.....	123
Figure 81 : Factors affecting Indian residential design. ....	123
Figure 82 : Layout one with setback model .....	126
Figure 83 : Layout -2 With Courtyard model.....	126
Figure 84 : Shading analysis of courtyard model ( 21 <sup>st</sup> June) .....	127
Figure 85: Shading analysis of courtyard model ( 21 <sup>st</sup> Dece mber).....	127
Figure 86: Shading analysis of Setback model ( 21 <sup>st</sup> June).....	128
Figure 87: Shading analysis of Setbackmodel ( 21 <sup>st</sup> Dece mber) .....	128
Figure 88 :Layout showing Hypothetical models .....	129
Figure 89 :Typical Plan and view of setback model. ....	131
Figure 90 :Typical Plan and view of Courtyard model.....	131
Figure 91 ;Graphical Representation (summer) .....	132
Figure 92: Graphical Representation (summer) .....	132
Figure 93 :Graphical representation (Winter) .....	133
Figure 94 :Graphical Representation (winter) .....	133
Figure 95 :Conceptual plan of setback (A) and courtyard mode(B)l, Ground floor).....	134
Figure 96 :Daylight levels for different model of the north facing plot.....	138
Figure 97 :Daylight levels for different model of the South facing plot.....	138
Figure 98: Daylight levels for different model of the East facing plot. ....	138
Figure 99 :Daylight levels for different model of the West facing plot. ....	139
Figure 100 :Site location .....	141
Figure 101 :Photographs of sample case (source: Author).....	142
Figure 102 :Trade off involved in urban courtyard Houses .....	151



## **LIST OF APPENDICES**

Appendices -A1: Questionnaire for users of courtyard and Non courtyard house

Appendices –A2: Questionnaire for Architects/Experts

Appendices –B1: SPSS analysis of questionnaire

Appendices –C1: Building byelaws of different cities.

Appendices –D1: Lucknow building byelaws recommendations

# CHAPTER 1- INTRODUCTION

## 1.1. INTRODUCTION

Globalization is causing political, economic, and cultural borders to blur. Without a doubt, globalization has facilitated the growth of the global economy and enhanced living standards. The advancement in technology and communication has promoted the flow of information, people, or commodities; across national boundaries (Brauneck, 2007). In India, globalization came with the Liberation Act of 1991. Therefore, it gets increasingly difficult to deny the effect of globalization on Indian architecture. As a result, the architectural traits of various geographic and climatic locations have begun to lose their distinctiveness and sense of place. It has lost its essence and fails to influence people and society (R. Gupta & Joshi, 2021). This has resulted in the use of design principles and materials which are not consensuses with the climatic and regional context of the built environment, which ultimately leads to environmental degradation (Bahga & Raheja, 2020). Buildings today do not have any relevance to their context, climate, and the user. The construction industry at present creates countless wastes in terms of space, skills, materials, and finance. As we are aware that the built surroundings have a major impact on the physical, mental, and social well-being of humans, it becomes essential to learn and understand the sensible design solutions practised in the past, which were highly contextual and region-specific.

A thought Mahatma Gandhi once expressed to master architect Laurie Baker strengthens the concept of vernacular architecture, that is, “the perfect house should be built using resources found within a five-mile radius of the construction site” (Maddipati, 2020). Besides, the dilemmas of vernacular practices, that they single-handedly could not stand the growing need for urbanization, it seems quite old-fashioned also to look back in time and place, and dedicate ourselves to the cause of vernacular building practices. To create a sustainable future, a balance of technological advancement and past experiences must be achieved. The ethnic customs and way of life of India’s diverse population are directly reflected in the country’s residential architecture.

Numerous studies have been done on the vernacular architecture of different climatic zones. The studies have mostly focused on the climate responsiveness and the thermal comfort that exists in the vernacular structures (Indraganti, 2010)(Gangwar & Kaur, 2020a)(J.

Gupta et al., 2017). But the unexplored areas are, the design elements adopted in these structures, the flexibility of the spaces, cultural sustainability, and assessing its appropriateness in the present context. In the sub-domain of vernacular architecture, this study examines the socio-cultural and bioclimatic advantages of courtyard houses and further supports their inclusion in byelaws for city areas.

## **1.2 SIGNIFICANCE OF RESEARCH**

Native Indian dwelling forms include traditional courtyard houses. These dwelling types have been created throughout the ages by trial and error method and reached general acceptance (Myneni, 2022). They fulfil the needs of their inhabitants in every aspect whether it is functional requirements, micro-climatic, socio-cultural, thermal performance, religious demands, day lighting or energy saving, etc. (Jayasudha et al., 2014). Since Western architecture has such a strong impact on us, the residential typology that results is mostly unrelated to our local context and climate. However, this notion is completely against Amos Rapoport (1969) perspective where he identifies climate and culture as the two most important determinants out of multiple determinants for deciding housing typology (Patherya & Lau, 2012). Rural regions merge with urban areas as a result of growing urbanization in the global environment. The principal outcome of this process is a change in the local dwelling typologies, which eventually influences the user's physiological health. Unfortunately, traditional courtyard homes have become less significant and extinct in India over the past several decades, and there may be multiple explanations for this. Family structures are changing, placing a high value on privacy while disregarding the integration of space (Gangwar, 2016). Due to a shift in behavioural and lifestyle patterns, the family lounge replaces the courtyard as the new normal (Sanjune & Guneratne, 2018). The existence of open spaces like courtyards in dwellings is further put into question through enhanced experiences like air conditioning. Further to complicate the situation, the need for high rise, high density, full ground coverage, and F.A.R., apartment living has replaced courtyard homes. Additionally, the courtyard choice has been limited by the building bye-laws because of front and rear setbacks on medium and small small-sized plots (Emhemed, 2005)(Hakmi 2006)(Gangwar, 2016)(Elmansuri, 2018). In order to determine the appropriate courtyard design solutions for urban settings and to list potential design solutions in various climatic zones, it became clear that both traditional and modern courtyard designs should be evaluated in terms of environmental, behavioural, and aesthetic parameters.

Traditional homes and building types have a high level of endurance and durability and are the true representations of their inhabitants. In terms of built form, every residence unknowingly expresses the user (Sinha, 1990). Therefore, the house must be planned such that it immediately meets all of the user's fundamental needs in terms of its spatial arrangements. Traditional homes are extremely valuable to society since every single component and space has been carefully thought out. Due to their intimate ties to the culture; these structures have evolved into a link between the user and the wider society (Gulati & Pandya, 2014).

India has a rich architectural history that resulted from the country's environment, culture, and resources over a long period (Gulati et al., 2019). To provide a microclimate well shielded from the intense heat, building forms in India have historically been structured around courtyards and verandas. Most constructed designs have a central courtyard that serves as both an outdoor living area and a source of light and ventilation for the rooms that surround it. Creating areas with reciprocal shade and thermal comfort is crucial since India has a predominately hot environment (Rewal, 1997). Thus, knowledge gained from Indian traditional architecture might be applied to improve solutions to today's problems (Jayasudha et al., 2014). Research on courtyard houses in traditional civilizations has shown that they are contextual, responding to people's requirements in terms of climate and culture (Sthapak & Bandyopadhyay, 2014) (Verma & Bano, 2023). In Indian housing, the courtyard possesses a distinct identity; nevertheless, urban lands are under a lot of pressure due to a growing population and rapid urbanization. Further to make matters even more complicated, there are other variables like strict Bye-laws, FAR calculations, significant investments, and irresponsible behaviour that cause open spaces or courtyards to vanish (Gangwar, 2016).

The methods utilized nowadays to create open spaces distort their fundamental essence. Therefore, the goal of this study is to understand and assess the courtyard form's applicability in the present scenario. Modern architecture must constantly "be localized and contextual" to avoid becoming "global architecture." Many contemporary architects and designers who support traditional architecture mistakenly believe that there are two conflicting forms of dwelling: detached/Row housing and courtyard housing. In reality, courtyards are maybe the greatest introverted places in traditional dwellings as they suit the family demands of seclusion, quiet, and security in detached homes (Qureshi et al., 2019). For some architects who wanted to meet the social and cultural needs of their Indian clients, the modernist movement's controlled notion of "function" felt unsuitable (Bahga & Raheja, 2020)

Along with architects, users must comprehend the significant resources and possibilities that courtyard dwellings will provide for improving the look of the area and increasing the desirability of family life.

Professional associations, local governments, and town planning departments should implement strategies to raise awareness among builders and inhabitants of the inclusion of holistic and transitional spaces in their home plans. By using prototype courtyard dwelling designs, new design options within the limits of building regulations might be communicated to them.

The ancient art of building, known as Vaastu Shasta, may be of help since it encourages the use of courtyards such as Brahmasthana, or centre courtyards, in homes.

Aiming to create new concepts of courtyard dwelling designs relevant to the present and the future, architects and designers should examine traditional housing elements. Finally, it may be concluded that in order to generate interest in this style of housing, a deliberate effort on the part of architects, designers, and other stakeholders to have an understanding and appreciation for the courtyard housing is required.

### **Scope towards society and environment**

There are countless impacts of academic research, but the research should not be solely done to fulfil the academic obligation. The researcher has some responsibility toward society, the environment, and the government. Any form of research be it industrial innovation, medical findings or environmental issues ultimately affects mankind directly or indirectly.

Society is a complex arrangement of humans and a built environment in which an individual house acts as a basic unit in a similar fashion to a cell, which is the basic unit of the human body (Nair et al., 2005). The study will explore the most optimized typology of houses that will satisfy the physiological and emotional needs of human beings. A happy individual leads to a happy society. The approaches of the study would affect all three subsets of sustainability namely; social, environmental, and economic.

**Social:** Spatial organization in the house improves the overall social fabric of family and society.

**Environmental:** Building typologies can lessen the burden on non-renewable resources and reduce carbon footprints caused by the construction industry.

**Economical:** Energy efficiency and resource conservation in buildings directly convert into monetary benefits

- ✓ Orientation, extension, and rotation angle of the courtyard.
- ✓ The ratio of open and built mass.
- ✓ Dimensions and proportions of open spaces.
- ✓ Location of courtyard

The best design concept for courtyards, a comprehensive transitional area for future sustainable living in a composite climate, is finally proposed after the integration of all survey-based data. If all design cases are located in the same area and have comparable environmental circumstances, the proposed model may be applied to all design instances. Furthermore, the study may contribute to the design solutions for sustainable urban housing, by adopting the explored courtyard typologies.

### **1.3 RESEARCH GAP IDENTIFICATION**

Systematic reviews of the literature are the gold standard tool for assessing the current state of scientific knowledge and identifying research gaps (Müller-Bloch & Kranz, 2015). A review of the literature provides a broader picture and throws light on the spatial significance of courtyard houses, as well as attempts to explain why these traditional dwellings have not found notable expression in modern housing typologies of densely populated cities.

In the book “ Courtyard Housing Past, Present and Future”. the author explored the historical, socio-cultural, and environmental dimensions of courtyard dwelling, as well as the prospect of courtyard housing for a sustainable future (Brian Edwards, Magda Sibley, Mohammad Hakmi, 2006). The researchers widely explored the environmental parameters of a courtyard for different climatic zones and established the fact that a courtyard has a substantial environmental impact. (Soflaei et al., 2020)(Marafa & Alibaba, 2018)(Aldawoud, 2008)(Zamani et al., 2018) (Taleghani & Tenpierik, 1986). The socio-cultural aspects of courtyard houses have been investigated and research provides evidence that courtyard houses have an favourable socio-cultural impression on its inhabitants. (Al-zamil,

n.d.)(Mezerdi et al., 2022) (Nelson, 2014). The study of Courtyard house typological behaviour is limited to traditional settlements, although their applicability in contemporary settlements is hardly explored with few exceptions. Based on a typological analysis of the two forms of residential architecture—traditional and modern—the transformation of residential architecture was examined for Lahore city and it was concluded that traditional elements like courtyards, verandas, and high ceilings could be effortlessly blended with modern residences(Malik & Hassan, 2019). Another study, also based in Lahore, analysed traditional and modern houses on three levels: functional, typological, and archetypal, and concluded that courtyard houses perform better on all three levels, implying that hybrid designs (combining traditional and contemporary) can be used for modern development (Qureshi et al., 2019). The study hypothesized that Libya’s contemporary courtyard house meets its inhabitants’ socio-cultural aspirations. Furthermore, the study claimed that contemporary courtyard house offers an alternative to Western housing typologies that are rapidly being embraced in Arab countries, as well as an alternate approach of addressing social and environmental sustainability (Elwerfalli, 2016).

In Indian context comprehensive research papers are available on vernacular settlement and traditional dwellings such as Havelis of Rajasthan, Nalu-kettu of South India (Widiastuti, 2019), Wada of Maharashtra (Alapure et al., 2017), PoI houses of Ahmedabad(Gangwar & Kaur, 2020a), Mud dwellings of Jharkhand(J. Gupta et al., 2017). In the book “Peasant Life in India: A Study in Indian Unity & Diversity”, Biswas and Behura wrote a chapter ‘Types of cottage (1969)’, which describes in depth the many types of houses dispersed over the country and their responsive behaviour towards climate and context. Das. N investigated the traditional courtyards of Kolkata and found that occupant surveys confirmed that residents strongly supported the design superiority of courtyard houses over modern high rise apartments. In addition, further simulation and a comparative case study approach corroborate the climatic and sociocultural impacts of courtyard designs (Nibedita Das, 2006).A study in context of south Indian houses compares the transitional space in traditional and urban houses, and it was established that courtyard is one of the extremely efficient transitional spaces that is missing in urban dwellings (Sadanand & Nagarajan, 2020).

To widen the knowledge base, the numerous literatures explored are summarized in a table (Table -1) under subheadings such as parameters, methodology, location/ context etc.

Table 1 :Summary of Literature Review

Reference	Studied Parameters	Methodology	Location/ Context
Attributes/Impacts: Functional			
(Amiriparyan & Kiani, 2016)	Spatial organization	Case Study	Iran
(Qureshi et al., 2019)	Functional ,typological and archetypal Analysis	Case Study	Pakistan
(S. S. Khan, 2020)	Functional & typological Analysis	Field survey	Bangladesh
(Agarwal & Thussu, 2020)	Spatial arrangement	Field survey	India
(Malik & Hassan, 2019)	Spatial arrangement	Field survey	Pakistan
(Sadanand & Nagarajan, 2020)	Spatial arrangement	Literature review	India
(Rapoport, 1995)	Spatial arrangement	Literature review	Across the world
(Yasmin, 2022)	Spatial arrangement	Field survey	Bangladesh
Attributes/Impacts : Environmental			
(Zamani et al., 2018)	Microclimate and Thermal comfort	Literature review	Across the world
(Almhafdy et al., 2015)	Thermal comfort	Simulation of Hypothetical Model	Malaysia
(Taleghani et al., 2014)	Microclimate	Simulation of Hypothetical Model	Netherlands
(Soflaei et al., 2017)	Microclimate	Field Survey	Iran
(Abdulkareem, 2016)	Thermal comfort	Literature review	Middle Eastern Countries
(Al-Masri & Abu-Hijleh, 2012)	Energy consumption and Daylight	Simulation of Hypothetical Model	Dubai, UAE
(Nugroho et al., 2020)	Cooling effects	Field Survey	Indonesia
(Al-Hafith et al., 2017)	Thermal comfort	Simulation of Case Example	Iraq
(Lalit Akash Verma, 2021)	Daylight	Literature Review	Across the world
(Verma & Bano, 2023)	Daylight and thermal comfort.	Case studies	India



(Kedissa et al., 2016)	Microclimate and Thermal comfort	Simulation of Hypothetical Model	Algeria
(Tablada et al., 2005a)	Natural ventilation	Simulation of Hypothetical Model	Cuba
(Ferreira et al., 2019)	Daylight	Simulation of Case Example	Swedish
(Bulus et al., 2017)	Thermal performance	Field survey	Malaysia
(J. Gupta et al., 2017)	Thermal performance	Simulation of Case Example	India
(Erdemir Kocagil & Koçlar Oral, 2016)	Energy performance	Simulation of Hypothetical Model	Turkey
(Meir et al., 1995)	Microclimate and Thermal comfort	Field survey	Israel
(Freewan, 2011)	Daylight	Simulation of Hypothetical Model	Jordan
(Guedouh & Zemmouri, 2017)	Daylight and thermal comfort.	Field survey	Algeria
(Guedouh et al., 2019)	Daylight and thermal comfort.	Simulation of Hypothetical Model	Hot and Arid Climate
(Samir, 2015)	Daylight	Simulation of Hypothetical Model	Hot and Arid Climate
(Kocagil & Oral, 2015)	Thermal performance	Simulation of Hypothetical Model	Turkey
(Patherya & Lau, 2012)	Thermal performance	Simulation of Hypothetical Model	India
(Muhaisen, 2006)	Shading Analysis	Simulation of Hypothetical Model	Kuala Lumpur, Cairo, Rome Stockholm.
(Tayari & Nikpour, 2022)	Daylight	Field Survey	Iran
(Ratti et al., 2003)	Daylight, Built potential	Simulation of Hypothetical Model	Morocco
Attributes/Impacts : Socio-cultural /Religious			
(Mezerdi et al., 2022)	Spatial ,Psycho-social analysis	User's perception	Algeria
(Nibedita Das, 2006)	Impacts of courtyard.	Field survey &simulation	India

(Mohammed Al-Hussayen, 2015)	Courtyard size and proportion	Case studies	Saudi Arabia
(Gulati et al., 2019)	Courtyard as Space	Case studies	India
(Luo & Huang, 2022)	Courtyard as design concept	Case studies	China
(Nikeghbali, 2017)	Design principles	Analysis and Focus group Discussion	Iran
Attributes/Impacts : Psychological			
(Al-zamil, n.d.)	Psychological wellbeing, privacy	User's perception	Kuwait
(Marafa & Alibaba, 2018)	Impacts of courtyard.	User's perception	Cyprus
(Elwerfalli, 2016)	Impact of courtyards	User's perception	Libya
(Gangwar & Kaur, 2020b)	Impact of courtyards	User's perception	India
(Lee & Park, 2015)	Courtyard as design concept	Case Study	UK, Korea & India
(Almhafdy et al., 2013)	Healing Impact	Field survey	Malaysia
Attributes/Impacts : Economic			
(Cremers et al., 2015)	Efficient land use	Prototype Analysis	Germany
(Lall et al., 1991)	Efficient land use	Case Study	India
(Kim, 2001)	Efficient land use and density	Parametric study of housing layouts	Korea
(Khalili, 2017)	Efficient land use and density	Parametric study of housing layouts	Canada

### 1.3.1 Daylight as Parameter

The analysis of the literature review suggested that the researchers mostly focused on the environmental parameters of the courtyard as compared to social, cultural, functional, and economic parameters. Furthermore, around 75% of the research publications examine the thermal efficiency and microclimate of a courtyard, whereas 25% examine daylight as a variable (Table 1). The researcher identified daylight as a parameter because it is less explored by the researcher as compared to the thermal performance of the courtyard. Since the study is centred on the courtyard's topological perception, geometry has a significant influence on daylight (Dabe & Adane, 2018) (Majeed et al., 2019). As Louis Kahn once said, "a room is not a room without daylight," the daylight potential of the courtyard typology has

been investigated since daylight utilization has a substantial impact on energy efficiency and inhabitants' well-being.

A chapter in the book “Courtyard housing past, present, and future” argues that romanticizing traditional architecture or advocating acceptance of all of its principles is not a viable solution; while, effort must be taken to bring back principles that have proven their effectiveness in terms of climatic and social aspects that characterize local residential environments, such as the existence of the courtyard as an essential architectural element within each housing unit. Traditional structures should be viewed as typologies representative of continuous historical processes rather than as objects with little relevance to contemporary design practice (Brian Edwards, Magda Sibley, Mohammad Hakmi, 2006).

Martin, March, and Trace investigated the courtyard not just for its built potential but also for its daylight intake. Martin and March observed that, in general, courtyards perform better than pavilions depending on how they are built in terms of light penetration and land utilization(Khalili, 2017).

Though the present study is focused on courtyard typology and its adoption in a contemporary context, it is quite impossible to mimic all the traditional elements such as thermal mass, mutual shading, Fenestration etc. however courtyard typology as a concept can be considered for future sustainable habitat. Using Martin and March's study as a basis, which established the relationship of typology with daylight penetration, the daylight parameter was used to provide quantitative findings while comparing the models.

Preliminary study and literature review focus on the following valid research questions which ultimately form the research gap.

- What is the current status of the traditional settlements and new developments in cities having composite climates?
- How traditional dwellings are performing in terms of their space arrangement, climate response, physiological well-being of users, etc., in the changing urban scenario?
- How to derive adequate area and suitable dimensions of land for courtyard house design concepts?
- How much flexibility in building setbacks is desirable in order to accommodate the reduced permissible ground coverage?

- How to find the appropriate design principles which could be suitable from present built environment?
- How far are the vernacular dwellings suitable in accommodating the changing activities and life styles of today?

**Research Gap:** There is no disagreement in the fact that the courtyard is a holistic space with multiple implications such as climatic, social, religious, physiological, economical as well as cultural. Numerous studies have been done to assess the impact of courtyards in thermal comfort, daylighting, and physiological user health but researchers have yet to explore the optimum size, form, orientation and location of courtyards in medium-sized plots for the Indian context. We need to find out the lacunae which prevent us from using the architectural tradition of providing the courtyard in the spatial structure of modern housing and planning Bye-laws of Lucknow

#### **1.4 RESEARCH HYPOTHESIS**

The advantages of the universal courtyard design and determining the suitability of the traditional courtyard form in modern dwellings crisscross the way to sustainable development.

**Hypothesis:** *Courtyard typologies are best suited typology in the Indian context and could be efficiently used in plotted development of medium size plots.*

#### **1.5 RESEARCH OBJECTIVES**

The major objective of this research is:

- ✓ *To identify, document, and describe the impact of courtyard houses and enlist the challenges in adopting courtyard houses in Indian cities.*
- ✓ *To validate the unanimity among the experts and end users regarding the importance of the courtyard concept and the need for its adoption in residential units.*
- ✓ *To develop a set of courtyard design prototypes applicable to the contemporary urban lifestyle and dense residential development through the needed variations in predominant Bye-laws of Lucknow and proving their suitability with respect to the day-lighting as an identified parameter.*

The major objective will be achieved only when the following tasks are carried out and completed successfully.

- ✓ Studying and analysing the characteristics of Traditional dwellings in composite climate regions, in terms of settlement planning and individual structures.
- ✓ Assessing the impact of urbanization and changing lifestyle on the houses typologies and inadequate land resources.
- ✓ Evaluating the performance of the courtyard houses in terms of spatial design, climate responsiveness, thermal performance, day lighting and physiological aspects, etc.,
- ✓ Studying and understanding the form and orientation concepts of courtyard dwellings, and their relevance in the modern context.
- ✓ Analysing the ability of the courtyard typologies to accommodate stringent bye-laws of the city area.

#### **1.6. SCOPE AND LIMITATIONS OF THE STUDY**

1. The geographic study area is confined to traditional houses of composite climate and urban courtyard houses as representative of best design practices irrespective of their climate.
2. Though traditional housing consists of varied dwelling types, ranging from a rudimentary rural hut to large haveli, the study is focused only on the medium size houses.
3. Bye-laws study of only low-rise medium-density settlement for the case of new development has been considered.
4. The analysis is limited to spatial qualities and flexibility, climate responsiveness of the structures and daylight performance, to identify the generic sustainable principles.
5. The various impacts of courtyards have been studied thoroughly; however, only daylight has been identified as a parameter for conducting the simulation.
6. The daylight performance analysis of the dwellings will be carried out, using ECOTECH in hottest month of the year and the coldest months (Summer and Winter solstice) of the year.

## **CHAPTER 2: LITERATURE REVIEW**

Charles Correa, one of India's best-known housing experts at the time, demolished the high-rise apartment model during an address at the SPA in Delhi (1996), later clarifying that low-rise, medium- to high-density housing is affordable in a tropical climate like India's, where houses are traditionally clustered around shared courtyard spaces (Maddipati, 2020). The courtyard house is one of the world's oldest and most prominent residential prototypes, featuring different regional variations. In India, Courtyards are the direct manifestation of the social, cultural and religious beliefs of society. As a result, various kinds of courtyard houses, such as haveli, Wada, nalu-kettu, rajbari, and so on, are prevalent throughout India reflecting the culture and tradition of particular regions. The shift from a courtyard to a Western-style house symbolizes the transition from a joint to a nuclear family. There are numerous reasons for the acceptance of Western-style house forms in urban settings, including an affection for modernity, a lack of space that limits the construction of traditional dwellings with wide courtyards, and architectural training in the western idiom (Sinha, 1990).

With this insight, the study aims to create a knowledge base on courtyard houses and their elements in order to explore fresh ways to revitalize the courtyard typology in urban settlements. This chapter gives background information on the historical evolution, spatial arrangements, and chronological alteration of the courtyard form in India and around the world. The aim of this chapter is to establish the relevance of the courtyard house and to comprehend how this deeply rooted and time-tested typology might be revitalized in current development.

### **2.1. COURTYARD: A DEFINITION**

A courtyard or court is a small, open space that is typically enclosed by a building or complex. Courtyards have been used as the main focal areas of homes since the beginning in order to provide optimum lighting and ventilation. Oxford's Dictionary defines courtyard as: "An unroofed area that is completely or partially enclosed by walls or buildings, typically one forming part of a castle or large house." Moreover, The National Building code (2005) defines the courtyard as: "Space permanently open to the sky, enclosed fully or partially by building and may be at ground level or any other level within or adjacent to a building." (Kisan et al., 2005). In India; courtyards were more than just a type of architecture. A well-known architectural design that is typical of conventional residential architecture is the

courtyard-style building. The courtyard space, as the center of the house, is not only an important place for daily life and family gatherings, but it also reflects the family spirit(Luo & Huang, 2022). Although classic courtyard houses are deeply rooted in tradition and culture, changes are unavoidable. The underlying challenge, however, is to meet the sociocultural demands of the inhabitants while also incorporating lifestyle changes, innovative material and construction techniques (Vedhajanani & Amirtham, 2023). As most architects embrace the concept of critical regionalism, hence there is scope for transforming traditional courtyard in contemporary urban courtyard is feasible.(Fig-1).

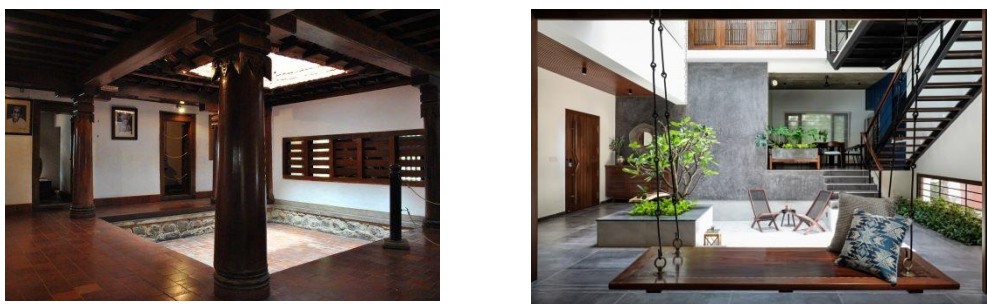


Figure 1 Traditional and modern courtyard.

(Source: <https://tiesofindia.indiatimes.com/>, [www.buildofy.com](http://www.buildofy.com))

## 2.2. COURTYARD: ELEMENTS AND FORM

Courtyards fall under the category of "Transitional space," a specific type of architectural space. Transitional spaces are architectural spaces that act as a 'in-between' spaces where the interior and outdoor microclimates are moderated without the need of active strategies (Taleghani & Tenpierik, 1986). Three general categories might be used to classify these transitional spaces (Fig 2). The first group includes courtyards, and atriums. The second kind consists of attached semi-open areas such a porch, balcony, hallway, arcade, or veranda. The third group includes buildings that are surrounded by outside areas like gardens or pavilions.

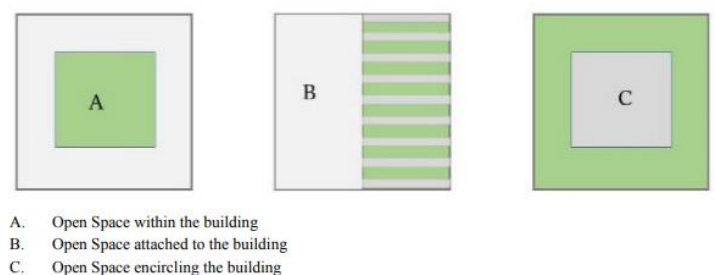


Figure 2 Different type of transitional space

(Source: Illustration by Author based on Taleghani et al., 1986)

Furthermore, Researchers have recently mentioned the benefits of courtyards to explain their importance in a house (Markus, 2016). Amos Rapoport recognized the functional importance of courtyard spaces in the house (Rapoport, 1995). Through an extensive literature study Zamani et. al highlighted the environmental component of courtyards (Zamani et al., 2018).

Zhang studied the socio-cultural characteristics of courtyards in six different cultures around the world (Zhang, 2020). Zamil.F establishes the Psychological impact of the courtyard in his study of occupant satisfaction survey (Al-zamil, n.d.). The economic benefits of courtyards were emphasized by their energy-efficient compact designs (Sthapak & Bandyopadhyay, 2014). Hence, Courtyard typology can be characterized by the following benefits/Parameters as shown in Figure 3.

The performance and behavior of courtyard designs and features at both architectural and urban scales have been examined in a number of studies. This research aids in defining the constraints, challenges, and opportunities for improving the design in residential dwellings.

The earliest style of courtyard house is often rectangular, square, and circular. Courtyard does not have a precise plan. In order to develop new forms, these forms have been modified to on the basis of topography, site restrictions, building orientation, climatic context and purpose. The courtyard's dimensions and scope may be adjusted to be anything from little to enormous (Meir et al., 1995). A literature analysis revealed that a courtyard design can have walls that totally, partly, or only partially enclose it .Various studies are conducted to critically evaluate the functionality of courtyard shapes and features at both the urban and architectural levels. This research helps to define the shortcomings, challenges, and opportunities of design development. One of the study suggested a rectangular courtyard arrangement to shield the building from solar radiation and dusty wind (Tablada et al., 2005b). The three side courtyards created an ideal environment, particularly when ventilation and orientation were taken into account during the design phase. The study investigated the rectangular form courtyard in four different climate zones to analyses the shading pattern that



Figure 3 Attributes of courtyard  
Source: Illustration by Author based on (Rapoport, 1995)(Zamani et al., 2018)(Zhang, 2020) (Al-zamil, n.d.)(Sthapak & Bandyopadhyay, 2014),)



are useful in extreme effect in summer and winter (Muhaisen, 2006). Meanwhile, a study concluded the potential for courtyards to act as passive cooling can be correlated with building composition with respect to airflow rate and pattern (Rajapaksha et al., 2003).

### 2.2.1. Shape

Although a courtyard can be of any shape; the most typical designs are rectangle, square, and circular. But more complex designs, like the U, L, I, or double line shape might be used to overcome restrictions like site limitations, terrain, building orientation, or specialized functions (Fig 4)(Nibedita Das, 2006). Meir (2000) defined a suitable courtyard as a semi-enclosed area with a thoughtful orientation that may maximize its microclimatic effectiveness

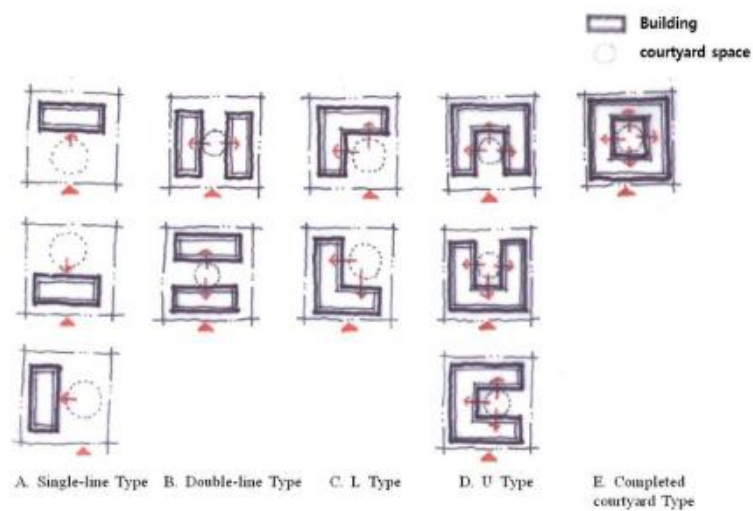


Figure 4 : Different shapes of courtyard

(Source: Lee. M et.al)

### 2.2.2. Orientation

Another design variant that appears to be insufficiently explored is courtyard orientation. However, Antonio and Carvalho (2015), who studied the impact of courtyard orientation on its environmental performance using both experimental and simulation methods, have made contributions in this regard (Bulus et al., 2017). He discovered that increasing the height of the courtyard walls reduces the degree of air temperature in the courtyard as well as the in adjacent rooms. Although accurate courtyard orientation can improve thermal conditions, orienting it regardless of solar angles and wind direction can cause thermal distress (Meir et al., 1995). The following factors have a direct impact on courtyard microclimatic behavior: sun position, wind direction, shading effect, and radiant heat (Bagneid, 2020).

### **2.2.3. Wall enclosure**

A courtyard's design varies according to the size and shape of the surrounding walls in different geographical areas. Additionally, despite the different effects of culture, economic, social, and environmental conditions, the design of the courtyard is similar in basic nature (Meir, 2000). The phrase "wall enclosure" refers to components that create the shape of a courtyard with a building, such as walls, windows, and vegetation which play important roles in microclimate conditions. Additionally, designers can use these components to their advantage during the design phase to enhance the courtyard.. According to studies, the aspect ratio and cantilevered roof have a significant impact on wind speed which consequently impact thermal comfort (Almhafdy et al., 2015). The courtyard's geometry was found to have a significant impact on the amount of day lighting in the adjacent rooms (Pawar et al., 2019) The courtyard's dimensions and size will greatly increase its ability to achieve greater environmental efficiency (Markus, 2016).

## **2.3. HISTORIC EVOLUTION OF COURTYARD IN WORLD**

The primary goal of researching the historic evolution of courtyard houses in the world timeline is to visualize the global spread of courtyard houses. Taleghani et al. thoroughly researched the literature on the historic evolution of courtyards and concluded the four primary eras for courtyard evolution as outlined above (Taleghani & Tenpierik, 1986).

### **2.3.1. Ancient Civilization**

According to Schoenauer and Seeman's book "The Court-Garden House," a troglodyte hamlet in southern Tunisia's Matmatas area is the most primitive and cohesive society to build courtyard homes. The first rectangular homes in Morocco, the Kraals of Bechunaland in South Africa, the Douars in North Africa, and nomadic tribes' encampments in West Africa laid the cornerstone for the traditional courthouse (Nibedita Das, 2006) Archaeological excavations uncovered the oldest courtyard residence in China from the middle Neolithic Yang Shao culture (5000-3000BC). A courtyard and a light well are features of a Chinese house. A courtyard serves as a conceptual link between heaven and earth. On a similar principle, early Chinese courtyard residences were constructed. Later Japanese courtyard dwellings likewise adhere to the same principles as early Chinese courtyard buildings.

### **2.3.2. Classic Civilization**

The classical era of architecture, which is marked by the specific genius of Greek and Roman design, supports the widespread popularity of courtyard design. Greece developed its first courtyard dwelling in the fourth or fifth century BC. Greek hall-style homes in urban settings were gradually displaced with peri-style homes. The creation of the Roman atrium residence was influenced by both Greek peri-style buildings and Etruscan atrium homes. (R. Gupta & Joshi, 2021) Late Roman urban residences frequently included the atrium, a smaller quadrilateral inner court garden, and the peri-style, a larger quadrilateral inner court garden.

Renaissance Civilizations

### **2.3.3. Renaissance Civilization**

Following the collapse of the Roman Empire in A.D. 476, the courtyard homes suffered a setback. During the middle Ages, the only traces of courtyard homes were discovered in Italian cortile buildings and monastery cloisters. At the time of the Moorish invasion, there were still remnants of a thriving Roman civilization, and the Moors introduced their culture to Mediterranean towns. Despite the stark differences between the two religions, Islam has incorporated elements of both Greek and Roman thought. The Ur homes have had an impact on the style of traditional Islamic courtyard structures (YU, 2002). The idea of "privacy and isolation with a limited show of the occupant's socioeconomic standing to the outer world" is upheld in traditional Arab homes (Norbert Schoenauer & Stanley Seeman, 1962).

### **2.3.4. Modern Civilization**

The patio was introduced to Northern America by the Spanish between 1890 and 1930, and Southern California swiftly embraced it as a result of Spanish colonial influences. Some architects are still incorporating patios and other features of Spanish Colonial architecture into their modern constructions. The modern atrium home in Northern Europe may have a historical predecessor. The majority of modern courtyard villas, on the other hand, were built after World War I and may be separated from any traditional Mediterranean style (Abass et al., 2016).

## **2.4. HISTORICAL CONTEXT OF COURTYARD IN INDIA**

During this process of transformation and amalgamation of architecture and society, there has been continuity in the subcontinent's vernacular buildings and cities. One architectural style that has persisted in being expressed repeatedly throughout India's evolving and diverse range of architectural styles is the courtyard type. Even though courtyard forms are largely being

replaced by Westernized box architectural types nowadays, T.S Randhawa in his book argues that they were traditionally a "way of life," particularly in relation to Indian residential architecture. Thus, courtyard planning is one of the oldest and most durable architectural features, with roots in India.

## **2.5 EVOLUTION OF COURTYARD IN INDIA**

### **Ancient Period**

3000 B.C. -1500 B.C

Indus Valley Civilization, Courtyard Houses Found in Mohenjo-Daro

### **Vedic Period**

1500 B.C.-500 B.C

Vaastu Shashtra: Basic of Architecture

Praangan are designed at the centre of house that are called Brahmsthan

### **Buddhist Period**

563 B.C. – 200 A.D

Courtyard in Buddhist Monasteries, Ajanta Caves etc.

### **Medieval Period**

1000 A.D -1707 A.D

Courtyard in Jaisalmer Fort, Jahangir Mahal, Islamic courtyards

### **Colonial Period**

1650 – 1947 A.D

Colonial Bungalows of Bengal

### **Contemporary 1947- onwards**

1947- Onward

Sarpanch house of Gujarat, three courtyards house, house in south India etc

It is quite important to understand the journey of courtyard space through the timeline of Indian history. The courtyard dwellings as primitive structure travel all to the era of modernization and urbanization. The various literatures available for the courtyard space in different time period has been reviewed, however the main purpose of the study to generate timeline for the courtyard spaces. In his research, S. Sem van der Straaten created a timeline for the European atrium, opening the door for subsequent studies to create timelines of spaces for other parts of the globe (Van der Straaten, 2021). The primary objective of the study is to understand the various Hindu scriptures, which depict the central portion of a dwelling as a void or courtyard. The mythological understanding implies that the central space of the house

is the focal point of the house. Nowadays, there is a trend to follow Vaastu Shastra in Indian homes. However, people still follow its principles half-heartedly without fully accepting its essence. Without understanding the foundation of any society's scriptures, it's difficult to adopt any cultural influence.

### 2.5.1 Ancient Period

The Indus Valley Civilization is thought to be the origin of the courtyard's architectural style. India's first courtyard home dates to about 6000 and 6500 B.C. The Indus Valley Civilization, the oldest civilization in the world, dates to the third millennium BCE, making it one of the first civilizations ever. Courtyard planning is one of the oldest and most durable architectural features, with roots in India. The courtyard as a space first developed on the Indian subcontinent during the growth of first civilization along the banks of the great river Indus.. Harappa, Mohenjodaro, Lothal, and Kalibangan were primarily the sites where this civilization's residential colonies thrived. Indus Valley Civilization as an agrarian society, it valued the rich, cultivated land along the river and believed that it should be used cautiously and wisely for non-productive reasons such as dwelling. This, together with the area's hot and dry climate, led to the settlement's dense built structure, which included deep, long buildings in a continuous row with shared walls on almost three sides and an inner court that was exposed to the sky. The houses were designed around the courtyard, a large open area that was generally uncovered (Fig 5). The climatic and cultural circumstances of the region influenced the courtyard dwelling typology developed during those period (Kak, 2005) (Abhi Shah, 2022).

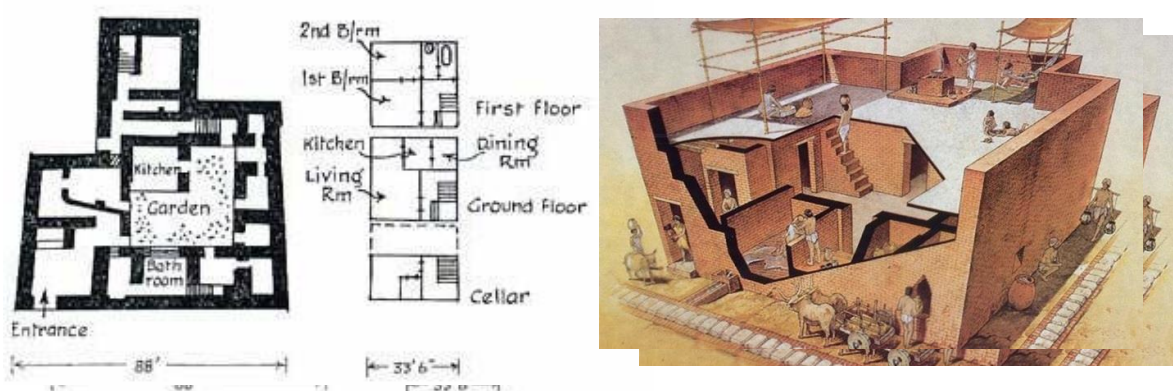


Figure 5: Courtyard Planning in Indus Valley Civilization

Source: (Abhi Shah, 2022).

Mohenjo-Daro is one of the sites discovered during the excavation of the Harappa Valley Civilization. To provide a social meeting area within, the dwellings at Mohenjo-Daro were built as a series of rooms that opened onto a central courtyard (Myneni, 2022). In Mohenjo-Daro, the typical house was a courtyard house with an inward gaze

The smaller homes featured only one courtyard, as opposed to the bigger ones, which were frequently situated along the north wall. For dwellings and public buildings in both the great cities of Harappa and Mohenjo-Daro, standardized burnt brick of good quality was the usual building material. All the houses had a similar design, a square courtyard encircled by multiple rooms, but varying in size and frequently having two or more stories (Kak, 2005). The typical house was designed as a sequence of rooms that open into a central courtyard. This courtyard served several purposes, including illuminating the rooms, functioning as a heat absorber in the summer and a radiator in the winter, and offering an open area within for communal events. There were no openings towards the main street, preserving homeowners' privacy. In reality, the sole openings in the houses are quite modest, preventing the strong summer sun from heating the inside. Every house was evaluated based on numerous factors, including access to the rooms, as well as their size, shape, and purpose. Jansen.M investigated the existing documentation of Mohenjo-Daro and analysed the architectural features of the houses and for this particular house southern entrance that leads to a central courtyard is observed (Fig.6)(Jansen, 1985).

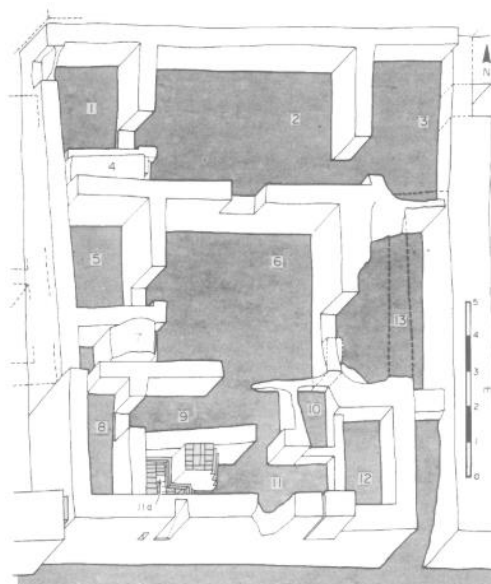


Figure 6 Observed house at Mohenjo-Daro, 6- central courtyard

Source : (Jansen, 1985).

Unfortunately, none of the Indus Valley civilization's buildings has survived intact to this day. However, the planning concepts and architectural elements responsive to climate are few lessons for all of us. If by 'urban' we mean the urge to construct civilization, establishing cities with all their associated regulations, then the Harappa's people did it brilliantly

### **2.5.2 Vedic Period (1500 B.C.-500 B.C)**

The courtyard received further validity and credibility during the Vedic era as society advanced from the earlier one thanks to the philosophical undertones associated to it. The house was considered a microcosm, a fundamental component of a universe (a higher order). The Vaastu Purusha Mandala was used as a blueprint to orient the building, divide its spaces, and plan its activities. The Vaastu Purusha is made up of 45 gods, each of them has an impact on many parts of human existence. Even though the proportions and scope of the gods' positions within the scheme may change, their relative positions stay the same. The mandala acknowledges that the middle cell is a void and that it is where Brahma, the creator, resides.

All other activities change in reaction to this focal void, thus the housing architecture develops around the court rather than being a leftover of the construction. The court is described in detail in the design guidelines as the foundation of the residence and its proportions for various building types are suggested based on their scale. Thus, the court acquired a new significance throughout the Vedic era, one that was both physical and spiritual, and it could be found in different kinds of structures (Hotwani & Rastogi, 2022). The holy writings known as the Vedas serve as the foundation for Hinduism, sometimes referred to as Sanatan Dharma, which means "Eternal Order" or "Eternal Path." In the sense that they are believed to contain the essential information relating to the underlying source of, function of, and individual response to existence, the name "vedaas" means "knowledge". They are sometimes referred to as "scripture," which is accurate, because they might be characterized as holy books that describe the nature of the Divine (Ghom & George, 2021). The Vedas were originally oral and were transmitted from teacher to pupil for many generations before they were put down on paper. India's so-called Vedic Period began around 500 BCE. In order to maintain the integrity of what was initially heard, masters would make

students learn them both forward and backward, with a focus on correct pronunciation (Hotwani & Rastogi, 2022).

The four texts that make up the Vedas are as follows:

- ✓ Rig Veda
- ✓ Sama Veda
- ✓ Yajur Veda
- ✓ Atharva Veda

Grhas was the home of the individual or joint family, and grama was a group of grhas. The devata known as vstospati presided over each dwelling. The fact that a dwelling has so many names suggests a vast range of forms and sizes from a cognitive perspective. A mansion with multiple rooms, parents, numerous women, and even a guard dog at the door was named a harmyam; a regular house with a roof was called a chardis; and a multi-residence complex with halls for animals was called a gotra. According to the description, harmyam featured female-only apartments in the back and an open courtyard in the centre (Kak, 2022).

#### *Impact of Ancient India's texts on Indian Architecture.*

The Sthapatya Veda, a division of the Atharva Veda, is the source of Vaastu Shastra. The pursuit of spirituality and receiving divine favors is highly valued in Indian culture. The wellbeing, health, and happiness of the populace are said to be greatly benefited by it. The importance of our traditional design knowledge is not given priority in the present day. Nevertheless when the sole focus of architecture is on comfort creation, it adopts a limited perspective, taking the site, Bye-laws, client requirements, and fancies into account. It has been established that celestial bodies constantly exert their magnetic and gravitational forces on us. Additionally, the earth itself has a magnetic aura of its own. Therefore, it seems sense to claim that these magnetic forces will affect our minds and, in turn, our lives. The art of architecture and planning known as Vaastu shastra focuses on the study and application of the interactions between natural forces, celestial bodies, and supernatural aspects in the universe. Man is viewed as a cosmic being that must coexist peacefully with other cosmic components in order to survive.

#### *Vaastu Shashtra: Logic behind Architecture*

The Vedas, a collection of texts originating in Hinduism between 1500 and 1000 BC, are where Vaastu shastra first emerged. Each of these four Vedas has supplementary Veda that goes into the details of further topics. The word "Veda" means "knowledge" or "to know,"



and each document reveals diverse aspects of spirituality, natural forces, and philosophical views. The Sthapatya Veda, a supplement to the Atharva Veda, contains the Vaastu Shastra. The Sthapatya Veda section is devoted to all aspects of architecture, including home design and urban planning. Even though these scriptures are Hindu in origin, they do not specify that only Hindus should read and comprehend them. Panch Maha Bhutas (Five elements) and Vaastu Purush Mandala are two of the fundamental concepts of Vaastu Shastra (Karani, 2014).

*Vaastu Purush Mandala*

The Vaastu Purusha Mandala (Fig 8) is an essential component of Vaastu shastra and provides the diagrammatic and mathematical foundation for the creation of designs. It is the metaphysical building plan that takes the movement of the celestial bodies and supernatural powers into account. A Purusha is a cosmic man, energy, a force, or a soul. Any map or chart that represents the cosmos figuratively is known as a mandala (Piplani & Brar, 2020)

A building site is aligned with the four cardinal and four ordinal directions—north, south, east, west, northeast, northwest, southeast, and southwest—by using the Vaastu Purush mandala. A construction-friendly site is always depicted as a grid of squares with the bindu at its core.

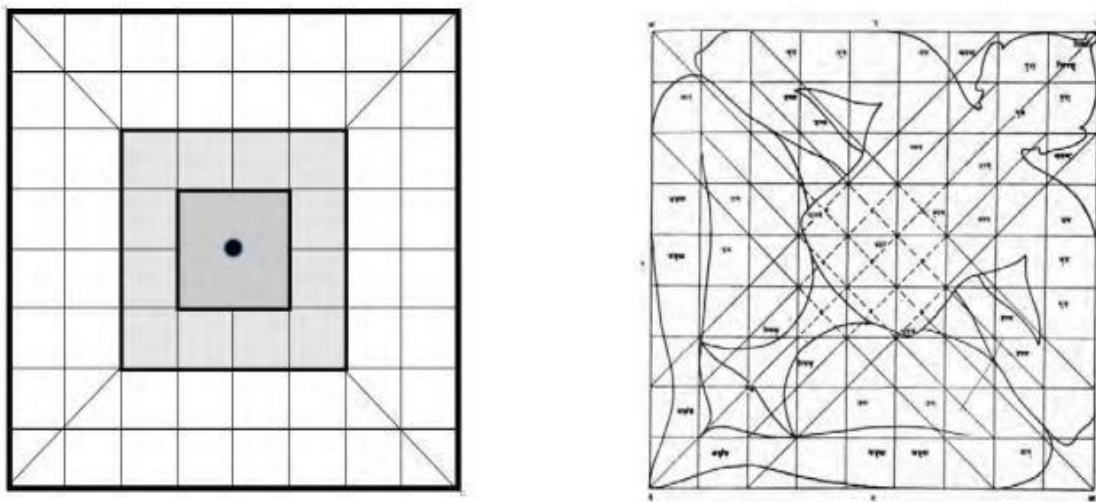


Figure 7: Vaastu Mandala & Vaastu purush mandal

Source: (Piplani & Brar, 2020)

The site's vacuum and soul are both contained in this point of reference. The "figure of Man" or "Vaastu Purusha" overlaid on mandala or a grid is "beyond form." This "figure of Man" is described as the "Spirit of the site" by the Samarangana Sutradhara. The feet of the Purusha

are located in the southwest, while the head is towards the northeast. The knees and elbows stand for the north and south, respectively.

Indian courtyards: combination of cosmic and mythology

The four cardinal directions—East, West, North, and South—of the particular geographic area are echoed in architecture's orientation. The Vaastu Shastra also takes into account the wind and sun directions. Other factors include the context of intangible and tangible traits of human behavior that fall under the category of culture, social, moral, religious, and economic aspirations (Ghom & George, 2021).

Mandala

The Brahmasthana, which is the center of the universe, is void but have all the significance, like everything in nothing (M. Shakya, 1970). Depending on the type, scale, function, and complexity of a building, one of 32 different types of mandalas could be used on a site. Each plan type assigns a specific location to the presiding deity, who then determines the purpose or use of that area in a structure. The first is called Sakala and is a single-plot facility. A plot may be circular, square, rectangle, oval, or polygonal. Four-plot sites are referred to as Paisācha, nine-plot sites as Pitha, sixteen-plot sites as Mahapitha, twenty-five-plot sites as Upapitha, and so on. (Piplani & Brar, 2020).

Each plan type assigns a specific location to the presiding deity, who then determines the purpose or use of that area in a structure. The first is called Sakala and is a single-plot facility.

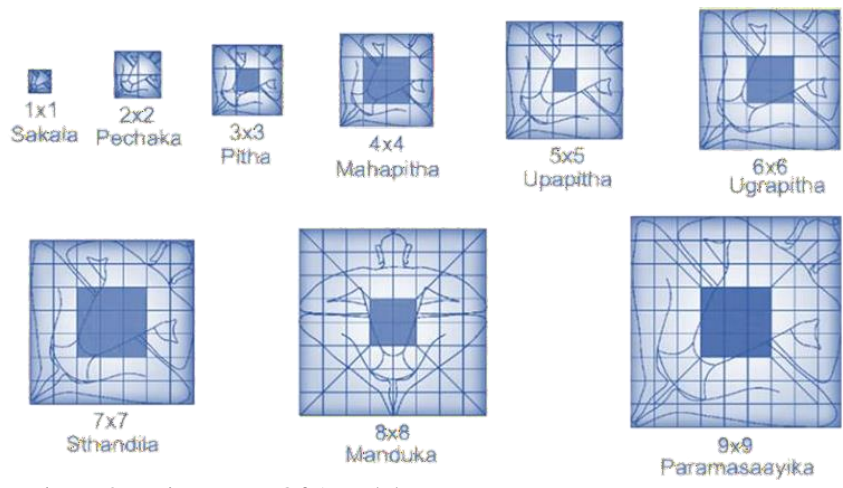


Figure 8: Various Type Of Amndal ,

Source: (Piplani & Brar, 2020)

A plot may be circular, square, rectangle, oval, or polygonal. Four-plot sites are referred to as Paisācha, nine-plot sites as Pitha, sixteen-plot sites as Mahapitha, twenty-five-plot sites as Upapitha, and so on. (Piplani & Brar, 2020).

The images above show just a few of the numerous ways that the notion of mandala might be used to split up a block of land (Fig 8). An architect could use the aforementioned technique of generating plots to create a customized mandala or grid plan for a particular location, use, and building type.

**Brahmasthan**

In the Manduka Mandala (Fig 9), for example, the Brahman, or the Brahmasthan, is spread across four adjacent squares, and over nine squares in the Paramaasyika Mandala. The Brahman always occupies the center, serving as the cosmic man's nabhi (navel). The mandala can be used to illustrate a number of characteristics characterizing the quality and character of vastness, including the spring of life, incomprehensible infinite, sources and final destination, void or shunya, and bipolar unity. It represents the ultimate objective of architectural space as a cosmic diagram.

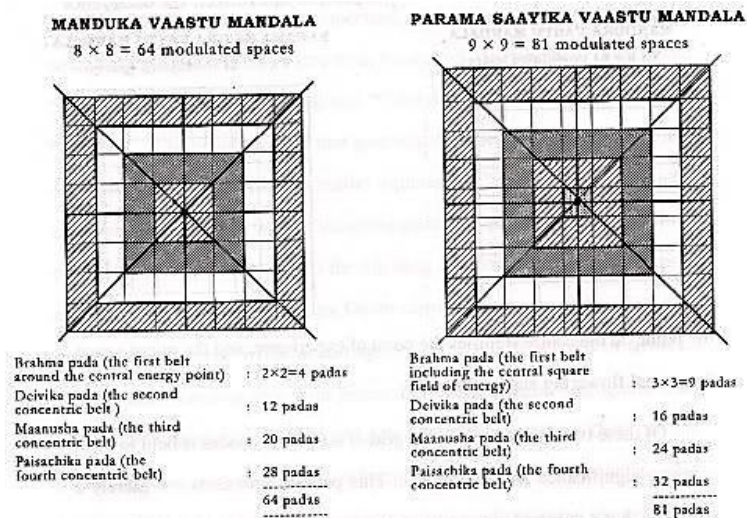


Figure 10: Manduka Vaastu Mandala And Parma Soyinka Vaastu Mandal, Source: (karani 2014)

**Brahmasthan as courtyard**

In the expressions of Indian constructed form, the idea of central space is distinct and evident as the conceptual, ideational, and expressed center but not always as the geometric or physical center of the thing. According to Indian architectural texts, including the Vaastu Shastra, Brahman is allotted the center area of every built form, giving rise to the term

Brahmasthan, or the central courtyard, as stated by Kami agama (a religious text from south India). The term "angan" is also used to describe this center courtyard. The fundamental idea is that all entity, whether man made or natural, has a center or assigned central space that absorbs and disperses all opposing energies, establishing the general core of that organism (Dokras & Stockholm, n.d.)

### Shri Yantra

The Sri Yantra is symbolized by nine interlocking triangles arranged around a bindu. Because it contains nine (nava) triangles, it is also known as a Navayoni Chakra (yoni). These nine triangles have four triangles pointing up, representing Siva, and five triangles pointing down, representing Sakti (feminine force) (masculine energy). The Sri Yantra depicts the numerous expressions of Sakti's descent. A point serving as the centre of condensed energy represents the para bindu, which is the first step of manifestation. It embodies both the static and the dynamic qualities of Siva and Sakti. When the centre swells and assumes the shape of a triangle, this changes into apra bindu, signalling the start of creation. The Mula, trikona, or triangle is formed as a result of the interaction between static and dynamic energy (Huet, 2002).

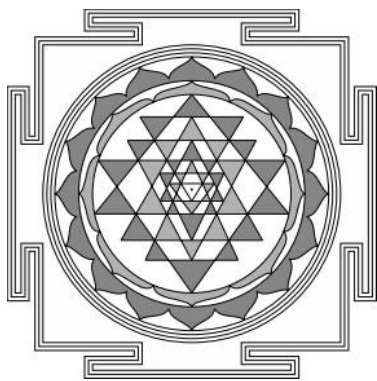


Figure 11:Sri Yantra, [Source : \(Huet, 2002\).](#)

According to the aforementioned study, the courtyard typology has a strong cultural foundation in India and is a crucial component of Hindu mythology and texts. Hindu homes consider their courtyards sacred spaces, mostly utilized for the worship of Tulsi.

It's fascinating to consider how our extensive Vedic knowledge may be applied to revive the custom through a courtyard. The idea can pave the way for further research in this topic.

### 2.5.3 Buddhist Period (563B.C - 200A.D )

The courtyard in the Buddhist era maintained its vibrancy and central role in the spatial organization of architectural forms, but it also experienced a variety of resolutions, mostly because of the building methods and monks' way of living. Here, courts were made by scooping out the gaps from the monolithic rocks, as opposed to the architectural form accreting around it. The first and most centrally scooped-out vacuum was the courtyard, from which the subspaces (cells) were further extracted. As a result, the spatial arrangement was centered on the court, with lateral cells connecting to it. This emphasized the need for the central void to serve as both the organizational hub and the only source of light and ventilation (L. Shakya, 2018) The basic courtyard form is retained in the modern construction of monasteries (Fig 12)



Figure 12: Courtyard in Buddhist Monastery

Source: <https://www.exploretibet.com/>

### 2.5.4 Medieval Period (1000 A.D -1707 A.D)

The North Indian architecture of forts and palaces is the main focus of medieval residential architecture. A fort wall with a surrounding moat and drawbridge gate was added to the architectural forms during the mediaeval era for defensive purposes. Land usage was optimized, resulting in a dense constructed fabric with long, deep buildings grouped in a row with more than two sides shared, in order to limit the perimeter of the settlement that needed to be defended. This condition, similar to that of early civilization, called for an internal void, or courtyard, for the ventilation of interior spaces without windows or any other external exposure.

Women folk were kept in veil and secluded from public exposure because to the introverted lifestyle and threat of hostility. The court's role as an outdoor area within an interior setting made it perfectly suited for a way of life where women could go outside, take in the scenery,



and enjoy the seasons while yet being protected from outside environment. A spirit wall was frequently erected at the entry to obscure the inner spaces from view and prevent intrusion. Due to their strong beliefs in privacy, both Hindu (Rajput) and Muslim farming communities found this to be advantageous. The court also dealt with the subcontinent's scorching temperature well in haveli of Rajasthan (Fig 13).

Courts evolved into essential elements of architectural design, whether they were a modest home or the harem of a palace. However, these courts were more intimate in size and properly encircled by the proportionate architectural form in order to more effectively lessen the climatic hostilities. In addition to impairing the defensibility and privacy gradient, a too big court would be ineffectual at lowering solar gain/heat and moderating connecting wind currents.

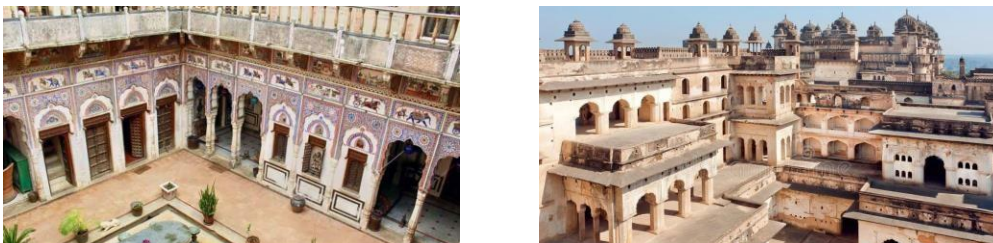


Figure 13 Courtyard in Rajasthan Haveli

Source: <https://www.thrillophilia.com/>

The Courtyard was very popular in India during the Islamic era for two reasons. One was a response to the oppressive heat, and other is strong opinions on female privacy and family values, an introverted lifestyle, and defensible spaces. As a result, the typology was easily introduced into the area from Persia, where it originated

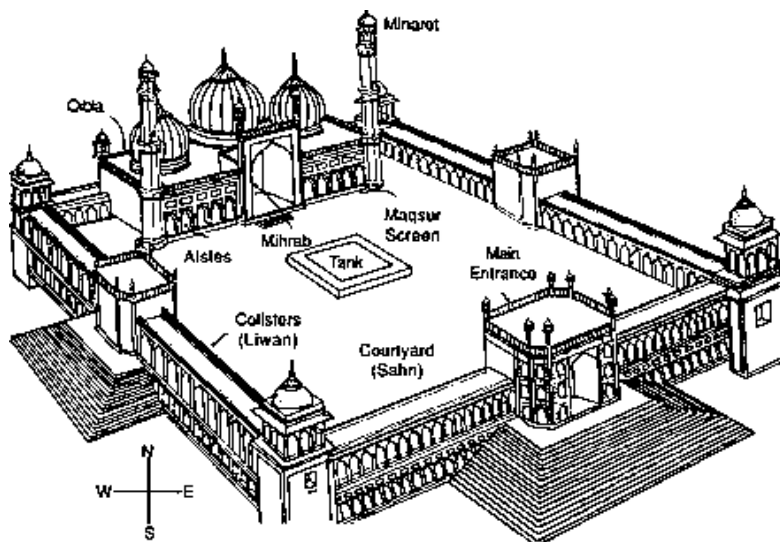


Figure 14: Indian Mosque  
Source : NCERT Book based on Percy Brown.B, "Indian Architecture (Islamic period) ; plate No-I ,Essential parts of mosque.

The concept of Jannah (the enclosed garden or court), which was spiritualized as "paradise" in Islam, was present and contributed to the consolidation and spread of the courtyard dwelling. These court gardens had been incorporated into Islamic monuments, and the idea was continued in domestic design, particularly in nobility's palaces and dwellings(Sharma & Kumar, 2019) (Fig 14).

Nivedita.D in her study correctly calls the Islamic adaption of courtyard homes an "oasis concept." The proportions of these structures retained a stunning responsiveness to the hot-arid environment seen in the majority of Muslim nations - "where there exists an intentional contrast between the stark, bright, heat of the outside and the intimate confinement, shade, and coolness of the interior"

### **2.5.5. Colonial Period (1650 A.D – 1947 A.D)**

In this environment, the bungalow emerged as an alien-looking housing design. Its origins can be traced back to the early attempts made in Bengal by British military engineers in the 18th century to convert a model of a traditional domestic construction into a standardized and permanent home for the East India Company while they were still traders on the subcontinent. The traditional bungalow as it evolved in the 19th century was a modest, one-story, spacious home with a symmetrical internal arrangement, a veranda all around, and it was located in a sizable, manicured complex.

The bungalow was the standard residential house form for British military officers linked with the Indian Army, colonial officials and business people, as well as a small group of wealthy Indian elites, at the beginning of the 20th century. The bungalow was located in a large lot. Early bungalows were often modest in design, made of stone or brick, with a stark whitewashed exterior. It had a symmetrical shape and a mainly symmetrical layout. It featured a verandah in front facing the garden and occasionally on both sides, rooms on either side, and a hall in the center(Bouwkunde et al., 2016) (Fig 16).

By the 1930s, the middle classes had enhanced and customized the bungalow as a model. The elimination of the verandah on three sides, with the front verandah becoming a traditional receiving area at the entrance, was one significant modification. Between the 1930s and 1960s, cooperative housing groups used it as a suburban model for planned lots. In various parts of India, this well-liked style underwent diverse transformations. The designs for the wet tropics and for the scorching desert climes are the most egregious examples of specific

reactions to climatic and cultural variances. For instance, a courtyard was frequently added as a typical element of Indian architecture(Dokras & Stockholm, n.d.).



Figure 15 : Courtyard in Colonial Bungalow (A & B)  
Source : (Desai & Desai, 2011)

### 2.5.6. Contemporary 1947- onwards *Courtyard in vernacular architecture*

Vernacular architecture is a type of regional or local construction that makes use of common materials and resources found in the area where the structure is located. This architecture is thus closely connected to its surroundings, aware of their unique geographic and cultural characteristics, and greatly affected by them.

Distinct Indian states have different names for courtyards houses. It is known as a Wada houses in Maharashtra, pols houses in Gujarat, a haveli in Rajasthan, and a Nalu-kettu (Fig 18) (the central courtyard surrounded by a set of rooms) in Kerala (Widiastuti, 2019). In Goa, both rural and urban regions still have a significant number of "Rajangann" or courtyard homes. This style of architecture is related to the Havelis of Rajasthan, the Chettinad style of Tamil Nadu, and the Thottimane style of Karnataka.



Figure 17: Chettinad Courtyard, Tamil Nadu

(Source:  
<https://www.livspace.com/in/magazine/lifestyle-design-chettinad-house/>)



Figure 16: Nalukettu Courtyard, Kerala

(Source: [www.hindu.com](http://www.hindu.com))



## **Courtyard in Urban Area**

The courtyards of the past have served as a source of inspiration for many modern courtyard designs. A change in trend and in people's thinking is indicators of changing times. The fact that the population has multiplied and that we now reside in crowded, dense cities is another angle to consider. Apartments with multiple floors are created from individual homes. There won't be enough room to construct a courtyard with the same magnificence as in this scenario. Having balconies, open doors and windows, or terrace farming—if it's possible—are alternate plans that are frequently used today.

The "private courtyard" that, individuals have today balance out all the rooms and balconies that surround it. These areas are frequently used for relaxing or for gardening. Modern additions to the courtyard include verandahs, spacious halls, and enclosed yards. On one side where the courtyard finds it difficult to remain in use as a design element in the modern day, there are still communities that use this traditional style of construction. This idea of a courtyard has been extensively curated in modern architecture. In addition to providing light and ventilation, courtyards have started to increase the value of a home. They separate spaces, bring nature into the home, and enhance the aesthetic value of the area. Here are 5 instances of how courtyards have been designed in contemporary homes, each with a unique personality.

### *The Three Courts Residence*

Strongly inspired by Vaastu, this gorgeous home in Bangalore, India, was created for a family of four. Three courts were added to the home in order to accommodate the five components of life—water, earth, air, and space. Strongly inspired by Vaastu, this gorgeous home in Bangalore, India, was created for a family of four. Three courts were added to the home in order to accommodate the five components of life—water, earth, air, and space.

The three courts each stand in for fire, earth, and water, while all three together bring space and air into the home (Fig 19). On the southern façade of the house, a court that captures the flavor of fire absorbs a significant quantity of heat throughout the day. By constructing a green corridor within the home that leads to this court, the landscape design brings the outside inside. A little body of water in the third court adds to the area's aesthetic appeal by merging in with the design's simplicity and minimalism. These courts are neatly incorporated into the house's room arrangements.



Figure 18 : Three court Residence

Source: <https://www.archdiaries.com/story-of-three-courts-collage>

## 2.6. REGIONAL VARIATION IN COURTYARD FORMS

The term "house" as a geographic element encompasses not only the dwelling house, which can range in size from small thatched huts to the most intricate massive mansions, but also any other human structure. (Dougallii, 1972). These places are where people congregate, store their belongings and material goods, and find fulfillment for their social and cultural needs. It is the best representation of the surroundings, which may be observed in the design, plan, morphology, and kind of construction materials. House types are significant components of the cultural environment and are determined by habits and historical elements (Dougallii, 1972). India is endowed with a great climate and cultural diversity due to its large geographic size and its impact on dwelling is quite visible. In India, courtyards were more than just a type of architecture. They appeared to be a way of life. The character and ambiance of a home were controlled by the courtyard, which mirrored the social fabric of society. The atmosphere inside the home was dominated or authoritatively influenced by the courtyard. They assisted individuals in adjusting to the harsh summers and freezing winters of the Indian subcontinent.. The current study has focused on many aspects of these cross-cultural interactions of courtyard spaces that led to the development and evolution of Indian residential architecture. Examining and evaluating sample residential complexes and buildings from the South, East, West, North, and Centre zones, it can be concluded that courtyard spaces marks their vast presence on map of India.

### 2.6.1. Courtyard in Different Region of India

India is divided into 5 zones based on traditional residential architecture as discussed below

- a) North zone
- b) South zone
- c) Central zone
- d) East zone
- e) West zone

**a) North Zone**  
**Uttar Pradesh, Punjab**

**Climatic Condition**

- ✓ Extreme summers and winters.
- ✓ Worst months are June-August.
- ✓ The climate has major influence on the size and form of the building(Fig 20)..

**Design Philosophy**

- ✓ Courtyards are built in the north zone to combat the harsh summer and winter because they are able to regulate the temperature during both seasons, making them comfortable for people (Fig 21).
- ✓ They are used for natural light and ventilation
- ✓ Interaction space
- ✓ Segregation of public and private space



Figure 19 : Courtyard in North Zone of India

Source: [www.Archinomy.Com/Case-Studies](http://www.Archinomy.Com/Case-Studies)

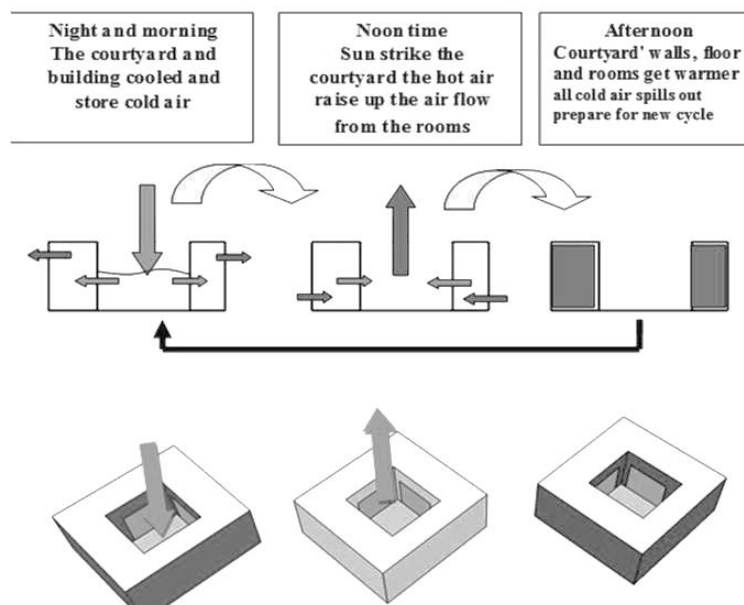


Figure 20 : Courtyard Effect

Source: <https://www.intechopen.com/chapters/69228>

## b) South Zone

Andhra Pradesh:	Manduka Logili
Tamil Nadu:	Chettinad Homes
Karnataka:	Guthu houses
Kerala:	Nalukettu

### i. Andhra Pradesh

Even in Andhra, the open courtyard is a well-known design element. Homes in this region of the country would also have spacious hallways extending the entire length of the building. Due to the influence of the local kings, traditional homes in this area display an intriguing blend of Muslim and regional architectural styles. Homes in circular clusters known as Chuttillu or Middillu can be found along Andhra Pradesh's seashore. Even while contemporary homes are replacing traditional homes, many households still like the use of red bricks, teakwood, and ornately carved doorways (Pradesh, 2020).

### ii. Tamil Nadu

As a traditional dwelling, the house was viewed as a cosmos within a cosmos, and all daily rituals were based on the sun's movement across the sky, the houses of Chettinad were built with an East-West axis in mind. The unrestricted movement of the wind inside the house was also made possible by this orientation. The houses were arranged longitudinally according to the occupants' gender and how much space they used. The males occupied the outer portions of the house, while the females and servants occupied the inner portions. The longitudinal axis of the house also has an increasing grade between public and private areas. The five main parts of the house are Valavu, Mugappu, Nadu Vaasal, Kattu Irandan and Moonran Kattu. (Patwardhan, 2017) (Fig 22).

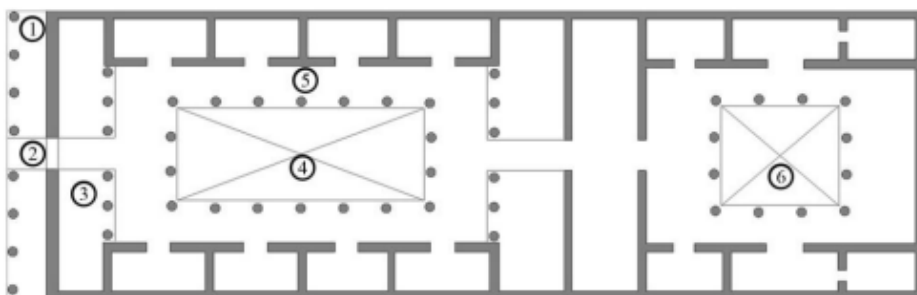


Figure 21: Typical plan of Chettinad House 1-Thinnai, 2-Entrance door 3-Pattalai 4- Nadu Vasaal- Courtyard 5- Corridor

Source : (Patwardhan, 2017)

### iii. Karnataka

Guthu houses are prestigious residences. Built to meet the needs of matrilineal joint families, these lovely homes are traditional Dakshina Kannada manor houses. These homes' architecture was based on Vaastu principles. Guthu homes have an exterior that resembles a small temple. Guthu houses (Fig 23) are a throwback to a different time because of their sloping roofs made of Mangalore tiles and large courtyards that look out over paddy fields. Like many traditional homes, this one had a central area set aside for the women of the household.



Figure 22 The Guttu Mane of Kodethur Guttu near Kinnigoli in Mangalore

Source : [www.thehindu.com](http://www.thehindu.com)

### iv. Kerala

Tarawad is another name for this typical Keralan housing arrangement. A single courtyard with four sides is known as a nalu-kettu (Fig 25). The compact building is located in a larger compound next to a kullam, or bathing tank, and is made up of four blocks arranged around a courtyard with sloping tiled roofs on all sides to shield an interior and exterior Verandah from rain and sunlight. Rich people in Kerala historically lived in homes with "parambu," which means farm or a large open space. The open spaces surrounding the house, also known as the "thodi," were used for the plantation (V. Kumar, 2014). Kerala is known for its interior courtyards, which frequently have a well within courtyard. Additionally, there would be a courtyard outside where the male household members could congregate (Widiastuti, 2019).

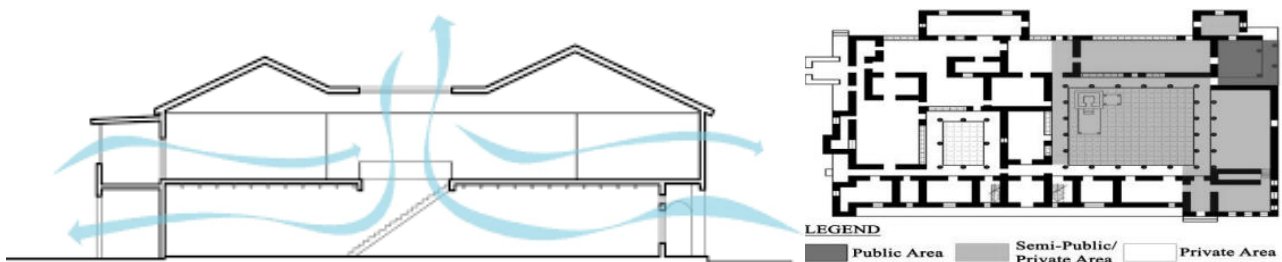


Figure 23 : Cross Breeze Phenomenon in Courtyard House

Figure 24 : Nalukettu Courtyard Dwellings

Source : (V. Kumar, 2014)

**c) Central zone**

**i. Chhattisgarh**

- A fence made of bamboo, bushes, or twigs usually surrounds the homes to demarcate the area between the street and the courtyard area in front and behind the huts.
- The house benefits much from having this courtyard exposed to the sky, especially throughout the day in the winter and the evenings in the summer.
- In this area, the majority of daily activities take place.
- This courtyard frequently has a well that provides water for drinking, bathing, washing, and cooking (Fig 26).
- During the day, people use this courtyard to dry their clothing, cooking food
- This serves as a relaxation space for the elderly residents of the home, who watch the kids while they play (GAUTAM, 2008).

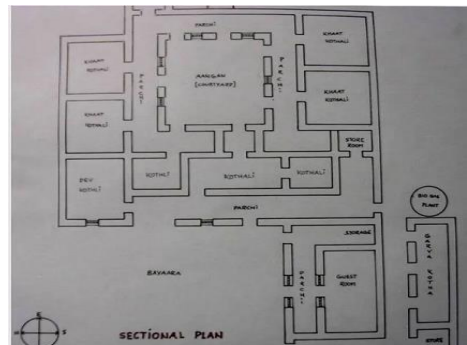


Figure 25 : Courtyard Dwelling in Chhattisgarh

Source: <https://www.archinomy.com/case-studies/traditional-house-in-chhattisgarh-india>

**d) East Zone**

**i. Orissa**

The Orissa Dwelling's features include:

- Danda - The entrance court (parking)
- Bari - Back courtyard (crop harvesting)
- Duara - The central courtyard (courtyard effect, cooking, dining etc.)
- Penda- The veranda that encircles the main courtyard (movement).
- Tulsi Chaura - Place of worship
- Khanja- Rooms at each of the four corners that encircle the main courtyard.
- The handi sala - Kitchen is located in the veranda to the south-east.

The building materials utilised include bamboo, palm tree trunks, hay, and soil, all of which are abundantly and reasonably priced locally. The village is made up of several groups of people living in different lanes, such as milkmen's lane, goldsmith's lane, etc. (Narang, 2013).

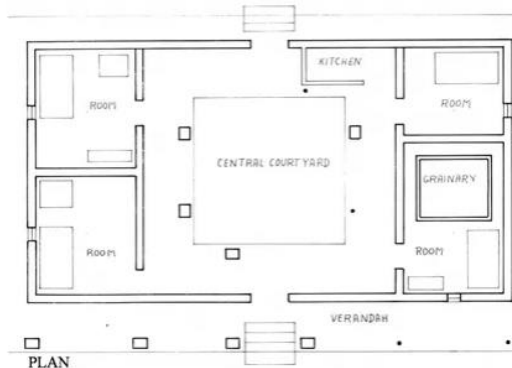


Figure 26: Typical Plan of Orissa Dwellings

Source: [www.archinomy.com/case-studies](http://www.archinomy.com/case-studies)

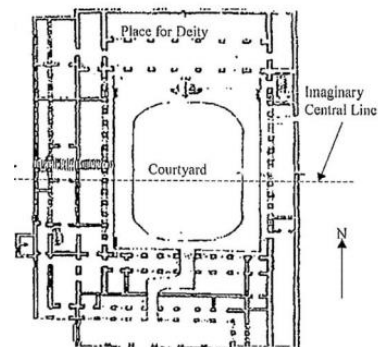


Figure 27 : Typical plan of Kolkata House  
Source : (Taylor et al., 2008)

## ii. West Bengal

Whether large or small, typical north Kolkata buildings all include inner courtyards and are hence commonly referred to as 'courtyard houses'. The courtyard was created to combat the hot, humid environment of Kolkata (Fig 28). Cross ventilation was thought necessary, thus the courtyard was left open to the sky, allowing fresh air to flow in, down, and into the numerous rooms that surrounded the central area. (Taylor et al., 2008)

### e) West zone

#### i. Gujarat

It is believed that settlements made of pol homes date back 300–400 years. Because of the plot's greater depth (about 15 m) and smaller frontage, streets can be kept to a minimum length. This design strategy best reflects the idea of a contemporary neighbourhood. The roads are narrow, which is beneficial for the mutual shading in summers. It aids in keeping the house and the street cool. In Pol homes, there is a very cost-effective concept known as sharing walls. (Gangwar & Kaur, 2020a). The only open space in Pol residences is the courtyard; front and back open spaces are rare. The entire structure depends on courtyard for lighting and ventilation. The houses' entrances and open areas are built in an odd way. Outside the house is an opla. There is a little area inside the main gate that is used to store items like traditional cots and other stuff. Then there is a place called chowk that is exposed to the sky. The distinctive features of the pol's homes are the chowk and parsal (Fig 29). There is a sitting area in the central hall where the housewife can prepare meals (Gangwar & Kaur, 2020b). Everyone in a Pol was familiar with one another. Every family was required to



attend other families' weddings and funerals as well as Pol council meetings. The families received a sense of social and physical security, a sense of belonging, and a sense of position in the larger community in exchange for adhering to the social system's demands for certain behaviours . The Otlas is where the social nature of Pols is most fundamentally found. While the chowkdi (wash areas), water taps, and drainage connections are available on the front otlas and street margins. In the early morning hours, washing, cleaning, and water filling activities bring the street to life.

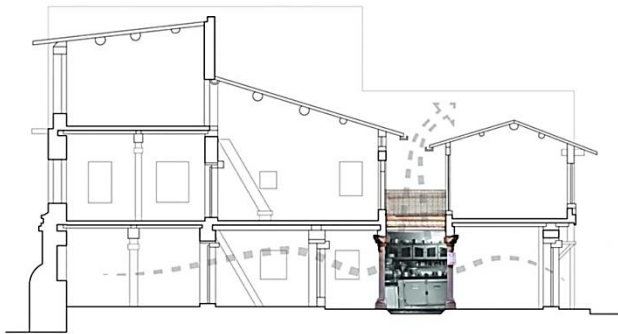


Figure 29 : Passive cooling strategies used in Pol house

Source: [www.banduksmithstudio.in](http://www.banduksmithstudio.in)

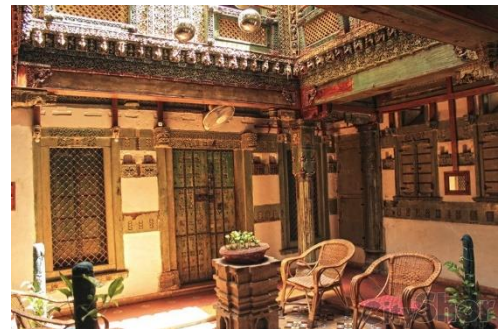


Figure 28 : Typical courtyard of a pol house

Source: <https://architectureindevelopment.org>

### i. Rajasthan

The havelis of Rajasthan are wonderful illustrations of regional identity and customs; they are a type of building that reflects answers to the different culture and climate; they speak a language of architecture that is represented via a way of life, aesthetics, stunning facades, and diversity in the components. The courtyards are the most fascinating because they not only illustrate the ideal spatial organisation of the time but also served as the focal points for social gatherings, rituals, marriages, and festivals (Fig 30 & 31).



Figure 31 : Courtyard in Rajasthan Haveli

Source (Phot, n.d.)

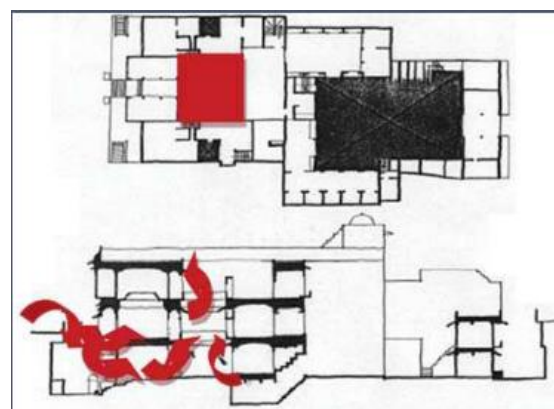


Figure 30 : Typical Floor plan of Haveli in Rajasthan

Source (Phot, n.d.)



## 2.7. COURTYARD IMPACTS

Over time, various benefits of courtyard have been stated by scholars to define courtyard social and ecological roles. Courtyard plays a vital role in determining the climatic climate, both physically and Psychologically, in the courtyard house. These advantages include psychosocial advantages, cultural advantages, religious advantages, economic advantages, climatic advantages, and architectural advantages.

### 2.7.1. Psycho- Social Impact

The courtyard's benefits are based on a discovery of its internal structure, which provides the form and structure of the house with a sense of enclosure and confidentiality (Sthapak & Bandyopadhyay, 2014) Nevertheless, according to several theories, the court serves as:

Courtyard act as living room for entertaining visitors in the evening and a kitchen's extension in the morning. A place for family members to interact with one another and promote group behavior. Visual seclusion, achieved by walled or screened entrances, when the court is visually segregated. Between the courthouse and the surrounding region, acoustical seclusion and enclosure components serve as a noise barrier.

According to Rust (2010), courtyard features such as shade, water, trees, and flowers, as well as wind towers, paving, and colors, might all have a good impact on the body's five senses and play a role in the healing process. These features could also be included to buildings as a design component. To create a healing environment on university campuses, a study conducted at the campus of the University of Hong Kong (Lau & Yang, 2009) revealed that the meditation garden, which is located close to the campus library, and the garden within a courtyard, which is typically near the entrance, has a very positive impact on users.

### 2.7.2. Climatic Impact

Due to its capacity to reduce extreme heat, direct breezes, and modify the level of humidity, courtyards are frequently referred to as microclimate changers. Courtyards served as a source of airflow and thermal comfort for the house. Self-shading and thermal lag

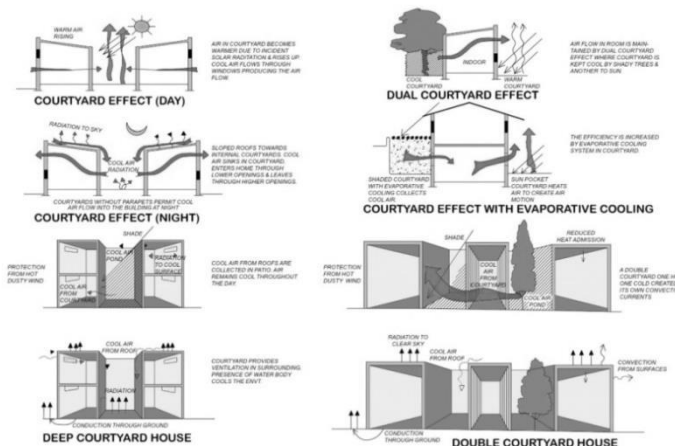


Figure 32 Environmental impacts of Courtyard

Source: [gharpedia.com/blog/understanding-courtyards-housing-typology-in-houses](http://gharpedia.com/blog/understanding-courtyards-housing-typology-in-houses)

features will work effectively with the right placement in relation to the house and the right material to limit heat gain (Fig 33). Finally, a courtyard functions as a reservoir for cold air, especially in hot, arid areas (Sthapak & Bandyopadhyay, 2014).

### 2.7.3. Religious Impact

Both symbolically and religiously, the courtyard has significance. This enclosed space that is exposed to the sky within a house's exterior walls has traditionally been seen as the main magnet for visitors (Fig 34). The courtyard could represent a variety of things: the main point of interest in the home; a concentration of wind, water, sand, and light; a personal, secure, and life-sustaining sanctuary.

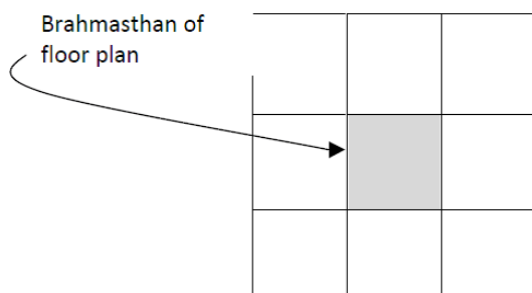


Figure 33 : Brahmasthana as per vastu shastra

Source: (Karani, 2014)

### 2.7.4. Spatial impact

In most houses and structures, the courtyard serves as a hub, tying together the many rooms and purposes. The courtyard's significance lies in its central location, which is surrounded by numerous landscape and tree components that are significant to our social and professional lives (Meir, 2000). The courtyard's geometry and the finishing materials' should take precedence during the design stage to achieve a high level of thermal comfort since it also provides the structure with auditory, visual, and climatic protection (Meir, 2000).

### 2.7.5. Cultural impact

In many instances, more than one courtyard is used. Usually, this is done to divide the house's public and private areas. The public is typically used by men and is mostly for visitors (particularly in Islamic nations). The inner court is more exclusively used by the family as a space for outdoor recreation and by women.

## **2.8 REASONS FOR DISAPPEARANCE OF COURTYARD**

The native forms of homes in India are traditional courtyard residences. These home typologies were created using a tried-and-true process, and they are now widely accepted. The requirements of those who live in courtyard homes are met in a number of ways, whether they are practical, sociocultural, religious, environmental, or economic. A home typology that is mostly unrelated to our surroundings and climate results from the shifting demands, requirements, and urban lifestyle. Rural regions in the world scenario merge with surrounding cities and metropolitan centres as a result of growing urbanization. The primary result of this process is a change in the local dwelling typologies, which eventually influences the user's physiological health.

### **2.8.1. Transformation of Courtyard**

The requirement for a courtyard has diminished due to the morphology of modern homes and changes in household lifestyle. Verandas and terraces, for example, have made it possible to host some of the activities that were formerly restricted to courtyards. Courtyards have been replaced by balconies, pergolas, and other outdoor seating areas. These spaces now serve as an alternative to the courtyard as the gathering place, whether it be the dining room or family room (Adegun et al., 2019).

### **2.8.2. Factors affecting the disappearance of courtyard**

1. Traditional homes that used courtyards have been replaced by high-tech constructions. Today, residential buildings use artificial means to solve ventilation and lighting issues. Because artificial lighting and ventilation are now available, the owner of a house without a courtyard validates that "people don't need a courtyard for ventilation"(Elantary & Eldeeb, 2023)(Adegun et al., 2019).
2. Here, is inadequate protection from the weather for the structure and its residents with courtyards. Homes with courtyards reportedly found that mosquitoes and other creepy creatures generally get in as it is open. Even the home is getting wet (rain), and the insects enter the house due to open courtyard. Additionally, it was observed that the surrounding courtyard walls take on a yellowish appearance due to the "activity of rain and sun over a long time"(Nibedita Das, 2006)(Elwerfalli, 2016).
3. Courtyards are infrequently incorporated into the design of residential buildings for a variety of reasons, chief among them the lack of client desire. Courtyard typology is perceived as sign of backwardness, while western typologies are considered as progressive(Nibedita Das, 2006)(Al-zamil, n.d.)(Elwerfalli, 2016)(Elmansuri, 2018)

4. Spaces are increasingly arranged compactly due to rising land and construction costs. People desire to construct homes with just enough space for themselves and their nuclear family(Sinha, 1990)(Elwerfalli, 2016)(S. S. Khan, 2020)(Nikeghbali, 2017).
5. In general, courtyards are considered as waste of space. Poor courtyard design and maintenance set a poor example that discourages from finding courtyards appealing and interesting(Qureshi et al., 2019)..(Adegun et al., 2019)

## **2.9 BUILDING BYE-LAWS: AN OVERVIEW**

- **Definition**

Building bye-laws and planning regulation are the tools by which local governments control and manage development. These include sub-division regulations, floor area ratios (FAR), height limitations, set-backs, zoning regulations, plot sizes, and so on. Building bye-laws are a set of guidelines that must be followed during the building process. In order to safeguard buildings against any structural failures and threats like fire and natural disasters like earthquakes, regulations are in place regarding coverage, height, architectural design, and safety measures.

The built environment of an area is the result of construction regulations that are implemented in the region on a regular basis, and it so defines the pattern, build form, and character of cities and towns. Building regulation is formulated to answer two main questions i.e. what is to be developed? And How should we develop?

Building regulations, according to the Building regulation explanatory guide (2005), provide baseline regularity standards to guarantee that buildings are accessible, safe, healthy, and energy efficient for everyone who lives in and works near them.

In order to provide statutory guidelines for the planning, design, and construction of buildings and related work, as well as making provisions for matters related to the enforcement and approval of the relevant authorities, Hui sddie chi-man (2001) defined building regulations as a set of laws that are imposed on urban development projects.

They basically give guiding principles for how structures must be planned and erected, which may be utilized by a citizen/developer to start a building on urban property. Additionally, they outline the application process to be followed, the supporting papers and drawings to be attached, the undertakings to be made, the certification process, and the inspection/monitoring method. They are frequently completed by the city's Master/ Growth

Plan, which specifies zoning regulations, permitted land uses, and the kind and level of development to be expected. (Mishra, 2019)

- **Historical context**

Building regulations have existed in some shape or another since antiquity. Hammurabi, king of Babylon (1758 B.C.), introduced the first known written building rule, which was based on the "an eye for an eye" principle. "In case of defective building, the master builder/architect is to be put to death if owner is killed by accident due to collapse of building; and architect's son if the son of owner loses his life," according to Esienburg D. (2011) . Although there are no written records of the Indus valley civilization's ancient townships, most are thought to have been planned and to have had various building regulations and controls (Hui, 2001). British local government legislation that was created in the 19th century out of concern for the public's health and safety gave rise to the present building regulation/bye laws. These regulations included various provisions for structural and fire safety, and later provisions for minimum habitable room size and height, size of daylight and ventilation openings, setback requirements, type and width of roads, and land use were added to development or building regulations. Eventually, the scope of building regulations was expanded to include exercising architectural control over the nature and pattern of buildings (Hui, 2001). Since the building regulations have been continuously updated to reflect modern demands and include provisions for day lighting, energy efficiency, rain water harvesting, as well as consideration of architectural character,

### **2.9.1. Building bye-laws in india**

India is changing from a predominantly rural to a semi-urban nation. This causes difficulties for sustainable development, but it also offers a tremendous chance to take advantage of the of urbanisation by putting strong mechanisms in place. Utilizing technology and ensuring planned growth that can increase economic and social advantages across the nation are essential at this point. Numerous Indian towns have severely strained infrastructure due to uncontrollable expansion. They also suffer the most from poverty and climate change. According to the Ministry of Finance (2021), one in three poor people now reside in urban area, compared to one in eight at the beginning of the 1950s. If this scenario and the expected levels of urbanisation are not planned for and are handled poorly, it might have negative effects on society, the economy, and the environment.(NITI Aayog, 2021). The following sections discuss the situation of the environmental policies National building codes,

standards, and guidelines because they influence and regulate local construction rules in one way or another.

The problem in the urban environment is getting worsen worse due to lack of adequate buildings bye-laws, the high rate of urbanisation, declining vegetation and water levels, excessive pollution, waste output, and climate change.(A. Kumar & Pushplata, 2017) (Grosso, 1998).

Indian municipal law embraced the principles and provisions of British municipal law, which gave local governments the power to make rules and enforce compliance with them. In order to assist or direct the formulation of legislation in various states related to development, the central government now develops guidelines, model laws, and building bye-laws. Building Bye-laws are the laws which are related to development of any area that are controlled by various state governments. Local governing entities including municipalities, development authorities, and town planning departments are given the authority to create building laws with the guidance of relevant state legislative bodies. Prescriptive building regulation that are strict and stringent govern the urban form and development patterns of cities and towns in India but are poorly enforced and monitored (Sridhar, 2010).

The National Building Code, Model Building, various IS Codes Bye-laws and Delhi Master Plan are the primary bases for the building regulations that are enforced in various towns and cities throughout India. According to the Indo-USAID FIRE (D) Project from 2005, rigidity and uniformity are just two of the problems with Delhi's building codes. Similar problems are echoed in other towns' construction rules, which are based on Delhi's building standards despite these towns possess unique geo-environmental, social, cultural, and infrastructure aspects (Kumar and Pushplata, 2008)

Through the 42nd Constitutional Amendment Act (CAA) of 1976, specific measures for the conservation of the environment and natural resources were added to the constitution in order to ensure its adherence to the principles of environmentally responsible urban development(F. . Khan, 2015). Additionally, Central, State, and Local levels of government have periodically enacted additional legislative measures to safeguard the nation's urban environment.

Over the past 10 years, there has been an increased focus on urban change as a result of how human behaviour affects urban ecosystems (Sudhira et al., 2004). Therefore, the function of

building laws is being reconsidered as a tool to enhance the standard of living for the existing population and leave behind a sustainable housing solution for future generation. In order to achieve major goal of environment protection, the revisions of Urban and Regional Development Plans Formulations and Implementation Guidelines (URDPFI) in 2014, the National Building Codes (NBC), and Model Building Bye-laws (MBBL) in 2015, has been done to prioritize the concepts of environmental sustainability, and energy efficiency have recently gained priority in India.

### **Urban and Regional Development Plans Formulations and Implementation Guidelines (URDPFI).**

The "Urban and Regional Development Plans. Formulation and Implementation Guidelines (URDPFI)" were developed as the result of extensive consultations with planning peers in the various Ministries, experts, professional and academic institutions, and other stakeholders. Since 1996, a lot has changed in the realm of urban development, particularly in light of the new needs and requirements that urban settlements are experiencing due to rapid population expansion as well as other factors like globalization and liberalization. Towns and cities are dynamic entities that experience unheard-of unanticipated shifts in terms of the needs for infrastructure and other fundamental services and amenities.

### **National Building Code**

To standardise building laws across the nation for use by governmental agencies, local governments, and other construction companies. The first unified guideline, known as the National Building Code (NBC), was created in 1970 to assist municipalities, development authorities, urban improvement trusts, and other urban development organisations in developing performance-oriented Bye-laws and regulations to control construction practises across the nation (Kisan et al., 2005)

Based on the comments and suggestion received over the time the National Building Code of India 1970 was revised in 1983, 2005 and 2016. Initial changes aimed to update and take into account the standards for Landscaping, energy conservation, fire safety, earthquake safety etc (BIS, 2005). Second revision further detailed out the fire safety, earthquake, energy conservation and sustainable construction technique chapters of the code (BIS, 2016). The most recent revision and amendment to the NBC (SP-7:2016) features a specific "Part 11"

that is focused on a strategy for sustainability in addition to improved safety and technology developments. The Part 11 demonstrated a comprehensive and integrated approach for numerous built and unbuilt environment components, starting with site selection, building element design, construction practises, energy optimization techniques and methods for orientation of buildings, façade design, choice of materials, to building services, operation, maintenance and tracking of building performance, integration of renewable energy, etc .(Lau & Yang, 2009) (Jawaid et al., 2018)

### **Model building Bye-laws**

The Ministry of Urban Development (MoUD) first released the Model Building Bye-laws in 2004 to establish a legal framework at the national level for highlighting provisions for structural and fire safety, rainwater harvesting, trash recycling, solar assisted heating, barrier free public buildings, etc (TCPO, 2016). These Bye-laws have undergone extensive revision as the model Building Bye-laws 2016 to take into account, among other things, the increasing environmental concerns for sustainability and green buildings, increased safety and security, technological advancements, standards for low-income housing and high-rise buildings, and the availability of flexible FARs (TCPO, 2016). The state of Rajasthan is one of the states whose government has created the model construction Bye-laws. Due to the advising nature of the model building Bye-laws, some rules and recommendations could not be included into the city-level building Bye-laws created by urban local bodies/development authorities. The Rajasthan government has made an effort in this area by enforcing newly revised “Unified Building Bye-laws 2017” that is applicable to all of the state's cities and urban centres.

### **Local authority Bye-laws**

Taking the insights from the Model Building Bye-laws and National Building code, the state authorities along with local authorities formulate building Bye-laws by considering the local context of town. The building plans must be approved by a municipal authority, such as an Urban Local Bodies, Development Authority, or other entity authorized to sanction building plans. For a quicker and more transparent process of building approvals, the ULB should implement an online application procedure for building approvals together with digital formats of documents and drawings. It is necessary to establish a specialist cell inside the Authority that is staffed by knowledgeable individuals familiar with the processes and the interpretation of development regulations.



The use of building regulation in Architecture is always been controversial issue. A detailed study conducted by Imrei .R based on the interviews with architect concluded that the building regulations influence aspects of creative practice and process in architecture. It is believed that regulation are a technical activity and governed by bureaucratic machine alien to design process.(Imrie, 2007). While studying the challenges in using building regulation in architecture. Moradi .A et al analysis three different approaches of building regulation and design process namely: Analysis vs. Synthesis oriented, Reduction vs. Variety oriented, Evaluative vs. generative and suggested the use of simulation tools to analyse the impact of building regulation on design process(Mohammad-Moradi et al., 2017). Kumar .A et al argues that the fundamental problem with building regulations is that they are primarily taken from other places without taking into account the specific needs of the local community hence more prescriptive in nature. Talking about the impact of building regulation on typologies, setback and height regulation is one the major regulation which defines the shape and form of houses. In India , most low- rise dwellings are based on row and detached house types borrowed from European context . When architects attempt to create traditional courtyard homes, they must adhere to the same front and rear setback requirements as regular row housing. Consequently, the courtyard's size is smaller than anticipated, changing its function from being a living area to a light well

### **2.9.2. Challenges in Building regulation.**

Nearly 11% of the world's urban population lives in Indian cities, making it the second-largest urban system in the world. In terms of absolute numbers, India has a larger urban population than many other highly urbanized nations and areas. In terms of its economic change, the nation has reached a turning point when, in a few decades, half of the nation will be "urban."(NITI Aayog, 2021) In countries like India which is facing huge urbanization, reforms in building regulation is much needed to create space to accommodate anticipated urban growth within core areas of city, and reduce future suburban sprawl. Cities frequently are ignorant of the results, efficacy, financial implications, or unintended repercussions of regulations since they were developed decades ago and have not since been rigorously assessed, merely updated on an as-needed basis. Land that can be developed or urbanized is expensive and scarce. Therefor careful planning and execution of building regulation is much required.

In Most of the cities, development control regulation came into existence decades ago but they have been arbitrarily modified without sufficient empirical evidence of their effectiveness. Most States and UTs recently updated their bye-laws in accordance with the Model Building Bye Laws 2016 (MoHUA, 2016). The local governments must alter the guidelines to meet their own environmental and economic strategies. In order to guarantee the best use of urban land and permit development based on an appropriate urban form, it is also necessary to switch from text-based to form-based rules.

The general goal of these rules is to protect people's health and safety. It is argued that they have unexpected consequences for residents and reduce the functionality and efficiency of planning. Additionally, they frequently promote urban sprawl rather than promoting a dense pattern of growth.

These rules have an impact on the construction cost, investment yield, availability of affordable housing, and other factors at the user's end.

According to research, these laws frequently result in the underuse of valuable urban land at the city level. The fragmented and underutilized private open areas take up a greater amount of the land. These biases must be experimentally evaluated on a city-by-city basis and eliminated by thoughtful changes of the development regulation.

Other concerns with building regulations include a complicated administrative structure, ambiguous authorities of enforcement, and insufficiently accountable professionals to ensure compliance. Building rules in all Indian towns/cities reflect similar challenges and problems, resulting in improper growth in Indian cities.

Another drawback that experts have pointed out is that the standard text-based laws do not give end users—citizens and property developers—the ability to choose the permissible building envelopes. Additionally, they do not give decision-makers the ability to evaluate the skylines, Façade, urban forms, infrastructure costs, or land-use utilization pattern.

To maximize the efficient use of land, several residential typologies can be investigated using various combinations and permutations of FAR, Height, and ground coverage's.

## CHAPTER 3: RESEARCH DESIGN

The chapter discusses the outline used for conducting the research and various tools used for achieving the objectives. Further, the chapter provided the background for selecting the base case as Lucknow and a brief introduction to the study area.

### 3.1. RESEARCH METHODOLOGY

The methodology of the research approach has been detailed to formulate the theoretical framework for researching to achieve final objectives. The Research design, data sources, and sampling techniques have been discussed in this section. The research design is intended to provide an appropriate framework for a study.

Problems in built environment research frequently call for a combination of research methods and approaches from many disciplines (Day & Gunderson, 2018). Due to the interdisciplinary character of the research, a mixed methods approach that is based on both quantitative and qualitative research methodologies has been used. Elmansuri.S used a mixed approach of questionnaire survey and spatial syntax in their study to investigate traditional courtyard typologies in Libya and their applicability in a contemporary environment(Elmansuri, 2018). Another study, undertaken by Khan.S in Bangladesh, used historical research and a case study approach to examine the possibility of courtyard space for incorporation into high-rise apartments(S. S. Khan, 2020). Das. N conducted a thorough literature review, as well as case studies and simulations, to determine the current situation of courtyard houses in Kolkata (Nibedita Das, 2006). Elwerfalli. M used a hybrid strategy to achieve the goals and objectives of his study, dividing his research into three phases: Literature evaluation, fieldwork, and interviews (Elwerfalli, 2016). This study has combined modelling and simulation with both qualitative and quantitative methodologies to achieve the main research objectives. The qualitative data has provided support for the analysis and conclusion of the quantitative data. Since both qualitative and quantitative data types will be used in the data analysis, the outcome will be triangulated. The study analysed the courtyard houses from different perspective to get specific design solutions for urban settlement.

#### *Phase I: Qualitative*

Data was freely collected from many sources to build a knowledge base using an inductive method and several strategies, including observation, Literature survey and case studies or discussions which would facilitate testing of hypothesis that emerged in the process.

The context of the study includes:

- ✓ Historical context of courtyard houses.
- ✓ Traditional courtyard dwellings and settlements,
- ✓ Form, shape, orientation, climate responsive behaviour of courtyard typology.

***Phase II: Quantitative***

The study followed the quantitative research process. In this, the structured questionnaire, drawings, photographs, Data reports etc. will be used to measure variables such as spatial quality, build-open ratio day lighting etc

***Phase III: Data analysis (Qualitative & Quantitative)***

In the third phase of the research, all the knowledge gathered in the first two stages is critically analysed, which eventually establishes the criteria on which more research has been conducted. Software like M.S. Excel or Google sketch up will be used to identify the parameters and the interdependency of variables.

***Phase IV: Modeling and simulation***

In the fourth phase, a framework developed by the end of the above three phases will facilitate simulation modelling as a generative tool in architecture. The research will be carried out by using software such as ECOTECT, so that a series of typologies combined with various street orientations and other arrangements could be analysed and compared.

***Phase V: Validation of hypothesis & conclusion***

In the fifth and final phase validation and testing of the hypothesis will be done and the recommendation and conclusion will be derived from all the data based on quantitative, qualitative or simulation research approaches

**3.1.1 Data Collection:** The Primary data sources include case studies of traditional courtyard houses especially for composite climates to determine their spatial layouts, configurations, functions, and attributes. (*Through observation, pictures, photographs, interviews, questionnaires and discussions*). Further data has been collected through the questionnaire survey from the end user and stake holder.

Secondary data has been obtained from available literature regarding courtyard housing typology concerning different climatic zones, and the other data from the building Bye-laws, urban planning norms, and design standards. Well-documented courtyard houses are used for

analysing the spatial layouts, configurations, functions, and attributes of contemporary courtyard houses. Reputable journals, books, different articles, periodicals, proceedings, magazines, newsletters, newspapers, websites, and other sources on housing and vernacular elements have been considered for conducting in-depth literature study.

### **3.1.2 Sample Design :**

This study employed two different sampling methods. Strict criteria were used to pick the right interviewers from among architects, planners, property developers, and local authority officials, based on their expertise in modern courtyard home design and their input on such projects. However, for the residents, a judgmental or purposive sampling method will be used to get the sample size, based on the identified parameters. Residents were given their surveys in two groups first group consists of the residents having courtyard houses while others are residing in other housing typologies. In order to elicit a relevant range of thoughts and ideas on the modern courtyard house special care was taken to distribute them to households with a variety of backgrounds. The physical survey of traditional houses as well as the in-depth study of documented courtyard houses was conducted by keeping the following parameters in mind.

- Size of plot
- Age of House

However, a few of the selection criteria will be taken into consideration for selecting a sample which are discussed below:

#### ***Climate selection:***

There are various geographical regions and sub-regions with specific climate characteristics in India. A composite climate zone can be defined as a zone with year-round variations in hot, dry, warm, humid, and cold seasons, even during times of moderate climate. In general, the warm-humid and hot-dry periods have similar relative intensities and their period are longer as compared to others. (Ali et al., 1993). This study focuses on composite climate where there is largely predominantly hot climate for the whole year. However, because of the complexities of the climatic zone, we must consider passive design solutions for both heating and cooling. A universal prototype for the building is quite difficult to achieve

The National Building Code of India's (NBC) bioclimatic categorization divides India into five main climatic zones (Table 2). The study done by Ali et al. in 1993, which was primarily meant for architectural design, serves as the foundation for this categorization.

Table 2: Classification of climatic zones in India (Source: ECB Ccode)

S. no.	Climatic zone	Mean monthly maximum temperature (°C)	Mean monthly relative humidity (%)
1.	Hot-dry	Above 30	Below 55
2.	Warm-humid	Above 30 Above 25	Above 55 Above 75
3.	Temperate	Between 25 and 30	Below 75
4.	Cold	Below 25	All values
5.	Composite	A zone that does not have any of above season for more than six months.	

**City selection:** To gain a better understanding of the present context of Lucknow's building bye-laws, four other cities were chosen to compare and contrast with. Four out of five cities are from the composite climatic zone, while one is selected from a warm and humid climatic zone. The cities were chosen based on their urban settlement. Three cities reflect an amalgamation of old and contemporary development, while two cities represent anticipated future development.

*Identified cities for the study purpose are:*

- Amaravati, AP
- Bhopal, MP
- Chandigarh, Punjab
- Jaipur, Rajasthan
- Lucknow, UP (Study context)

Nevertheless, Lucknow was chosen as the case for the prototype's development out of the five, primarily because its Bye-laws are more explanatory in nature.

**Courtyard selection:** Modern houses with courtyards, having various geometrical properties and orientations, would be chosen to examine as case studies. All the contemporary houses are designed by eminent architects of India and have been documented by various journals and architectural magazines. Traditional courtyard houses were designed by non-professionals

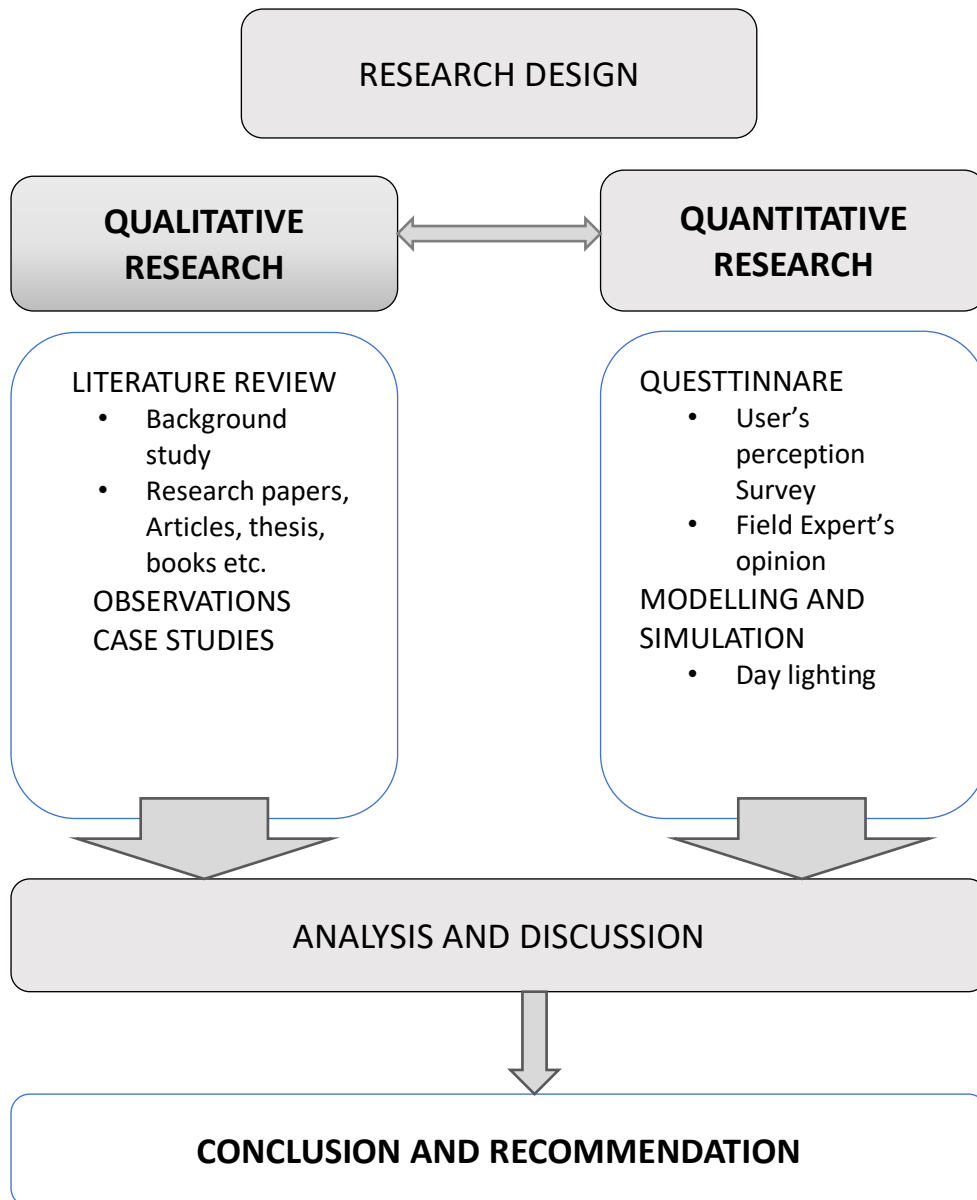


Figure 34 : Research methodology framework

### 3.2. Lucknow: Study Context

The study explores courtyard houses within the Indian context, without restricting itself to specific geographical boundaries. Additionally, the analysis of building regulations is based on urban settlement criteria, focusing on cities that serve as the capital of their respective states. The study contrasts building regulations between cities with organic growth and those with planned development. Lucknow has been chosen as the base case, representing a composite climate, organic growth (Amalgamation of traditional and contemporary settlement), and clear building regulations that largely adhere to Model Building bye-laws.

- **Background:** Learning from previous generations' traditional wisdom through traditional building lessons may be a great tool for enhancing future structures. Lucknow is situated in Northern India's plains on the bank of River Gomti. It is the capital city of U.P, the most populous state of India.
- **Geographical Location and Regional Linkage:** Lucknow is located at 26<sup>0</sup> 30' and 27<sup>0</sup>10' north latitude and 80<sup>0</sup> 30' and 81<sup>0</sup>, 13' east longitude, 123 metres above sea level. Barabanki district borders the city on the east, Unnao district on the west, Raibareilly district on the south, and Sitapur and Hardoi district on the north.

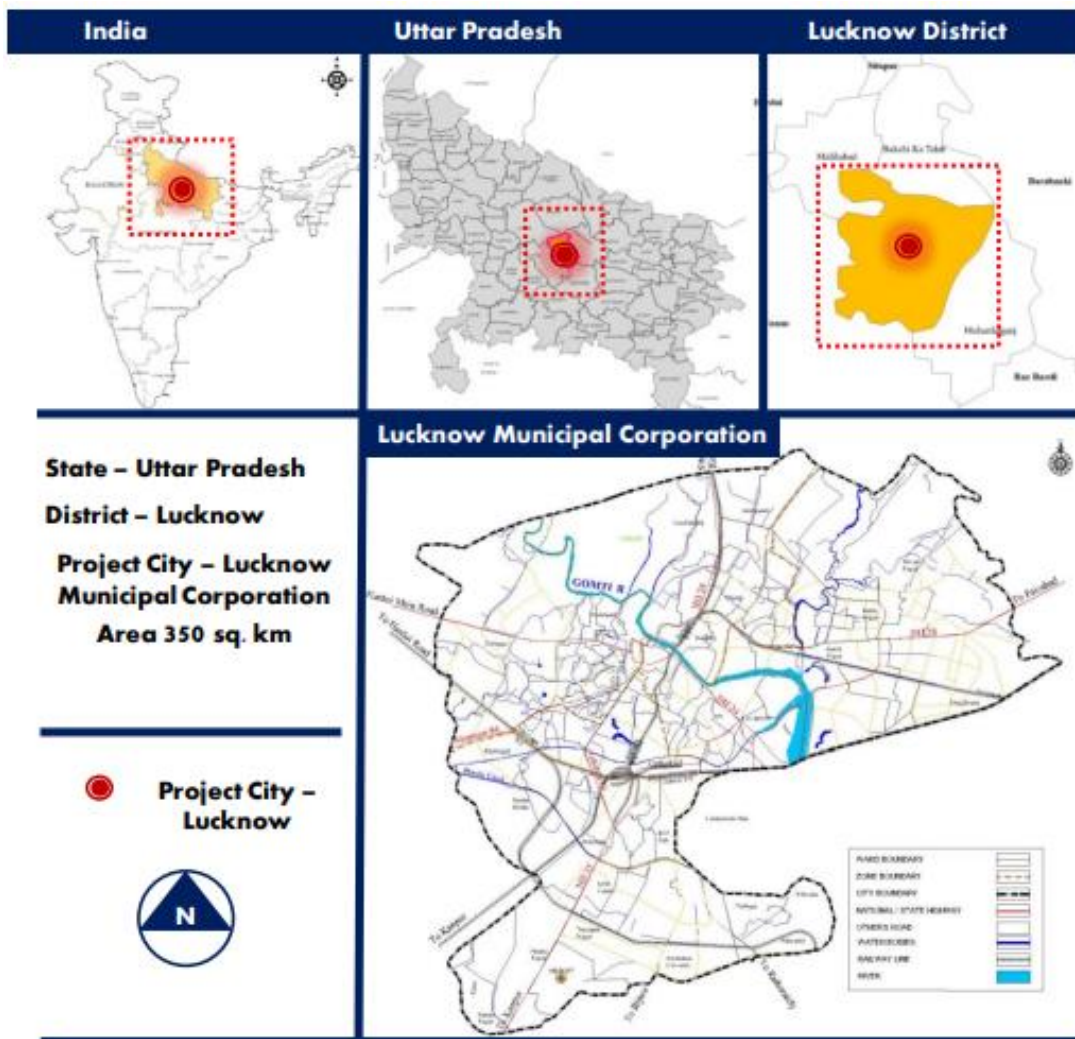


Figure 35: Geographical location and linkage

Source: City development plan, Lucknow, 2040



- **Climate:**

The city experiences a composite climate, with a hot summer from April to June and a cold, dry winter from December to February. The extreme temperature ranges are between 3-10 degrees Celsius in the winter and 40-45 degrees Celsius in the summer. About 100 centimetres of rain fall on the city each year, primarily from the southwest monsoons between July and September.

- **Lucknow Architecture**

The city is renowned for its vibrant Nawab culture, customs, and elaborately carved structures. In addition to building beautiful structures in traditional forms and experimenting with European architecture, the Nawabs of Lucknow also developed a unique hybrid style that included both European and Indian components. The city is divided into a historic core and planned development all around it. The modern neighbourhoods surround the older structures, which are found in the city's heart. High densities and pre-colonial settlement architecture define the city's oldest sections. The majority of settlement during the post-independence period was in the outskirts and periphery. (Kamal, 2021)

- **Street patterns**

The earlier urban area was small and built mostly around courtyards, which handled both the demand for social contact and the climate. In the old communities, the urban fabric is tightly knit and the streets are narrow. The streets serve as places for activity, interaction, and connectivity. In order to provide a shaded atmosphere where people may walk and engage in social activities in the streets, the height of the buildings is larger than the width of the streets.

- **Housing typology**

A. Traditional

The residents' religion and ideals have a significant impact on Lucknow's distinctive customs and society. Seclusion, gender segregation, and climate adaptability were the three main considerations while designing Lucknow's traditional dwellings. The architecture of the houses that people are still living in now is significantly influenced by these factors. The two types of traditional residential constructions are determined by the social status of its residents. The kothis, and havelis, for the affluent class, small courtyard houses for middle class(Municipal corporation, 2015).

## B. Contemporary housing

In the city, LDA and UPAVP began building planned colonies with the individual plotted housing typology in the 1960s. The majority of the city is covered with developments that seem like planned independent housing. Private builders first entered the city more than 30 years ago, offering planned plotted development and multi stories apartments (Municipal corporation, 2015).

### 3.3. PROCEDURE AND MILESTONE

Table 3: Summary of research tools

Proposed objective (With respect to methodology)	Methodology used to achieve objective	Status of the work done till date	Expected outcome (Publication/ IPR Generation etc.)	Status of the outcome (Data collection/ manuscript or IPR Application is under progress or under review or revision or granted)
To identify, document and describe the different typologies of courtyard houses in cities having composite climate and further analyse them in terms of spatial qualities.	Through the reading of books, articles, research papers on the related subject of research area	Literature survey: Books Articles of journals, Research paper Observation, Documented drawings Photography of 35 papers reviewed	To write a research paper based on the literature reviewed for Scopus Indexed Journal.	Paper published in Civil Engineering and Architecture, Vol. 9, No. 7, pp. 2261-2272, 2021. DOI: 10.13189/cea.2021.0907 13
To validate the unanimity among the experts	Formation and finalization of semi	Analysis of the Questionnaire	Understanding g about scale and magnitude of problem.	Interview Conducted Analysis Tools: SPSS. Paper presented in 3rd

regarding the importance of the courtyard concept and need for its adoption in residential units.	structured questionnaires for interviewing Experts. Study of Bye-laws of three cities as a case study.	Case study, Analysis of Bye-laws		International Conference on Emerging Trends in Engineering and Technology Title :Review of Building Regulation for Achieving Sustainable Development in Lucknow, India
To analyse the perception of End User regarding the Housing Typologies.	Formation and finalization of questionnaires for conducting User perception Survey	Two groups of users have Been identified and for survey first residing in courtyard typology and second residing in other typologies	Understanding g the current status of housing typology preferences. To present a paper of findings in International conference	Paper presentation in and Technology “2nd International Conference on Civil Engineering, Paper title : Conceptualizing Residential Open Space In Contemporary Houses
The prototype development on the results achieved till date and further analysing it on the basis of daylight performance	Simulation Tools: Ecotect and Radiance	Modelling of the prototype and analysis on basis of identified parameter	Compilation of result, Conclusion and recommendation. Report writing.	Result Compiled and Final report

## CHAPTER 4: CASE STUDIES

This chapter discusses a case study for courtyard houses along with the building regulations of various cities. The chapter is divided into two sections, the first section deals with individual courtyard houses, and the second section compares the Bye-laws of various cities to reach a conclusion. The primary goal of this case study of houses (field survey and secondary sources) is to examine the differences in spatial organization, and courtyard ratio to plot ratio of traditional courtyard houses and urban courtyard houses. Convenient sampling was used to choose the case studies of traditional houses, while well-documented urban residences were chosen for the contemporary homes case study irrespective of their location. The major purpose of building regulations is to examine the influence of byelaws on the prevalent typology of residential units. As a result, cities with organic growth and pre-planned cities have been selected as case studies.

### 4.1. Case Study: Courtyard Houses

Built spaces and open areas both play a significant role in society. Both are interdependent, although frequently these open areas are ignored and considered as leftover space. We prefer to develop as much livable space as possible now because of the growing population and shrinking amount of land available, yet we sometimes assume functional spaces solely as built spaces and consequently ignore the relevance of open space. These open places have no particular purpose or activity associated with them. We frequently disregard the functional qualities of open spaces like the front or back lawns and treat them as recreational areas. (Agarwal & Thussu, 2020). The study investigates the various physical parameters of courtyard houses situated in traditional settings as well as in urban settings. The intent is to study both categories of courtyard houses house so that the transition of courtyard spaces over time can be explored. Further, the contrast of morphological parameters such as zoning, form, scale, and proportion can be well understood for the two categories.

#### 4.1.1. Traditional house (Not designed by the professionals)

Six case studies were chosen to represent the research sample for traditional courtyard houses, designed without the help of professionals Researchers in the study used a case-study approach to analyse examples of courtyard houses from Lucknow or nearby cities having similar climatic and regional contexts. Six old courtyard homes were initially chosen for the investigation so that their domestic courtyards could be observed and assessed. Second, short interviews with the chosen family members were held. The conversation helped the

researchers comprehend the courtyard's importance from the perspective of a user. Last but not least, the houses and their interior courtyards were physically measured to create drawings, pictures were also taken with the families' prior consent and observations of activity patterns were listed. The selection of the six courtyard samples was based on other research carried out in similar ways. Eight residences in Delhi were analysed by Thussu.M., out of eight, four were in traditional settings and four were in contemporary contexts. Elmansuri.S examined the spatial organisation of the three courtyard dwellings from the three distinct housing schemes of Libya. Khan.S examined eight classic courtyard homes in Bangladesh and determined whether a courtyard would be appropriate for a high-rise apartment. To determine the different effects of courtyard houses, Das.N examined the ten traditional courtyard houses in Kolkata.

#### **4.1.2. Contemporary Houses (Designed by the professionals)**

A total of eight case studies were chosen to analyse the significance of the courtyard and its possible modern adaptation. The courtyard's purpose depends upon its size, location, proportion, scale and user. Hence to identify specific characteristics on which courtyards may be created nowadays, all these parameters must be considered together with their physical aspects.

Information has been gathered through secondary sources. These particular case studies were taken from buildofy.com's subscription-based eMagazine. The platform published PDF material, conducted architect interviews, and used video to document the house. The sample was taken in such a manner that selected houses are situated in urban settings and represent the exemplary work of the architects. The rationale for picking modern houses is to understand the influence of building regulations on courtyard designs. The traditional courtyard houses have been excluded from the study since they were constructed without considering the building regulations. The selected houses are documented on numerous platforms due to their distinctive architectural solution and inclusion of vanishing spaces like courtyards. A thorough investigation of spaces at both the micro and macro levels was performed by examining project drawings obtained through secondary sources. The different nomenclature such as Inward looking house, Urban courtyard house etc of contemporary residences is offered by the architects or the owners and is well documented. The dwellings are given numbers, but the old nomenclature has been retained for simple identification.

### House No 1 (Mr .Talib's House)

The owner of the house built it for himself; it is a first-generation house, situated in an unorganised neighbourhood for low/middle-income groups on the outskirts of Lucknow city. The house is approached from the front street facing the west side

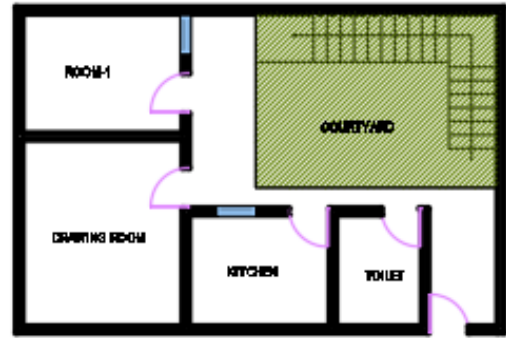


Figure 36 Plan of House No-1



Figure 37 View from main entrance



Figure 38 Bird eye view of courtyard

### House No 2 (Nistha's House)

Approximately 100 years old house in Varanasi with a variety of traditional elements on its façade, however, house is in very dilapidated condition

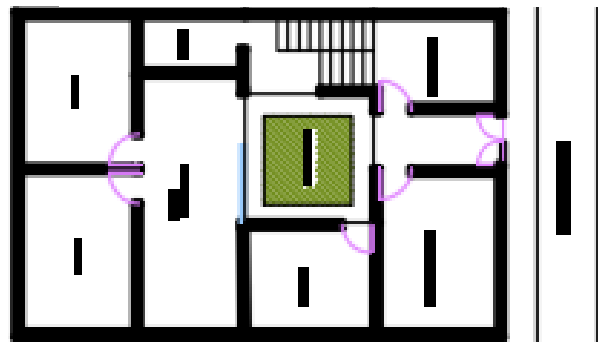


Figure 40 Plan of house 2

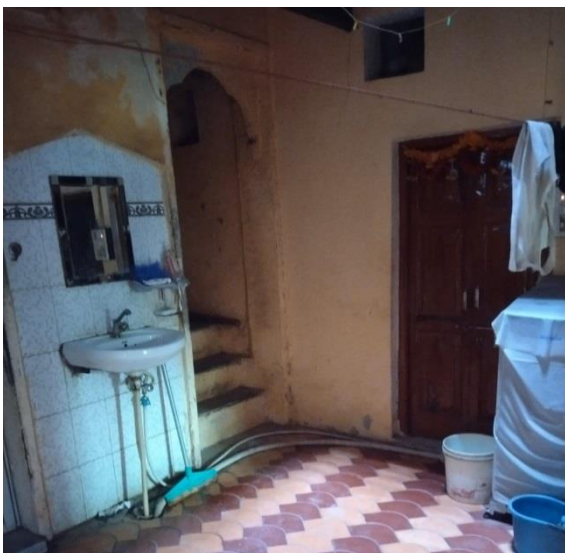


Figure 39 View from main entrance



Figure 41 View from inside the courtyard

### House No 3 (Mr.Gupta's House)

The house was renovated in the 1960s, but it still has its traditional wooden roofing, which is still in place today. It is located on a very busy road of Kanpur

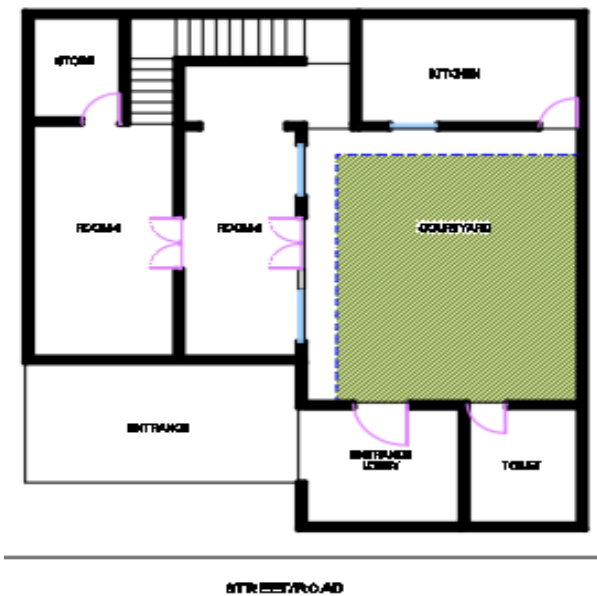


Figure 44 Plan of house no 3



Figure 42 Upward looking view of courtyard



Figure 43 Courtyard showing entrance of the house

### House No 4 (Preeti Patel's House)

Although the house has an adequate-sized courtyard, it was apparently renovated from government LIG housing and being entirely constructed of modern materials.. the house is located in Lucknow.

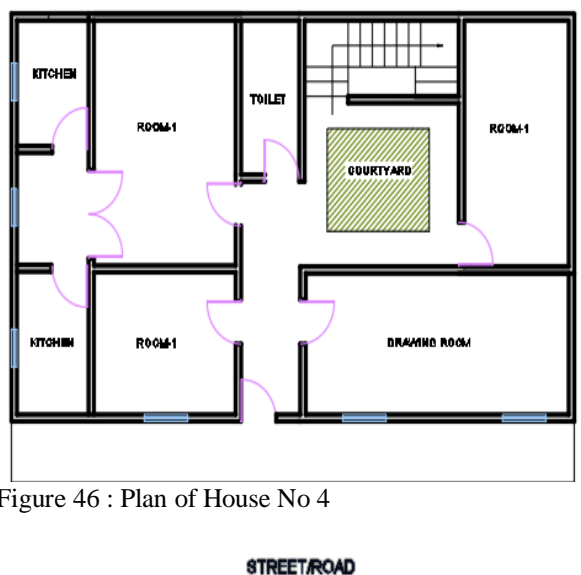


Figure 46 : Plan of House No 4



Figure 45 View of courtyard from top.



Figure 47 : Security grills at opening of the courtyard



### House No 5 (Mrs Shilpi's House)

The home was constructed in Prayagraj in 1960 by the current owner's father and features a traditional courtyard typology.



Figure 50 : Plan of House No 5



Figure 48 : Views of courtyard

### House No 6 (Mr Vihaan's House)

Despite being situated in an unorganised, extremely densely populated area of Lucknow, the house has kept its courtyard, which is most distinguishing feature of the house.



Figure 51 : Plan of house No-6

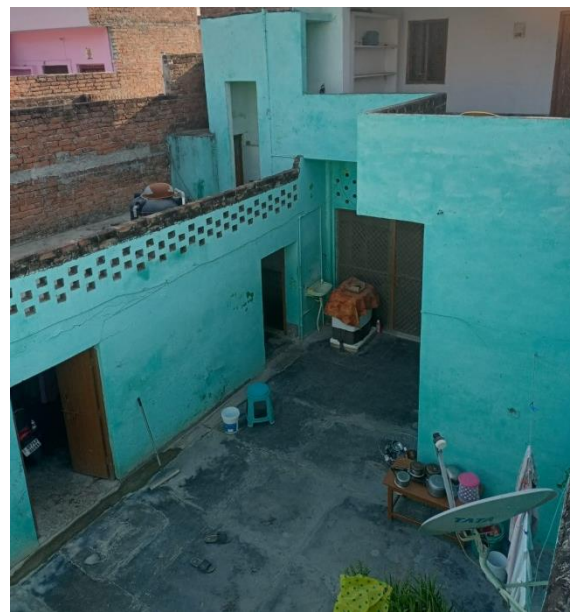


Figure 49 View from courtyard from entrance

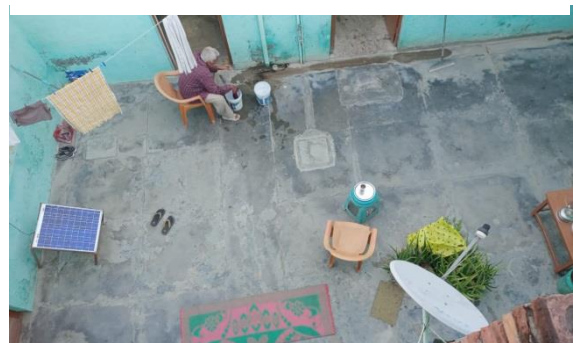


Figure 52 : View of courtyard from Top



**Detailed Description of Six Courtyards: Spatial and Physical Elements/Residents perception.**

Based on on-site observations, pictures, and drawings, Table 4 discusses the six courtyard houses’ spatial configuration and physical characteristics. The inner courtyards of these houses are the specific subject of the discussion, which examines the formation, organisational components, spatial character, function, and privacy mechanisms of the courtyards. This section’s goal is to comprehend the typical spatial traits of these traditional courtyards so that we can use them in forthcoming design solutions. The activities in the courtyard that were observed and identified during the site survey and interviews are analysed in detail for activity mapping of courtyard space..

The various parameters for analysing the courtyard configuration of these houses are identified from the similar studies such as (S. S. Khan, 2020)(Agarwal & Thusu, 2020)(Nibedita Das, 2006)(Yasmin, 2022)(Elmansuri, 2018). The sole purpose of the study is to analyse the character of the courtyard within the house

Table 4: Comparison analysis of six case studies.

Parameters	House no 1	House no 2	House no 3	House no 4	House no 5	House no 6
House Type:	Extrovert House	Introvert type	Introvert type	Introvert type	Introvert type	Extrovert House
Year Built	1980	1930	1960	1980	1950	1970
Main Entrance	Directly to the courtyard	Access through living areas	Access through living areas	Access through living areas	Access through living areas	Directly to the courtyard
Secondary Entrance	No	No	No	No	Yes	No
Courtyard configuration	Rectangular	Rectangular	Rectangular	Square	Rectangular	Rectangular
Courtyard orientation	North-south	North-south	North-south	East-West	North-south	East-West

Courtyard furnishing	Chairs, plants	Electrical appliance	Electrical appliance, plants, chairs, water source	Almost vacant	Household items	Chairs, plants
Courtyard Encl::open ratio	2:2	4:0	3:1	4:0	3:1	3:1
Activity pattern	Drying clothes and food items, Washing clothes, Sitting	Cleaning, Drying clothes, Washing clothes	Drying clothes, Washing clothes, Sitting, Religious puja, family function	Storage of household items	Washing utensils, Drying clothes, Storage of household items	Sitting, doing household repair works, drying clothes, solar light etc
Advantage	Sufficient Daylight and privacy	Central space connecting all the area, Privacy to the indoor activities	Can accommodate varieties of activity, act as living room, household activities etc.	Good visual connection within the house, Daylight,	Ample of space for household activities. Suitable space for keeping plants and greenery.	Sufficient Daylight and sense of openness
Disadvantage	Courtyard houses seem old fashioned, Difficult to maintain	No impact on Daylight, prone to insects.	Require expensive coverings, Wastage of expensive land	Security concerns, Not suitable for rental floors	Require expensive coverings, Wastage of expensive land.	Not suitable for rental Floors, Suitable in Winters

### House No-7 (Inward-Looking house)

The house is closed from all three sides, having only open access towards the north side road which is only 9' wide. The formation will obviously require maximum privacy with no compromise on air and light. So the architect adopted for the staggered section concept accommodating a variety of spaces, placed at every half-level

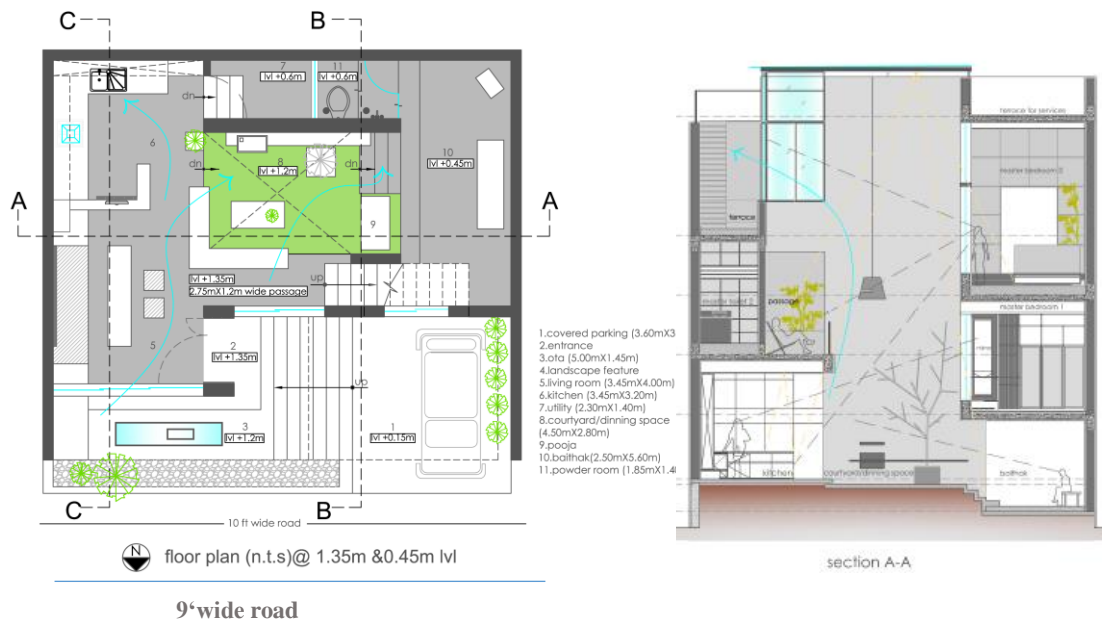


Figure 53: Plan and View of House No 7,

Source: [www.buildofy.com](http://www.buildofy.com)

A Courtyard served as the centre of the spatial scheme, which improved connection and interaction (Fig 54). Visual connections have been made on and between floors, giving the area a sense of spaciousness while also giving it an exploratory aspect. As the courtyard is covered at top, therefore it act as daylight well and means for enhancing visual connection between floor.

Name	Location	Architect	Plot Area	Courtyard Area	Built-up area	Court/Plot	FAR	Open Space
Inward looking Courtyard house	Aurangabad	Amruta Associates	1080	135	2200	0.13	2.04	Only front Setback

## House No -8 (25 X 50 COURTYARD HOUSE)

The site is 50' long and 25' wide and can be interpreted as a compact volume. The new house is built after demolishing the old house. The old house hardly received any natural light and air during the daytime, due to the high-rise apartments that blocked the flow of these elements. The site was divided into three sections, with the central section acting as a void for light and ventilation as the planning for the interior spaces began. The courtyards, have always been an essential component of Indian traditional architecture (Fig 55). Inspired by these features, the design strategy for this house resulted in the house being recreated as a fusion of modern and traditional components. The interior areas of the home are oriented inward, with the courtyard as their focal point.

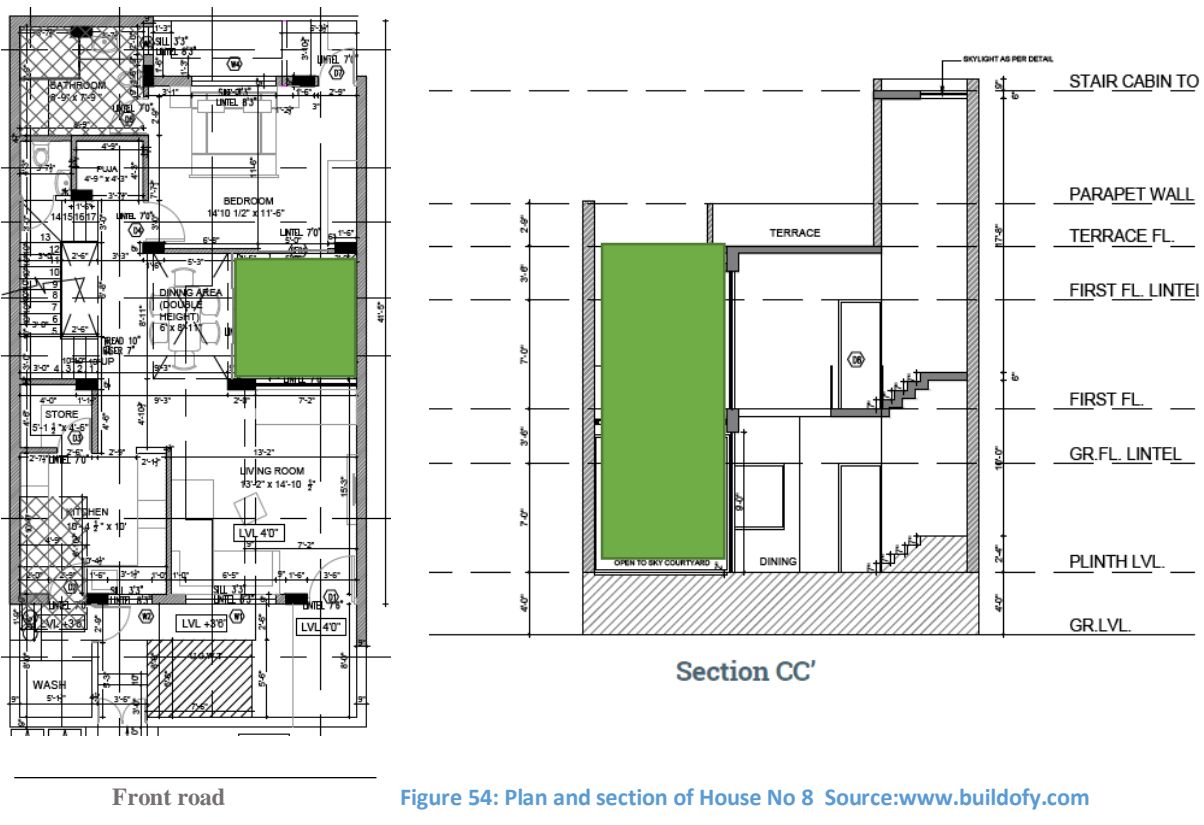


Figure 54: Plan and section of House No 8 Source:www.buildofy.com

Name	Location	Architect	Plot Area	Courtyard Area	Built-up area	Court/Plot	FAR	Open space
25 x 50 courtyard house	Jaipur	Neha Rajora Designs	1250	80	2100	0.06	1.68	Only front Setback, back OTS & Courtyard

## House No-9 (Soul Garden House)

The smallest plot size accessible in the majority of residential layouts in Hyderabad’s historic urban fabric is around 200 square yards or 170 square meters. This 1,820 square foot property, which is not very large, is located in an area with several densely packed buildings. The house had a lot of specifications that needed to fit on a tiny property. The spatial program includes the open space in one side of the plot which serves as a courtyard. All the functional spaces are arranged on three sides of the courtyard (Fig 56). The internal court is furnished with natural plants and water bodies to soothe the microclimate. The eye-catching feature is the well- proportioned courtyard space that has been elegantly positioned inside the standard plot(1:2 plot ratio).

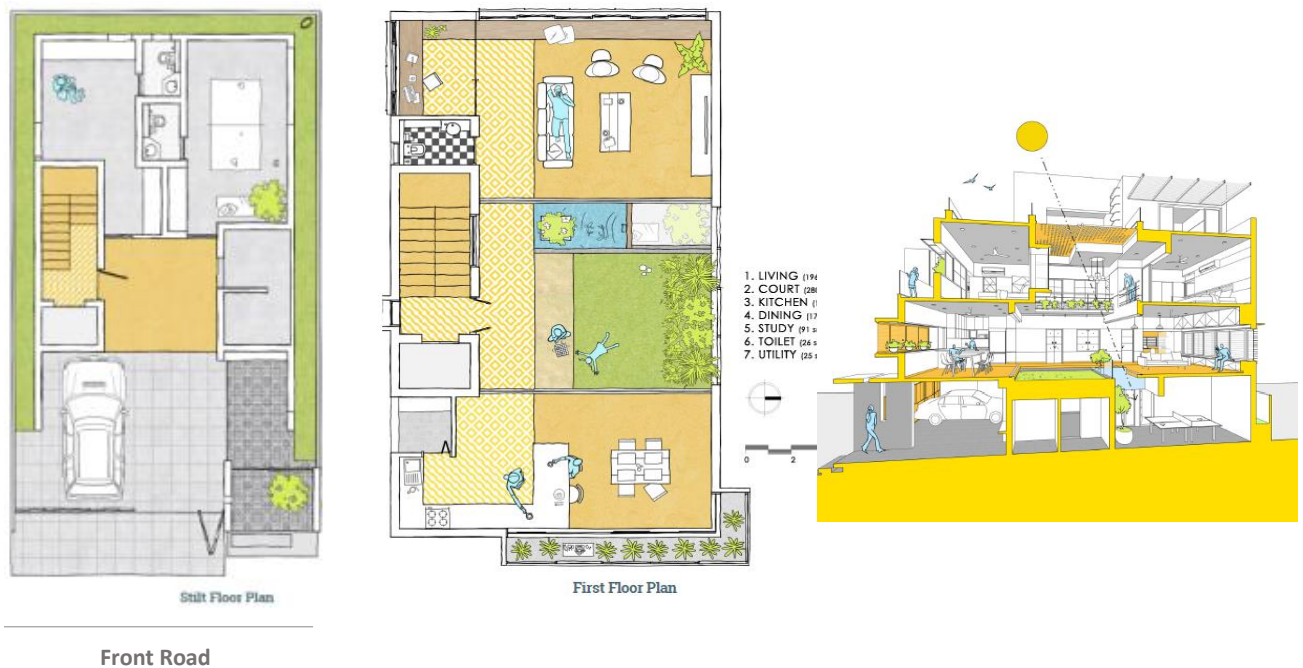


Figure 55 :Plan and section view of House No 9

Source: [www.buildofy.com](http://www.buildofy.com)

Name	Location	Architect	Plot Area	Courtyard Area	Builtup area	Court/Plot	FAR	Remark
Soul Garden House	Hyderabad	Spacefiction Architects	1820	280	3900	0.15	2.14	Nominal Setback All around

### House No- 10 (Samruddhi house)

Samruddhi is a residence placed in a newly established suburban Surat neighbourhood. The plot, which is 190 square meters in size and situated in a well-planned and heavily inhabited area it is a relatively small piece of property. It was difficult to maintain the bungalow’s humble scale and avoid giving the impression that it was a low-rise apartment, even though the site size restriction suggested that it would rise to four storeys. The courtyard, which connects all levels, is a physical and visual extension of each area that overlooks another (Fig 58). The skylight lets in plenty of natural north light till sunset, which reduces the need for artificial lighting

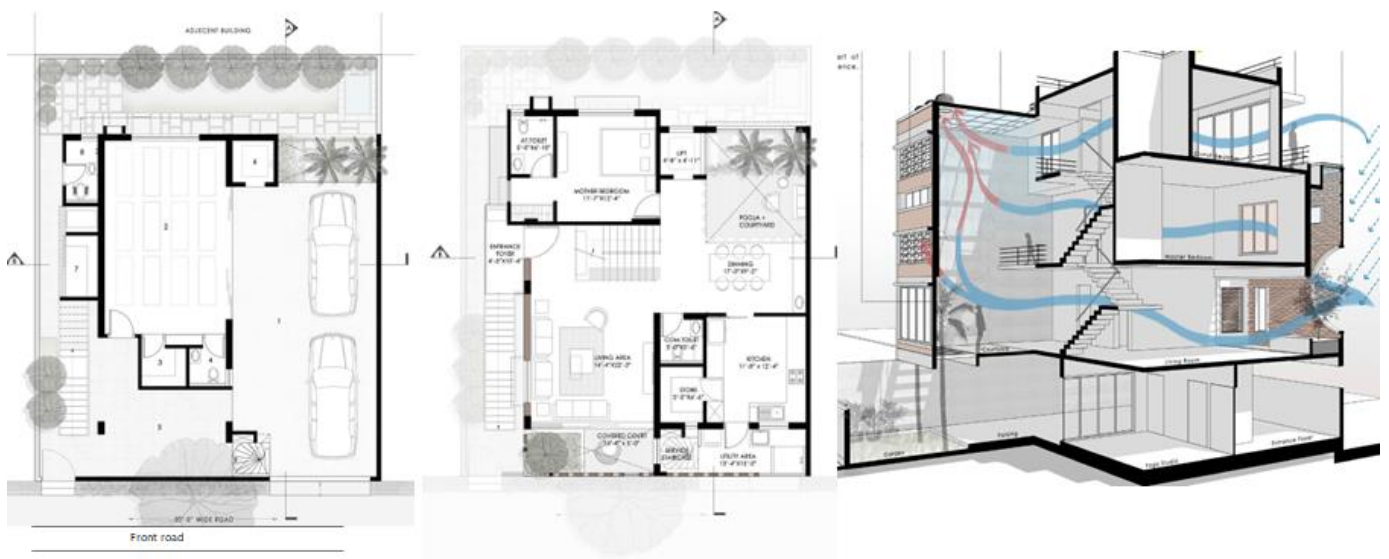


Figure 56 : Plan and Section View of House no-10

Source: [www.buildofy.com](http://www.buildofy.com)

Name	Location	Architect	Plot Area	Courtyard Area	Built up area	Court/Plot	FAR	Open spaces
Samruddhi house	Surat	Aangan Architects	2042	156	4630	0.08	2.27	Optimum Setback on three Side

### House No-11 (Belaku house)

This modern home in Bengaluru’s urban setting is interpreted as an ensemble of geometric shapes made of cubes and volumes with a hint of rustic materiality. The Belaku’s design emphasizes a cantilevering cubical bulk and the building’s harmonious integration with its surroundings. The house’s interior is in the style of an open plan with a sizable void serving as a courtyard and water features in the middle (Fig 59).



Figure 57: Plan and View of House No 11

Source: [www.buildofy.com](http://www.buildofy.com)

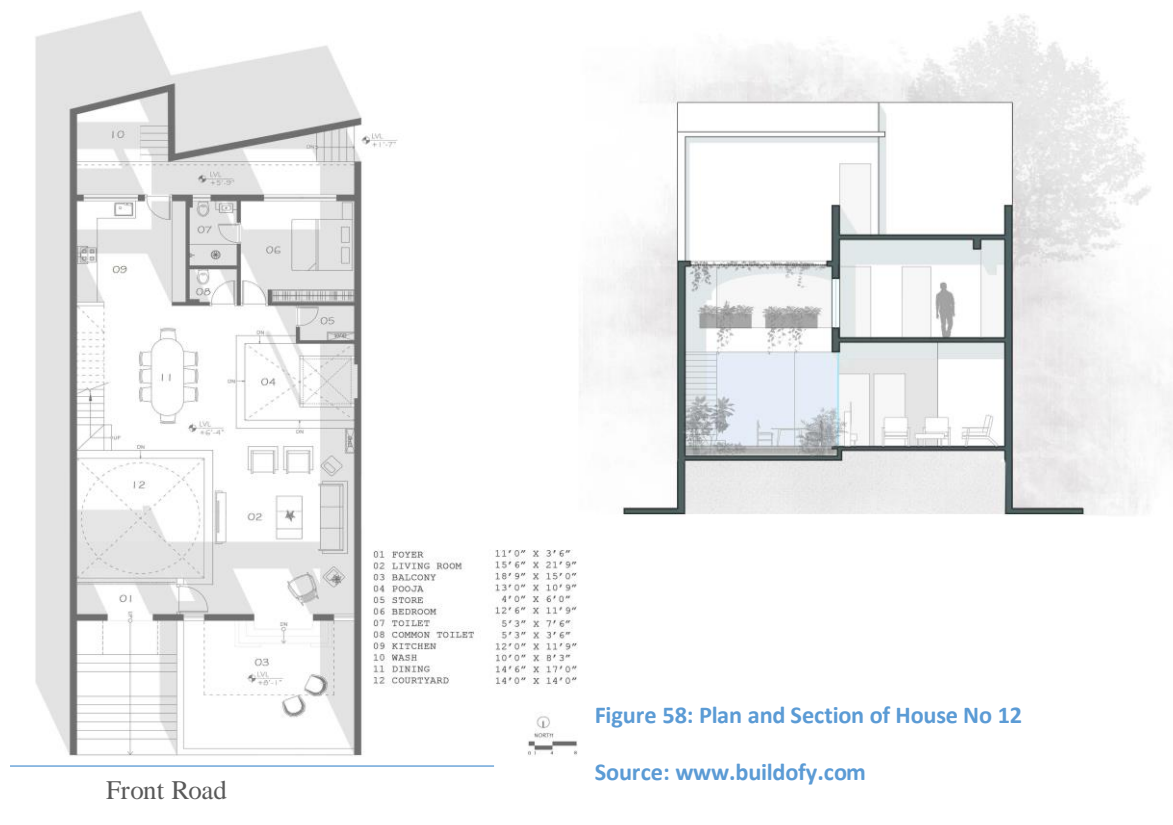
Name	Location	Architect	Plot Area	Courtyard Area	Built-up area	Court/Plot	FAR	Remark
Belaku house	Bengaluru	Techno architecture	2400	143	7000	0.06	2.92	Nominal setback all around



## House No-12 (Junglow house)

The house is located on the outskirts of the city, separating it from the urban chaos. The site has south access. The adjacent buildings on the other two sides of this site are semi-urban row dwellings the design aims to provide a constructed form that is economically modest. The G+2 volume keeps the user in intimate contact with nature

The internal spatial orientation follows a zone approach based on the activity of the spaces. the ground floor courtyard serves as the home's central focus (Fig 60). The screen that is facing the entryway acts as a green curtain to exclude direct west sunlight from entering the home and serves as a buffer. It has a circular skylight that nurtures the plantation of the courtyard. ume keeps the u ser in intimate contact with nature.



Name	Location	Architect	Plot Area	Courtyard Area	built-up area	Court/Plot	FAR	Remark
Junglow House	Surat	Ace Associates	2500	150	4200	0.06	1.68	Optimum Setback Onthree Side



### House No-13 (The small courtyard house)

A busy road and residential properties are located on the east and north sides, respectively, of the 2,500-square-foot property with an existing constructed mass. The constructed bulk is slightly modified, and the design is primarily focused on achieving a sense of openness and privacy. As a result, this property has adopted the historically significant courtyard area, and the other spaces are designed around it (Fig 61). The aesthetics of traditional charm in the contemporarily designed house are enhanced by this double-height court, which is located on the east. An exquisitely built screen with a variety of jharohka designs brings the nostalgia of traditional forts and dwellings. Further water body enhances the essence of the space. The sun roof allows the user to safeguard the area from changing weather conditions.



Figure 59 : Plan and Section of House No 13

Source: [www.buildofy.com](http://www.buildofy.com)

Name	Location	Architect	Plot Area	Courtyard Area	Builtup area	Court/Plot	FAR	Remark
Small courtyard House	Anand	Ace Associates	2500	150	4200	0.06	1.68	Optimum Setback On four Side

## House No-14 (Urban courtyard house)

The Urban Courtyard House is a 2750-square-foot house built on a plot of land in Chennai's Ashok Nagar neighbourhood. This house takes a traditional and modern approach to blend Indian and traditional elements. Only a little alleyway leading to the road led to the plot, which was encircled by structures on all four sides. Because the plot's margins lacked any significant vistas and seclusion, Architect decided to build an inward-looking residence. Client wanted a light filled and well ventilated home, where their daughter live and experience her childhood as she grows up. The open to sky courtyard allows both sunshine and rain to come into the house, bringing an outdoor experience to the indoors (Fig 61). The architects were able to achieve a beautiful space to look into without compromising any privacy. But the courtyard is not just about the light and ventilation, it is also the nucleus of the house that brings the family together.

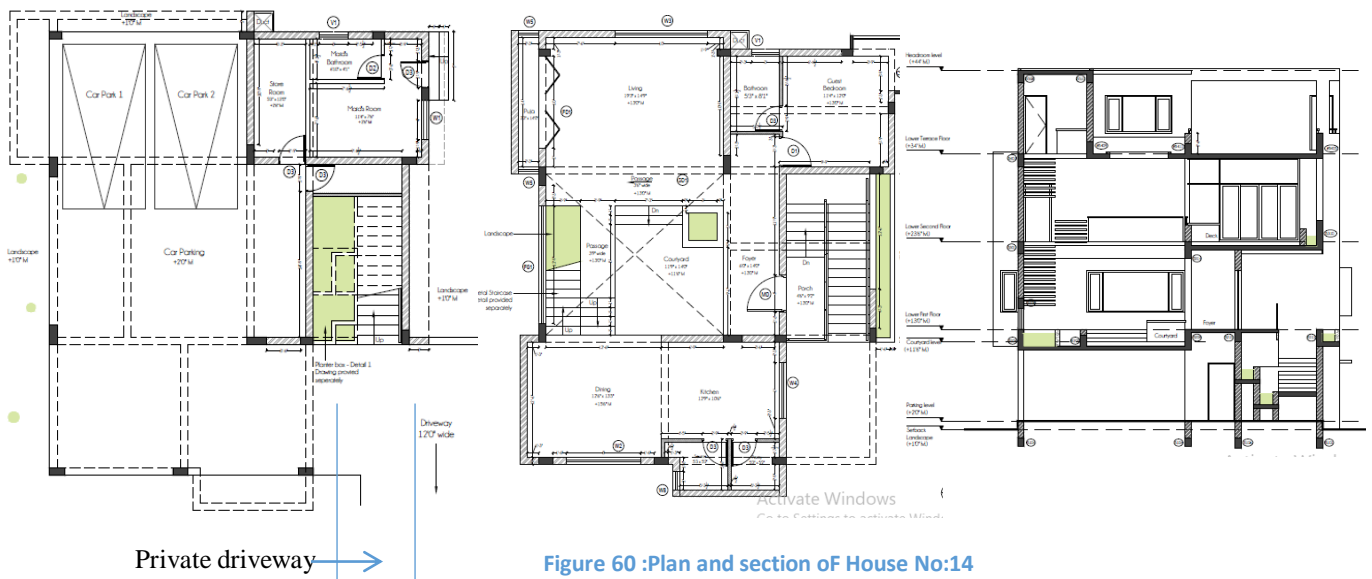


Figure 60 :Plan and section of House No:14

Source: [www.buildofy.com](http://www.buildofy.com)

Name	Location	Architect	Plot Area	Courtyard Area	Builtup area	Court/Plot	FAR	Remark
Urban courtyard House	Chennai	Studio Context	2750	168	3500	0.06	1.27	Nominal Setback All around

After analysis of the case studies the parameters of the courtyard such as width, and plot to courtyard proportion are summarised below. Therefore a mode of all the courtyard sizes and ratios are taken to calculate the optimum court size and other proportions (Al Hussayen, 1991)

Table 5.

Table 5 :Summary of Courtyard Houses

House Nomenclature	House No.	Plot area (sq ft.)	Courtyard Area	Opening Ratio	Width (W)	Length (L)	Height (H)	W/L	W/H	House facing
Traditional Houses: Not designed by the professional ,Built without the consideration of building regulation										
Talib's house	H.No - 1	950	156	0.16	13	12	20	1.08	0.65	West
Nistha's House	H.No - 2	1080	100	0.09	11	10	30	1.11	0.35	East
Mr.Gupta's House	H.No - 3	1400	357	0.26	17	21	20	0.81	0.85	South
Preeti patel' House	H.No - 4	1350	100	0.07	10	10	20	1.00	0.50	East
Shilpi's house	H.No - 5	2200	120	0.05	10	12	20	0.83	0.50	West
Vihaan 's house	H.No - 6	1650	175	0.11	13	14	20	0.89	0.63	North
Urban Houses: Designed by the professional, Built with the consideration of building regulation										
Inward looking Courtyard house	H.No - 7	1080	131	0.12	15	9	37	1.61	0.39	North
25 x 50 courtyard house	H.No - 8	1250	77	0.06	9	9	21	0.94	0.40	East
Soul Garden House	H.No - 9	1820	272	0.15	17	17	20	1.00	0.83	East
Samruddhi house	H.No - 10	2042	132	0.06	11	12	30	0.92	0.37	South
Belaku House	H.No - 11	2400	143	0.06	13	11	20	1.18	0.65	East
Junglow house	H.No - 12	2420	196	0.08	14	14	20	1.00	0.70	North
Small courtyard House	H.No -13	2500	140	0.06	10	14	20	0.71	0.50	South
Urban courtyard House	H.No - 14	2750	168	0.06	12	14	20	0.86	0.60	South
MODE	-	-	100	0.06	10	14	20	1	0.5	-

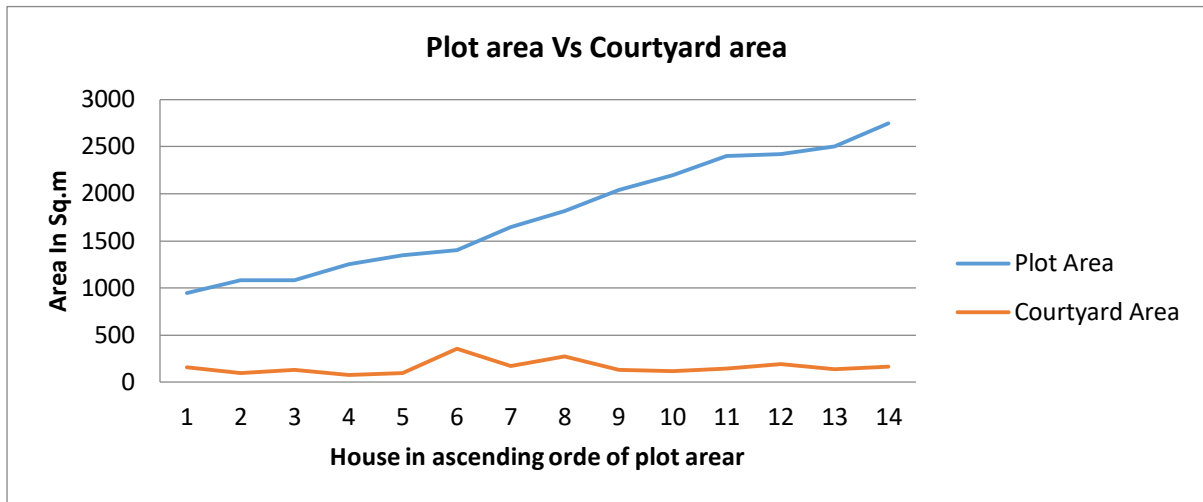
Table 6: Calculated Proportion from case studies.

Geometry of courtyard	Ratio
Width to length ratio of the courtyard (W/L)	1:1
Width to height ratio of the courtyard (W/H)	1:2
Courtyard-to-plot ratio	1:15

The aforementioned ratios derived from Table 5 are presented in Table 6 can be used as base ratios in the initial design phase for courtyard typology, however there is always a possibility to validate these result with modelling and simulation. After analysing case studies the result has been compared with the literature review where the courtyard proportion has been analysed. The summary of the studied research paper is given below

Table 7: Summarizing research paper for courtyard parameters.

Research papers	W/H	W/L
Gulati, Ritu, et al. “Architectural Spaces as Socio-Cultural Connectors: Lessons from the Vernacular Houses of Lucknow, India.” <i>ISVS E-Journal</i> , vol. 6, no. 4, 2019, pp. 30–48.	1:1-2	NA
Taleghani, Mohammad, and Martin Tenpierik. “Environmental Impact of Courtyards — a Review and Comparison of Residential.” <i>Journal of Green Building</i> , vol. 7, no. 2, 1986, pp. 113–36.	NA	1:2 (for Daylight)
Al Hussayen, Mohammed. “Significant Characteristics and Design Considerations of the Courtyard House.” <i>Journal of Architectural &amp; Planning Research</i> , vol. 12, no. 2, 1991, p. US.	1:3	1:1.3, 1:1.5 1:1.7
Zareh S.Amadouni. “Courtyard Housing- A Typological Analysis.” <i>Angewandte Chemie International Edition</i> , 6(11), 951–952., 1967.	1:2(Summer Shading) 1:1.3(for winter)	1:1.7 1:1.5
TERI : prescription for affordable housing in india	NA	1:2.5 (Max)
Agarwal, S., & Thussu, M. (2020). The conception of open spaces- A Case of Delhi Courtyard Houses. <i>Journal of Science and Technology</i> , 05(Volume 5), 87–105. <a href="https://doi.org/10.46243/jst.2020.v5.i4.pp87-105">https://doi.org/10.46243/jst.2020.v5.i4.pp87-105</a>	1:3	NA



The graph above suggested courtyard area is unrelated to plot area and build-up area.

### 4.1.3 Spatial organization

Traditional courtyard house	Contemporary setback house	Contemporary courtyard house
<p>In traditional house courtyard act as central core of the house, all other activities were planned around the courtyard.</p> <p>Kitchen area is not directly connected with, dining area or living area which is not practical now days.</p> <p>Services like toilet are accessible through courtyard, which is further not practical in today's time of attached toilets.</p>	<p>In conventional setback typology living zone act as circulation space for connecting various activities. Hence the space does not work as full-fledged functional space.</p> <p>Open area located at back of the house which is mostly underutilized as functional space, used as junk yard.</p> <p>Living Area is the core of the house which may got not sufficient daylight</p>	<p>An urban courtyard can give a touch of luxury to a home's interior and can blur the boundary between indoor and outdoor space. Nonetheless, the achieved spatial arrangement is comparable to that of the traditional house, which was tailored as per user's need.</p> <p>In contemporary courtyard typology courtyard act as leisure space rather than household activity space.</p> <p>Courtyard in contemporary typology act mostly act as light well which provide sufficient light to adjacent space.</p> <p>Limited cases utilized courtyard for natural ventilation and microclimate modification.</p>

## **4.2. CASE STUDIES : BUILDING REGULATION**

In this study, the study investigated the bye-laws of residential zones up to the plot size of 500 sq m. of five different cities namely Bhopal, Jaipur, Amaravati, Chandigarh, and Lucknow. The major objective of the study is to fully explore the potential of courtyard typology in urban development. It is crucial to comprehend the nature of open space within residential plots in the existing building bye-laws in order to carve the niche for different residential typologies such as courtyard houses. The study summarizes the primary Bye-laws for residential buildings of five cities at the first place and then a detailed analysis of Lucknow has been done in the second place. The sub-section of this chapter compares the bye-laws of two cities with respect to plot proportion and Ground coverage.

All these cities are the capital of their respective states and have composite climates except for Amaravati, and Andhra Pradesh.

After a preliminary examination of residential building norms of three different cities, the Lucknow Bye-laws as a case has been selected for detailed study and prototype development.

### **4.2.1 Amaravati: an overview**

The AP Re-Organization Act in 2014 resulted in the bifurcation of the former state of Andhra Pradesh, leaving the state without a capital city. This created an urgent need for comprehensive planning and the creation of a new state capital with top-notch infrastructure that would reflect the people's vision and aspiration for a "happy," "liveable," and "sustainable" city. Due to its advantageous location in the Capital Region between the two nodal urban centres of Vijayawada and Guntur, Amaravati was chosen as the new capital of Andhra Pradesh. On October 22, 2015, Indian Prime Minister Narendra Modi laid the cornerstone during a formal ceremony in the village of Uddandarayunipalem.

#### **Building bye-laws in Amaravati**

The government of Andhra Pradesh has enacted Andhra Pradesh capital region development authority act.2014. APCRDA as the planning agency is having jurisdiction over handling everything in the APCRDA region. Building regulation in the capital region of Amaravati is governed by Amaravati zoning regulation 2016. In order to control the density of the area the residential zone has been divided into 5 zoning districts. On the basis of the zoning district, the density is controlled with help of setbacks. FAR, setback, height, etc.

### ***Residential building norms***

Development control regulations for residential zone depend on the specific residential zoning district which is as follows

R1 -Village planning zone

R2 - Low-density zone

R3 -Medium to high-density zone

R4-High density zone

Norms such as FAR, Ground coverage, Height, and setback vary according to the typologies (Detached, semi-detached, attached) of plotted development and the location of the plot in the specific zoning district. All the regulations are compiled in appendix II of zoning regulation 2016, Amaravati.

#### **4.2.2 Bhopal: An Overview**

The political, social, and economic life of the state of Madhya Pradesh is centered in the well-planned, rapidly growing metropolis of Bhopal. The development of Bhopal's architecture and urban planning is a reflection of the city's strong appreciation for its natural topography and sustainable planning methods.

The city has survived effectively by modifying its current built environment on a regular basis to provide an adaptable environment in response to the shifting demands of its citizens. Bhopal has experienced remarkable development in recent decades, making it extremely difficult for city planners to keep the city's expansion within the boundaries of its original plans.

#### **Building bye-laws in Bhopal**

The Madhya Pradesh Bhumi Vikas Niyam 2012 was formulated under the Act Madhya pradeh Nagar tatha gram Nivesh Adhinyam 1973. The Madhya Pradesh Bhumi Vikas building regulation provides a legal framework for the growth of the Bhopal city. The Bhopal Development Plan provides area-specific building norms which vary according to the local context. These rules are applicable whenever there is new construction, alteration, and change in occupancy, or demolition of a building.

#### ***Residential building Norms:***

Plotted development is categorized into three categories namely: Detached building

Semi -detached buildings and row houses. The basis for this categorization depends on the frontage of the plot. Each Plot shall have a minimum size and frontage corresponding to the road width as shown in Table 8.

**Table 8 : Types of residential plot**

Type of development	Plot size(Sq.m)	Frontage (in meter)
Detached Building	Above 225	Above 12
Semidetached building	125-225	8-12
Row type building	50-225	4.5-12

### **Setback norms/ Open Area Norms**

**Front Open Space:** Front setback shall be governed by the Abutting road width.

Abutting road width up to 9 m:	3 m
Abutting road width from 9 -12 m:	3.6 m
Abutting road width from 12-18 m:	4.5 m
Abutting road width above 18 m:	6 m

**Rear Open Space:** Rear setbacks depend shall be governed by the area of plot

Upto 40 Sqm	0
40-150 sqm	1.50 m
150-225 sqm	2.50 m
Above 225 sqm	3 m

**Side open space:** Side setback shall be governed by the category of the plot.

Detached Building:	3 m open space on both Side
Semi-detached Building:	3 m open space on one side
Row type building:	No side margins

**Inner courtyard:** If any habitable space is not opening towards any rear, side, or front open space than they shall abut inner court. The minimum side of the inner courtyard should not be less than 3 meters. Additionally, the inner courtyard must have square footage that is at least one-fifth the height of the tallest wall bordering the courtyard throughout its whole height.

### **4.2.3 Chandigarh: An Overview**

Chandigarh is a capital city of Punjab and Haryana and also a union territory in India. Punjab to the north, west, and south, and Haryana to the east, encircles Chandigarh. The Greater Chandigarh area, which also encompasses the neighbouring satellite towns of Panchkula and Mohali, is mostly made up of it. It is located 260 km (162 miles) north of New Delhi and 229 km (143 miles) southeast of Amritsar. One of India's first planned cities after independence, Chandigarh is



renowned around the world for its architecture and urban planning. Le Corbusier, a Swiss-French architect, devised the city's master plan, which was based on earlier designs made by Macie Nowicki, a Polish architect, and Albert Mayer, an American urban planner. A group led by Le Corbusier, Jane Drew, and Maxwell Fry developed the majority of the city's housing and public facilities. Chandigarh's Capitol Complex—as part of a global ensemble of Corbusier's buildings—was declared a World Heritage Site by UNESCO at the 40th session of the World Heritage Conference in July 2016

Chandigarh has been widely acclaimed as a mecca of planning and architecture in view of various innovations in corporate in planning, designing, and development of the capital city of Punjab. The city today is valued universally for being the first realization of the Le-Corbusier's urban concept.

### **Building bye-laws in Chandigarh**

To control and regulate the development of the city in accordance with the founding concept and idea, various acts/rules were put in place. Development control within the city has its genesis in the capital of Punjab act(development and regulation) 1952 which ultimately formulated the Chandigarh building rules(urban) 2017. Chandigarh has put in operation following two distinct sets of development control regulations.

- 1) Zoning regulation
- 2) Architectural control regulation

### **Residential building Norms:**

The various categories on the plotted development are MARLA, 1 KANAL, 2 KANAL, and ABOVE 2 KANAL.

Ground coverage changes from 65% to 35 % as per the category of the plot i.e. (MARLA, KANAL)

FAR ranges from 2 to 1 per the category of the plot

Height depends on the category of the plot

Set back are governed by the zoning plans /Frame control plans.

### **4.2.4 Jaipur: An Overview**

The tenth-largest metropolitan area is Jaipur. In a typical elevation of 432 m, Jaipur is situated at coordinates 26°55' N 75°49' E. It was established in 1727 as the seat of the former Dhoondhar kingdom to meet the demands of an expanding population and address Amber's water shortage. It

is the capital of Rajasthan, the biggest Indian state, and an important multi-functional metropolitan center in the northwest. The walled city still functions as the city's commercial hub and is home to a significant number of tourist attractions and businesses, accounting for 60% of all business activity there (MacDonald, 2015). The walled city of Jaipur's gridiron planning features a broad, hierarchical street network with elaborately carved figures that continue to meet the demands of modern automotive traffic (Jawaid Pipralia, & Kumar et al., 2018) which the majority of the traditional Indian towns cannot handle. Since its inception, the city's planning development has placed a strong emphasis on nature and the environment in its built form, planning arrangement, and architectural elements

### Bye-laws in Jaipur

New Rajasthan Building Bye Laws - 2020 has just been approved by the state of Rajasthan's Urban Development and Housing (UDH) Department, which will aid in the orderly growth of urban areas. All building designs, constructions, reconstructions, and renovations are subject to these ordinances. They have also been incorporated into the Jaipur Development Authority's Master Plan (JDA).

### Residential building Norms:

The various Parameters like FAR, Setback, and Height for residential development are described in Table 9.

Table 9: Summary of Jaipur Building bye-laws (Source: Rajasthan Building Bye Laws – 2020)

S.No	Plot size(sq.m)	Setback				Max permissible Height* LV-HV	Permissible FAR
		Front <sup>#</sup>	Side-1	Side-2	Rear		
1	Upto 90	-	-	-	-	9-15	-
2	90-167	3-9	-	-	1.5	9-15	2
3	167-225	3-9	-	-	2	9-18	2
4	225-350	3-9	3	-	3	12-18	2
5	350-500	3-9	3	-	3	12-18	2
6	500-750	3-9	3	3	3	12-18	2
7	750-1000	3-9	4.5	4.5	4.5	15-1.5 of RW+FS	2
8.	1000-1500	3-9	4.5	4.5	4.5	15-1.5 of RW+FS	2
9.	1500-2500	3-9	6	6	6	15-1.5 of RW+FS	2

# Front setback depends on width of abutting road (As per Table).

\*Max permissible height depends on the width of the road on which plot is situated. I.e the permissible height increases with abutting road width.

LV-Lowest Value

HV- highest value

RW- Road width

FS- Front setback

Ground coverage within the setback is permissible

The front setback will be governed by the width of the abutting road as shown in Table 10

**Table 10 : Setback requirement with respect to road width (Source: Rajasthan Building Bye Laws – 2020)**

Width of Road (in meter)	Minimum Setback
Upto 18 m	3 m
18m -24 m	4.5 m
24m-30 m	6 m
Above 30 m	9 m

#### **4.2.5 Lucknow: An Overview**

India's Uttar Pradesh state has Lucknow as its capital. After Delhi, it is the biggest and most advanced city in North India. The administrative center for the Lucknow District and Lucknow Division. This city is the location of the Division. As the hub of culture and the arts in North India, Lucknow has long been recognized as a cosmopolitan city. The metropolis, which has a population of about 2.8 million, is dispersed over both sides of the River Gomti. and covers an area of 350 square kilometres. In the state of Uttar Pradesh, Lucknow City accounts for 6.33% of the urban population. The city is well-known for its historical nature and for being the Nawabs' seat. The city is now one of those in India with the highest population growth, and it is quickly becoming a center for commerce and shopping. As the nation's capital and the center of commerce for neighboring towns, Lucknow is also known as the "Golden City of the East." (CDP, Lucknow)

- **Building bye-laws in Lucknow**

The government department responsible for creating zoning development plans and master plans for cities and towns is the Town & Country Planning Department, U.P. Additionally; the Department serves as the Government's technical advisor on all issues pertaining to urban planning. All of the Development Authorities, Regulated Areas, and Urban Local Bodies of the State of Uttar Pradesh also receive advice and technical support from it. In addition to this, the department is responsible for formulating state housing policies, building bye-laws, and zoning regulations in accordance with the administrative oversight of the Housing and Urban Planning Department of the State of Uttar Pradesh. Other government departments, such as the Lucknow Development Authority and the Awas Vikas parishad, are in charge of sanctioning maps and ensuring that these Bye-laws are adhered to. The building bye-laws of 2008 now govern the

Lucknow region. These Bye-laws were partly updated in 2016 and 2017 to meet the guidelines of the Model Building by-laws and NBC.

- **Residential building Norms:**

Residential building norms are categorized on basis of two zones namely developed area and non - developed area. The various parameters like FAR, Ground Coverage vary according to these zones.

- **FAR, setbacks, ground coverage, and building height norms:**

The various norms of FAR, Ground coverage, Setback, and Building height are summarised in the Table 11.

**Table 11: Summary of building Bye-laws (Source: Building Bye-Laws Amended 2016, Lucknow)**

S.No	Plot size(sq.m)	Ground Coverage (%) Developed/ undeveloped	Setbacks (in mts)				Max Height*	Permissible FAR
			Front	Side-1	Side-2	Rear		
kk1	Upto 50	75/65	1	-	-	-	10.5	2
2	50-100	75/65	1.5	-	-	1.5	10.5	2
3	100-150	65/60	2	-	-	2	10.5	2
4	150-300	65/60	3	-	-	3	10.5	1.75
5	300-500	55/55	4.5	3	-	4.5	10.5	1.50
6	500-1000	45/45	6	3	1.5	6	10.5	1.25
7	1000-1500	45/45	9	4.5	3	6	10.5	1.25
8	1500-2000	45/45	9	6	6	9	10.5	1.25

\*Max height without stilt floor, 12.5 m permissible with stilt floor.

40 % of the rear setback can be covered with a maximum height of up to 7m. The minimum lot size for any residential unit is 40 sq., however, the limit can be further reduced for houses of the economic weaker sections with special conditions.

- **Environment protection:**

The provision of compensatory FAR for LEED/IGBC-rated buildings

Rain water harvesting for plots above 300 sq. m. solar water heating for plots above 500 sq. m

- **Open spaces & greening provisions:**

10 % area of the total layout area shall be designated for green space.

The minimum width of open space shall be 7.5 m.

- **Architectural character and built form:**

The following parameter in elevation can be modified by the development authority depending on the situation and the necessity.

Building height

Colour Scheme

Balcony cornice or sunshades designs

Height of floors and building height

▪ **Light and ventilation Norms**

Any habitable room's windows or ventilators opening toward an open space or verandah must have a minimum width of 3 m. Provision of windows or ventilators (excluding door) in a room must not be less than 10% of the room's carpet area. Any area of the room will not be considered illuminated if it is more than 7.5 meters away from the open space. However, the air-conditioning space is exempted from the requirement. If any room receives light from internal open space, then residential developments up to 12.5 m in height must contain 7.5 sq. m of internal open space with a width of no less than 2.5 m.

The criteria for comparing the byelaws of various cities, has been drawn for the following studies(A. Kumar & Pushplata, 2017)(Jawaid et al., 2018)(Imsong & Kumar, 2023)(Madangopal, 2015). Observations made after reviewing the bye-laws of five cities for the plotted development up to 500 sq. m plot are summarized in the table below (Table 12).

Table 12: Summary of Bye-laws of Five cities: Amaravati, Bhopal, Chandigarh, Jaipur, and Lucknow

Parameters	Amaravati	Bhopal	Chandigarh	Jaipur	Lucknow
<b>FAR</b>	FAR changes with predefined zone district/typology	Constant for any plot sizes of the above-mentioned category	FAR decreases with an increase in plot size	Constant for any plot sizes of the above-mentioned category	FAR decreases with an increase in plot size
<b>Ground Coverage's</b>	GC varies according to zone district/typology	GC decreases with an increase in Plot Area	GC decreases with an increase in Plot Area	Area within setback	GC decreases with an increase in Plot Area
<b>Building Height</b>	Building height depends on the building typology and density zones.	No impact of road width	No impact of road width varies as per plot size	Height depends on the width of the abutting road	No impact of road width
<b>Setback</b>	Setback varies as per zones however maximum setback of 2 m is prescribed for	Front setback depends on abutting road width Rear setback on an area of plot	Setbacks are strictly governed by zoning plans and architectural control	Front setback depends on abutting road width. Rear and side setback depends on the	Front, Rear and side setback depends on Area of plot

	independent houses.(D,SD. A)	Side setback on frontage of plot	drawings.	Area of plot	
<b>Environment protection Norms</b>	No specific Guidelines for low rise independent houses.	Rain water harvesting for plot above 140 sq. m	Upto 420 sq m plot, the segregation of waste is mandatory.	Provision of compensatory FAR for LEED/IGBC-rated building. Rain water harvesting for plot above 300 sq. m Solar water heating/ solar lighting for plot above 500 sq. m	Provision of compensatory FAR for LEED/IGBC-rated building. Rain water harvesting for plots above 300 sq. m Solar water heating for plot above 500 sq. m
<b>Open spaces &amp; greening provisions</b>	In zone R1, there is no rigid guideline for green spaces, however in Zone R2, specific percentage of green spaces to be left as green cover.	One tree per 100 sq. m area of Plot.	Provision of minimum 1 tree / every 80sqmt of plot area for plot sizes > 100sqmt and planted within the setback of the plot.	Two tree per 50 sq. m area of Plot.	Open area norms at level layout plan only.
<b>Architectural character and built form</b>	Height and material restriction for fencing and signage.	No specific guidelines for fenestration and built mass	Strictly governed by the architectural control drawing for specific zones.	Architectural guidelines for Walled city only. No specific guidelines for fenestration and built mass in new development	No specific guidelines for fenestration and built mass.
<b>Light and ventilation</b>	No specific mention regarding lighting and ventilation of interior spaces.	Min. 10 % of floor Area. Space should be within 7,5 from the opening	Minimum 1/8th of the floor area of the habitable space. Minimum area 9.0 sq. m with minimum 3.0 m width	Min. 10 % of floor Area Space should be within 7,5 from the opening	Min. 10 % of floor Area Space should be within 7,5 from the opening

As discussed in Table 7, existing building regulations have a significant influence on numerous areas of the urban environment, including the natural environment, existing buildings, social infrastructure, development patterns, open spaces, and townscape. The FAR, Setbacks, GC, and Height regulating rules have a significant influence on building masses and residential typologies. Prescribed setbacks also regulate the ratio of constructed to open space, which in the end shapes the development pattern. The analysis of five cities' building Bye-laws revealed key factors, which are used to determine the setback for houses. They are as follows.

- Plot size
- House typology ( i.e Row, Semi-detached, Detached)
- Abutting road width
- Zoning/Architectural Control

According to URDPFI Guidelines, a building layout's minimum setbacks should be established subject to building height, ventilation, and fire safety criteria. There are two ways to offer setbacks, namely

- 1) Based on plot sizes
- 2) Based on abutting road widths.

These two methods as described above may be adopted for providing setbacks (Ministry of Urban Development, 2014). However, the guidelines of URDPI do not consider the plot proportion as the measure for deciding the setbacks which has an impact on ground coverage after leaving the mandatory setback.

### **The Example Illustration of building regulation for five cities.**

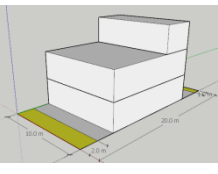
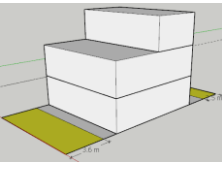
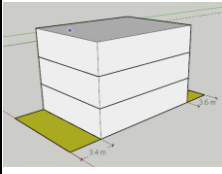
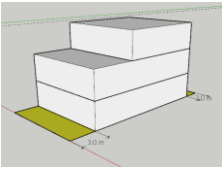
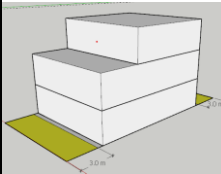

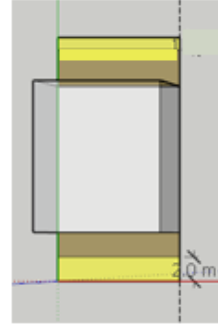
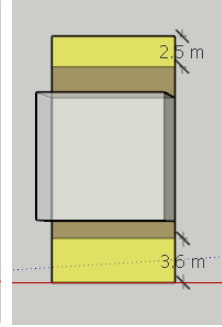
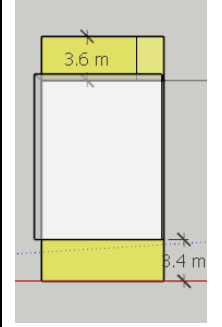
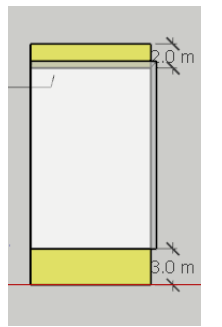
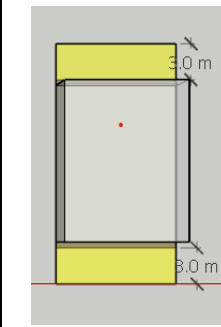
Case: Medium-sized plot, Row/attached type house

Plot size: 200 sq. m

Plot proportion 1:2 (10 x20)

Abutting road: 12 m

Table 13: Comparison of Bye-laws for a Case example

City/Town	Amaravati	Bhopal	Chandigarh	Jaipur	Lucknow
FAR	1.75	1.25	2	2	1.75
Built up area (sq.m)	350	250	400	400	350
Ground Coverage (sq.m)	120 (60%)	100(50 %)	140 (65 % + 5)	Within setback	130 (65 %)
Height (m)	13 m	12.5	10.06	15	10.5
Storey	G+3	-	G+2	-	G+2
Front setback (m)	2	3.6	3.4	3	3
Rear setback (m)	2	2.50	3.6	2	3
Illustrations					
Prescribed setback					
Margin left after using full potential of GC					

The main finding shows that bye-laws of Amaravati and Bhopal provide ample marginal space after utilizing the full potential of ground coverage and leaving the mandatory setback, which could be well utilised by the designers for creating the interior courtyards, however, Lucknow bye-laws provided nominal marginal space for the same. In the case of Jaipur and Chandigarh building block lies within the setback line, therefore, designers have very little flexibility for experimenting with internal courts.



After a preliminary examination of the residential Bye-laws of cities, it was established that Bhopal's Bye-laws mostly adhere to the standards outlined in the NBC 2016 and Model building bye-laws of 2016 in terms of FAR and Setback. However, The Lucknow Bye-laws have been noted to be stringent and less detailed in nature. Additionally, it has been determined that there are serious concerns regarding the effective compliance of existing building regulations, i.e., it is not possible to satisfy all building regulations for various plot proportions, in addition to the issues and problems with existing building regulations that have already been mentioned. Since plot sizes for different building types (detached, semi-detached, and row) are generally comparable across the nation, current construction standards may not be effectively followed if plot proportions are not taken into account (A. Kumar & Pushplata, 2017). Many times, plot proportions (front-to-depth ratio) are left out of the standards, which lead to noncompliance with several statutory requirements. Therefore, to have the efficient fulfilment of different guidelines on all plots, it is essential to understand the influence of plot proportions on ground converges so that a proper built-to-open ratio can be worked out for residential buildings. It is quite clear that the relation of built and open masses further decides the typology of the house and helps designers to opt for any different residential typology.

Chandigarh zoning plan fixed the front setback and any ambiguities occur due to the plot proportion having been adjusted in the rear setback. Additionally, the bye-laws of Jaipur, Lucknow and Amaravati do not consider the plot proportion for deciding the setback. However, in the case of Bhopal, there is the impact of plot width on deciding the typology of the house (Detached, semi-detached / row houses) which ultimately influences the prescribed setback.

It was found that setback lines and the percentage of ground coverage are the two main factors used to regulate the built-to-open ratio. However, rigid setback lines encourage the pavilion building type and offer very little flexibility for designing other residential typologies. On the other hand, street setbacks protect residents' privacy while preserving the distinctiveness of the neighbourhood. Further, setback regulations outline the area that must be kept open around buildings in order to maintain proper lighting and ventilation inside buildings. This open space around buildings can be used for landscape purposes (Imsong & Kumar, 2023). It is questionable whether this strict setback actually gives the house enough light and ventilation because they don't take climate or orientation into account. According to the study, although Lucknow, Amaravati, and Bhopal have both ground coverage and setback regulations in place, these regulations actually cause confusion regarding compliance and make it challenging to monitor the breach of building regulations on a practical level. While the setback line is the deciding factor for the calculating built-to-open ratio in Chandigarh and Jaipur, it results in very monotonous design solutions. In

their study, S. Azad et al. suggested that FAR and BCR are seriously inadequate for assessing the quality of open space and do not allow us to differentiate between various housing designs. Applying modern indices like SOI (Spatial openness index) and WPI (Wall perimeter index) can be a productive way to create high-quality residential environments. By making these provisions, residential open space amenities are improved to meet user demands (Azad et al., 2018). The majority of parameters, including FAR, building height, and ground coverage, are chosen from an urban planning perspective; the architectural quality of residential open space and the aesthetics of streets have not been addressed. However, regulation must be such that it provides better neighborhood quality to residents, whether that be through appealing street facades or usable residential open space. Additionally, the use of open space itself must be justified, as is the case with rear setbacks where storage and utility are the primary uses of the space, while side and front setbacks are designed to accommodate parking spaces. Residential open space must be designed to satisfy the user's senses not for the car or the utilities.

It is difficult to ignore front setbacks because they are essential in determining street elevation, parking availability, and future service expansion. However, building height must also be taken into account when determining street elevation before we can begin working on architectural controls. Given that it is more appropriate for commercial land use, FAR is a vague concept for residential development. Height regulation, Building line, and the ratio of open space within the plot must be key factors for designing sustainable and aesthetically appealing residential neighbourhoods.

The Lucknow Bye-laws have been selected for in-depth analysis to look for opportunities for providing high-quality residential open space, like courtyards, which ensure enough light and ventilation to any plot proportion.

#### **4.2.6 Concerns of Lucknow bye-Laws**

##### **FAR, setbacks, Ground coverage, and building height**

- The Lucknow Building Regulations do not clearly link parameters like FAR, coverage, setbacks, and building footprint to the type and character of the built form.
- The definition of Developed/constructed/undeveloped zone given in the bye-laws does not provide a clear-cut distinction of area.
- Setback norms of Lucknow Bye-laws do not have any correlation with the abutting road width on which the plot is situated. The setback, FAR, and Ground coverage norms are uniform irrespective of the road width. The recommended parameters are largely related to the area of

the plots whereas plot proportion (Length: Breadth) has been not taken into account which ultimately creates ambiguities in ground coverage's

### **Environment protection**

The building regulatory measures for environmental conservation in Lucknow are currently restricted to the general use of rainwater harvesting and some provisions for solar energy in buildings, but only for large projects, but the nature and extent of the provision and its implementation and incorporation into the small scale residential buildings still need to be thoroughly studied and analyzed. The provisions of groundwater recharge, water recycling and reuse are almost absent.

There is no dedicated section for old Lucknow city and further no guidelines regarding the conservation of old typology houses, however, Bye-laws segregated the city area as constructed area, developed area, and non-developed. The lack of a precise definition of these zones in the Bye-laws further fosters the turmoil. The guideline also lacks any reflection for the climatic context and hence forth no guidelines for climate-responsive architecture. However, there is a compensatory FAR for LEED/IGBC-rated buildings that is also applicable to large projects only.

Although NBC has been expanded to include climate, wind, and solar orientation, landscape design, envelope optimization techniques, water and waste management, and other environmental and energy efficiency factors, their incorporation into building regulations and design is extremely tricky because NBC lacks an appropriate framework and implementation guidelines. (Jawaid et al., 2018).

### **Open spaces & greening provisions**

There are no specific regulations for the type and amount of open spaces and greenery, The percentage of soft surfaces for water catchment and absorption, and other environmental factors in residential development are not defined. The handling of open spaces, site vegetation, and climatic design considerations are not regarded as parts of the construction requirements, while the requirement for 15% landscaping has been legislated for layout-level plans only.

### **Architectural character and built form**

The type and character of built forms are not specifically regulated, especially in older historic cities. There are no descriptive guidelines in the building regulations that apply to other parts of the city regarding the nature and character of developments in terms of mass and volumes or bulk of development, the ratio of mass and void, surface area, and volumes, which are significant

factors affecting the energy performance of the buildings. There is still no clear connection between the urban form and the legislation controlling it since Lucknow's building regulations only regulate the physical dimensions of land or 2-dimensional spaces rather than in volumetric terms in 3-dimensional shapes.

### Light and ventilation

There are no specific guidelines regarding the fenestration and architectural elements which must be taken into account for cohesive development. The Regulatory Bye-laws suggest 10 % fenestration of the carpet area of the room, though the wall-to-window ratio is not taken into the consideration. Further, the fenestration guidelines are not orientation specific. The guidelines for internal open spaces are rigid and do not have any practical implications. This must adhere to the guidelines of Eco-Niwas Samhita 2018

#### 4.2.7 Impact of plot proportions on compliance with building regulations ( A case of Lucknow)

To examine the ambiguities in ground coverage and setback norms, as well as how they apply to various plot proportions. Sample Plots of 100, 150, 200, 250, 300, 350, 400, 450, and 500 square meters in size are taken into consideration in order to analyse the potential impacts of plot proportions on ground coverage. For the aforementioned plot sizes with various plot proportions (front-to-depth ratios), such as 1:1, 1:4, 1:2, 1:1.5, and 1:1, the actual ground coverage that may be accomplished after meeting the mandated setback criteria is determined.

**Table 14** :Calculated ground coverage for different plot sizes and proportion

Plot Size	Plot Proportion	Area within setback (In sq.m)	Area Within setback in %	Permissible Ground Coverage	Permissible Ground coverage in %	Potential for providing open Areas like courtyard	Potential Open space in %
		(A)	(A %)	(B)	(B %)	A-B=(C )	(C %)
100	1:3	94.2	94.2	75.0	75.0	19.2	19
	1:2.5	93.3	93.3	75.0	75.0	18.3	18
	1:2	92.8	92.8	75.0	75.0	17.8	18
	1:1.5	91.8	91.8	75.0	75.0	16.8	17
	1:1	90.0	90.0	75.0	75.0	15.0	15
150	1:3	121.7	81.1	97.5	65.0	24.2	16
	1:2.5	119.1	79.4	97.5	65.0	21.6	14
	1:2	115.4	76.9	97.5	65.0	17.9	12
	1:1.5	110.0	73.3	97.5	65.0	12.5	8
	1:1	101.1	67.4	97.5	65.0	3.6	2

200	1:3	150.9	75.4	130.0	65.0	20.9	10
	1:2.5	146.2	73.1	130.0	65.0	16.2	8
	1:2	140.0	70.0	130.0	65.0	10.0	5
	1:1.5	130.7	65.4	130.0	65.0	0.7	0
	1:1	115.1	57.5	130.0	65.0	-14.9	-7
250	1:3	195.3	78.1	162.5	65.0	32.8	13
	1:2.5	190.0	76.0	162.5	65.0	27.5	11
	1:2	182.9	73.2	162.5	65.0	20.4	8
	1:1.5	172.5	69.0	162.5	65.0	10.0	4
	1:1	155.1	62.0	162.5	65.0	-7.4	-3
300	1:3	240.0	80.0	195.0	65.0	45.0	15
	1:2.5	234.0	78.0	195.0	65.0	39.0	13
	1:2	226.5	75.5	195.0	65.0	31.5	11
	1:1.5	215.1	71.7	195.0	65.0	20.1	7
	1:1	196.1	65.4	195.0	65.0	1.1	0
350	1:3	182.5	52.1	192.5	55.0	-10.0	-3
	1:2.5	181.0	51.7	192.5	55.0	-11.5	-3
	1:2	178.6	51.0	192.5	55.0	-13.9	-4
	1:1.5	170.8	48.8	192.5	55.0	-21.7	-6
	1:1	152.5	43.6	192.5	55.0	-40.0	-11
400	1:3	219.0	54.7	220.0	55.0	-1.0	0
	1:2.5	218.0	54.5	220.0	55.0	-2.0	-1
	1:2	214.8	53.7	220.0	55.0	-5.2	-1
	1:1.5	206.5	51.6	220.0	55.0	-13.5	-3
	1:1	187.0	46.8	220.0	55.0	-33.0	-8
450	1:3	256.6	57.0	247.5	55.0	9.1	2
	1:2.5	255.0	56.7	247.5	55.0	7.5	2
	1:2	252.0	56.0	247.5	55.0	4.5	1
	1:1.5	243.2	54.0	247.5	55.0	-4.3	-1
	1:1	222.3	49.4	247.5	55.0	-25.2	-6
500	1:3	294.6	58.9	275.0	55.0	19.6	4
	1:2.5	293.0	58.6	275.0	55.0	18.0	4
	1:2	289.8	58.0	275.0	55.0	14.8	3
	1:1.5	280.6	56.1	275.0	55.0	5.6	1
	1:1	258.6	51.7	275.0	55.0	-16.4	-3

Table 15: Calculated ground coverage and F.A.R. for different plot sizes.

Plot Size	Plot Proportion	Area within setback (In sq.m) (A)	Permissible Ground Coverage (B)	Permissible FAR	Permissible BUA	No of stories w.r.t area(A)	No of stories w.r.t area (B)	Achieved FAR w.r.t area(A*)	Achieved FAR w.r.t area(B*)
100	1:2	92.8	75.0	2.0	200	2.2	2.7	2.8	2.3
150	1:2	115.4	97.5	1.75	263	2.3	2.7	2.3	2.0
200	1:2	140.0	130.0	1.75	350	2.5	2.7	2.1	2.0
250	1:2	182.9	162.5	1.75	438	2.4	2.7	2.2	2.0
300	1:2	226.5	195.0	1.75	<b>525</b>	2.3	2.7	2.3	2.0
350	1:2	178.6	192.5	1.5	<b>525</b>	2.9	2.7	1.5	1.7
400	1:2	214.8	220.0	1.5	600	2.8	2.7	1.6	1.7
450	1:2	252.0	247.5	1.5	675	2.7	2.7	1.7	1.7
500	1:2	289.8	275.0	1.5	750	2.6	2.7	1.7	1.7

\*Assuming the absolute no of stories that is 3 storey



Figure 61 Illustrating ground coverage for different plot proportion and sizes (Lucknow)

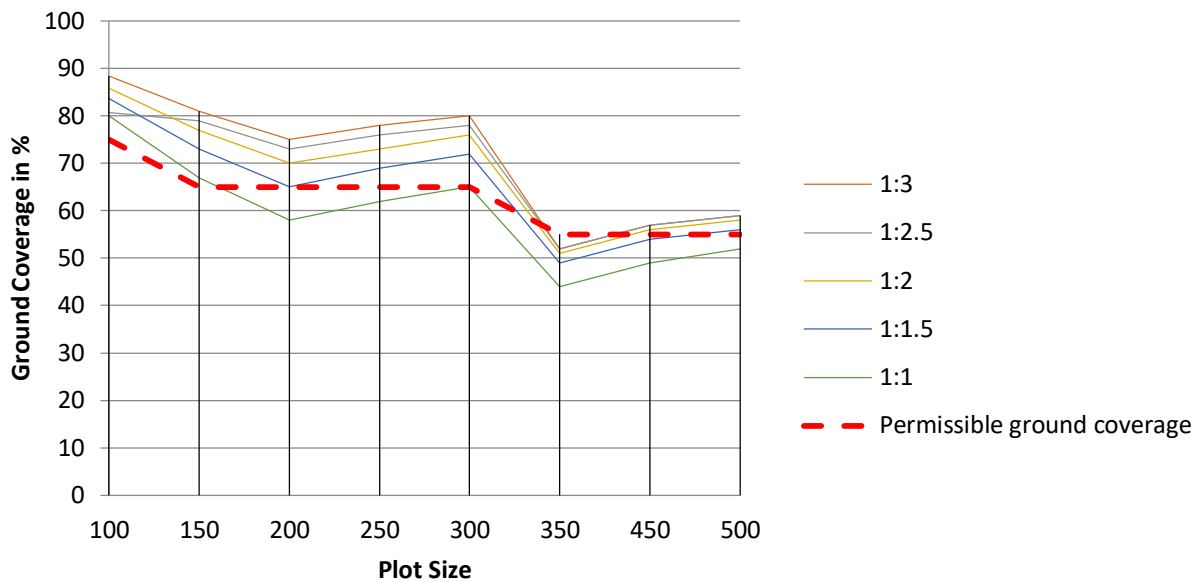


Figure 62 Graphical representation of relation of GC and Plot Proportion (Lucknow)

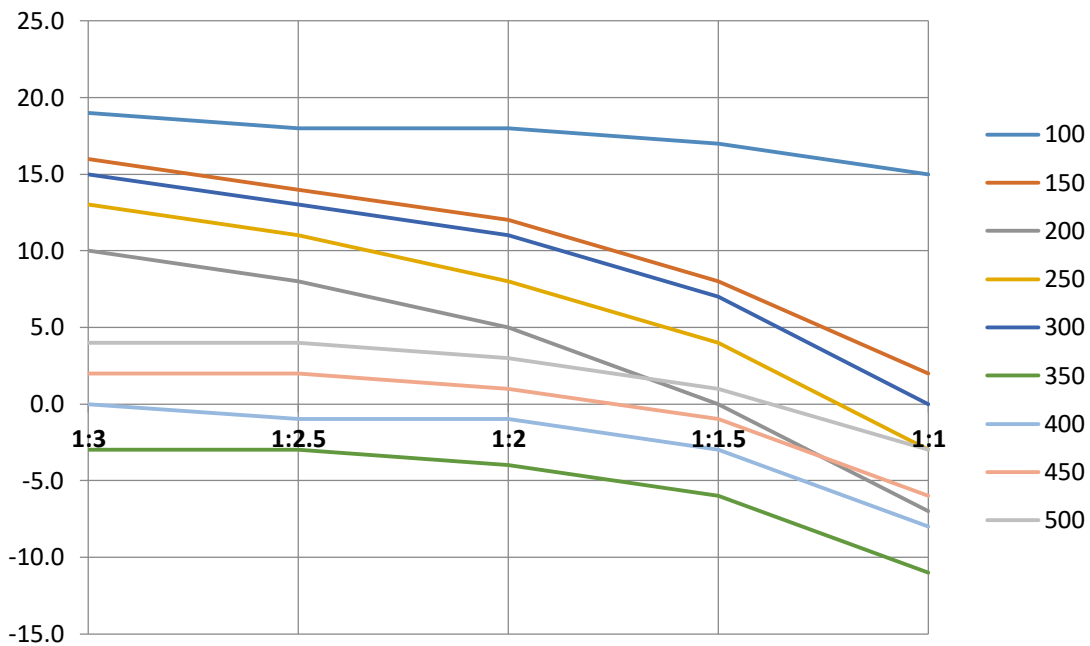


Figure 63 Graphical representation of potential space for the courtyard in different plot sizes.

Various observations drawn from this study are as follows:

- It has been observed that as the setback norms depend on the area of the plot therefore plot area of 300 sq. m achieves more ground coverage in every plot proportion as compared to the 350 sq. m plot (Table ). As there is a capping of Ground coverage of 65 % in Lucknow bye-laws this ambiguity can be overcome. It is also to be noted that up to the plot size of 300 sq.m, the area within the setback is always greater than the permissible ground

coverage for each plot proportion and size. This may further lead to uneven building lines and built mass.

- The predicted number of stories for various plot sizes appears to not be the absolute number due to existing setbacks and F.A.R rules; it varies for all plot sizes as well as changes for the various front-to-depth ratios (Table 14 ). It is difficult to prevent residents or owners from building more than the total built-up area in accordance with F.A.R. standards without active enforcement and frequent monitoring since the computed number of storeys is not absolute.
- Despite the preconceived notion that larger plot sizes are more appropriate for courtyard typologies, analysis shows that smaller plot sizes allow for more flexibility when it comes to introducing courtyards after complying with regulations. Plot size up to 300 sq m plot may accommodate a courtyard in their designs without violating any regulation. However, the suitable size of the courtyard must be taken into account for ensuring light and ventilation.
- Plot proportion of 1:3 provides maximum potential open space as compared to the plot proportion of 1:1, potential open space decreases with a decrease in the depth of the plot.
- Instead of fixing FAR, the number of stories can be fixed in order to achieve straight building lines and uniform façade heights. The issue of varied plot proportions (width: depth) can be addressed more effectively by adding a built-to-open ratio parameter rather than strict setback lines.

#### **4.3 INFERENCES FROM CASE STUDIES (TRADITIONAL AND CONTEMPORARY HOUSES)**

Study of traditional house suggests, courtyard act as the central core of the house, and all other activities were planned around the courtyard. The kitchen area is not directly connected to dining area or living area which is not practical nowadays. Services like the toilet is accessible through the courtyard, which is further not practical in today's trend of attached toilets. Activity mapping of courtyard shows that courtyard work as full-fledged functional space (Spatial Organization study).

Courtyards in contemporary typology act as light wells which provide sufficient light to adjacent space, further the other private space can open towards the courtyard, which is not possible in Non - courtyard typologies. In contemporary courtyard typology courtyard act as a landscape space rather than a functional space (Analysis of plans of contemporary houses).



In conventional setback typology living zone act as circulation for connecting various activities. Hence the space does not work as a full-fledged functional space rather as circulation lobby(Spatial Organization study)..

Analysis of the different parameters of case studies demonstrates that the courtyard sizes are unrelated to the built-up area and plot area. The research also demonstrates that a courtyard of the optimum size may satisfy every Psychological and practical demand of the user. Due to the fact that all houses are built in urban settings and subject to building regulations, the courtyard along with the setback provides the house with light and ventilation (Table 5) .

Further, the results are compared with an available research paper in the domain regarding the W/L, W/H, and courtyard ratio. It has been observed the results are within the range suggested by the literature review (Table 5 and 6).

#### **4.4 INFERENCES FROM CASE STUDIES (BUILDING REGULATION)**

After comparing the Bye-laws of all five cities it has been observed that Jaipur's bye-laws are provides very monotonous design solution (Built mass within setback line), however, the guideline like capping of ground coverage as in the case of other cities bye-laws can be effectively used for maintaining the balance between open and built mass. Bhopal bye-laws address the issue of plot proportion by keeping the guideline of plot frontage however the rules further create chaos and uneven performance of different plot proportions for different plot sizes. Chandigarh bye-laws are very specific regarding architectural control therefore front setback has been kept constant for MARLA plot groups. Any possibilities for interior open space can be worked out from rear and side setbacks. (Table 13).

It has been also observed that “ground coverage within setback” provides very limited flexibility to the designers in terms of open spaces. But they can maintain the uniform building line along the road which ultimately organizes the street elevation (Table 12).

Bhopal and Amaravati Bye-laws provides more flexibility to the designers for experimenting with built mass, and creating combination by employing internal court/open spaces. After comparing the norms based on case. It has been observed that all cities employed different method for fixing the front and rear setback, however is no specific thumb rule for the same. Out of five, four cities have front setback is greater or equal to the 3 M. But for the case of the rear setback, there is significant difference in rear side setback all the studied cities.

Building standards for ground coverage and setback lines are not synchronized, as was determined in the case of Lucknow. These building regulations are difficult to understand even for experienced technical personnel, which leads to compliance with one regulation leading to non-compliance with another.

#### **4.5 CONCLUSION**

It has been observed that it is difficult to mimic the traditional typology in contemporary times due to the change in lifestyle and advancement in technologies, however the experience from the past can be well utilized for creating typologies that are sustainable in nature. The achieved physical parameters such as the width/length of the courtyard, the height of the courtyard, and court to plot ratio, can be further used to derive the optimum size of the courtyard in an urban settlement.

As the study attempts to establish the relation between courtyard typology and modern bye-laws, it can be said that the rear setback must be rethought to provide more flexibility to the designers; further, the issue of plot proportion must be addressed properly so that even ground coverage can be achieved for any plot proportion. However, the method of built and open percentage will be more efficient in this after leaving the mandatory front setback. After studying the pros and cons of different bye-laws, Lucknow has been a case for prototype development.

Case studies indicate that byelaws are stringent in nature, offering limited flexibility to the designer. However, it is not only byelaws that are responsible for courtyard disappearance, difficulty in maintaining these spaces and architects' perception and willingness is also the contributing factors for extinction of courtyard typology.

## **CHAPTER 5 RESULT AND DISCUSSION**

This chapter has been divided into two sections; the first section summarizes the findings of the questionnaires. In this section, findings of the primary quantitative data collected through survey questionnaires have been compiled. The results are presented in the form of Bar graphs or pie charts. In the second section, the Daylight potential of two typologies has been compared via a simulation tool namely Ecotect with Radiance plug-in. Finally, the results were examined in order to build prototype designs.

### **5.2 INTRODUCTION**

The survey findings may be divided into two main components – one as a User's perception survey and the other as an Expert's survey. During the User perception survey, responders are divided into two groups: those who live in courtyard homes make up the first group, while those who live in other types of residential typologies make up the second group. The purpose of the survey was to learn how users felt about the many physical and sociocultural variables that affect their lives and how they view their homes. The occupant of each dwelling was given a brief questionnaire (Appendix A 1) that took about fifteen minutes to complete. The purpose of the second structured questionnaire (Appendix A2) was designed to gain insight into the practical challenges that architects and planners must address in order to provide contemporary housing in the urban settlement.

Group: G1 (Respondents having courtyard house)

Group: G2 (Respondents having other types of house)

In total, 140 questionnaires were distributed to respondents, out of which 55 responses from group one and 65 responses from group two were received. 120 out of 140 were completed - that is, about 85.1%.

The analysis of the questionnaire was done using M.S Excel; the second structured questionnaire for experts and stakeholders was distributed by getting in touch with experts by phone, in person, or by mail. Each of the questions in the survey is narrowly focused, allowing for the collection of quantitative information. However, the thoughts and opinions of the respondents are taken into account for the research part. Out of 42 Architects/Planners that were contacted, about 35 Experts answered favourably.

The significance of this chapter lies in the fact that the views, opinions, and experiences of residents of courtyard houses or any other types of houses provide a clear perspective to the researcher regarding the performances of these houses.

The same set of questions has been asked to both groups to get a fair idea about their perception of their houses and how the user interacts with these spaces.

## 5.2 DESIGNING THE SURVEY QUESTIONNAIRE

- **User's Perception Survey:** The survey questionnaire has been developed after taking insights from two research papers titled "User Perception of Courtyard as a Thermal Regulator in Households, Famagusta, Cyprus" by Marafa et al. and "User's Perception of the Relevance of Courtyard Designs in a Modern Context: A case of Traditional Pol Houses, Ahmedabad" by Gangwar et al. There are 20 questions designed, most of which were related to identified attributes like Environmental, Functional, religious, Cultural, and Psychological. of courtyard was exempted from the study part as the respondents are not aware of the technical know-how of courtyard planning. The number of questions for every parameter is designed, according to the importance and specific need of the parameter. There are 20 questions designed, most of which were related to identifying design to meet the research's desired objectives. However, the Economic attribute has been attributes like Environmental, Functional, religious, Cultural; and Psychological of courtyard design to meet the research's desired objectives
- **Expert Survey:** The survey questionnaire has been developed after taking insights from research papers titled "Housing and household practices: Practice-based sustainability interventions for low-energy houses in Lahore, Pakistan" by Khalid et al. and thesis "Courtyard Housing As a Subtropical Urban Design Model" by Antonio et.al .
- **Sample design** The study involves a convenient sampling method because the user of plotted development can provide better insights in the study. The questions are designed in a manner that it can extract the data from both users and non-user of the courtyard spaces. Plot size and respondent economic status have been taken into consideration since it is crucial to comprehend how middle-class people perceive their houses. Although there is no restriction for the minimum lot size, it has been decided to keep the maximum plot size limit of 500 sq .m to meet the objective of the research. For the Expert Survey, a structured and brief questionnaire is provided to the experts on the subject. In order to incorporate the input of specialists from diverse fields, the convenient sampling approach is used. Each respondent's significant expertise and understanding of the subject area were taken into account. The researcher contacted all respondents to explain the aim of the research and request them to complete the Google form for the same, so the collected data can be analysed as quantitative data

### 5.2.2 User's perception survey

The major objective of the survey is to examine how well a house performs across a range of parameters from the viewpoint of the users.

This section of this chapter is divided into five subsections, each with subheadings corresponding to a questionnaire as follows: A) General Information, B) Functional, C) Environmental performance of houses, D) Religious and Cultural E) Psychological

**A. General Information**

Characteristics of the respondents and their householders

Basic information such as gender, age, family type, and dwelling type are taken into account while evaluating the attributes of Users. These elements are anticipated to have a significant impact on the inhabitants' views about their dwellings; however other factors are also anticipated to have an impact on their degree of contentment. Therefore, this section presents a general assessment of the population surveyed.

**Gender**

The findings show that more than 56% of the respondents in this survey were men and 43 % were women. The gender difference among responders is attributable to the structure of the question.

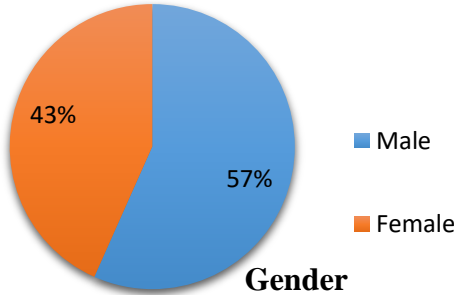


Figure 64 : Gender statistics

**Age** The respondents' desired age range was 20 - 60 yrs. Four responder groups were found by evenly splitting this range into ten-year periods. 30.3% of the respondents are over 40, and almost a 25.2% are over 30, as seen in Fig 4.2. 50+ and 21–30 respondents make up 26.9 % and 17.6 %, respectively, of the total respondents.

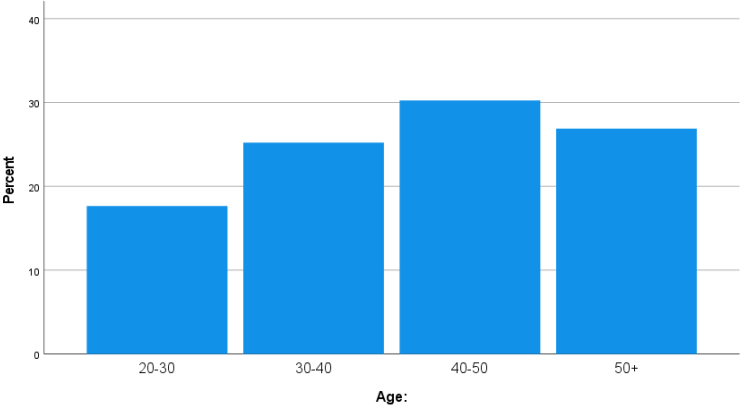


Figure 65: Age statistics

### Family type

The nature of the family has a huge impact on housing typologies. Joint families prefer more gathering spaces within the home as compared to the nuclear family. As shown in the figure, over 55% of households are nuclear families.

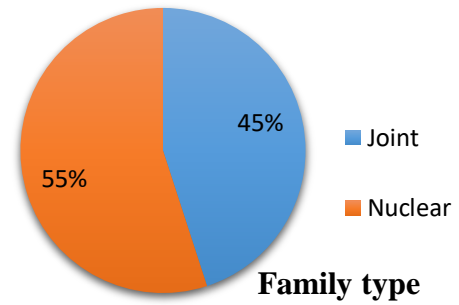


Figure 66 Family type statistics

### Religion:

Various cultural beliefs and religion impacts the lifestyle of the house owner which ultimately influences the design and planning of the house. In every religion, open spaces have a unique character and significance. For instance, in Hinduism, the central open area is known as Bhramsthan, whereas in Islam, the inner courtyard offers the required privacy.

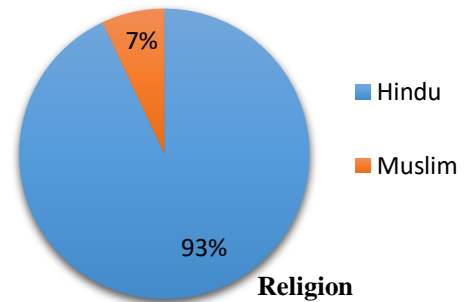


Figure 67 Religion statistics

### House typology

The respondents are categorized into four groups based on the location and type of houses in which they are residing.

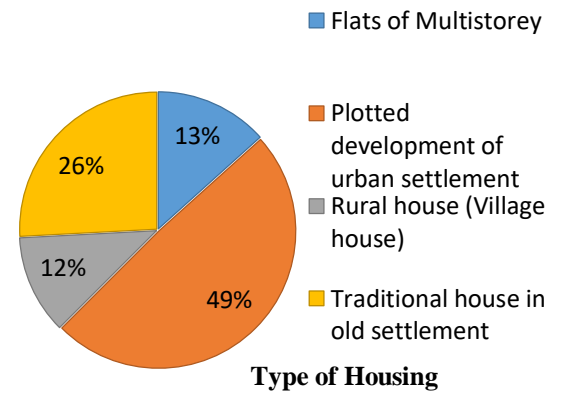


Figure 68 : House type statistics

### Type of open space

The primary question is what kind of open space these homes have, and these questions aid in classifying the answers into two groups.

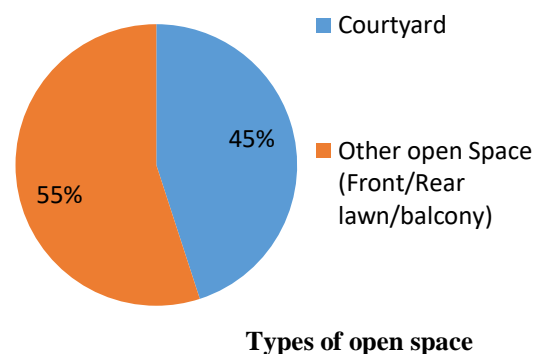
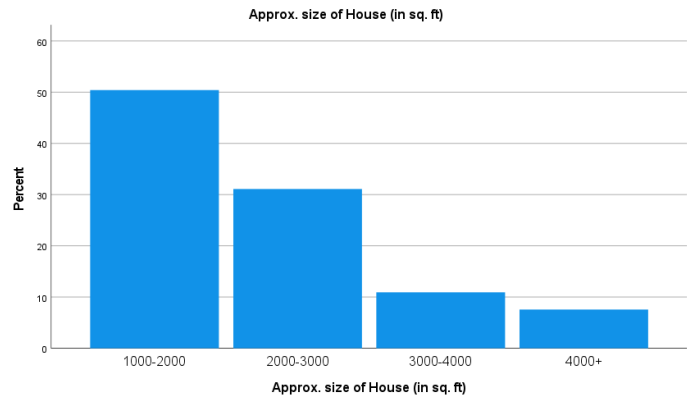


Figure 69 Type of open space

### **Approx. size of plot**

The size of the lot plays a crucial role in designing a house. Being a single dwelling unit the target size of the plot is 1000 -4000 sq ft. By dividing this range in at the gap of 1000 sqft, four groups have been identified

The results are compiled on the basis of two groups (G1 and G2) as discussed earlier Completion of the result has been done under the following subheads as discussed below.



### **B. Functional Attribute of open spaces as described by respondents**

This section examines the physical characteristics of open space in terms of numbers, uses and importance. Additionally, both the benefits and drawbacks of open places are taken into account. Residents' perspectives on a few technological features of their houses provide useful information.

### **C. Environmental Attributes of Open Spaces**

In this part, respondents were questioned on the environmental performance of their open space and their interactions with it during various times of the day and seasons.

### **D. Religious & Cultural:**

The study seeks to understand the significance of courtyards in both religion and culture.

### **E. Psychological**

Given that courtyard dwellings are an ancient and native typology, every individual has encountered this typology at some point in their lifetime. The respondents were asked about their perceptions about courtyard houses regardless of the type of residence they currently residing.

In order to understand their preferences for spaces, the respondents were asked for a last comment about their choice of houses.

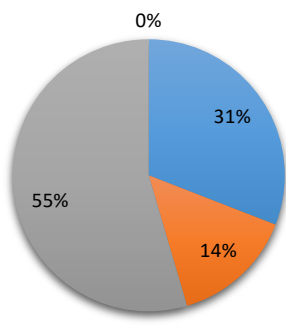
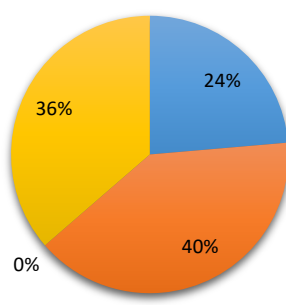
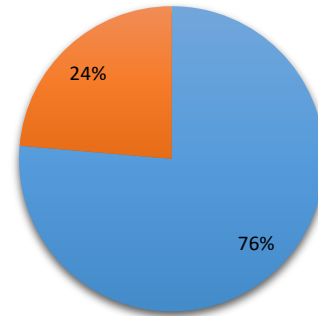
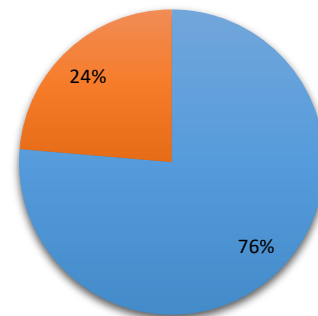
The result of the user perception survey is summarized in the form of pie charts/bar graphs as mentioned below.

✓ **Group 1 (Courtyard Houses)**

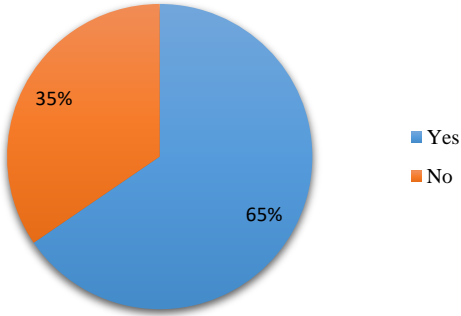
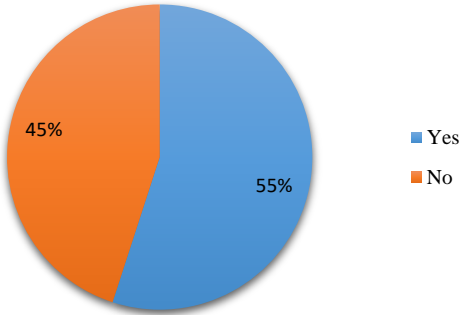
*No of Respondent: 55*

**a) Functional**

**Table 16: Compilation of Function related questions (Courtyard House)**

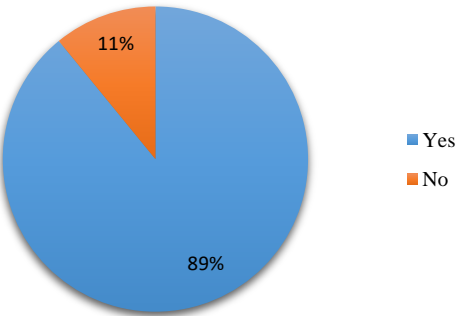
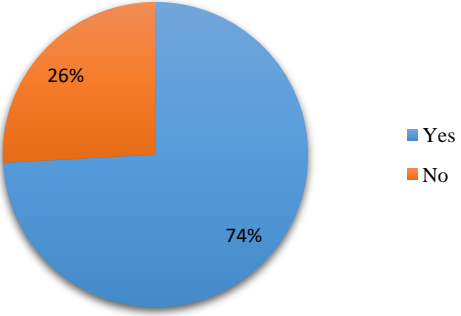
<p><b>1. For which purpose you use your open spaces?</b></p> <p><i>Interpretation:</i> Sitting and relaxing is the major function of courtyards.</p>	 <ul style="list-style-type: none"> <li>■ Domestic Activities (Washing, Cloths drying etc.)</li> <li>■ Ornamentation (Plants and Decoration)</li> <li>■ Sitting and relaxing</li> <li>■ Storage</li> </ul>
<p><b>2. How do you furnish your domestic open space?</b></p> <p><i>Interpretation:</i> Furniture's are widely used for furnishing the courtyard. this shows that courtyard also act as living room</p>	 <ul style="list-style-type: none"> <li>■ Household Utilities</li> <li>■ Table &amp; chairs</li> <li>■ Washing line</li> <li>■ Water feature &amp; plants</li> </ul>
<p><b>3. Do the open areas of your house have sufficient level of privacy?</b></p> <p><i>Interpretation:</i> 76 % feels that their open spaces provide enough privacy to the inhabitants, therefore suitable for performing various household chores.</p>	 <ul style="list-style-type: none"> <li>■ Yes</li> <li>■ No</li> </ul>
<p><b>4. Do you feel that your home's layout maintains the required level of connection between the floors?</b></p> <p><i>Interpretation:</i> Maximum people feel so. Courtyard act as cut out which connects two floor visually and physically</p>	 <ul style="list-style-type: none"> <li>■ Yes</li> <li>■ No</li> </ul>

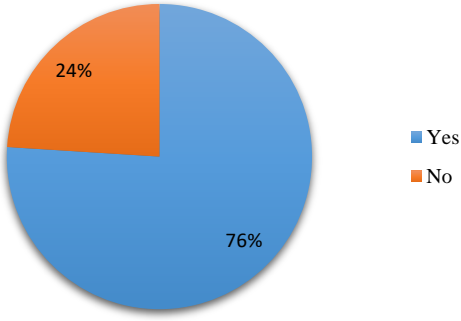
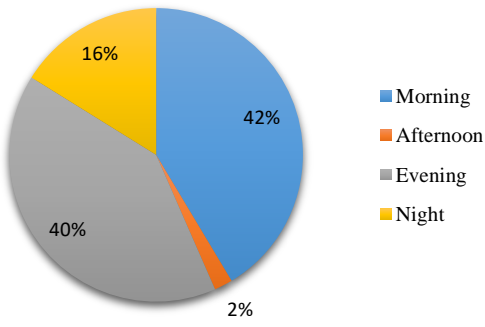
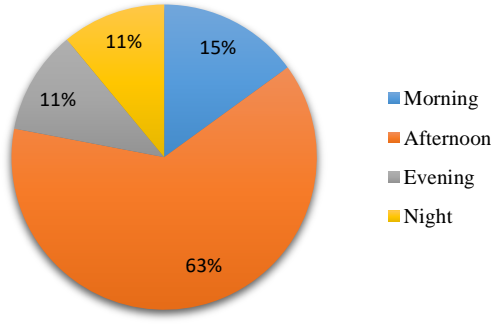
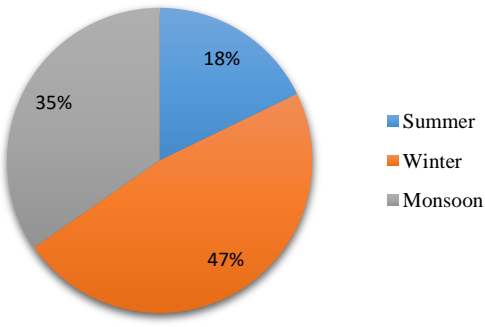


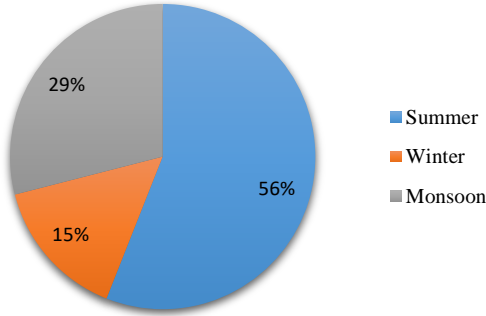
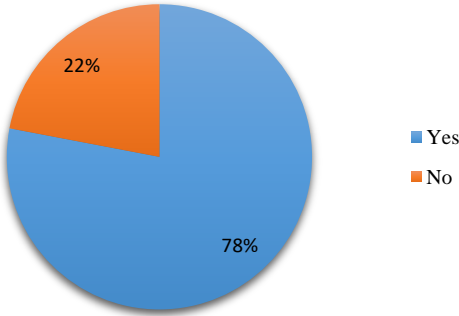
<p><b>5. Do you have proper space in your house for small family gatherings or functions (Like puja, Birthday celebration , etc)</b></p> <p><i>Interpretation:</i> 65 % courtyard user assumes that they have proper space for activities. This further substantiate that courtyard is functional space</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>65%</td> </tr> <tr> <td>No</td> <td>35%</td> </tr> </tbody> </table>	Response	Percentage	Yes	65%	No	35%
Response	Percentage						
Yes	65%						
No	35%						
<p><b>Do you use your open space for daily household activities?</b></p> <p><i>Interpretation:</i> The response is not concluding however majority feels so.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>55%</td> </tr> <tr> <td>No</td> <td>45%</td> </tr> </tbody> </table>	Response	Percentage	Yes	55%	No	45%
Response	Percentage						
Yes	55%						
No	45%						

**b) Environmental**

**Table 176** Compilation of Environment related questions (Courtyard House)

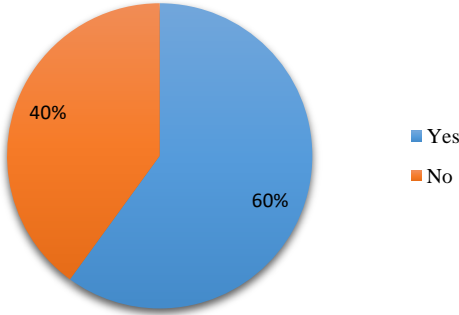
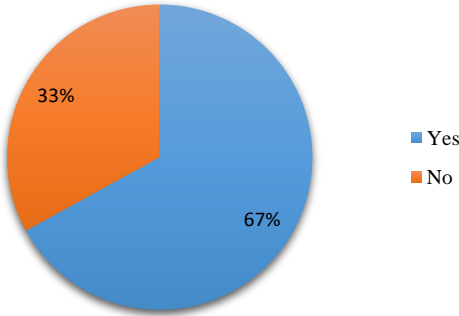
<p><b>1. Does the open space provide sufficient light to all the habitable spaces?</b></p> <p><i>Interpretation:</i> Courtyard act as light well for the adjoining rooms.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>89%</td> </tr> <tr> <td>No</td> <td>11%</td> </tr> </tbody> </table>	Response	Percentage	Yes	89%	No	11%
Response	Percentage						
Yes	89%						
No	11%						
<p><b>2. Do the open spaces of your house provide any kind of thermal comfort to the adjacent spaces?</b></p> <p><i>Interpretation:</i> Courtyard house has impact on thermal behaviours of the house, however it is difficult for the respondent to feel and quantify the</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>74%</td> </tr> <tr> <td>No</td> <td>26%</td> </tr> </tbody> </table>	Response	Percentage	Yes	74%	No	26%
Response	Percentage						
Yes	74%						
No	26%						

<p><b>3. Does the open space provide sufficient ventilation and air movement within the house?</b></p> <p><i>Interpretation:</i> Courtyard also provides ventilation in the houses.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>76%</td> </tr> <tr> <td>No</td> <td>24%</td> </tr> </tbody> </table>	Response	Percentage	Yes	76%	No	24%				
Response	Percentage										
Yes	76%										
No	24%										
<p><b>4. Which is your most preferred time in the open space of your house?</b></p> <p><i>Interpretation:</i> Courtyard provides maximum comfort in morning.</p>	 <table border="1"> <thead> <tr> <th>Time</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Morning</td> <td>42%</td> </tr> <tr> <td>Evening</td> <td>40%</td> </tr> <tr> <td>Night</td> <td>16%</td> </tr> <tr> <td>Afternoon</td> <td>2%</td> </tr> </tbody> </table>	Time	Percentage	Morning	42%	Evening	40%	Night	16%	Afternoon	2%
Time	Percentage										
Morning	42%										
Evening	40%										
Night	16%										
Afternoon	2%										
<p><b>5. Which is your most uncomfortable time in open space of your house?</b></p> <p><i>Interpretation:</i> Courtyard provides maximum discomfort in afternoon. therefore, well shaded spaces are required</p>	 <table border="1"> <thead> <tr> <th>Time</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Afternoon</td> <td>63%</td> </tr> <tr> <td>Morning</td> <td>15%</td> </tr> <tr> <td>Evening</td> <td>11%</td> </tr> <tr> <td>Night</td> <td>11%</td> </tr> </tbody> </table>	Time	Percentage	Afternoon	63%	Morning	15%	Evening	11%	Night	11%
Time	Percentage										
Afternoon	63%										
Morning	15%										
Evening	11%										
Night	11%										
<p><b>6. In which season these open spaces create maximum comfort.</b></p> <p><i>Interpretation:</i> Open spaces provide maximum comfort in winter. Hence proper penetration of sunlight is equally important.</p>	 <table border="1"> <thead> <tr> <th>Season</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Winter</td> <td>47%</td> </tr> <tr> <td>Monsoon</td> <td>35%</td> </tr> <tr> <td>Summer</td> <td>18%</td> </tr> </tbody> </table>	Season	Percentage	Winter	47%	Monsoon	35%	Summer	18%		
Season	Percentage										
Winter	47%										
Monsoon	35%										
Summer	18%										

<p><b>7. In which season these open spaces create maximum discomfort</b></p> <p><i>Interpretation:</i> Summer is most uncomfortable in open spaces.</p>	 <table border="1"> <thead> <tr> <th>Season</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Summer</td> <td>56%</td> </tr> <tr> <td>Monsoon</td> <td>29%</td> </tr> <tr> <td>Winter</td> <td>15%</td> </tr> </tbody> </table>	Season	Percentage	Summer	56%	Monsoon	29%	Winter	15%
Season	Percentage								
Summer	56%								
Monsoon	29%								
Winter	15%								
<p><b>8. Do you feel that present houses need more mechanical devices (like fan or AC) for achieving comfort due to absence of central open spaces?</b></p> <p><i>Interpretation:</i> Maximum people feel so.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>78%</td> </tr> <tr> <td>No</td> <td>22%</td> </tr> </tbody> </table>	Response	Percentage	Yes	78%	No	22%		
Response	Percentage								
Yes	78%								
No	22%								

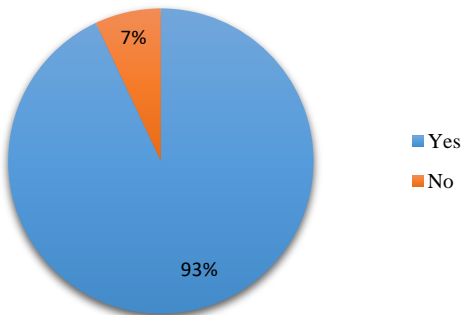
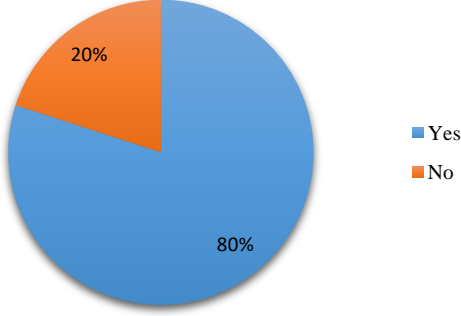
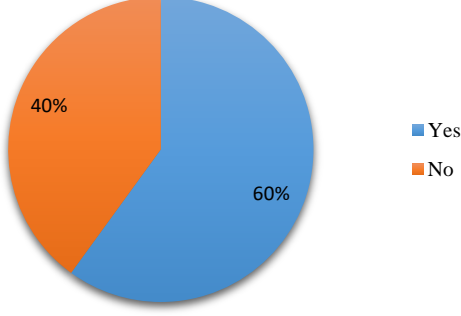
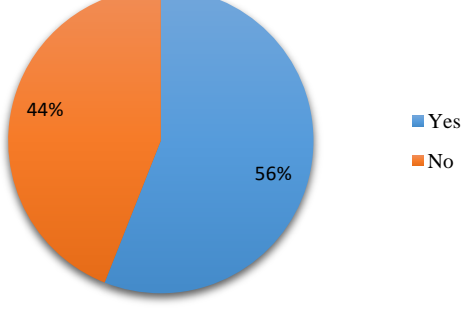
### c) Religious & Cultural

Table 18: Compilation of Religious and culture related questions (Courtyard House)

<p><b>1. Does the courtyard possess any traditional, cultural or religious value?</b></p> <p><i>Interpretation:</i> The majority of people believe that the courtyard brings back memories of their roots and culture.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>60%</td> </tr> <tr> <td>No</td> <td>40%</td> </tr> </tbody> </table>	Response	Percentage	Yes	60%	No	40%
Response	Percentage						
Yes	60%						
No	40%						
<p><b>2. Do they agree courtyard is the basic element of Vaastu in residential architecture?</b></p> <p><i>Interpretation:</i> Most of the people assumes that courtyard is basic element Vaastu must be furnished with Tulsi plants.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>67%</td> </tr> <tr> <td>No</td> <td>33%</td> </tr> </tbody> </table>	Response	Percentage	Yes	67%	No	33%
Response	Percentage						
Yes	67%						
No	33%						

## d) Psychological

Table 198 Compilation of psychology/ preference related questions (Courtyard House)

<p><b>1. If given a choice, would you like to reside in courtyard type house?</b></p> <p><i>Interpretation:</i> Approx. 93 % people feel that they would prefer to live in courtyard house and it gives them nostalgia of their childhood</p>	 <p>A pie chart with a blue slice representing 93% and an orange slice representing 7%. A legend to the right shows a blue square for 'Yes' and an orange square for 'No'.</p> <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>93%</td> </tr> <tr> <td>No</td> <td>7%</td> </tr> </tbody> </table>	Response	Percentage	Yes	93%	No	7%
Response	Percentage						
Yes	93%						
No	7%						
<p><b>2. Do you agree, a well-designed courtyard (open to sky) affect the Psychological wellbeing of resident.</b></p> <p><i>Interpretation:</i> Approx. 80 % people feel that open spaces impact their mental well-being.</p>	 <p>A pie chart with a blue slice representing 80% and an orange slice representing 20%. A legend to the right shows a blue square for 'Yes' and an orange square for 'No'.</p> <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>80%</td> </tr> <tr> <td>No</td> <td>20%</td> </tr> </tbody> </table>	Response	Percentage	Yes	80%	No	20%
Response	Percentage						
Yes	80%						
No	20%						
<p><b>3. Is the changing family pattern being the reason behind the non -popularity of courtyard houses?</b></p> <p><i>Interpretation:</i> Most of the people think that nuclear family concept abolished the need of courtyard houses.</p>	 <p>A pie chart with a blue slice representing 60% and an orange slice representing 40%. A legend to the right shows a blue square for 'Yes' and an orange square for 'No'.</p> <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>60%</td> </tr> <tr> <td>No</td> <td>40%</td> </tr> </tbody> </table>	Response	Percentage	Yes	60%	No	40%
Response	Percentage						
Yes	60%						
No	40%						
<p><b>4. Do the size and proportion of plot create hindrance in creating courtyard?</b></p> <p><i>Interpretation:</i> Majority of people prefer to include courtyard instead of covered family lounge. As they are currently residing in this type of house. They don't want to lose this space.</p>	 <p>A pie chart with a blue slice representing 56% and an orange slice representing 44%. A legend to the right shows a blue square for 'Yes' and an orange square for 'No'.</p> <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>56%</td> </tr> <tr> <td>No</td> <td>44%</td> </tr> </tbody> </table>	Response	Percentage	Yes	56%	No	44%
Response	Percentage						
Yes	56%						
No	44%						

Further to quantify the result, the dichotomous question of the questionnaire has been summarised for further analysis and testing of the hypothesis.

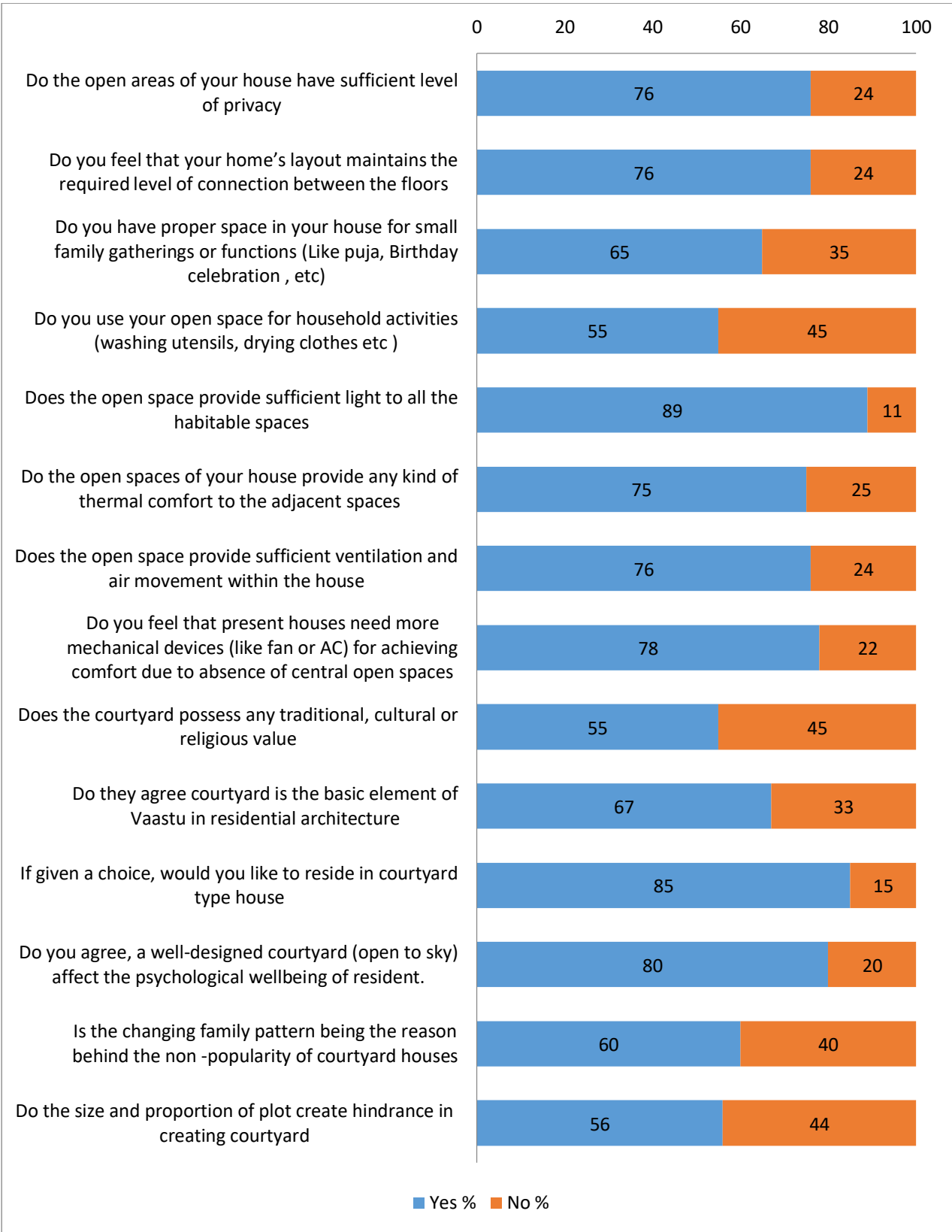


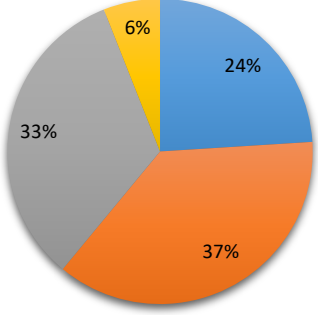
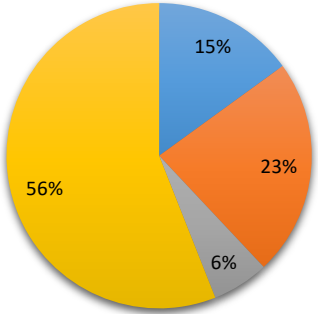
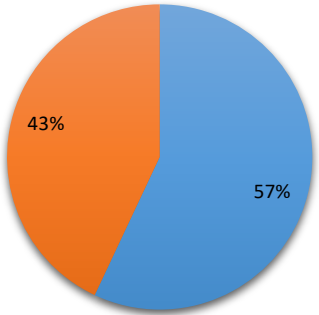
Figure 70: Compilation of group-1 Result

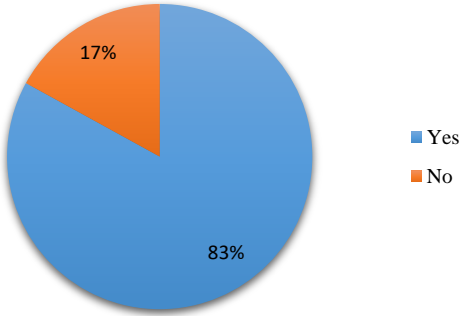
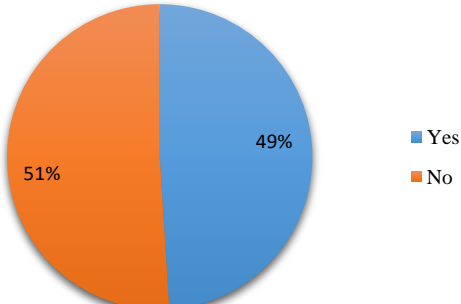
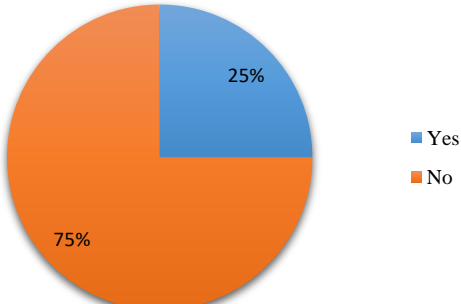
✓ **Group 2 (Non Courtyard House)**

No of Respondent: 65

**a) Functional**

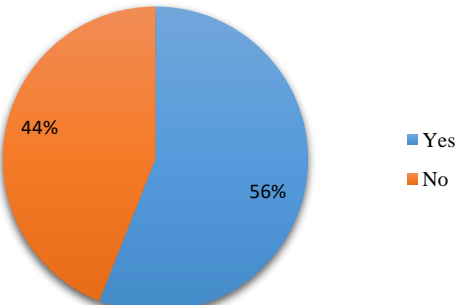
Table 20; Compilation of Function related questions (Non courtyard House)

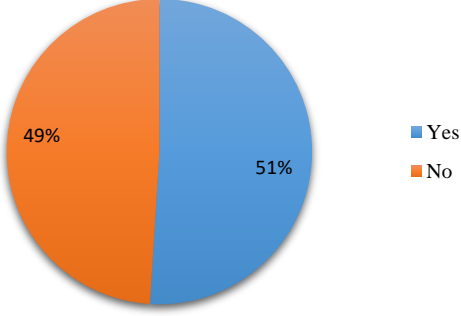
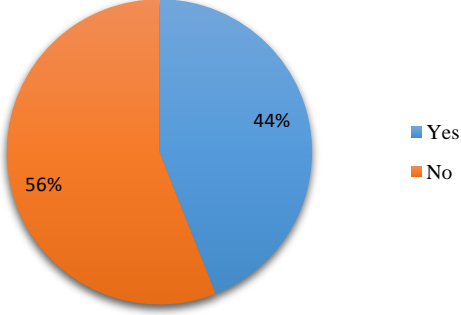
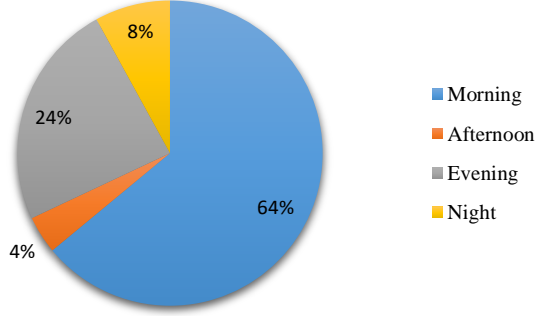
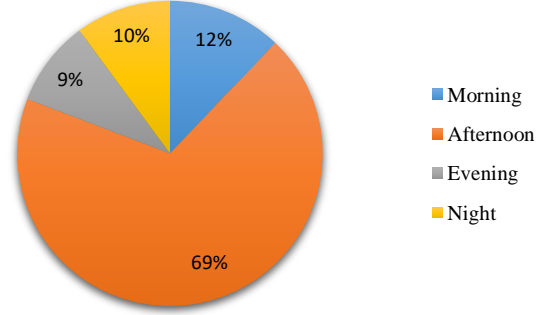
<p><b>1. For which purpose you use your open spaces?</b></p> <p><i>Interpretation:</i> Sitting and relaxing is the major function of open spaces.</p>	 <ul style="list-style-type: none"> <li>■ Domestic Activities (Washing, Cloths drying etc.)</li> <li>■ Ornamentation (Plants and Decoration)</li> <li>■ Sitting and relaxing</li> <li>■ Storage</li> </ul>
<p><b>2. How do you furnish your domestic open space?</b></p> <p><i>Interpretation:</i> Greenery is most important furnishing for open spaces.</p>	 <ul style="list-style-type: none"> <li>■ Household Utilities</li> <li>■ Table &amp; chairs</li> <li>■ Washing line</li> <li>■ Water feature &amp; plants</li> </ul>
<p><b>3. Do the open areas of your house have sufficient level of privacy?</b></p> <p><i>Interpretation:</i> 57 % feels that their open spaces provide enough privacy.</p>	 <ul style="list-style-type: none"> <li>■ Yes</li> <li>■ No</li> </ul>

<p><b>4. Do you feel that your home’s layout maintains the required level of connection between the floors?</b></p> <p><i>Interpretation:</i> Maximum people feel so.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>83%</td> </tr> <tr> <td>No</td> <td>17%</td> </tr> </tbody> </table>	Response	Percentage	Yes	83%	No	17%
Response	Percentage						
Yes	83%						
No	17%						
<p><b>5. Do you have proper space in your house for small family gatherings or functions (Like puja, Birthday celebration , etc)</b></p> <p><i>Interpretation:</i> Result is not conclusive in nature.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>49%</td> </tr> <tr> <td>No</td> <td>51%</td> </tr> </tbody> </table>	Response	Percentage	Yes	49%	No	51%
Response	Percentage						
Yes	49%						
No	51%						
<p><b>Do you use your open space for daily household activities?</b></p> <p><i>Interpretation:</i> Most of open spaces in these type of houses used for ornamental purposes instead of household activities.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>25%</td> </tr> <tr> <td>No</td> <td>75%</td> </tr> </tbody> </table>	Response	Percentage	Yes	25%	No	75%
Response	Percentage						
Yes	25%						
No	75%						

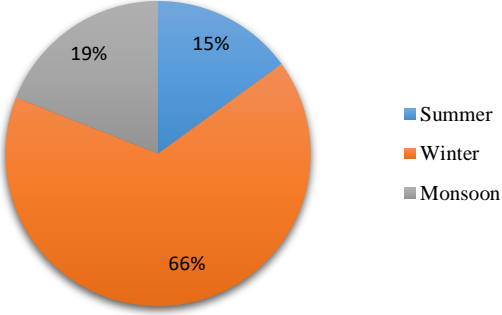
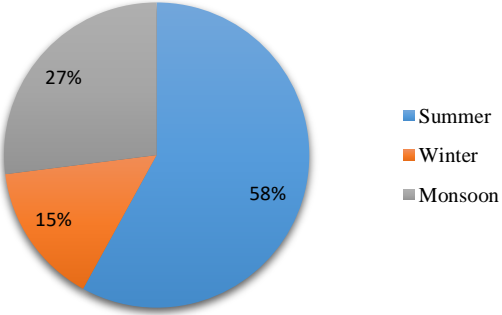
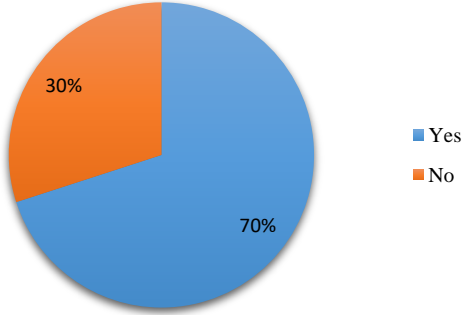
**b) Environmental**

**Table 21: Compilation of Environment related questions (other type of House)**

<p><b>1. Does the open space provide sufficient light to all the habitable spaces?</b></p> <p><i>Interpretation:</i> Open spaces are the source of daylight in their houses</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>56%</td> </tr> <tr> <td>No</td> <td>44%</td> </tr> </tbody> </table>	Response	Percentage	Yes	56%	No	44%
Response	Percentage						
Yes	56%						
No	44%						

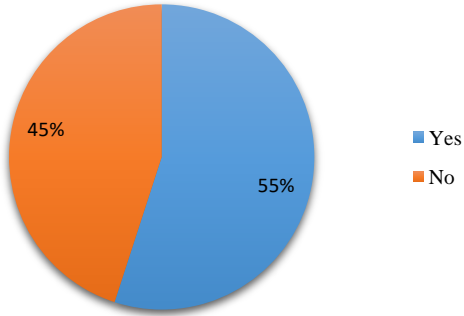
<p><b>2. Do the open spaces of your house provide any kind of thermal comfort to the adjacent spaces?</b></p> <p><i>Interpretation:</i> Open spaces also regulate the thermal comfort.</p>	 <p>A pie chart with two segments: a blue segment representing 'Yes' at 51% and an orange segment representing 'No' at 49%. A legend to the right shows a blue square for 'Yes' and an orange square for 'No'.</p>
<p><b>3. Does the open space provide sufficient ventilation and air movement within the house?</b></p> <p><i>Interpretation:</i> Open spaces also provide ventilation in the houses.</p>	 <p>A pie chart with two segments: a blue segment representing 'Yes' at 44% and an orange segment representing 'No' at 56%. A legend to the right shows a blue square for 'Yes' and an orange square for 'No'.</p>
<p><b>4. Which is your most preferred time in the open space of your house?</b></p> <p><i>Interpretation:</i> Open spaces provide maximum comfort in morning.</p>	 <p>A pie chart with four segments: a large blue segment for 'Morning' (64%), a grey segment for 'Evening' (24%), a yellow segment for 'Night' (8%), and a small orange segment for 'Afternoon' (4%). A legend to the right lists the categories with corresponding color swatches.</p>
<p><b>5. Which is your most uncomfortable time in open space of your house?</b></p> <p><i>Interpretation:</i> Open spaces provide maximum discomfort in afternoon. therefore, well shaded spaces are required</p>	 <p>A pie chart with four segments: a large orange segment for 'Afternoon' (69%), a blue segment for 'Morning' (12%), a yellow segment for 'Night' (10%), and a grey segment for 'Evening' (9%). A legend to the right lists the categories with corresponding color swatches.</p>



<p><b>. In which season these open spaces create maximum comfort.</b></p> <p><i>Interpretation:</i> Open spaces provide maximum comfort in winter. hence proper penetration of sunlight is equally important.</p>	 <table border="1"> <thead> <tr> <th>Season</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Summer</td> <td>15%</td> </tr> <tr> <td>Winter</td> <td>66%</td> </tr> <tr> <td>Monsoon</td> <td>19%</td> </tr> </tbody> </table>	Season	Percentage	Summer	15%	Winter	66%	Monsoon	19%
Season	Percentage								
Summer	15%								
Winter	66%								
Monsoon	19%								
<p><b>7. In which season these open spaces create maximum discomfort</b></p> <p><i>Interpretation:</i> Summer is most uncomfortable in open spaces.</p>	 <table border="1"> <thead> <tr> <th>Season</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Summer</td> <td>58%</td> </tr> <tr> <td>Winter</td> <td>15%</td> </tr> <tr> <td>Monsoon</td> <td>27%</td> </tr> </tbody> </table>	Season	Percentage	Summer	58%	Winter	15%	Monsoon	27%
Season	Percentage								
Summer	58%								
Winter	15%								
Monsoon	27%								
<p><b>8. Do you feel that present houses need more mechanical devices (like fan or AC) for achieving comfort due to absence of central open spaces?</b></p> <p><i>Interpretation:</i> Maximum people feel so.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>70%</td> </tr> <tr> <td>No</td> <td>30%</td> </tr> </tbody> </table>	Response	Percentage	Yes	70%	No	30%		
Response	Percentage								
Yes	70%								
No	30%								

### c) Religious & Cultural

Table 22: Compilation of Religious and cultural parameters (Non- courtyard House)

<p><b>2. Does the courtyard possess any traditional, cultural or religious value?</b></p> <p><i>Interpretation:</i> Maximum people feel so.</p>	 <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>55%</td> </tr> <tr> <td>No</td> <td>45%</td> </tr> </tbody> </table>	Response	Percentage	Yes	55%	No	45%
Response	Percentage						
Yes	55%						
No	45%						

<p><b>2. Do they agree courtyard is the basic element of vsastu in residential architecture?</b>  <i>Interpretation:</i> Approx. 55 % people feel that they would prefer to build house as per Vaastu principles</p>	<table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>45%</td> </tr> <tr> <td>No</td> <td>55%</td> </tr> </tbody> </table>	Response	Percentage	Yes	45%	No	55%
Response	Percentage						
Yes	45%						
No	55%						

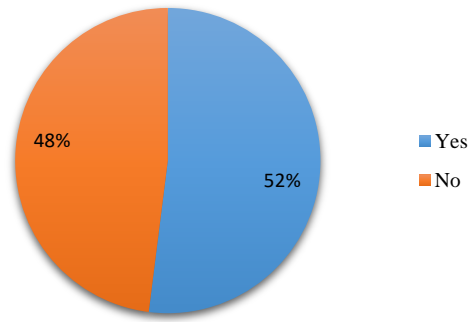
**d) Psychological**

**Table 23: Compilation of Environment related questions (other type of House)**

<p><b>1. If given a choice, would you like to reside in courtyard type house?</b>  <i>Interpretation:</i> Approx. 72 % people feel that they would prefer to live in courtyard house and it gives them nostalgia of their parental house</p>	<table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>70%</td> </tr> <tr> <td>No</td> <td>30%</td> </tr> </tbody> </table>	Response	Percentage	Yes	70%	No	30%
Response	Percentage						
Yes	70%						
No	30%						
<p><b>2. Do you agree, a well-designed courtyard (open to sky) affect the Psychological wellbeing of resident.</b>  <i>Interpretation:</i> Approx. 72 % people feel that open spaces impact their mental well-being.</p>	<table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>72%</td> </tr> <tr> <td>No</td> <td>28%</td> </tr> </tbody> </table>	Response	Percentage	Yes	72%	No	28%
Response	Percentage						
Yes	72%						
No	28%						
<p><b>3. Is the changing family pattern being the reason behind the non -popularity of courtyard houses?</b>  <i>Interpretation:</i> Most of the people think that nuclear family concept abolished the need of courtyard houses courtyard instead of covered family lounge.</p>	<table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>60%</td> </tr> <tr> <td>No</td> <td>40%</td> </tr> </tbody> </table>	Response	Percentage	Yes	60%	No	40%
Response	Percentage						
Yes	60%						
No	40%						

**6. Do the size and proportion of plot create hindrance in creating courtyard?**

*Interpretation:* A people residing in house with living area they prefer to continue the use of this space.



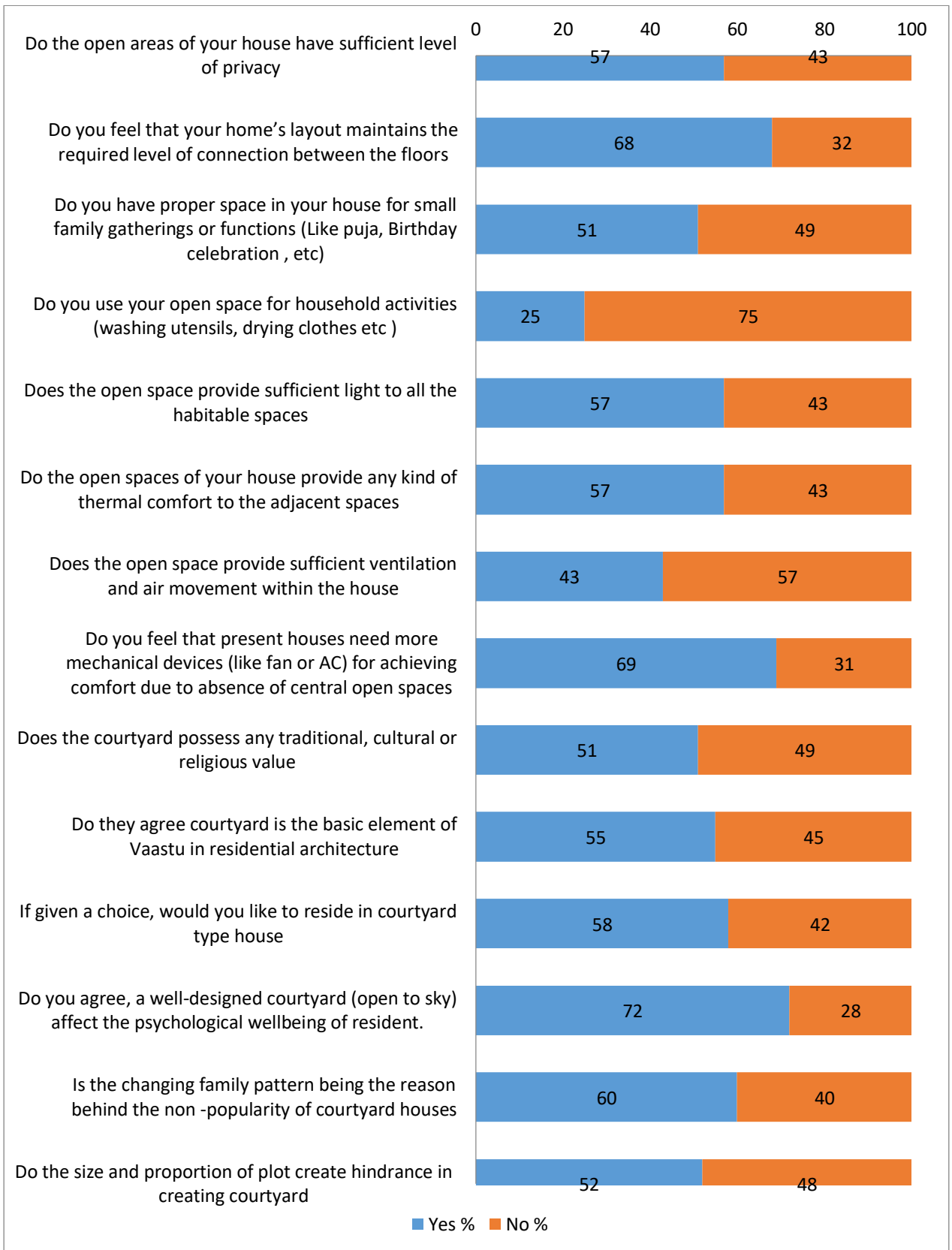


Figure 71 Compilation of Group,-2 Results

## 5.2.2 Analysis of responses (comparison of group 1 and group 2)

The dichotomous responses that have been received in the affirmative (Yes) are termed as agreed or responses in favour of the question. The percentage of affirmative responses has been compared for various parameters to compare the effectiveness of both types of houses from the users' perception

Table 24: Frequency of affirmative responses.

Parameters	Questions	Group -1 (Courtyard house) (In %)	Group -2 ( Non-Courtyard house)(In %)
Functional	Do the open areas of your house have sufficient level of privacy?	76	57
	Do you feel that your home's layout maintains the required level of connection between the floors?	76	68
	Do you have proper space in your house for small family gatherings or functions (Like puja, Birthday celebration , etc)	65	51
	Do you use your open space for daily household activities	55	25
Environmental	Does the open space provide sufficient light to all the habitable spaces?	89	57
	Do the open spaces of your house provide any kind of thermal comfort to the adjacent spaces?	75	57
	Does the open space provide sufficient ventilation and air movement within the house?	76	43
	Do you feel that present houses need more mechanical devices (like fan or AC) for achieving comfort due to absence of central open spaces?	78	69
Religious/cultural	Does the courtyard possess any traditional, cultural or religious value?	55	51
	Do they agree courtyard is the basic element of Vaastu in residential architecture?	67	55

Psychological	If given a choice, would you like to reside in courtyard type house?	85	58
	Do you agree, a well-designed courtyard (open to sky) affect the Psychological wellbeing of resident.	80	72
	Is the changing family pattern being the reason behind the non -popularity of courtyard houses?	60	60
	Do the size and proportion of plot create hindrance in creating courtyard?	56	52

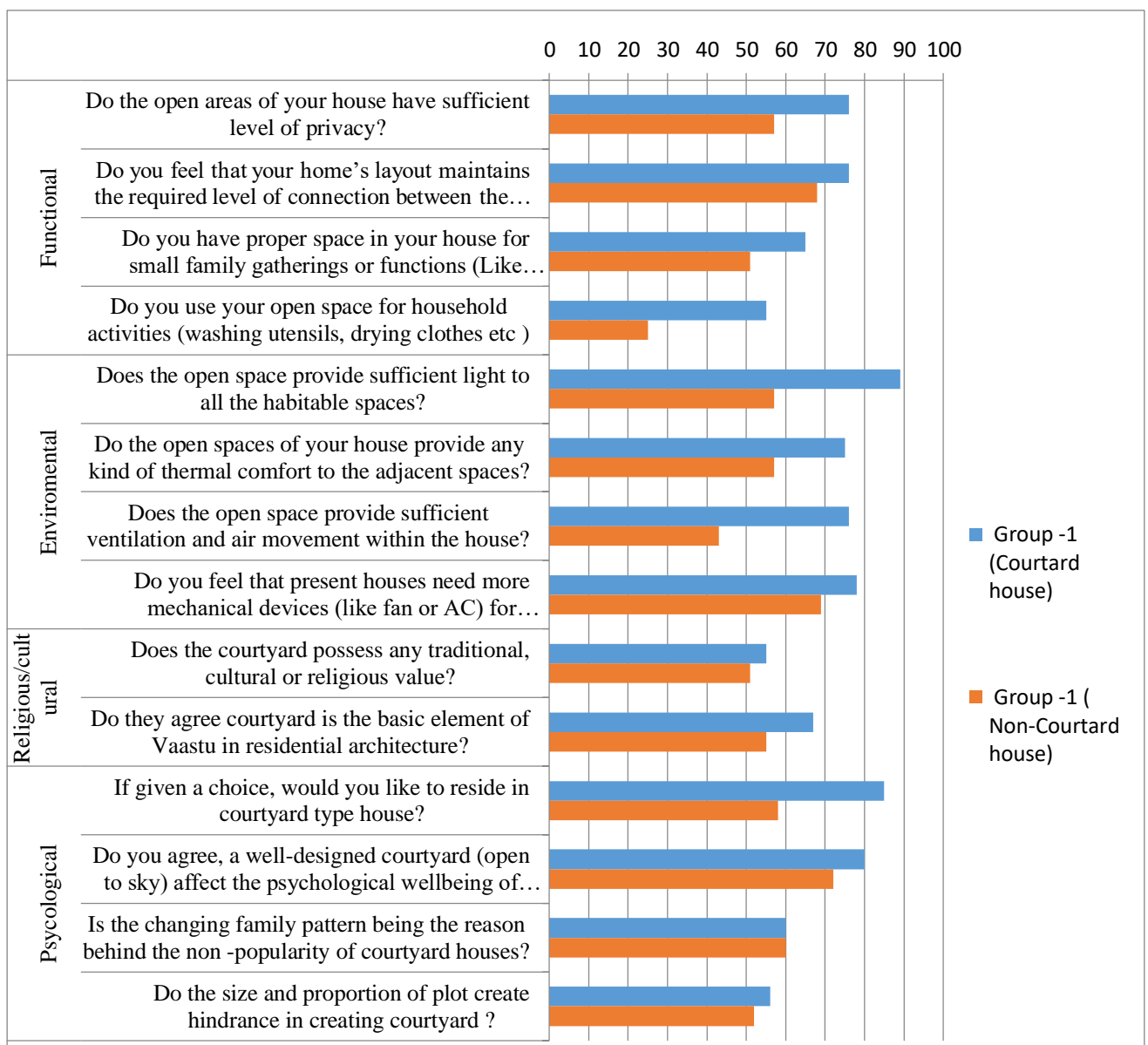


Figure 72 : Comparison of both groups response

### 5.2.3 Statistical analysis and hypothesis testing

Two populations have been identified, one as a courtyard house owner and the other as a courtyard house owner. The questionnaire provided contains dichotomous responses in an attempt to know the agreement of courtyard impact. For example, each affirmative answer shows agreement to the statement, so each affirmative answer for the question “Do you use your open space for daily household activities” indicates that respondents support the functional impact of courtyard / non-courtyard houses.

Two- sample t test (one-tailed) for different housing typologies

Group-1 (Courtyard houses)

Group-2 (Non-courtyard house)

Hypothesis: There is a significant impact of housing typologies on parameters such as Functional, Environmental, religious, cultural and psychological.

Statistical test: Two- sample t test (one-tailed)

The test has been carried out to compare the mean of favourable responses for each group for identified parameters by using MS Excel 2010. The affirmative response (Yes) indicates the positive and significant impact of open spaces of houses on below below-mentioned parameters.

- Functional
- Environmental
- Religious/cultural
- Psychological/Social

**Null Hypothesis H0:  $\mu_1 = \mu_2$  (Mean of favourable responses of two group is equal)**

**Alternate Hypothesis H1:  $\mu_1 > \mu_2$  (Mean of favourable responses of Group 1 is more than Group 2)**

**Use a significance level of  $\alpha = 0.05$**

t-Test: Two-Sample Assuming Equal Variances

	<i>Group -1 (Courtyard house)</i>	<i>Group -1 ( Non-Courtyard house)</i>
Mean	70.92857143	55.35714286
Variance	126.9945055	137.1703297
Observations	14	14
Pooled Variance	132.0824176	
Hypothesized Mean Difference	0	

df	26
t Stat	3.584717807
P(T<=t) one-tail	0.000683462
t Critical one-tail	1.70561792
P(T<=t) two-tail	0.001366924
t Critical two-tail	2.055529439

---

**Hypothesis**

**H<sub>0</sub>:  $\mu_1 = \mu_2$**

**H<sub>1</sub>:  $\mu_1 > \mu_2$**

**Rejection region**

**Reject H<sub>0</sub> if  $t_{stat} > 1.70$**

**Test statistics**

**$t_{stat} = 3.58$**

**p value**

**p value = 0.000683462**

**Decision/ Conclusion**

**Rejection region  
Reject H<sub>0</sub> if  $t_{stat} > 1.70$**

**Test statistics  
 $t_{stat} = 3.58$**

**p value  
p value = 0.000683462**

**Decision/ Conclusion  
Because  $t_{stat} > 1.70$  and **p value = 0.000683462 <  $\alpha$  (0.05)**  
**Reject Null Hypothesis****

**Interpretation:**

Since the alternate hypothesis has been accepted and the null hypothesis has been rejected, this indicates that there is enough evidence to prove the significant impact of housing typologies on parameters such as Functional, Environmental, religious, cultural and Psychological



### 5.2.4 Expert's survey

The architects or planners of different occupational backgrounds were included in the study so that different perspective can be achieved. Most of the architects who participated in the study are either from Lucknow or have an association with Lucknow in Past. Since practising architects frequently deal with clients, they are acquainted with both the supply and demand of the market. The government sector employees participate in the map-sanctioning and building regulations procedure. Academicians are actively involved in the learning process, which eventually influences the way that future architects think. Analysis has been done using SPSS (Annexure-B1)

Table 25: Architect/Planner statistics

Experts	Description	Number
<b>Practising Architect/Planner/Interior Designer</b>	Most of the architects have well established firms with experience in the bracket of 5 - 15 yrs.	<b>14</b>
<b>Academician</b>	Associated with reputed college and having immense experience of teaching budding Architects.	<b>9</b>
<b>Government Sector Employee</b>	Architects associated with organization like UPRNN, LDA, Awas Vikas Parishad.	<b>7</b>
<b>Private sector Employee</b>	Architect associated with large firms .	<b>6</b>

No of Respondent: 36

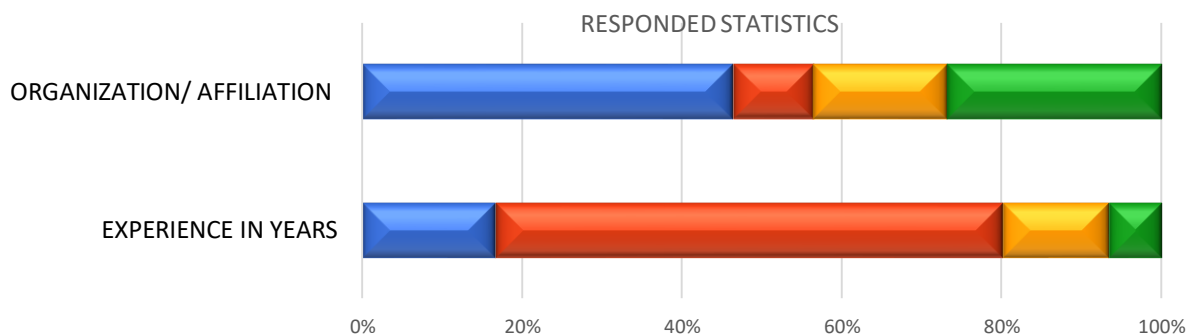


Figure 73 : Respondent general information



1. Which is the most preferred plot size for residential development of middle income group?

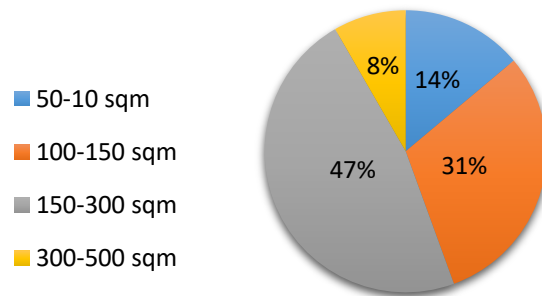


Figure 74: Plot size preference

2. Which is the most preferred proportion of plot for residential unit (i.e. Length: Breadth)

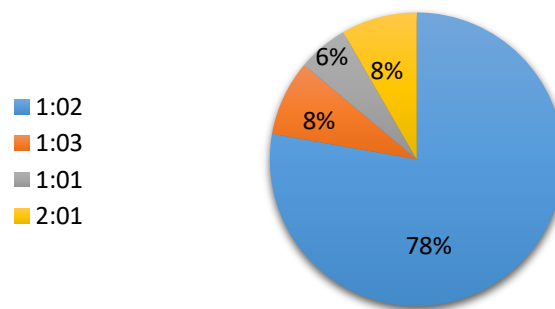


Figure 75 : plot proportion preference

3. The plot-ratio influence the decision of a designer in choosing a Courtyard typology

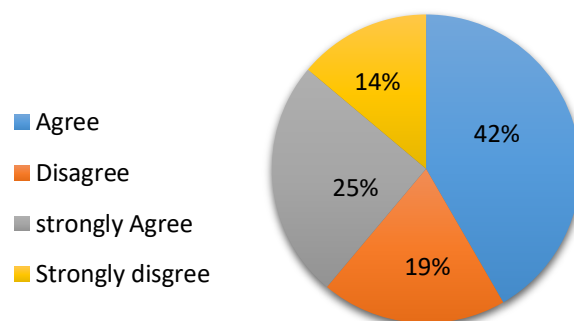


Figure 76 : Influence of plot ratio

4. The culture of Indian families promotes the courtyard typology.

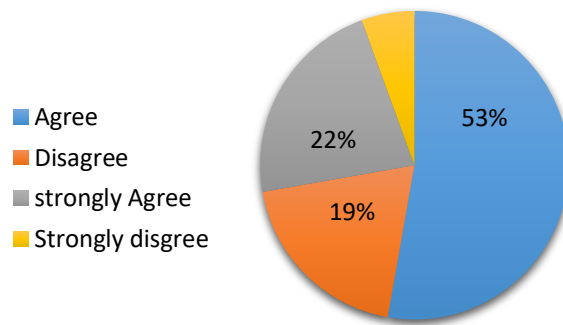


Figure 77 : Influence of culture on court typology

5. The current building Bye-laws create hindrances in adopting courtyard typology.

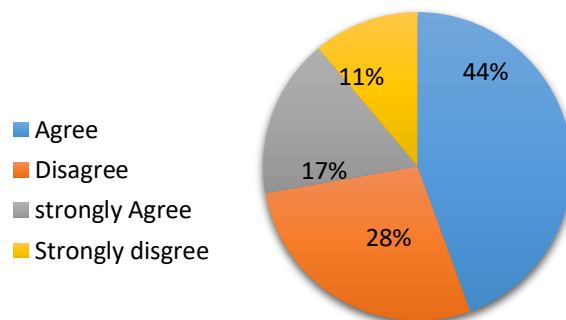


Figure 78 : Impact of building Bye-laws

6. The Parameters like FAR, setback, GC, Height regulation are sufficient to achieve Climate responsive designs.

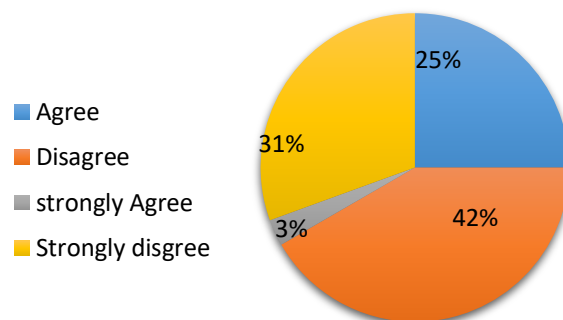


Figure 79 : Impact of building parameters

7. Using a scale (4 = Most important and 1= Least Important).Please rate the following factors that are responsible for the disappearance of the courtyard from Indian House

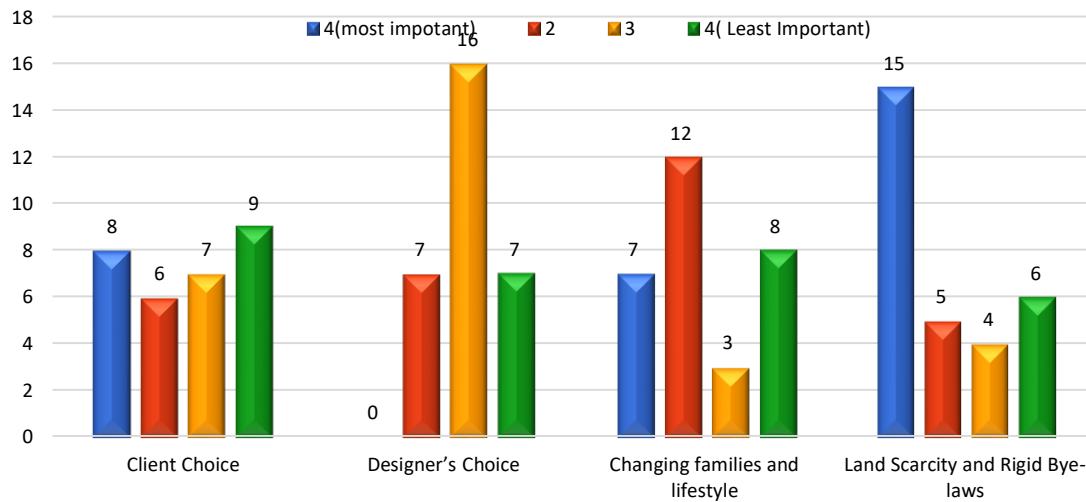


Figure 80 : Graph for reason of disappearance of courtyard.

*Result Interpretation: Most of the Architects agree on the fact Land scarcity and rigid Bye-laws are the main culprit behind the disappearance of the courtyard, further they ranked changing families and Designer's choice at second and third position respectively. Architect assumes that client has little say in deciding the typology of the housing; they are simply driven by the market nature.*

8. Using a scale (4 = Most important and 1= Least Important). Please rate the following factors that Indian family often consider while making a house.

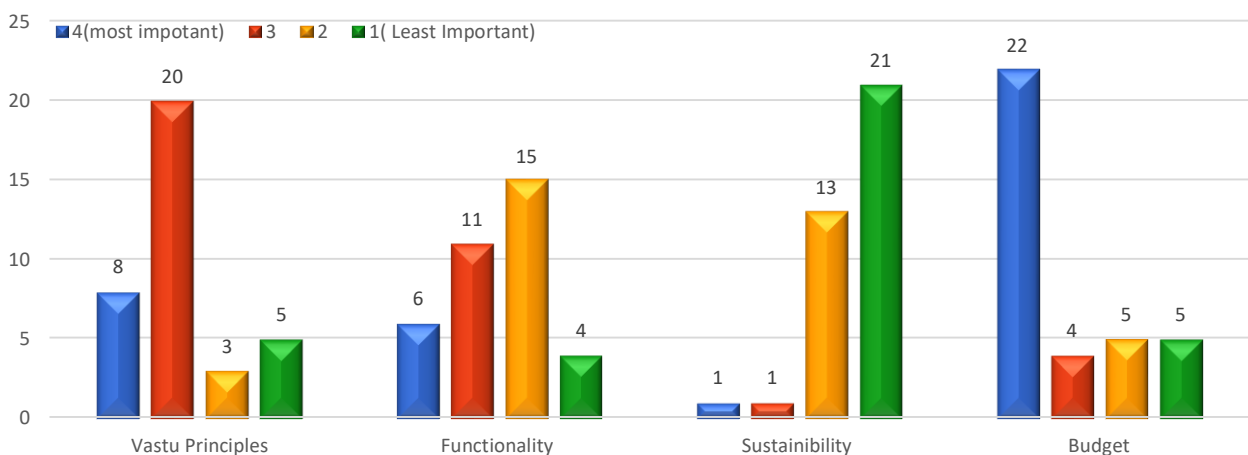


Figure 81 : Factors affecting Indian residential design.

*Result Interpretation: Architects agree on the fact that most of the Indian family give utmost importance to budget and second most important factor is Vaastu principles. Functionality and Sustainability comes at third and fourth position respectively.*

### **5.2.5 Inferences from Survey Findings**

This chapter has provided a detailed analysis and discussion of the findings related to design, social and cultural factors, environmental performance, rules and regulations, and economic drivers of vernacular and contemporary courtyard housing. Courtyard housing has deep historical roots and has been adapted over centuries to address changing cultural norms and lifestyles. Contemporary courtyard housing provides an alternative to the Western housing typologies that are increasingly being adopted in India and offers an alternative means of addressing social and environmental sustainability. Moreover, the flexibility of the typology allows for a range of lifestyles and family preferences. The statistical analysis of the responses has provided evidence to prove the hypothesis that the courtyard space has significant impact on Functional, Environmental, religious, cultural, and Psychological parameters of the houses,

**At Functional Parametern:** Courtyard spaces are mainly used for household chores, while front yard/backyards used for ornamentation purposes. The courtyard provides sufficient privacy for carrying many household activities, and being strategically located in the core of house provides better interconnection of spaces.

**At Environmental Parameter:** Courtyard houses undoubtedly perform better as compared to the Non Courtyard Houses. Daylight is the major benefit of courtyard houses.

**At Religious Parameter:** Vaastu compliances in the houses support the notion of a Courtyard.

**At Social / Psychological Parameter:** Changing family structure, difficulty in maintenance, and small plot size are the reasons for the non-popularity of courtyard houses among users. However, people adore the courtyard typology and realize the significant impact of open space within the house on their well-being.

#### ***Expert Survey:***

Expert survey preferred plot size for residential development has been identified as 150-300 sq.m and preferred plot ratio as 1:2. Additionally experts have a preference for the courtyard typology but they believe that rigid bye-laws and lack of available land hindered them from designing the courtyard house.

### 5.3 MODELING AND SIMULATION

To validate the research with data, an additional parameter was included to arrive at the final conclusion. In this section, Daylight analysis has been done for two prototype designs. The performance of prototype is judged at individual scale for daylight levels and further at cluster level for shading analysis. It is generally known that the temperature in the shaded region is often lower than the temperature in the exposed area, making the entire environment cool. (Patherya & Lau, 2012).

Day lighting has long been acknowledged as essential and as a practical strategy for the design of visually appealing and energy-efficient buildings. The presence of daylight enhances the occupants' sense of cheer and brightness, helps to create environments that are healthier and more appealing and improves their behaviour.(Freewan, 2011). Electricity usage for lighting purpose in residential sector accounts for 10-12%. Therefore, having regulations that incorporate day illumination into the housing sector seems essential, especially in a country like India with extensive daylight hours (Samhita, 2018). Significant research on daylight design in buildings has been conducted on a variety of issue like impact of courtyard on daylight (Guedouh & Zemmouri, 2017), influence of setbacks on interior illumination in residential buildings.(Myneni, 2022), Impact of building profiles on daylight (Dabe & Adane, 2018) etc. However, there hasn't been much research done comparing residential open space for low-rise houses, such as setback and courtyard.

The following investigation presents the comparison of two prototype one with courtyard and other with setback typology. It is aimed to develop designs on the basis of performances of prototype, which can be further accommodated with building Bye-laws. Building Bye-laws in Lucknow served as the base for prototype development.

A residential pocket of newly developed area of Lucknow has been identified for study purpose. The two types of hypothetical designs are created on plot size of 200 sq m with plot proportion of 1:2 for the study purpose.

Two type of layout has been developed on same site, In layout 1 the residences of setback typology are provided adhering to the Bye-laws of Lucknow. While the Layout-2 consist of the plots developed after slight modification in buildering Bye-laws. The residences in layout -2 are developed as courtyard houses .The three types of road are provided in layout i.e 18 m, 12 m, 9 m wide (Fig 84 & 85).

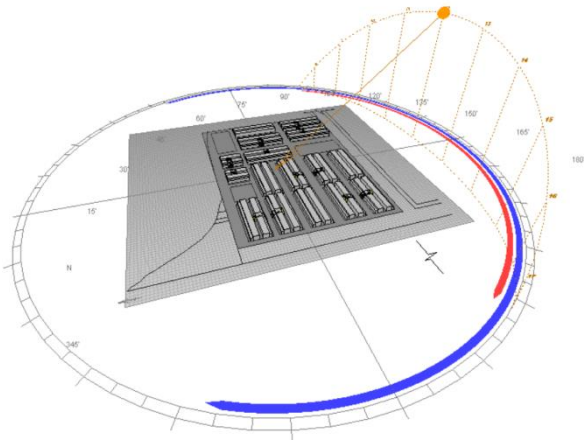


Figure 82 : Layout one with setback model

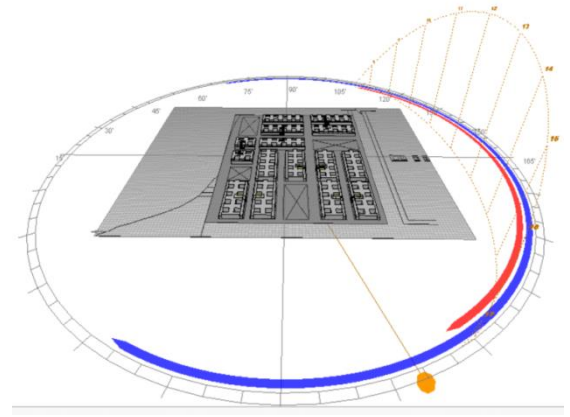
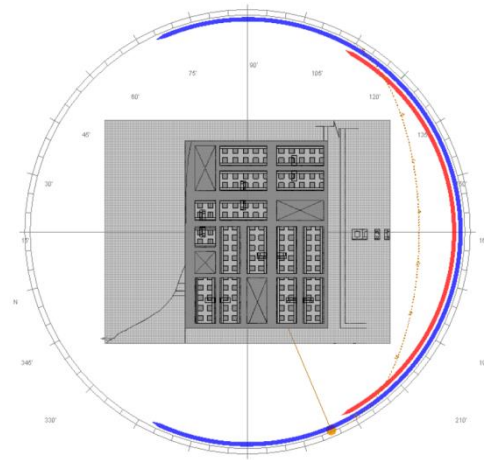
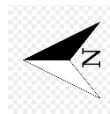
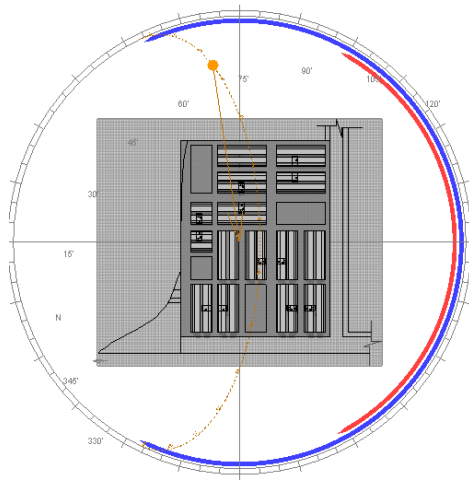


Figure 83 : Layout -2 With Courtyard model



### Computer simulation tools

Using the Auto Cad software, 2d designs for prototypes and clusters have been generated (Fig 84 &85).

A simulation of daylighting was run to gauge the degree of interior illumination. For simulation modelling and visualisation, Ecotect 2011 was utilised. Using the ray-tracing technique, Radiance simulates day illumination and works as an Ecotect plug-in. The day illumination in each model's livable regions was assessed using the Ecotect 2011 analysis tool in relation to the chosen parameters and reflectivity values. The Energy Plus weather data file was used to get the region's weather dataset.

**Shadow analysis:** Shadow analysis has been done to check the impact of typologies on the shadow patterns at the Cluster level (Fig 86-89). The regulation must consider the impact of their parameters on an individual level as well as at cluster level. As we generally discuss climate-responsive architecture although the climate climate-responsive urban planning is also important.

# Courtyard Model

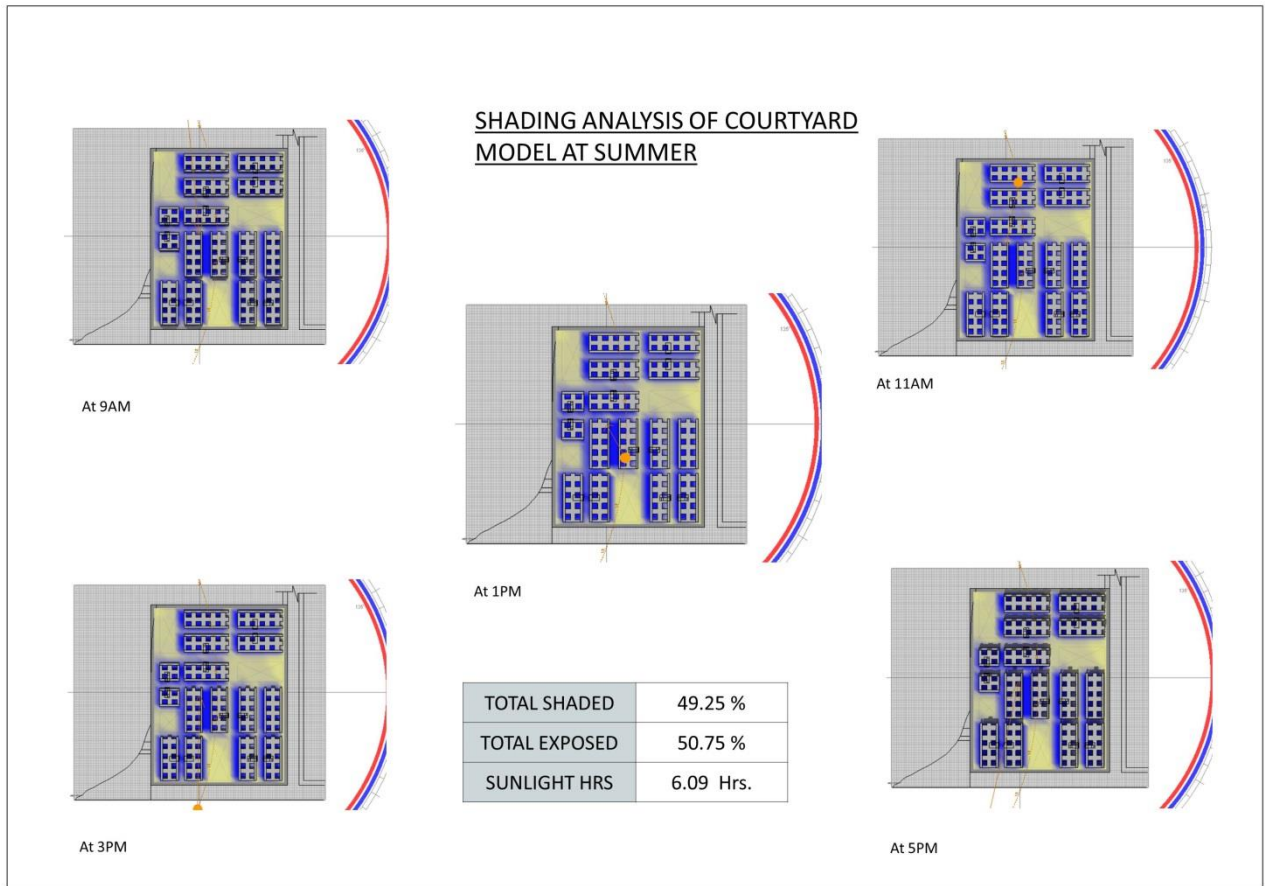


Figure 84 : Shading analysis of courtyard model ( 21<sup>st</sup> June)

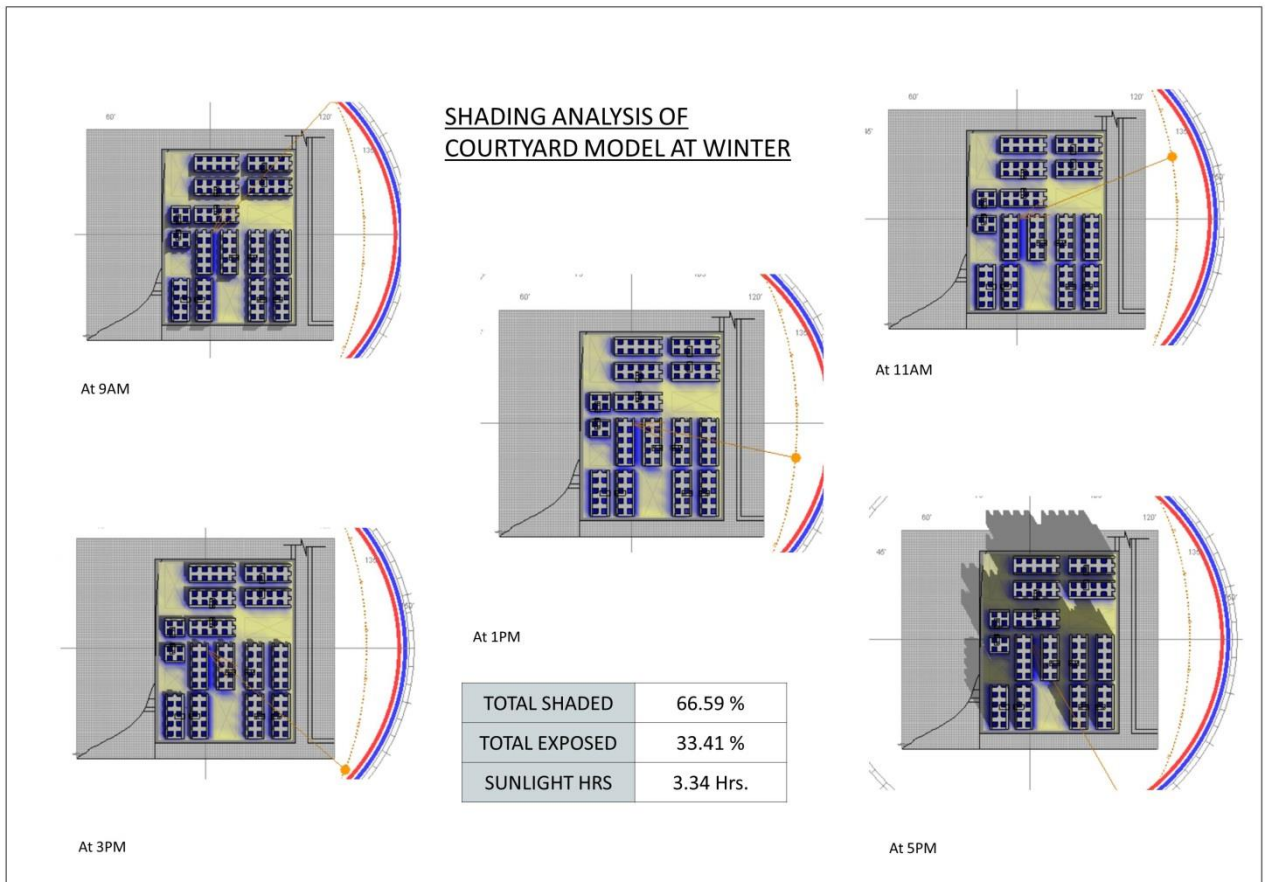


Figure 85 Shading analysis of courtyard model ( 21<sup>st</sup> December)



## Setback Model

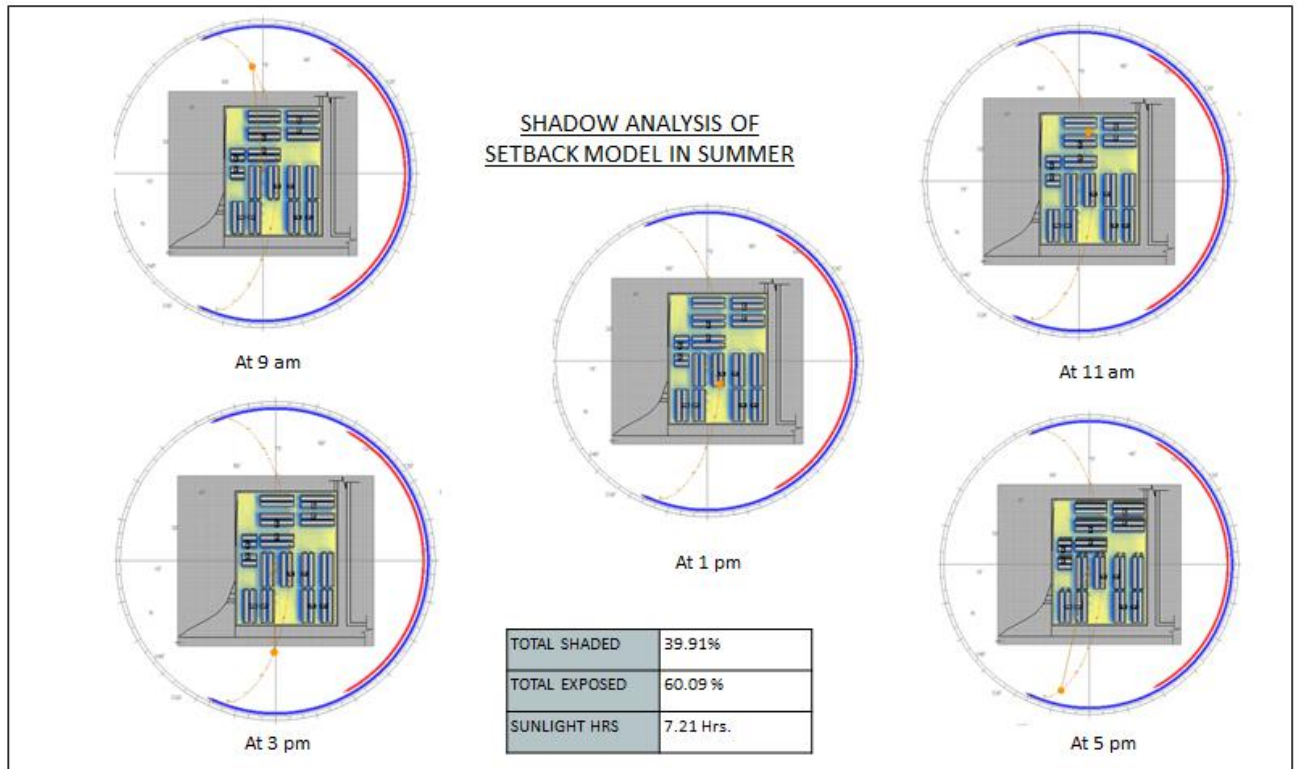


Figure 86 Shading analysis of Setback model ( 21<sup>st</sup> June)

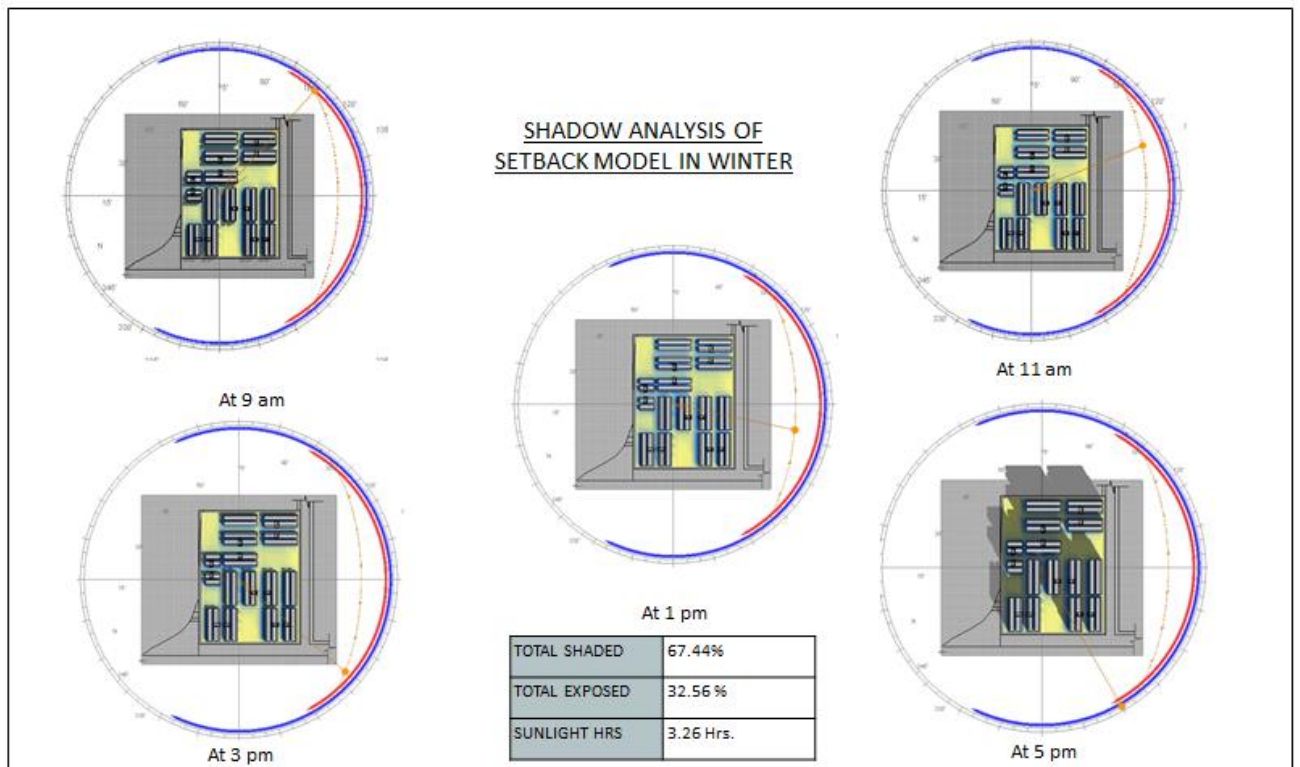


Figure 87 Shading analysis of Setbackmodel ( 21<sup>st</sup> December)

Table 26: Summary of Shadow analysis of both layout

Shadow Analysis on Grid	SETBACK MODEL		COURTYARD MODEL	
	Summer	Winter	Summer	Winter
Sunlight Hrs.	7.21 Hrs.	3.26 Hrs.	6.09 Hrs.	3.34 Hrs.
Total Exposed	60.09 %	32.56 %	50.75 %	33.41 %
Total Shaded	39.91 %	67.44 %	49.25 %	66.59 %

Bar Chart	SETBACK MODEL		COURTYARD MODEL	
	<p>60.09% Total exposed area in %</p> <p>39.91% Total shaded area in %</p> <p>7.21 Hrs. SUMMER</p>	<p>32.56% Total exposed area in %</p> <p>67.44% Total shaded area in %</p> <p>3.26 Hrs. WINTER</p>	<p>50.75% Total exposed area in %</p> <p>49.25% Total shaded area in %</p> <p>6.09 Hrs. SUMMER</p>	<p>33.41% Total exposed area in %</p> <p>66.59% Total shaded area in %</p> <p>3.34 Hrs. WINTER</p>

The above table summarises the shadow pattern and sunlight hours of both layouts for 21 June and 21 December (Table 26). In terms of sunlight hours, it refers to the total amount of time when a specific area's direct solar radiance intensity reaches or exceeds 120 W/m<sup>2</sup>. It must be noted that due to the occlusion of clouds and mist in the sky, as well as the various levels of sun-shading brought on by urban morphology, the actual sunshine hours of solar radiation received on the ground are less than the number of possible sunshine hours. Hence it can be concluded courtyard morphology has impact on sunlight hours especially in case of summer (21<sup>st</sup> June).

Further four models facing the North, south, east and west are detailed out from each layout

The nomenclature different models are given in the table 27 and Fig 91

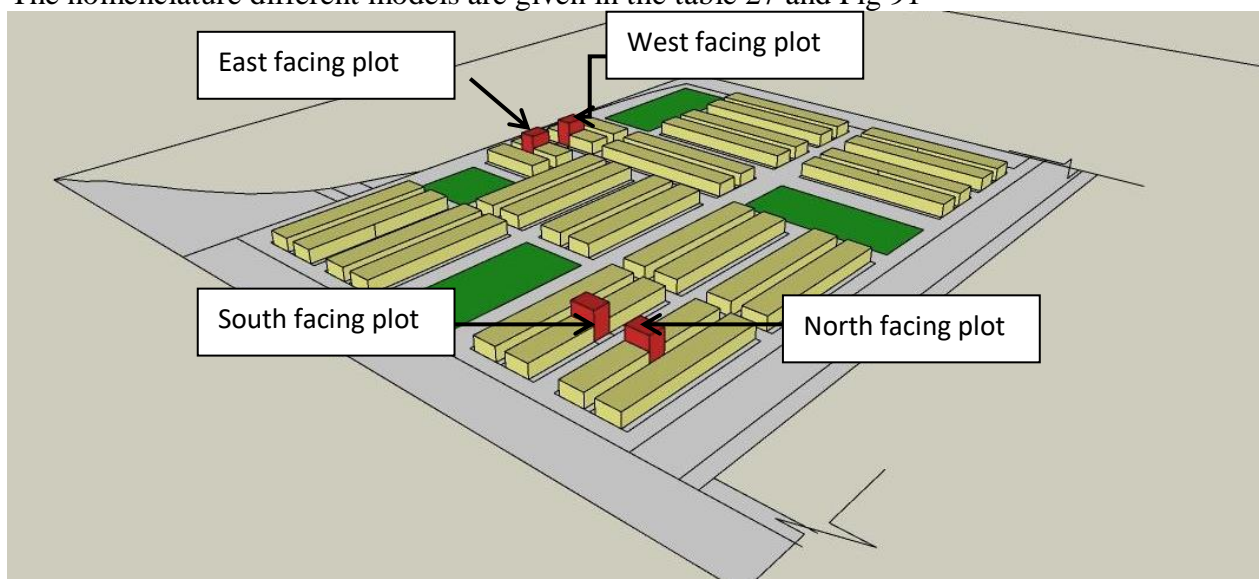


Figure 88 :Layout showing Hypothetical models

Table 27: Nomenclature of models

Layout type	North	South	East	West
Layout -1	NST	SST	EST	WST
Layout-2	NCT	SCT	ECT	WST
NST	North facing setback typology			
SST	South facing setback typology			
EST	East facing setback typology			
WST	West facing setback typology			
NCT	North facing courtyard typology			
SCT	South facing courtyard typology			
ECT	East facing courtyard typology			
WST	West facing courtyard typology			

The daylight factor and illumination Levels are used for evaluation of the performance of the daylight level. The reflectivity of the room surface (Kisan et al., 2005) and the optical transmittance of the glass (TERI 2006, Associate et al., and n.d.) are adjusted as follows in order to calibrate the simulation model.

**Reflectance of room Surface**

Ceiling	0.749
Wall	0.569
Floor	0.573
Visible transmittance of glass	0.356

Daylight: Most of the daylight performance assessment is carried out over an overcast sky condition (TERI 2006, Associate et al., n.d.). The average illumination levels are calculated for the ground floor for both setback typology and courtyard typology. The levels are calculated for 21<sup>st</sup> June and 21<sup>st</sup> December from 6 am to 6 pm. This analysis gives the average illumination for both typologies. The parameters for modelling and simulation are tabulated below (Table 28)

Table 28: Parameters for Simulation

Input for simulation	Parameters
Sky condition	CIE overcast sky
Type of calculation	Natural Light Levels
Calculation	Over Analysis grid
Ray tracing	Full precision
Window Cleanliness	Average
Calculated Room Average	Yes
Window Area	30 % WWR (Wall to window Ratio)

## TYPICAL PLAN OF BOTH MODELS (CONCEPTUAL)

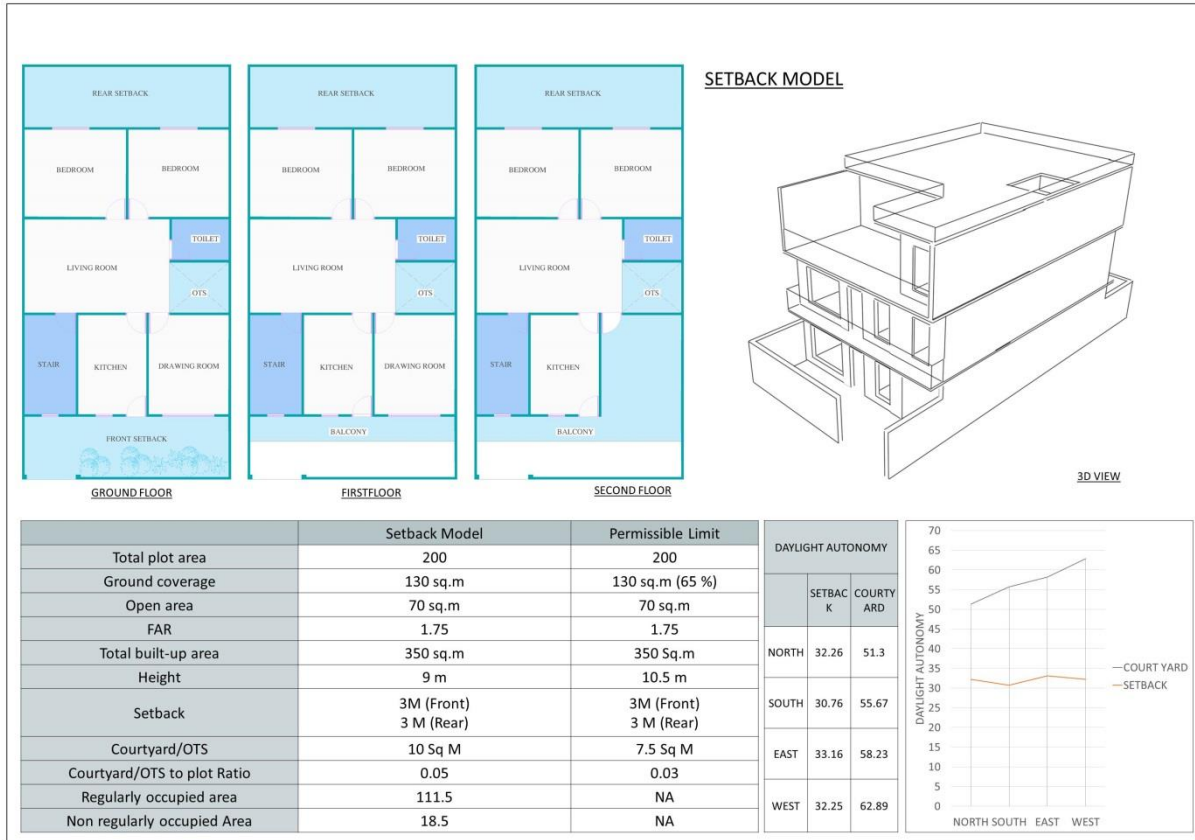


Figure 89 Typical Plan and view of setback model.

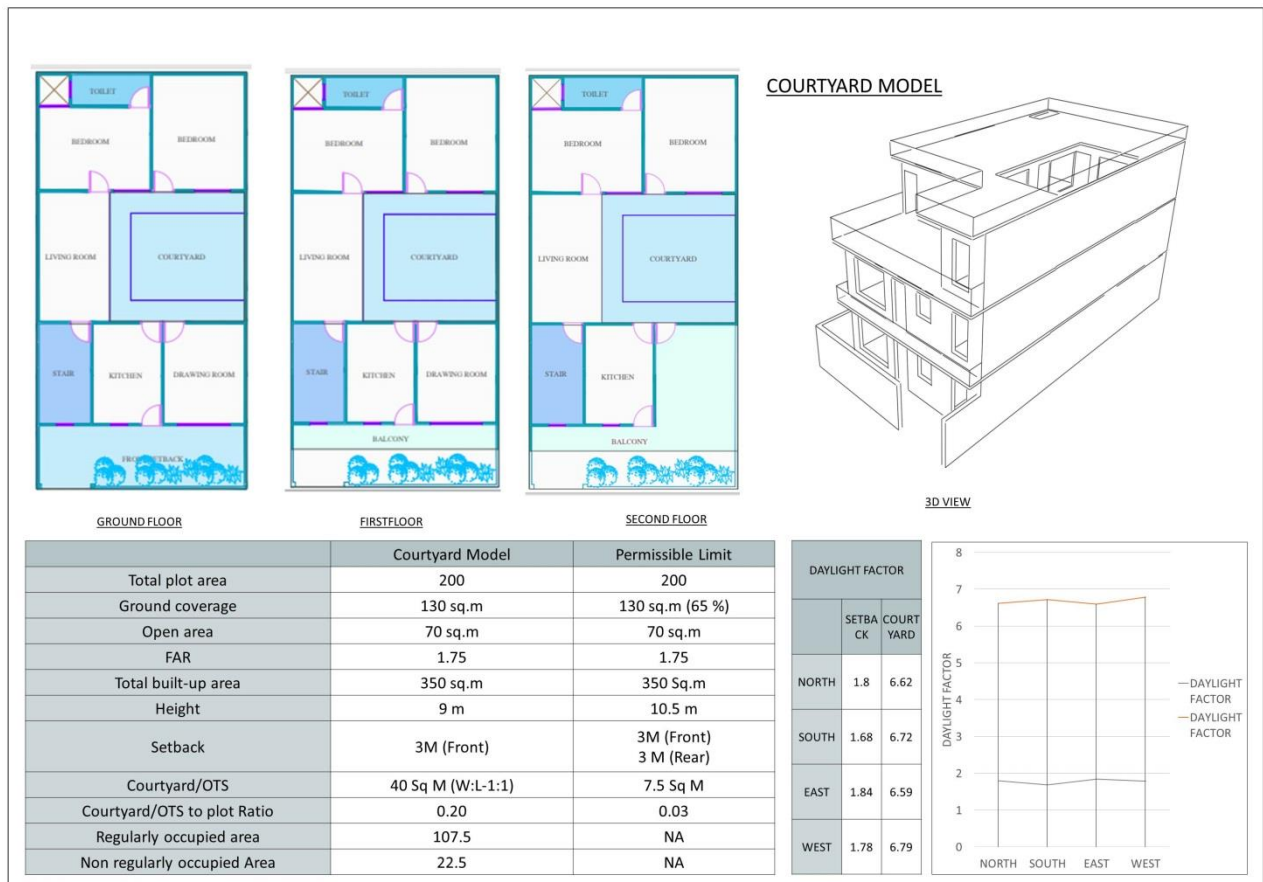


Figure 90 : Typical Plan and view of Courtyard model.

The average illumination on the ground floor for a plot facing North, South, East, and West has been summarised below (Table 29-32).

Summer solstice (21<sup>st</sup> June)

Table 29: Average Illumination of Fround floor setback model Summer

Time	Model Name			
	NST	SST	EST	WST
6	15.28	11.99	14.05	20.84
7	55.23	41.69	53.29	70.48
8	107.43	90.49	105.22	103.62
9	161.33	108.83	147.73	154.78
10	212.13	152.31	231.47	207.18
11	384.62	292.11	387.92	493.26
12	325.71	270.9	276.52	379.72
13	314.76	267.47	558.68	293.64
14	233.7	224.45	308.85	313.04
15	173.45	152.67	198.96	234.39
16	133.53	92.38	107.78	220.39
17	93.93	67.03	75.35	237.29
18	47.71	36.14	36.28	57.06

Figure 91 Graphical Representation (summer)

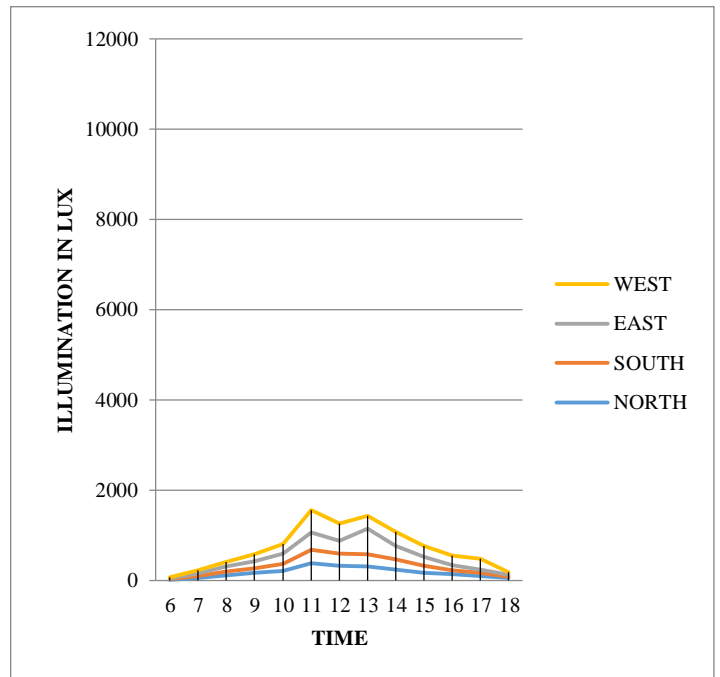


Table 30: Average Illumination of Fround floor Courtyard model Summer

Time	Model Name			
	NCT	SCT	ECT	WCT
6	81.2	74.31	115.74	88.5
7	242.1	208.6	374.71	250.3
8	443.5	440.3	604.74	529.1
9	637.6	655.1	756	765.1
10	3586.6	1515.1	822.6	820.7
11	3456.2	3493.1	910.9	915.94
12	2456	2345	1121.0	1051.9
13	1984	1867	1060.5	976.9
14	1490.9	1435.35	953.2	854.7
15	1576.5	1558.3	890.9	801.6
16	1005.05	886.62	796.92	728.75
17	624.13	496.74	474.08	511.3
18	296.36	232.55	198.06	290.48

Figure 92 Graphical Representation (summer)

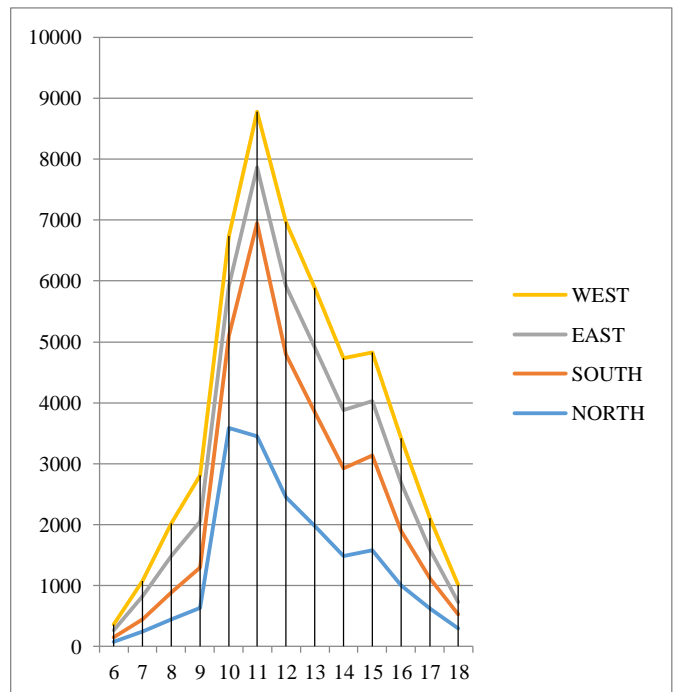




Figure 93 Graphical representation (Winter)

Table 31: Average illumination of Ground Floor  
Of setback model (winter)

TIME	Model Name			
	NST	SST	EST	WST
6	0.03	0.03	0.03	0.03
7	5.15	3.74	4.32	5.88
8	19.37	14.88	18.12	21.06
9	64.8	39.5	63.85	66.04
10	84.49	65.39	82.16	93.86
11	120.18	80.42	104.39	118.2
12	128.28	100.23	107.65	102.53
13	117.27	96.78	100.68	117.07
14	103.03	77.24	81.36	131.47
15	77.46	61.61	58.76	114.75
16	45.09	33.56	37.84	70.09
17	12.8	10.09	11.76	16.58
18	1.88	1.43	1.86	2.66

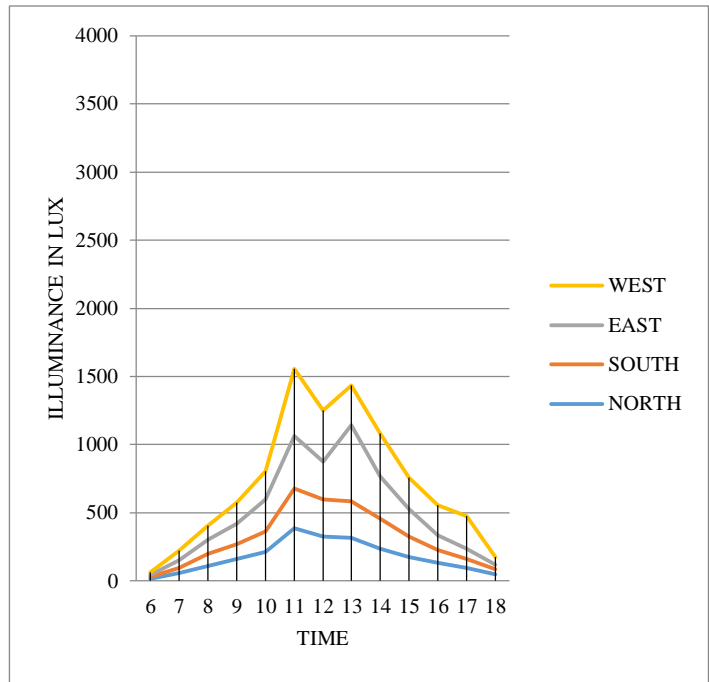
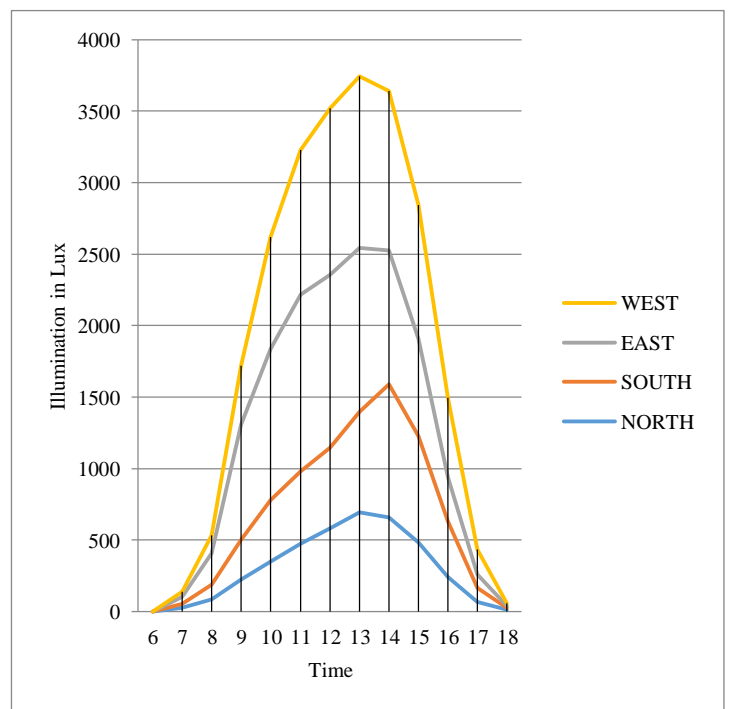


Figure 94 Graphical Representation (winter)

Table 32: Average illumination of Ground Floor  
Of courtyard model (winter)

TIME	Model Name			
	NCT	SCT	ECT	WCT
6	0.05	0.06	0.05	0.05
7	27.16	29.04	45.95	38.91
8	87.56	101.44	220.71	122.97
9	225.53	277.14	803.83	415.09
10	350.01	429.02	1057.48	783.48
11	473.9	507.57	1236.82	1010.47
12	583.96	561.26	1211.12	1164.1
13	693.25	704.85	1146.23	1201.52
14	660.39	930.24	936.88	1115.49
15	484.9	742.99	678.62	936.86
16	240.91	389.53	310.44	556.29
17	66.95	99.11	94.32	172.67
18	12.45	13.31	16.72	17.38



The average illumination levels of ground floor of courtyard model are quite higher as compared to setback model (Fig 94-97) . It may be noted that front zone of both the houses are similar,

might receive the same illumination, therefore the difference in the average illumination may be due to the spaces situated in the rear side of the house. The average illumination values are on higher side shows that front spaces adjoining the road receives sufficient daylight, in both the cases, but the illumination of space situated at the rear side of the plot need to be further analysed. Three habitable spaces have been identified in the rear side for the calculation (Fig 98).

- Living room, (LIVING)**
- Bedroom 1 (B1)**
- Bedroom 2 (B2)**

The average illumination of all these spaces are calculated for both models and for all four direction facing plot.

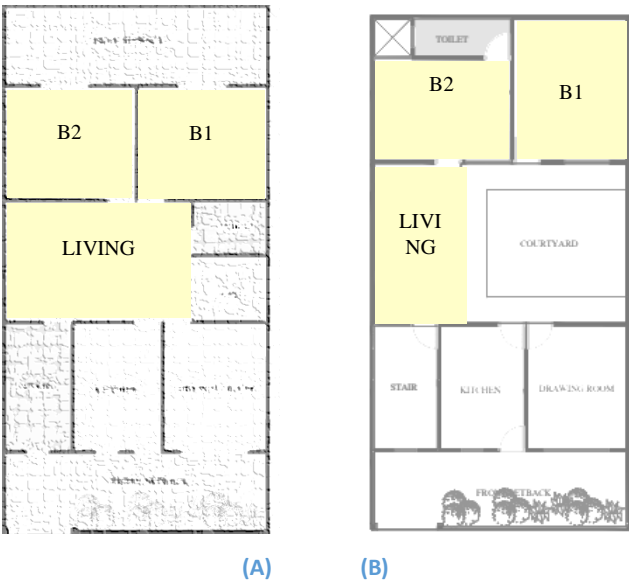


Figure 95 : Conceptual plan of setback (A) and courtyard mode(B), Ground floor)

The threshold of 100 lux has been decided and percentage of room area receives light more than this threshold is also calculated. This factor examines quality of light as how much area of the room receives light more than 100 lux. Room wise illumination levels are given in the tables below. The calculation has been done for 21<sup>st</sup> December, winter season under overcast sky condition.

Lucknow has predominated summer season, which faces lesser issues of sunlight, therefore winters are considered for calculation as worst case scenario. The potential of daylight has been judged for both the typologies. The calculation has been done three different times of the day i.e. at 9 am, 12 noon and at 3 pm. The various data calculated from the simulation are tabulated below in Table 33 & Fig 99-102

Table 33: Tabular summary of simulation findings for different models.

**North - Facing Plot (NCT & NST)**

BEDROOM-1				
	Setback model(NST)		Courtyard model(NCT)	
Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	154.51	38	<b>109.37</b>	36
At 12:00 Noon	462.22	44	<b>196.61</b>	37.8
At 3:00 pm	135.14	48	<b>121.8</b>	37.3

BEDROOM-2				
	Setback model(NST)		Courtyard model(NCT)	
Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	<b>170.91</b>	44.5	182.19	13.8
At 12:00 Noon	<b>166.94</b>	66.8	405.68	100
At 3:00 pm	<b>155.51</b>	31.2	277.32	100

LIVING ROOM				
	Setback model(NST)		Courtyard model(NCT)	
Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	<b>20.24</b>	6.5	482.47	45
At 12:00 Noon	<b>24.8</b>	5.4	843.52	89
At 3:00 pm	<b>16.68</b>	2.5	584.96	83

**South - Facing Plot (SST & SCT)**

BEDROOM-1				
	Setback model(SST)		Courtyard model(SCT)	
Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	<b>102.19</b>	26	186.7	60.9
At 12:00 Noon	<b>152.8</b>	35	238.44	58.2
At 3:00 pm	<b>230.77</b>	98	205.31	96.9

BEDROOM-2				
	Setback model(SST)		Courtyard model(SCT)	



Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	<b>110.79</b>	33	177.37	36
At 12:00 Noon	<b>345.82</b>	58	596.44	100
At 3:00 pm	<b>105.71</b>	29.51	377.444	99.6

LIVING ROOM				
	Setback model(SST)		Courtyard model(SCT)	
Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	<b>14.66</b>	0	76.71	13.8
At 12:00 Noon	<b>104.49</b>	13.8	1044.24	100
At 3:00 pm	<b>22.92</b>	3.9	803.6	100

**East - Facing plot (EST & ECT)**

BEDROOM-1				
	Setback model(EST)		Courtyard model(ECT)	
Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	<b>133.13</b>	28.7	210.54	38.77
At 12:00 Noon	<b>287.88</b>	100	382.52	100
At 3:00 pm	<b>196.91</b>	57.5	280.83	88.9

BEDROOM-2				
	Setback model(EST)		Courtyard model(ECT)	
Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	732.75	98	<b>72.02</b>	24.4
At 12:00 Noon	201.81	32	<b>124.45</b>	26.7
At 3:00 pm	141.36	33	<b>85.88</b>	25

LIVING ROOM				
	Setback model(EST)		Courtyard model(ECT)	
Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	<b>14.33</b>	3.9	166.12	44

At 12:00 Noon	<b>24.23</b>	5.1	270.55	100
At 3:00 pm	<b>23.8</b>	4.2	194.2	60

**West Facing Plot (WST & WCT)**

BEDROOM-1				
	Setback model(WST)		Courtyard model(WCT)	
Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	<b>485.41</b>	51	748.5	88
At 12:00 Noon	<b>616.7</b>	52.2	1356	100
At 3:00 pm	<b>482.5</b>	41.7	951.23	94

BEDROOM-2				
	Setback model(WST)		Courtyard model(WCT)	
Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	<b>166</b>	34	610.1	51.6
At 12:00 Noon	<b>572.1</b>	56	1109	69.1
At 3:00 pm	<b>289.18</b>	40	770.1	53.8

LIVING ROOM				
	Setback model(WST)		Courtyard model(WCT)	
Time	Avg. Illumination (In Lux)	Area of room above threshold* (in %)	Avg. Illumination (In Lux)	Area of room above threshold* (in %)
At 9:00 am	<b>19.18</b>	1	224.45	50.71
At 12:00 Noon	<b>120.54</b>	18	410.18	100
At 3:00 pm	<b>19.1</b>	1	299.32	94

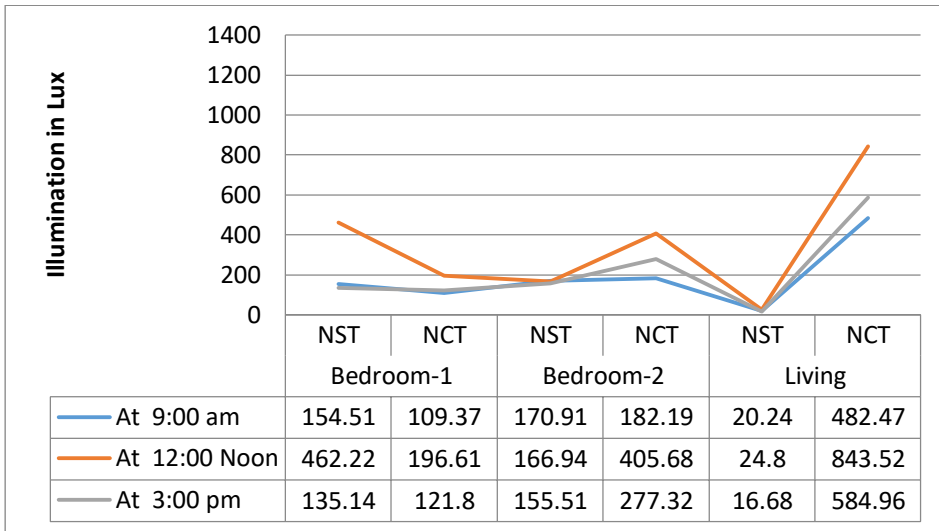


Figure 96: Daylight levels for different model of the north facing plot.

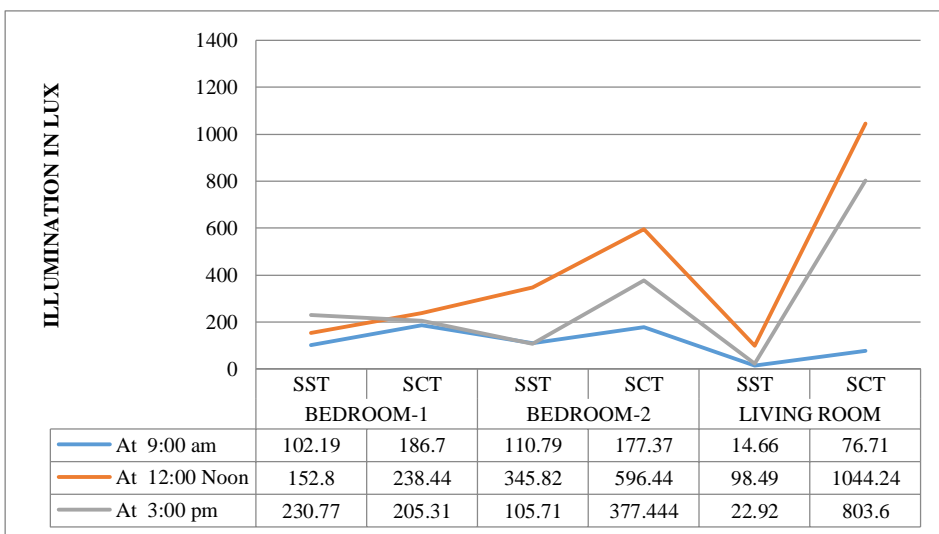


Figure 97 Daylight levels for different model of the South facing plot.

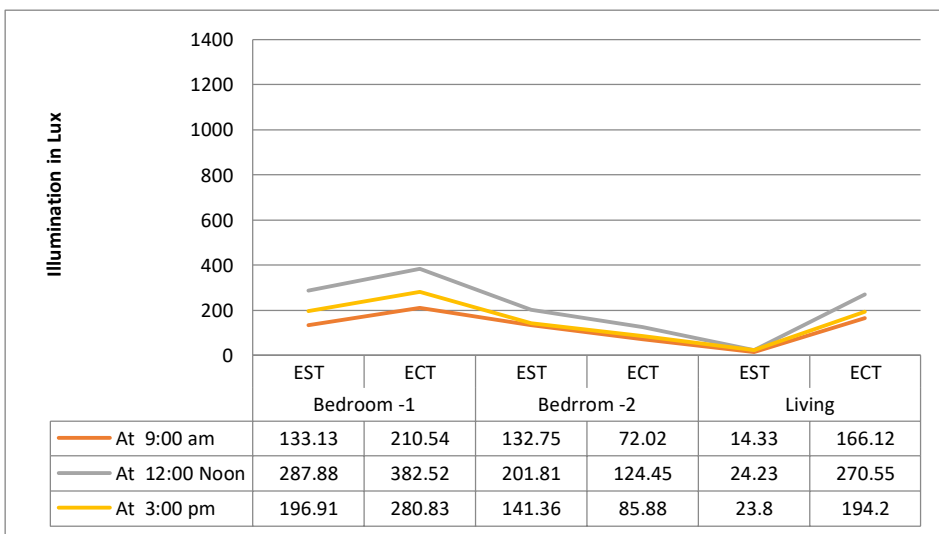


Figure 98 Daylight levels for different model of the East facing plot.

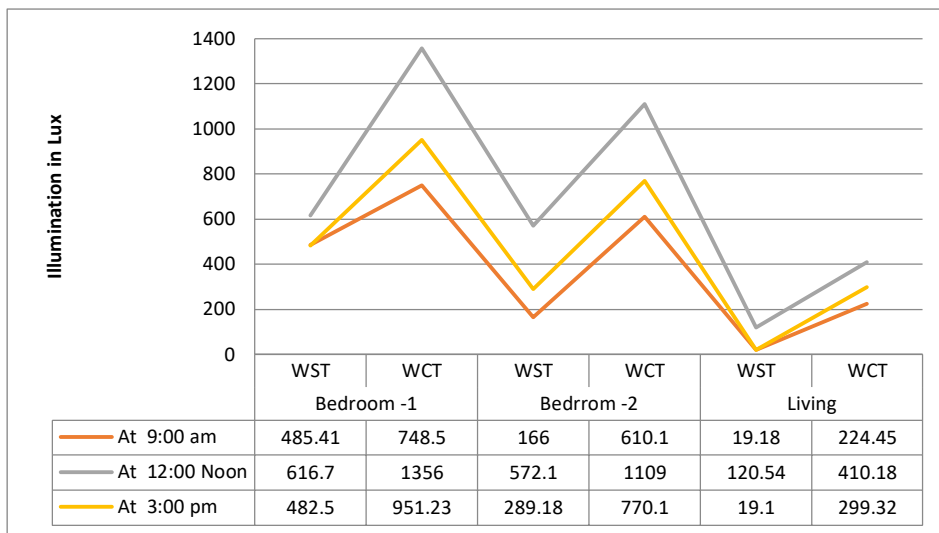


Figure 99 Daylight levels for different model of the West facing plot.

### 5.5.1 Inferences from Modelling and simulation

The performance of two prototypes is evaluated at the cluster level by comparing the shadow patterns and sunlight hours at the first level, Further at individual level both prototypes are compared for average illumination at ground floor level to assess the impact of orientation on daylight. To get the more precise result total eight models have been evaluated for three different room spaces i.e rear side bedroom-1, rear side bedroom-2 and Living room at three different time of the day

*Shading analysis at Neighbourhood level:* That cluster of courtyard model performs better as compared to setback model in summer because it receives less sunlight hours and more shaded area, which is desirable for summers. Courtyard cluster and setback cluster almost similar shaded area and sunlight hours for winter, therefore performance of both layout in winter is near about same.

#### *Illumination level at Ground floor.*

The daylight levels in courtyard model are greater as compared to setback model for all four directions facing the plot. Although the result cannot be interpreted in such a manner, as this is average of ground floor plate means some of the areas may get more light as compared to the others. The front zone of both houses are same so they will equal daylight but rear side of the houses are significantly different which ultimately impact their daylight level. Out of three rear spaces the least performing model for daylight levels has been identified and tabulated below for each type of plot facing i.e North, South, East and west. This is to be noted that these directions represent the facing of the plot abutting the road.

Table 34: Summary of the Lowest performing model (Low illumination level) in terms of daylight

Direction/Space	North –facing Plot	South-facing Plot	East- facing Plot	West- facing plot
Bedroom -1	<b>Courtyard Model (NCT)</b>	Setback Model (SST)	Setback Model (EST)	Setback Model (WST)
Bedroom -2	Setback Model (NST)	Setback Model (SST)	<b>Courtyard Model (ECT)</b>	Setback Model (WST)
Living	Setback Model (NST)	Setback Model (SST)	Setback Model (EST)	Setback Model (WST)

The above result suggests Courtyard model performs better in most of the case (Table 34) .The courtyard model only performs poorly in two of the twelve cases, while setback typology does so in ten of them. Also, living room of the setback model does not get the average threshold level daylight (i.e 100 lux) in a day for any of the directions.

Best models (highest illumination level) for the following space in terms of potential daylight.

Space	Highest Average luminance
Bedroom-1	WCT (Courtyard typology on west Facing Plot )
Bedroom-2	WCT (Courtyard typology on west Facing Plot )
Living	SCT (Courtyard typology on South Facing Plot )

The result shows that there is a significant amount of potential for daylight in the winter on a west-facing plot with windows of rear side spaces (bedrooms and living space) that open towards a north/south courtyard. The study comes to the conclusion that the orientation and location of open spaces have a significant impact on the daylight potential of adjacent spaces.

## 6.2 DESIGN INTERVENTION EXAMPLE

### Design context

The location for the design recommendations is Sushant Golf City in Lucknow, where the field study for one sample case example was conducted. Sushant Golf City is a 6465-acre hi-tech township in Lucknow. situated on the Lucknow-Sultanpur Highway and Amar Shaheed Trail. There are both residential and commercial developments in this ultra-modern township.

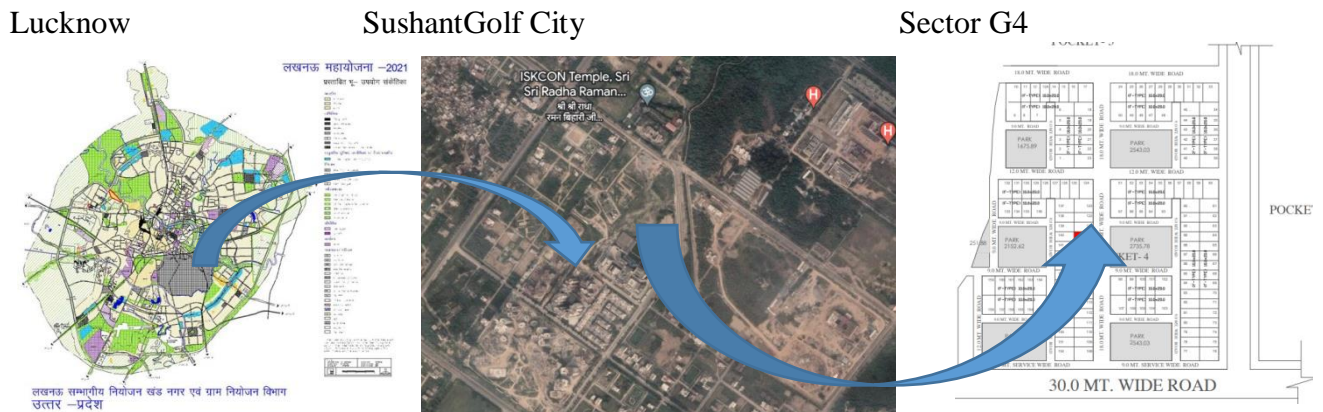
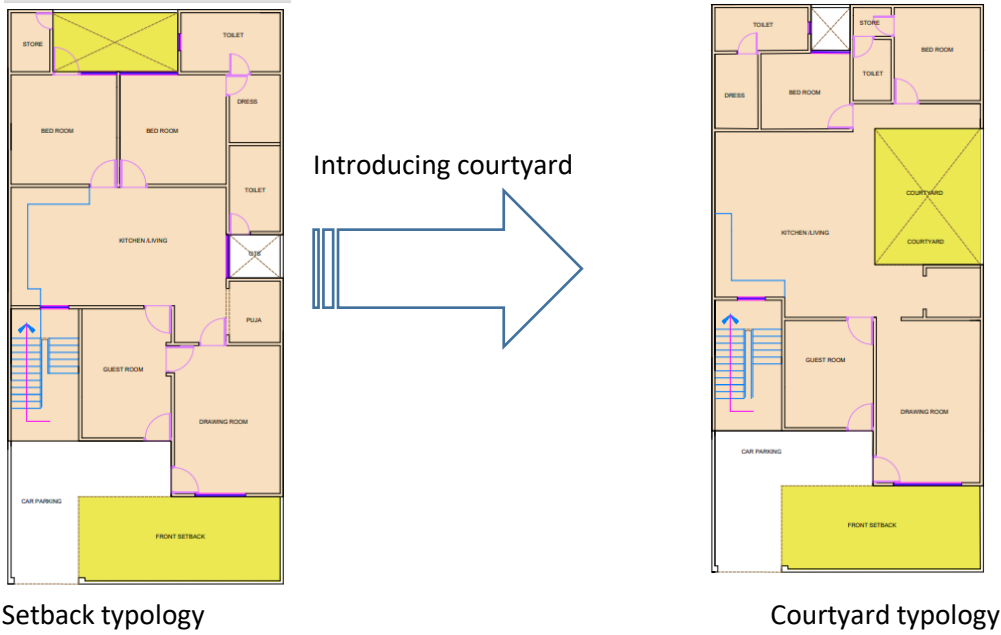


Figure 100: Site location

An existing house of sector has been studied built under the jurisdiction of Lucknow building Bye-laws, 2008. However the violation of building regulation has been observed in the case, specially for the rear setback. A courtyard space has been introduced in the existing house to understand the changes in the spatial quality of the spaces and impact in daylighting within interior of house.

The façade of the home is left untouched, and all the necessary spaces from the existing house are retained. The study's main objective is to figure out the changes in various parameters that are possible by introducing the courtyard space. Although the existing house does not adhere to the accepted standards for open spaces, a courtyard of the ideal size has been added, which eventually reduces the built-up area and further influences the proportions of rooms. The design intervention in the existing house could produce various design alternatives, so, the plan after introducing the courtyard typology is conceptual. Hence, the reduction in areas of space is shown in percentage. There is almost 26 % ( 6 sq m )reduction in the area rear side bedroom and a 12%( 4 sq.m) reduction in the roofed area of the living room. All the space requirements existent in the existing house have been preserved.

**Sample case at plot No 87**

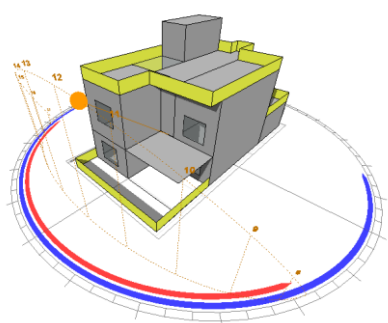


**Visual imagery of Sample case**

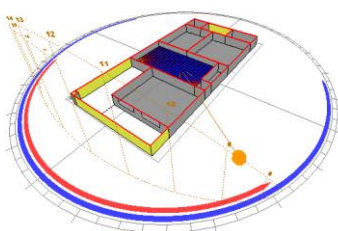


Figure 101 : Photographs of sample case (source: Author)

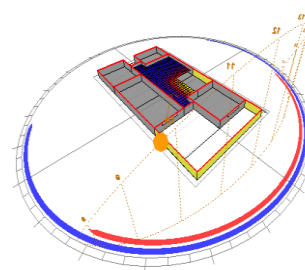
## Daylight Analysis



**Front view**



**Courtyard Model**



**Setback Model**

**Table 35 : Comparison of parameters for existing house with modified house**

Parameter	Setback Typology	Courtyard typology	Permissible or acceptable limits	Remark
Plot area	200 Sq.m	200 sq.m	-	
<b>Building regulation Parameters.</b>				
Ground Coverage	82%	76%	65 %	Regulation violation
FAR	1.9	1.8	1.75	Regulation violation
Storey	G+2	G+2	G+2	As per regulation
Front setback	3 m	3 m	3 m	As per regulation
Rear Open spaces	2.1 m wide with approx. 50 % coverage.	Open space in centre (W/L=1:1.2) W/H=1:1.6)	3 m	Encroachment in setback Research Findings: (W/L=1:1,W/H=1:2)
Windows	15%	15%	10% of Room area	As per regulation
<b>Daylight</b>				
Average Illumination in Living spaces	21 Lux**,35 Lux**, DF-0.26 %	428 Lux** DF-5.725 %	Illumination for Reading casual 150 lux Daylight factor:0.625 % Source :SP 41	*On 21 <sup>st</sup> December, on site readings of Ex. case ** Simulation readings of Ex.Ca *** Simulation



			(1987): Handbook on Functional Requirements of Buildings	readings of D.I 2100 % ,200%,510 % increase in illumination of living room, bedroom -1 & bedroom 2 respectively
Bedroom-1	45 Lux**, 54 Lux** DF- 0.56 %	136.01 Lux DF-1.60 %		200 % in Illumination
Bedroom-2	17 Lux**, 22 Lux**, DF-0.21 %	105.37 Lux D.F 1.24 %		510 % increase in illumination.

### Spatial organization

Interconnection of spaces	Setback typology	Courtyard Typology

#### 5.4.1 Inferences From Design Intervention

Integrating a courtyard of the appropriate size to a building provides advantages on environmental, Functional and Psychological level. Nevertheless, in order to adhere to all the regulations, the user must give up some built space in order to create a sustainable dwelling unit. The design intervention solution is somewhat in line with the Building regulations, such as ground coverage, FAR, etc (Table 35).

As seen in the table above, design intervention solutions have a major impact on the potential for daylight in various spaces.

An urban courtyard can give a touch of luxury to a home's interior and can blur the boundary between indoor and outdoor space. Nonetheless, the fundamental spatial arrangement is comparable to that of the existing house, which is tailored as per the user's need.

## 6.2 PROTOTYPE DEVELOPMENT

Research analysis findings are used to provide a solution that works in the majority of cases. Using study findings as a basis, the idea for spatially adaptable urban courtyard homes is developed. In the study, urban courtyards have been imagined for various plot proportions that are possible in plotted development. The modifications can help to reinforce the spatial relations of all the domestic spaces where courtyards will facilitate functions, circulation, day lighting, and

Table 36: Different plot proportion with different courtyard

PLOT RATIO /COURT TYPE	1:3	1:2.5	1:2	1:1.5	1:1
I Type					
L Type					
U Type					
O Type					

ventilation. The primary goal of the study is to evaluate the performance of various types of

courtyards for various plot proportions in order to establish a basic prototype design that will ultimately help the architects create sustainable homes. Various combination of courtyard type and plot proportion is tried to achieve the suitable prototype which perform better in term of residential density and spatial design (Table 36).

<b>Plot proportion</b>	<b>1:3</b>	<b>1:2.5</b>	<b>1:2</b>	<b>1:1.5</b>	<b>1:1</b>
<b>Possible configuration of open space</b>					
<b>No of units :30 in cluster</b>					
<b>Area of cluster</b>	<b>4473</b>	<b>4580</b>	<b>4725</b>	<b>4935</b>	<b>5282</b>

Taking into account that 200 square metres as a medium plot and 1:2 plot proportion as most acceptable ratio,

**Table 37: Different type of courtyard and their impact**

Plot Ratio-1:2	<b>I-TYPE</b>	<b>L-TYPE</b>	<b>U-TYPE</b>	<b>O-TYPE</b>
<b>Zoning (Space Arrangements)</b>				
<b>Cluster</b>				

Advantages	Provide the segregation of built mass and open mass. It resembles the contemporary pattern of setback layout.	Two faces of the house are opening to the courtyard. That makes it possible for living areas to link to and integrate with the courtyard area more effectively than I type courtyard. The house may have greater views, lighting, and airflow than I type.	The achieved proportion of courtyard might not be climate responsive. Linear circulation area will be maximum	Most introvert type of dwelling among all types and provides maximum integration with built mass. Maintains inner privacy from the surrounding.
Disadvantages	The courtyard is only connected to one façade. Thus, there is the least amount of opportunity for the remaining dwellings to interact with courtyard area. Corridors connecting to the courtyard may be needed depending on the house layouts. Due to its end placement, perhaps only bedrooms or areas at the edge of the residences will get a view of the courtyard.	The achieved proportion of courtyard might not be climate responsive. Linear circulation area will be maximum	Only one outer surface is attached to the neighboring unit, In appropriate aspect ratio may cause over shading	Not suitable for rectangular plot as the divide usable space in two halves. Linear circulation area will be maximum No outer surface is attached to the neighboring unit, may further reduce sky view factor .
Enclosure :openness ratio	1:3	2:2	3:1	4:0
Spatial quality of adjoining spaces	Not suitable	Suitable	Most Suitable	Suitable

### 5.5.1 Inferences from Prototype development

It has been observed that Plot proportion 1: 3 is most suitable in achieving the compact development which ultimately addresses issue of land shortage in urban areas.

1:2 and 1:1.5 plot proportion provides more option for providing courtyard, without hindering quality of adjoining spaces.

Further, analysis has been done to understand the behaviour of different courtyard types in cluster. It has been observed U type courtyard are better in cluster formation, as there is only one side adjoining the neighbouring property, therefore make the courtyard space more private.

The appropriate design prototype is created by taking the following factors into account.

**No of User :** With the change in social structure of families, families are mostly nuclear type, consisting of an average of five members that include both parents and children . ( Avg. household size : 5.12) This indicates that new domestic courtyards should be designed to serve at least five persons.

**Activity Pattern :** In contemporary homes bathing,cooking and washing clothes type of activities are taking place in attached bathrooms, kitchen and utilities. Therefore activities like sitting and relaxing seems more associated with courtyard in contemporary houses.

**Shape and Courtyard:** Shape such as I, U, O or L type can be adopted considering the plot proportion. However, U shape courtyard seems much suitable for the prevailing 1:2 plot proportion in current urban settlement.

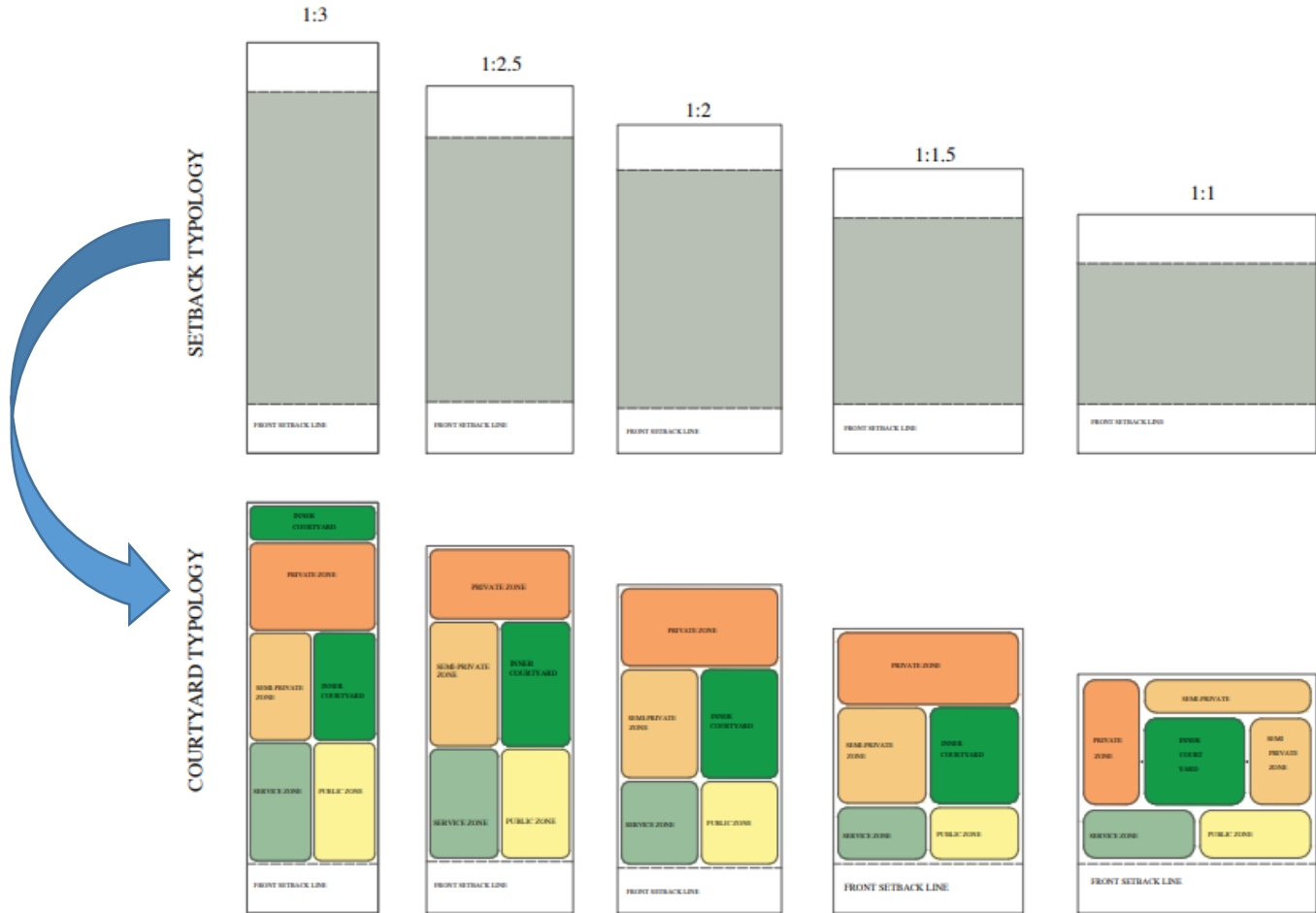
**Building regulation:** As the study suggested, the new town's building regulations place a lot of emphasis on architectural control and façade control. Therefore, front setback must be taken into consideration while defining the uniform building line, and after leaving the mandatory front setback, ground coverage must be capped.

**Flexibility in design:** Designer must have the flexibility to place the open spaces keeping the daylight, functionaliy , and inter-connectionof space in mind. This can be achieved by proposing a built-to-open ratio in place of rigid setback lines for rear side.

**Built to open ratio:** Study of various regulation suggested the optimum built to open ratio ranges between 35 to 40 percent.These open space can be divided into front open space and open space for the rear side of plot. Instead of making this as rigid setback, the open space can be utilised as courtyard.

## Prototype Design Sample for different plot proportion

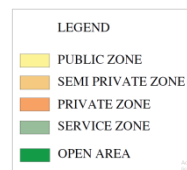
Based on the analysis a prototype for 200 sq m plot size is proposed below.



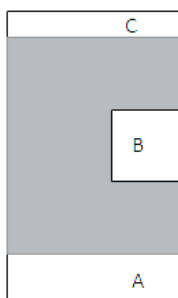
Plot size: 200 sq.m

Front setback line: 3M

Courtyard to plot ratio: 15 % -20%



Above plot size of 200 sq m. a combination of optimum size courtyard along with rear utility space or secondary court can be used as shown below.



- A- Front open space (To be governed by Setback Line)
- B- Central open space (Optimum Size)
- C- Utility space ( $C= O-(A+B)$ )
- Total open Area (O) =  $A+B+C$
- Plot Area= Total building Footprint (F) + Total Open area (O)

A design prototype is always subjected to rigorous scrutiny. Therefore, while evaluating a prototype, especially one as intricate as a house, it is essential to consider multiple parameters for a balanced and thorough assessment.

Designers have the responsibility and choice to achieve a balance between these criteria to find a solution that satisfies all the needs of end users. For instance, choosing the right design is a common dilemma in architectural practices for parameters such as functional vs. aesthetic, traditional vs. innovative, sustainable practices vs. luxurious lifestyles, and budget vs. quality. The study evaluated courtyard typology in urban settlements based on the various impacts of courtyards and identified the trade-off involved.

Functional: (Leisure Activity, Household Activity)

In traditional courtyard houses, spaces are flexible and multifunctional rather than being designated for a single specific purpose, allowing for various activities to be performed in courtyard. In contrast, urban courtyards are often more exposed, making it challenging to accommodate these traditional activities. However, the optimum rear side spaces in urban courtyard houses, hidden from the main living zones, can still be effectively utilised for similar purposes. For instance, these spaces can be used for drying clothes, washing utensils, and concealing services like AC outdoor units etc. Furthermore, a well-planned courtyard adds an interior element and can be effectively used for leisure activities such as relaxing and socialising.

Environmental (Thermal comfort, Natural ventilation, and daylight)

The study clearly established that courtyard spaces located in the middle of the house are quite effective for daylight penetration, depending on their orientation and proportion. However, due to maintenance issues, insects, or the need for rain shelter, users often cover the space with glass or sheets, creating an atrium that hinders the courtyard's primary function of providing ventilation. Additionally, urban courtyards are less likely to be surrounded by verandas and often serve as extensions of the living room. Verandas, however, act as buffer zones between the exposed courtyard and other habitable spaces, helping to mitigate the heat gain. Further courtyard planning can increase the S/V ratio as compared to setback typology, which ultimately adds to heat gain. However, a well-proportioned and well-shaded courtyard can indeed facilitate evaporative cooling and stack ventilation effectively (Taleghani et al., 2014)(Rajapaksha et al., 2003)(Muhaisen, 2006)(Gulati & Pandya, 2014). Further integrating natural elements such as vegetation and water features into courtyards is crucial for improving microclimatic conditions, reducing heat stress, and creating a more comfortable and sustainable built environment (Zamani et al., 2018).

Social (religious and cultural)

The courtyard typology presents a winning scenario across various parameters, making it highly desirable among users. A well-designed landscaped courtyard can serve as an open space for religious activities such as havan (fire rituals) or special pujas (prayers), providing a serene and sacred environment. The combination of a living room with an adjoining courtyard creates an expansive area suitable for large family gatherings. This configuration allows for seamless indoor-outdoor interaction, enhancing the social experience during events.

Psychological (Privacy and Enclosure)

Courtyards are highly effective in creating visual connections between spaces on the same floor and between two floors. However, this visual connection is not suitable for rental floor plates or when there are two different dwelling units stacked one above the other. Addressing privacy concerns in internal courtyards, particularly when neighbouring buildings are taller, requires a thoughtful integration of landscaping, architectural elements, and design strategies. By leveraging these solutions, designers can create private and comfortable courtyard spaces that enhance the overall quality of living and use of the environment.

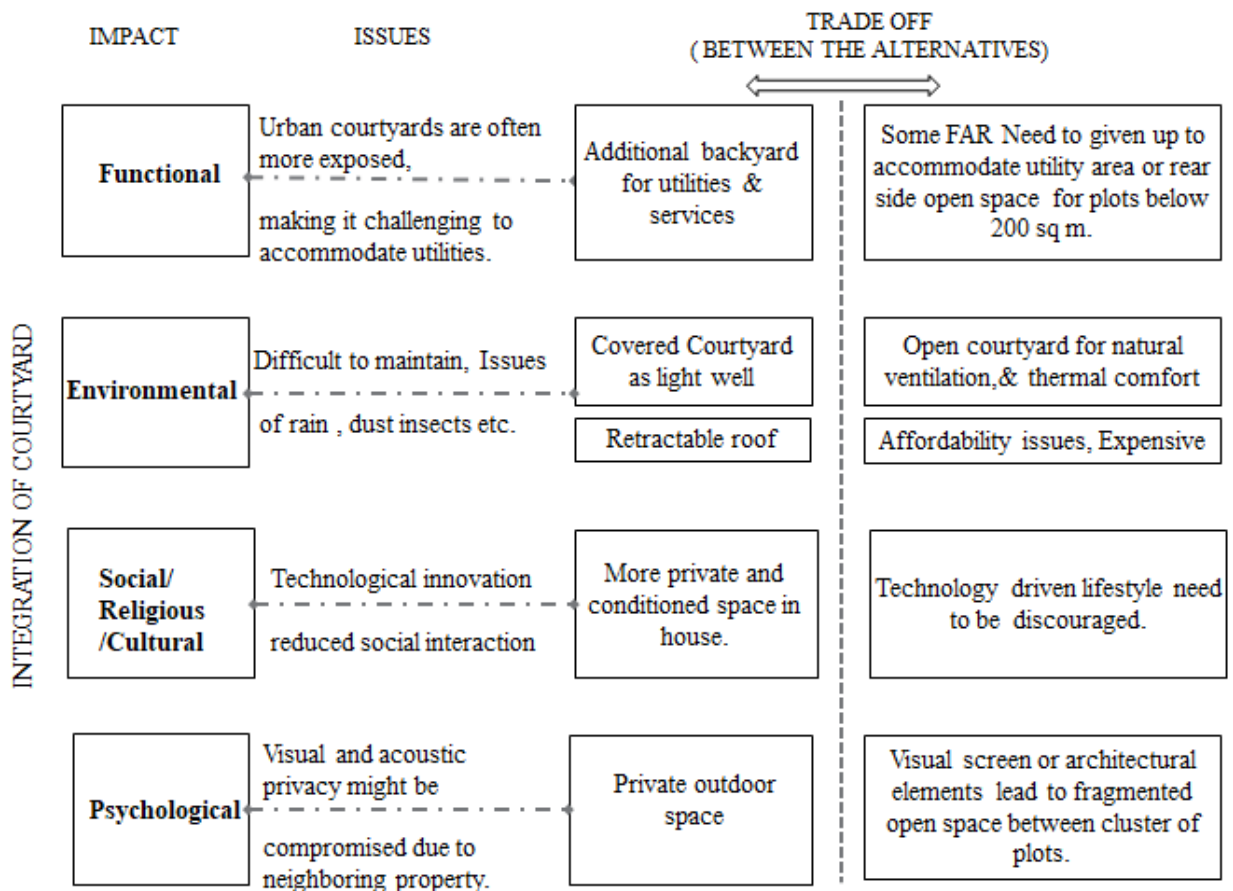


Figure 102 : Trade off involved in urban courtyard Houses



## 5.6. CONCLUSION

While it's crucial to respect the users' decisions regarding their homes, designers also have responsibility to create awareness among user regarding sustainable design solutions and take steps to experiment with various typologies. The study reveals that courtyard has countless impact on the designing of the houses and these space play pivotal role in conceptualizing the design of the houses. Most of the respondent feels that new housing typology somewhere lacks the openness in the house which can only be revived by reintroducing the central open spaces. Maximum respondent imagines their open space as fully functional space which could be used as gathering space or relaxing space with utmost privacy. The result also indicates the open spaces should be thermally comfortable and provide proper daylight in the house which is somehow missing in new house due to ill proportion an incorrect location of open spaces. However due to constraints of modern times, it difficult to imitate the traditional typology therefore a typology which satisfies all Environmental, behavioural, and functional aspects must be developed. Further study finds that sizing of plot, Plot proportion, client mind-set, Building Regulation and Market demands should also be minutely considered before deciding a residential prototype.

The result indicates that orientation and location of open area either in the form of setback or courtyard must be considered while choosing the window placement and orientation. The average illumination can be significantly raised by positioning the open spaces towards various cardinal directions. Therefore, the designer must have the freedom to place the open space according to the characteristics and orientation of the site Opening an atrium towards the north direction is beneficial as the light coming from this orientation is uniform and no shading devices are needed. Bye-laws must thus be performance-oriented rather than prescriptive in nature.

The research has recommended design changes to contemporary houses based on the spatial arrangement of traditional homes in order to accommodate courtyards in the domestic environment of the modern era. Introducing courtyard space in contemporary residences will help with circulation, functions, daylighting, ventilation, and indoor thermal comfort can be strengthened with the help of the changes. The lack of an outdoor connection in modern homes, which is crucial for residents' Psychological comfort and mental health, will be most importantly addressed. Courtyards will be very effective as an outdoor workspace in the current setting, when home-based enterprises and home-offices have become a part of the domestic environment.

## CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

This chapter summarises the main findings of the study and identifies the contribution to knowledge, the limitations of the research, and scope for future research.

### 6.1. BACKGROUND

In order to address the possibilities inherent in concepts associated with continuity, it is necessary to look at traditional buildings as types that reflect on-going process in history rather than as object with little bearing on modern design practices (Brian Edwards, Magda Sibley, Mohammad Hakmi, 2006). An introductory paragraph from the book “Courtyard Housing: Present Past and Future” suggests the courtyard typology is widely considered responsive to low –rise high density urban settlement. Historical context of courtyard houses shows that the concept of courtyard is not merely based on independent space surrounded by rooms rather it is thoughtful design concept based on set of principles. The courtyard typology seems out of place in the European urban system for family dwellings due to the presence of setback guidelines (Brian Edwards, Magda Sibley, Mohammad Hakmi, 2006).

Continuing with this notion, study attempts to find the reason for the disappearance native courtyard typology in context of Lucknow. This study attempts to establish a relation between the courtyard typologies and building Bye-laws. By drawing on the views and experiences of residents of courtyard housing and other type of housing as well as designers, academics and government officials, the findings have revealed how the courtyard housing typology has evolved over time and how it is addressing environmental and social sustainability goals.

The multi modal approach has been adopted to get the conclusion. Many researcher advocates the existence of courtyard but at the same time it is impractical to mimic the traditional houses, however the space with slight modification can be well fit in urban context. At first place the study identifies the reason for the disappearance on native courtyard space from contemporary home. The study reveals that courtyard has countless impact on the designing of the houses and these space play pivotal role in conceptualizing the design of the houses. Most of the respondent feels that new housing typology somewhere lacks the openness in the house which can only be revived by reintroducing the central open spaces. Maximum respondent imagines their open space as fully functional space which could be used as gathering space or relaxing space with utmost privacy. The result also indicates the open spaces should thermally comfortable and provide proper daylight in the house which is somehow missing in new house due to ill proportion an incorrect

location of open spaces. However due to constraints of modern times, it difficult to imitate the traditional typology therefore a typology which satisfies all Environmental, behavioural, and functional aspects must be developed. Further study finds that sizing of plot, Plot proportion, client mind-set, Building Regulation and Market demands should also be minutely considered before deciding a residential prototype.

The result also revealed that as pre notion that small plot size is the main reason for abandonment of courtyard space is proved wrong. As courtyard can be accommodated any medium size of plot if the user and architect desire so .The result discarded the hypothesis that plot size governs the choice of courtyard.

Further, the expert survey stated that Vaastu is important for Indian clients after budget while creating a home. However, sustainability is not a top priority for the users. In that case Courtyard typology can provide the solution for the users as has ability to achieve sustainability goals. Courtyard acts as a major element of Vaastu and also helps in modifying microclimate within the house se.

The contemporary courtyard house possesses several important features that are inherent in its concept and shape. Courtyard housing is an architectural approach that responds to the social, cultural and religious aspects of the region. It expresses cultural identity, emphasises family relationships, and promotes a sense of belonging to Indian society.

## **6.2 CONCLUSION**

Based on the research findings, a number of recommendations are suggested above for practice-based architects and designers. These recommendations are not restricted to the Lucknow Bye-laws context but are relevant to courtyard housing across the other Indian cities with similar climatic zone and regional context. At the design stage, concepts and issues of sustainability need to be introduced and articulated as an embedded philosophy early in the process. The architect must take the responsibility of creating the typology which provides holistic solution to users concerns of functional spaces. Further it will reduce the chances of monotonous design solutions. This will ensure that environmental performance and social preferences are realised in the built form. Furthermore, building policies need to incorporate principles of sustainable architectural design based on vernacular strategies. This will help to guide practitioners in implementing sustainability in their projects and can counter the dominance of Western architectural styles in regions with rich local architectural heritage and identity.

The first goal of the study has been achieved through the literature review, which covers the historical and present context, impacts and challenges of courtyard houses.

The favourable survey responses from users and experts aid in achieving the study's second objective, which seeks expert and user validation about the importance of the courtyard concept and its requirement for adoption in contemporary residential units. In order to achieve final objective of developing a courtyard design prototype, a design model that suggests modest modification to the building regulation has been developed. The study establishes the above hand of the courtyard model in terms of daylight which is backed by modelling and simulation findings

### **6.3. RECOMMENDATIONS**

#### **At Courtyard level**

- The examination of the case study results demonstrates that the courtyard sizes are unrelated to built-up area and plot area. The research also demonstrates that a courtyard of the optimum size may satisfy every psychological and practical demand of the user. In the case of traditional houses, courtyard is the sole source of daylight in adjacent rooms. On the other hand, modern urban homes, which comply with building codes, utilize both courtyards and setbacks to ensure proper lighting and ventilation within the house. Combination of front setback and optimum size courtyard has been worked out to get desired design solution for up to plot size of 200 sq m by renouncing rear setback. However above 200 sq m plot size, front & rear open space can be maintained along with optimum size courtyard (Prototype Design).
- Front setbacks are quite important to maintain the uniform street elevation. This setback area can be marked as green zone strictly to be used for parking and greenery without any exemption for development to enhance ground water recharge and reduce run off.
- Additionally, literature reviews have shown that courtyards can act as thermal regulators, when natural elements like vegetation and water bodies are consciously incorporated; they have the potential to enhance the microclimate of the house. Therefore, concept of rear open space is more effective rather than rigid setback lines for rear side. Consequently, the designers have the flexibility to locate the open space based on daylight requirement, thermal comfort, and functional requirements of house (Literature Review).
- Most of the respondents residing in courtyard or non-courtyard house agree on the fact that the courtyard has the capacity to add charm in their home. A maximum percentage of people like to add this holistic space in their house. However this space can only be created if the thoughts of the designer and clients are at the same pace, therefore awareness among architects and users is required regarding sustainable typologies, which can be achieved by increasing the role of government agencies and organizations (User Perception Survey).

- The W/L, W/H and courtyard to plot ratio (1:1, 1:1.5 and 1:15-20%) derived from the study can be used as base ratios in the initial design phase for courtyard typology, however there is always a possibility to validate these result with modelling and simulation. (Case Study of Houses, Literature Review & simulation).
- In addition, Expert questionnaire survey results indicate that a lack of land and strict regulations are the primary causes of the disappearance of courtyards, but this analysis contradicts those findings by showing that a courtyard of an optimum size may be incorporated in a plot as small as 100 square meters (Case study of House).
- The modelling and simulation model demonstrated the daylight potential of courtyard model on west and south facing plot and their suitability for providing daylight in rear side of house even in winter season. It is suggested that during housing layout the west and south -facing plot can be increased to gain maximum benefits of daylight, however the thermal performance and Vaastu issues of these plots need to be addressed (modelling and Simulation).

### **At the Building regulation Level**

#### **General Recommendations**

- The drawback that has been observed during case study of bye-laws, that the standard text-based laws do not give end users, citizens, the ability to choose the permissible building envelopes. To enhance readability for individuals who are not professional, it is advisable to incorporate illustration into the bye-laws in addition to the textual content (Reference :Amaravati Regulation)
- The regulatory framework to assess the impact of prevailing bye-laws is lacking. Additionally, housing policies are primarily driven by data rather than by human behavioural science. There is also a need to develop an institutional framework to obtain insights into the feasibility of implementing better regulations time to time.
- To reduce fragmented, elongated poorly designed spaces created due to the mandatory setback guidelines particularly rear and side margins need to be rationalized to improve land utilization. Therefore introvert planning with well-proportioned interior open space like courtyard is more functional and may reduce the pressure on public open spaces.
- We should encourage compact and dense urban designs, not only by easing Floor Area Ratio (FAR) or height restrictions but also by drawing inspiration from our historical towns. Cities like Barcelona and Jaipur demonstrate that it's possible to ensure proper light and ventilation in densely populated areas without mandatory setbacks (Byahut et al.,

2020). Similarly, Alwar and Riyadh offer sustainable examples of dense urban layouts that incorporate courtyards effectively (Dhingra & Chattopadhyay, 2016).

- Regulation should focus on area-specific regulations to optimize urban land use (NITI Aayog, 2021). The streetscape can be managed using façade control, but regulations must allow flexibility in the open-to-built ratio. This enables designers to freely create designs based on family structure, lifestyle, environment, sustainability, and other factors.
- Basic screening of day lighting of houses must be done during map approval stage. Using Daylight simulation software to assess how varying building orientations and spatial arrangements will impact the natural light intake of a space

### **Recommendations for Lucknow**

The detailed study of Lucknow Byelaws (Bhawan Nirman And Vikas Upvidhi 2008, Source: <https://www.ldaonline.com>) identified various observations in the regulation which are listed below and need to be taken care of at the time of releasing amendments in building byelaws (Appendices –D1).

- It is advised to review the setback regulations for Lucknow in order to have more daylight at rear side of houses throughout the year. The guidelines in Lucknow suggested for 7.5 sq m area inner court which is not appropriate. The analysis of the prototype suggested this open area does not suffice the daylight requirement of the living area.
- The study, using the case of Lucknow, revealed that the margin requirements for different plot proportions are not properly addressed. Plot margins are guiding factor for deciding the building envelope. Different plot ratios can lead to a variety of housing typologies, catering to diverse needs and preferences. For instance narrow plots achieve compact planning with efficiency in land and infrastructure planning.
- Further it has been observed that plot proportion plays a crucial role in ground coverage's. However building Bye-laws of Lucknow has capping of ground coverage for different size of plot. But this ultimately results in uneven building line and consequentially disturbs the street elevation.
- There are no specific guidelines regarding the fenestration and architectural elements which must be taken into account for cohesive development. The Regulatory Bye-laws suggest 10 % fenestration of the carpet area of the room, though the wall-to-window ratio is not taken into consideration. In contrast to existing regulations, the present research has indicated that the orientation plays a crucial role in daylight potential; therefore WWR for each orientation of residential buildings should be different. The guidelines for internal

open spaces are rigid and do not have any practical implications. This must adhere to the guidelines of Eco-Niwas Samhita 2018.

- In the case of 350-400 sq. m plot for the Lucknow Bye-laws the permissible ground coverage is more than the achieved ground coverage after marking the setback lines for any plot proportion. In order to achieve full potential of ground coverage designer do not get flexibly for designing open space. Therefore it is suggested that permissible ground coverage and achieved ground coverage must be in sync in each plot size and proportion
- Rear setbacks are most unutilized space and more prone to the violation of Bye-laws ((Boob & Rao, 2014)(Byahut et al., 2020). The Lucknow Bye-laws permitted 40 % of coverage setback up to 7 m height. It is very difficult to monitor the extent of coverage in rear setback. The guideline of 40 % does not describe from which side this area could be covered except for the corner plots. If the user covered area from both side of plot boundaries along with permissible projection this will further reduce the open space. The liveable areas in the back do not get access to natural light. Sometimes due to a violation and other times due to inappropriate designs.
- It has been noted that the permitted rear and front set back in the case of Lucknow are of similar width. Therefore, the two open spaces that are split reduce the quality of open space. Open spaces that are fragmented cannot meet the user's psychological needs. However front setback is quite necessary to maintain the uniform streetscape, future infrastructure expansion and providing space for soft-scape which enhance groundwater recharge and reduce runoff. The concept of providing rear open space is more effective than rigid setback lines for the rear side, allowing designers the flexibility to locate the open space based on daylight requirements, thermal comfort, and the functional needs of the space.
- The expert survey revealed that 1:2 plot proportions is the most acceptable for designing a house, however it is not efficient in terms of ground coverage as in case of Jaipur where the permissible ground coverage is within setback line. In case of Lucknow due to limitation of ground coverage, any plot proportion can be adopted as per the area specific needs.
- The calculated number of storey for different plot sizes and proportions based on F.A.R calculation must be in absolute number for effective monitoring of bye laws violation.

#### **6.4. RESEARCH CONTRIBUTIONS TO KNOWLEDGE**

The courtyard housing typology provides multiple strategies for the sustainable built form, based on its long evolution in India. The reuse of the vernacular courtyard form in contemporary houses provides environmental performance that can be combined with modern technologies. This

research provides detailed insights into how the courtyard housing typology contributes novel ideas to sustainable architecture that is not only environmentally responsible but also socially relevant.

As mentioned before, there is a shortage of realistic studies on contemporary courtyard housing in Lucknow. Most of the researches are focused on the environmental behaviour of the courtyard. However practical guide for implementation of this space in new development is missing. This research provides new insights on this understudied relationship of current building regulation and typology while making novel connections between traditional and contemporary housing design principles. The derived prototype designs can be utilized for any plot sizes and proportion of plot.

## **6.5. SCOPE FOR FURTHER RESEARCH**

The study focused on the environmental and social aspects of courtyard housing and did not substantially address economic issues. Future studies could provide insights into costs and benefits related to design, construction, and occupancy. This would provide another dimension to the study of courtyard housing.

The study focused on single-family courtyard housing and this restricts the study findings to a particular housing configuration up to plot size of 500 sq.m. Future studies could examine courtyard housing at a group housing scale to determine whether this changes findings with respect to neighbours, privacy, noise, the sharing of common courtyards, and other issues.

Building regulation has been studied up to the context of residential norms, though urban scale parameters can be included in the study to check the impact of these parameters on typologies.



## BIBLIOGRAPHY

- Abass, F., Ismail, L. H., & Solla, M. (2016). A review of courtyard house: History evolution forms, and functions. *ARNP Journal of Engineering and Applied Sciences*, 11(4), 2557–2563.
- Abdulkareem, H. A. (2016). Thermal Comfort through the Microclimates of the Courtyard. A Critical Review of the Middle-eastern Courtyard House as a Climatic Response. *Procedia - Social and Behavioral Sciences*, 216(October 2015), 662–674.  
<https://doi.org/10.1016/j.sbspro.2015.12.054>
- Adegun, O. B., Adedeji, J. M., & Adedeji, Y. M. D. (2019). Whither the courtyards? Understanding disappearance and transformation of courtyards in residential buildings in Akure, Nigeria. *IOP Conference Series: Materials Science and Engineering*, 640(1).  
<https://doi.org/10.1088/1757-899X/640/1/012010>
- Agarwal, S., & Thussu, M. (2020). Conception of open spaces- A Case of Delhi Courtyard Houses. *Journal of Science and Technology*, 05(Volume 5), 87–105.  
<https://doi.org/10.46243/jst.2020.v5.i4.pp87-105>
- Al-Hafith, O., Satish, B. K., Bradbury, S., & De Wilde, P. (2017). The impact of courtyard compact urban fabric on its shading: Case study of Mosul city, Iraq. *Energy Procedia*, 122, 889–894. <https://doi.org/10.1016/j.egypro.2017.07.382>
- Al-Masri, N., & Abu-Hijleh, B. (2012). Courtyard housing in midrise buildings: An environmental assessment in hot-arid climate. *Renewable and Sustainable Energy Reviews*, 16(4), 1892–1898. <https://doi.org/10.1016/j.rser.2012.01.008>
- Al-zamil, F. (n.d.). *Interior Courtyard and its Impact on the Well-being of Inhabitants*.
- Alapure, G. M., George, A., & Bhattacharya, S. P. (2017). *Climate Responsiveness of Wada Architecture*. 29–35. [https://doi.org/10.1007/978-981-10-2138-1\\_3](https://doi.org/10.1007/978-981-10-2138-1_3)
- Aldawoud, A. (2008). Thermal performance of courtyard buildings. *Energy and Buildings*, 40(5), 906–910. <https://doi.org/10.1016/j.enbuild.2007.07.007>
- Ali, S., Sharma, M. R., & Maiteya, V. K. (1993). Climatic classification for building design in india. *Architectural Science Review*, 36(1), 31–36.  
<https://doi.org/10.1080/00038628.1993.9696730>
- Almhafdy, A., Ibrahim, N., Ahmad, S. S., & Yahya, J. (2013). Analysis of the Courtyard

- Functions and its Design Variants in the Malaysian Hospitals. *Procedia - Social and Behavioral Sciences*, 105, 171–182. <https://doi.org/10.1016/j.sbspro.2013.11.018>
- Almhafdy, A., Ibrahim, N., Ahmad, S. S., & Yahya, J. (2015). Thermal Performance Analysis of Courtyards in a Hot Humid Climate Using Computational Fluid Dynamics CFD Method. *Procedia - Social and Behavioral Sciences*, 170, 474–483. <https://doi.org/10.1016/j.sbspro.2015.01.012>
- Amiriparyan, P., & Kiani, Z. (2016). Analyzing the Homogenous Nature of Central Courtyard Structure in Formation of Iranian Traditional Houses. *Procedia - Social and Behavioral Sciences*, 216(October 2015), 905–915. <https://doi.org/10.1016/j.sbspro.2015.12.087>
- Azad, S. P., Morinaga, R., & Kobayashi, H. (2018). Effect of housing layout and open space morphology on residential environments –applying new density indices for evaluation of residential areas case study: Tehran, Iran. *Journal of Asian Architecture and Building Engineering*, 17(1), 79–86. <https://doi.org/10.3130/jaabe.17.79>
- Bagneid, A. (2020). *THE CREATION OF A COURTYARD MICROCLIMATE THERMAL MODEL FOR THE ANALYSIS OF COURTYARD HOUSES*. November.
- Bahga, S., & Raheja, G. (2020). Complexities of practicing architectural regionalism in India: An interview study. *Frontiers of Architectural Research*, 9(3), 568–578. <https://doi.org/10.1016/j.foar.2020.03.003>
- Boob, T. N., & Rao, Y. R. M. (2014). Zoning within Plot – An Approach to Land Sub Division to Control Violation of Development Control Rules. *International Journal of Multidisciplinary and Current Research*, 2(4), 48–59.
- Bouwkunde, B., Discipline, W., & Varghese, P. (2016). *The Anglo-Indian Bungalow : A Colonial Architecture of the British Raj and its Social Impact*. 1–10.
- Brauneck, G. P. and P. (2007). *Courtyard houses\_ a housing typology - Gunter Pfeifer.pdf*. Birkhauser Verlag. <https://doi.org/10.1007/978-3-7643-7922-3>
- Brian Edwards, Magda Sibley, Mohammad Hakmi, P. L. (2006). Courtyard Housing Past, Present and Future. In *Taylor & Francis* (Issue 1). <https://doi.org/10.4324/9780203646724>
- Bulus, M., Hamid, M., & Lim, Y. W. (2017). Courtyard as a Passive Cooling Strategy in Buildings. *International Journal of Built Environment and Sustainability*, 4(1), 48–55. <https://doi.org/10.11113/ijbes.v4.n1.159>
- Byahut, S., Patel, B., & Mehta, J. (2020). Emergence of sub-optimal land utilization patterns in

- Indian cities. *Journal of Urban Design*, 25(6), 758–777.  
<https://doi.org/10.1080/13574809.2020.1752646>
- Cremers, J., Peter Bonfig, & BleicherVolkmar. (2015). High Density - High Privacy - Low Energy , Re-Interpretation of , Compact ‘ Courtyard Housing for Sustainable Urban Environments. *Plea 2015 Bologna: Architecture in (R)Evolution*.
- Dabe, T. J., & Adane, V. S. (2018). The impact of building profiles on the performance of daylight and indoor temperatures in low-rise residential building for the hot and dry climatic zones. *Building and Environment*, 140, 173–183.  
<https://doi.org/10.1016/j.buildenv.2018.05.038>
- Day, J. K., & Gunderson, D. E. (2018). Mixed Methods in Built Environment Research. *54th ASC Annual International Conference Proceedings, 2002*, 255–264.
- Desai, M., & Desai, M. (2011). The colonial bungalow in India. *The Newsletter*, 57, 26–27.
- Dokras, S., & Stockholm, U. D. (n.d.). *BUNAGLOWS ... then and now*. 1–17.
- Dougallii, S. H. A. N. D. S. (1972). Rural Dwellings and House Types. *Personality and Classroom-Seating*, 28(1 989), 374–379.
- Elantary, A. R., & Eldeeb, A. S. (2023). Courtyard Existence between the Past and the Present, Case Study: Central Region, Saudi Arabia. *Civil Engineering and Architecture*, 11(2), 675–695. <https://doi.org/10.13189/cea.2023.110211>
- Elmansuri, S. (2018). *Courtyard Housing in Tripoli: Tradition, Modernity and Users’ Perceptions*.
- Elwerfalli, M. (2016). *Contemporary Courtyard Houses of Libya: New Directions in Sustainable Housing Development*. 1–341.
- Emhemed, A. E. (2005). *Comprehensive Approach to Housing Legislation Thesis submitted for the degree of*.
- Erdemir Kocagil, İ., & Koçlar Oral, G. (2016). The effect of solar heat gain on climate responsive courtyard buildings. *A/Z ITU Journal of the Faculty of Architecture*, 13(2), 39–46.  
<https://doi.org/10.5505/itujfa.2016.93898>
- Ferreira, T., Bournas, I., & Dubois, M. C. (2019). Effect of atrium geometry and reflectance on daylighting in adjacent rooms. *Journal of Physics: Conference Series*, 1343(1).  
<https://doi.org/10.1088/1742-6596/1343/1/012167>

- Freewan, A. A. (2011). Modifying Courtyard Wall Geometries to Optimize the Daylight Performance of the Courtyard. *Smart Innovation, Systems and Technologies*, 7, 57–64. [https://doi.org/10.1007/978-3-642-17387-5\\_6](https://doi.org/10.1007/978-3-642-17387-5_6)
- Gangwar, G. (2016). Environmental, Behavioural and Aesthetic aspects of Courtyard Design: Literature Review. *Imperial Journal of Interdisciplinary Research (IJIR)*, 2(9), 1712–1716.
- Gangwar, G., & Kaur, P. (2020a). Traditional Pol houses of ahmedabad: An overview. *Civil Engineering and Architecture*, 8(4), 433–443. <https://doi.org/10.13189/cea.2020.080405>
- Gangwar, G., & Kaur, P. (2020b). User's perception of the relevance of courtyard designs in a modern context: A case of traditional pol houses, Ahmedabad. *Civil Engineering and Architecture*, 8(3), 379–389. <https://doi.org/10.13189/cea.2020.080323>
- GAUTAM, A. (2008). CLIMATE RESPONSIVE VERNACULAR ARCHITECTURE: JHARKHAND, INDIA. In *Thesis,2003: Vol. 49* (المجلة العلمية للعلوم (Issue المجلد 49)).
- Grosso, M. (1998). Urban form and renewable energy potential. *Renewable Energy*, 15(1–4 pt 1), 331–336. [https://doi.org/10.1016/S0960-1481\(98\)00182-7](https://doi.org/10.1016/S0960-1481(98)00182-7)
- Guedouh, M. S., & Zemmouri, N. (2017). Courtyard Building ' s Morphology Impact on and Thermal and Cooling and Courtyard Building ' s Morphology Impact on Thermal Luminous Environments in Hot and Arid Region Luminous Environments in Hot a. *Energy Procedia*, 119, 153–162. <https://doi.org/10.1016/j.egypro.2017.07.063>
- Guedouh, M. S., Zemmouri, N., Hanafi, A., & Qaoud, R. (2019). Passive Strategy Based on Courtyard Building Morphology Impact on Thermal and Luminous Environments in Hot and Arid Region. *Energy Procedia*, 157, 435–442. <https://doi.org/10.1016/J.EGYPRO.2018.11.208>
- Gulati, R., & Pandya, Y. (2014). Comparative Thermal Performance of Vernacular Houses at Lucknow : A Quantitative. *30th INTERNATIONAL PLEA CONFERENCE, December*, 1–8.
- Gulati, R., Sehgal, V., Qamruddin, J., & Raushan, A. S. (2019). Architectural Spaces as Socio-Cultural Connectors: Lessons from the Vernacular Houses of Lucknow, India. *ISVS E-Journal*, 6(4), 30–48.
- Gupta, J., Chakraborty, M., Paul, A., & Korrappatti, V. (2017). A comparative study of thermal performances of three mud dwelling units with courtyards in composite climate. *Journal of Architecture and Urbanism*, 41(3), 184–198. <https://doi.org/10.3846/20297955.2017.1355276>

- Gupta, R., & Joshi, M. (2021). Courtyard: A look at the relevance of courtyard space in contemporary houses. *Civil Engineering and Architecture*, 9(7), 2261–2272.  
<https://doi.org/10.13189/cea.2021.090713>
- Hui, E. C. M. (2001). Planning and development control through lease conditions. *Habitat International*, 25(4), 599–615. [https://doi.org/10.1016/S0197-3975\(01\)00028-5](https://doi.org/10.1016/S0197-3975(01)00028-5)
- Imrie, R. (2007). The interrelationships between building regulations and architects' practices. *Environment and Planning B: Planning and Design*, 34(5), 925–943.  
<https://doi.org/10.1068/b33024>
- Imsong, R., & Kumar, A. (2023). Building Regulations for North Eastern Region of India. *Bhutan Journal of Research and Development*, 2. <https://doi.org/10.17102/bjrd.rub.se2.037>
- Indraganti, M. (2010). Understanding the climate sensitive architecture of Marikal, a village in Telangana region in Andhra Pradesh, India. *Building and Environment*, 45(12), 2709–2722.  
<https://doi.org/10.1016/j.buildenv.2010.05.030>
- Jansen, M. (1985). Mohenjo-Daro, city of the Indus Valley. *Endeavour*, 9(4), 161–169.  
[https://doi.org/10.1016/0160-9327\(85\)90072-9](https://doi.org/10.1016/0160-9327(85)90072-9)
- Jawaid, M. F., Pipralia, S., & Kumar, A. (2018). Review of environment responsiveness of building regulations in Jaipur. *Journal of Urban Management*, 7(2), 111–120.  
<https://doi.org/10.1016/j.jum.2018.06.001>
- Jayasudha, P., Dhanasekaran, M., Devadas, M. D., & Ramachandran, N. (2014). A study on sustainable design principles: A case study of a vernacular dwelling in Thanjavur region of Tamil Nadu, India. *Indian Journal of Traditional Knowledge*, 13(4), 762–770.
- Kamal, M. A. (2021). Assessment of traditional architecture of lucknow with reference to climatic responsiveness. *Architecture and Engineering*, 6(1), 19–31. <https://doi.org/10.23968/2500-0055-2021-6-1-19-31>
- Karani, M. (2014). Understanding Vernacular: Vastu Shastra and Carl Jung's theories of Psychology. *ISVS E-Journal*, 3(1), 20–29.
- Kedissa, C., Outtas, S., & Belarbi, R. (2016). The impact of height/width ratio on the microclimate and thermal comfort levels of urban courtyards. *International Journal of Sustainable Building Technology and Urban Development*, 7(3–4), 174–183.  
<https://doi.org/10.1080/2093761X.2017.1302830>
- Khalili, S. (2017). The Courtyard House. In *The Courtyard House*.

<https://doi.org/10.4324/9781315086866>

- Khan, F. . (2015). Sustainable development: Environmental law with reference to town and country planning. *ITPI Journal*.
- Khan, S. S. (2020). SPATIALLY ADAPTIVE COURTYARD MODELS FOR HIGH-DENSITY, MULTI-STORIED RESIDENTIAL DEVELOPMENTS IN BANGLADESH. In *The Pennsylvania State University* (Vol. 68, Issue 1).  
<http://dx.doi.org/10.1016/j.ndteint.2014.07.001><https://doi.org/10.1016/j.ndteint.2017.12.003><http://dx.doi.org/10.1016/j.matdes.2017.02.024>
- Kim, S. (2001). *Optimising Courtyard Housing Design for Solar Radiation Within Dense Urban Environments*.
- Kisan, M., Sangathan, S., Nehru, J., & Pitroda, S. G. (2005). *NBC*.
- Kocagil, I. E., & Oral, G. K. (2015). The effect of building form and settlement texture on energy efficiency for hot dry climate zone in Turkey. *Energy Procedia*, 78(2315), 1835–1840.  
<https://doi.org/10.1016/j.egypro.2015.11.325>
- Kumar, A., & Pushplata. (2017). Problems and prospects of building regulations in Shimla, India – A step towards achieving sustainable development. *International Journal of Sustainable Built Environment*, 6(1), 207–215. <https://doi.org/10.1016/j.ijbsbe.2017.03.009>
- Kumar, V. (2014). Representation of Traditional Architecture in The context of Sustainability: a Case of Traditional Kerala Architecture. *JOURNAL OF INTERNATIONAL ACADEMIC RESEARCH FOR MULTIDISCIPLINARY Impact Factor 1*, 393(5), 282. [www.jiarm.com](http://www.jiarm.com)
- Lalit Akash Verma, F. B. (2021). Methodology for Effective Daylighting in Courtyard Houses of Composite Climate. *International Journal of Innovative Technology and Exploring Engineering*, 10(5), 103–116. <https://doi.org/10.35940/ijitee.e8687.0310521>
- Lall, A. B., Pandit, M., Kulshreshta, N., & Appasamy, P. (1991). Climate and housing form - a case study of New Delhi. *Energy and Buildings*, 16(3–4), 837–849.  
[https://doi.org/10.1016/0378-7788\(91\)90079-i](https://doi.org/10.1016/0378-7788(91)90079-i)
- Lau, S. S. Y., & Yang, F. (2009). Introducing healing gardens into a Compact University Campus: Design natural space to create healthy and sustainable campuses. *Landscape Research*, 34(1), 55–81. <https://doi.org/10.1080/01426390801981720>
- Lee, M.-S., & Park, Y. (2015). The Courtyard as a Microcosm of Everyday Life and Social Interaction. *Architectural Research*, 17(2), 65–74. <https://doi.org/10.5659/aikar.2015.17.2.65>

- Luo, X., & Huang, J. (2022). The Exploration of New Courtyard Architecture Based on the Guidance of Architectural Culture and Technology. *Advances in Civil Engineering*, 2022. <https://doi.org/10.1155/2022/5029647>
- Madangopal, A. S. (2015). *The Role of Building Byelaws in Shaping the Sustainable Built Environment - Comparative Analysis Between Portland Building Byelaws with Bangalore Building byelaws* .
- Maddipati, V. (2020). Gandhi and Architecture. *Gandhi and Architecture*, October. <https://doi.org/10.4324/9780429262517>
- Majeed, M. N., Mustafa, F. A., & Husein, H. A. (2019). Impact of building typology on daylight optimization using building information modeling: Apartments in Erbil city as a case study. *Journal of Daylighting*, 6(2), 187–201. <https://doi.org/10.15627/jd.2019.17>
- Malik, S., & Hassan, K. A. K. (2019). An investigation of house designs in Lahore: Transformation of residential architecture from traditional to modern. *Journal of Design and Built Environment*, 19(1), 49–59. <https://doi.org/10.22452/jdbe.vol19no1.5>
- Marafa, A. K., & Alibaba, H. Z. (2018). *User Perception of Courtyard as a Thermal User Perception of Courtyard as a Thermal Regulator in Households , Famagusta , Cyprus. January.*
- Markus, B. (2016). Review of Courtyard House in Nigeria: definitions, history, evolution, typology, and functions. *AFRREV STECH: An International Journal of Science and Technology*, 5(2), 103. <https://doi.org/10.4314/stech.v5i2.8>
- Meir, I. A. (2000). Courtyard microclimate: A hot arid region case study. *Architecture City Environment, Proceedings of the 17th PLEA International Conference, Cambridge, James & James, London, September*, 218–223. <https://doi.org/10.13140/2.1.3085.4403>
- Meir, I. A., Pearlmutter, D., & Etzion, Y. (1995). On the microclimatic behavior of two semi-enclosed attached courtyards in a hot dry region. *Building and Environment*, 30(4), 563–572. [https://doi.org/10.1016/0360-1323\(95\)00018-2](https://doi.org/10.1016/0360-1323(95)00018-2)
- Mezerdi, T., Belakehal, A., & Sfaksi, I. (2022). Impact of the socio-environmental quality of the courtyard house on occupant satisfaction: The case of M'chouneche oasis, Algeria. *International Review for Spatial Planning and Sustainable Development*, 10(1), 74–98. [https://doi.org/10.14246/IRSPSD.10.1\\_74](https://doi.org/10.14246/IRSPSD.10.1_74)
- Ministry of Urban Development, G. of I. (2014). Urban and Regional Development Plans

- Formulation and Implementation (URDPFI) Guidelines. *Town and Country Planning Organisation (TCPO) (2014). Urban*, 65–69. <https://doi.org/10.1201/9781482293500-22>
- Mishra, A. K. (2019). Development of Building Bye-Laws in Nepal. *Journal of Advanced Research in Construction & Urban Architecture*, 04(3&4), 17–29. <https://doi.org/10.24321/2456.9925.201904>
- Mohammad-Moradi, A., Ali Khan-Mohammadi, M., & Pour-Ahmadi, M. (2017). *Basic Studies and New Technologies of Architecture and Planning Challenges of Using Building Regulations in Architecture from the Perspective of Design Research*. 4, 6–10. [www.http://bsnt.modares.ac.ir/](http://bsnt.modares.ac.ir/)
- Mohammed Al-Hussayen. (2015). Significant characteristics and design considerations of the courtyard house. *Journal of Architectural & Planning Research*, 12(3), 240–258.
- Muhaisen, A. S. (2006). Shading simulation of the courtyard form in different climatic regions. *Building and Environment*, 41(12), 1731–1741. <https://doi.org/10.1016/j.buildenv.2005.07.016>
- Müller-Bloch, C., & Kranz, J. (2015). A framework for rigorously identifying research gaps in qualitative literature reviews. *2015 International Conference on Information Systems: Exploring the Information Frontier, ICIS 2015*, 1–19.
- Municipal corporation, lucknow. (2015). January 2015. *City Development Plan ,Lucknow*, 48(3), 315–315. [https://doi.org/10.1162/leon\\_r\\_01045](https://doi.org/10.1162/leon_r_01045)
- Myneni, K. K. (2022). Study about Courtyard as a Building Component: Role and Application in Developing a Traditional Built form in Athangudi Village, India. *Research Developments in Arts and Social Studies Vol. 5, 1(4)*, 140–152. <https://doi.org/10.9734/bpi/rdass/v5/2852a>
- Nair, D. G., Enserink, B., Gopikuttan, G., Vergragt, P., Fraaij, A., & Dalmeijer, R. (2005). A Conceptual Framework for Sustainable-Affordable Housing for the Rural Poor in Less Developed Economies. *The 2005 World Sustainable Building Conference, 2005(September)*, 4429–4436. <https://doi.org/10.13140/2.1.4140.7687>
- Narang, R. (2013). *CRITICAL ANALYSIS OF TRADITIONAL ARCHITECTURE OF COASTAL ODISHA WITH SPECIAL REFERENCE TO MAHURA VILLAGE, KHURDA*. 16(22), 119–128.
- Nelson, R. (2014). The Courtyard Inside and Out: a Brief History of an Architectural Ambiguity. *Enquiry The ARCC Journal for Architectural Research*, 11(1), 10.



<https://doi.org/10.17831/enq:arcc.v11i1.206>

- Nibedita Das. (2006). *Courtyards Houses of Kolkata : Bioclimatic , Typological and Socio-Cultural Study by Nibedita Das Submitted in partial fulfillment of the requirements for the degree Department of Architecture.*
- Nikeghbali, S. (2017). Adapting Design Principles of Traditional Courtyard Housing for Future Urban Design. *Journal of Sustainable Development*, 10(6), 200.  
<https://doi.org/10.5539/jsd.v10n6p200>
- NITI Aayog. (2021). Reforms in urban planning capacity in india. *Government of India, September*, 144. <https://www.niti.gov.in/sites/default/files/2021-09/UrbanPlanningCapacity-in-India-16092021.pdf>
- Norbert Schoenauer & Stanley Seeman. (1962). *The court-garden house*. McGill University Press, Montreal,.
- Nugroho, A. M., Citraningrum, A., Iyati, W., & Ahmad, M. H. (2020). Courtyard as tropical hot humid passive design strategy: Case study of Indonesian contemporary houses in Surabaya Indonesia. *Journal of Design and Built Environment*, 20(2), 1–12.  
<https://doi.org/10.22452/jdbe.vol20no2.1>
- Patherya, M., & Lau, B. (2012). Assessment of the behaviour of “courtyards” as a design element in India and its implication as an environmental solution. *Proceedings - 28th International PLEA Conference on Sustainable Architecture + Urban Design: Opportunities, Limits and Needs - Towards an Environmentally Responsible Architecture, PLEA 2012, November.*
- Patwardhan, A. (2017). Architecture : An Heirloom in the Context of Chettinad , India. *Athens: ATINER 'SATINER 'S Conference Paper Series ARC2017-2393*, 1–28.
- Pawar, P., Zhang, D., & Wu, X. (2019). *Effect of atrium geometry and reflectance on daylighting in adjacent rooms* *Effect of atrium geometry and reflectance on daylighting in adjacent rooms*. <https://doi.org/10.1088/1742-6596/1343/1/012167>
- Phot, S. (n.d.). *and their elements as the perfect perfect spatial organisation of those*. 18–21.
- Pradesh, A. (2020). *People ' s Acceptance of Vernacular Houses : The case of Ghantasala , . April.*
- Qureshi, R. A., Akhtar, M., & Shah, S. J. (2019). *Deep Beauty in Architecture : Comparative Analysis of the Traditional-Courtyard and the Contemporary Residences of Lahore*. 25, 64–79.

- Rajapaksha, I., Nagai, H., & Okumiya, M. (2003). A ventilated courtyard as a passive cooling strategy in the warm humid tropics. *Renewable Energy*, 28(11), 1755–1778.  
[https://doi.org/10.1016/S0960-1481\(03\)00012-0](https://doi.org/10.1016/S0960-1481(03)00012-0)
- Rapoport, A. (1995). The Nature of the Courtyard House: A Conceptual Analysis. *Nueva Antropología*, XIV(48), 111–113.
- Ratti, C., Raydan, D., & Steemers, K. (2003). Building form and environmental performance: Archetypes, analysis and an arid climate. *Energy and Buildings*, 35(1), 49–59.  
[https://doi.org/10.1016/S0378-7788\(02\)00079-8](https://doi.org/10.1016/S0378-7788(02)00079-8)
- Sadanand, A., & Nagarajan, R. V. (2020). Transition Spaces in an Indian Context. *Athens Journal of Architecture*, 6(3), 193–224. <https://doi.org/10.30958/aja.6-3-1>
- Samhita, E. (2018). *Energy Conservation Building Code for Residential Building Eco-Niwas Samhita 2018 Understanding of Eco-Niwas Samhita Electricity consumption pattern in India*. 1–61.
- Samir, G. M. (2015). Daylight Efficiency Prediction of Courtyard vs . Conventional Building Models Using Simulation Tool under Specific Climate Conditions. *International Scientific Journal Journal of Environmental Science*, May. <http://environment.scientific-journal.com/%0ADaylight>
- Sanjune, S., & Guneratne, and S. (2018). Proceedings morphology of the evolving courtyard with special reference to light house hotel in galle. *11TH INTERNATIONAL RESEARCH CONFERENCE GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY*.
- Sinha, A. (1990). From Tradition to Modernity: The role of the dwelling in social change. *Environmental Design Research Association*, 21, 157–162.
- Soflaei, F., Shokouhian, M., & Soflaei, A. (2017). Traditional courtyard houses as a model for sustainable design: A case study on BWHS mesoclimate of Iran. *Frontiers of Architectural Research*, 6(3), 329–345. <https://doi.org/10.1016/j.foar.2017.04.004>
- Soflaei, F., Shokouhian, M., Tabadkani, A., Moslehi, H., & Berardi, U. (2020). A simulation-based model for courtyard housing design based on adaptive thermal comfort. *Journal of Building Engineering*, 31, 101335. <https://doi.org/10.1016/J.JOBE.2020.101335>
- Sridhar, K. S. (2010). Impact of land use regulations: Evidence from India's cities. *Urban Studies*, 47(7), 1541–1569. <https://doi.org/10.1177/0042098009353813>
- Sthapak, S., & Bandyopadhyay, A. (2014). Courtyard houses: An overview. *Recent Research in*

*Science and Technology*, 6(1), 70–73.

- Sudhira, H. S., Ramachandra, T. V., & Jagadish, K. S. (2004). Urban sprawl: Metrics, dynamics and modelling using GIS. *International Journal of Applied Earth Observation and Geoinformation*, 5(1), 29–39. <https://doi.org/10.1016/j.jag.2003.08.002>
- Tablada, A., Blocken, B., Carmeliet, J., De Troyer, F., & Verschure, H. (2005a). Geometry of Building's Courtyards to Favour Natural Ventilation: Comparison Between Wind Tunnel Experiment and Numerical Simulation. *The 2005 World Sustainable Building Conference in Tokyo*, 8. <http://www.sb05.com/>
- Tablada, A., Blocken, B., Carmeliet, J., De Troyer, F., & Verschure, H. (2005b). The influence of courtyard geometry on natural ventilation and thermal comfort: CFD and thermal comfort simulations. *22nd International Conference, PLEA 2005: Passive and Low Energy Architecture - Environmental Sustainability: The Challenge of Awareness in Developing Societies, Proceedings*, 1(January), 75–80.
- Taleghani, M., & Tenpierik, M. (1986). Environmental Impact of Courtyards — a Review and Comparison of Residential. *Journal of Green Building*, 7(2), 113–136.
- Taleghani, M., Tenpierik, M., van den Dobbelen, A., & Sailor, D. J. (2014). Heat in courtyards: A validated and calibrated parametric study of heat mitigation strategies for urban courtyards in the Netherlands. *Solar Energy*, 103, 108–124. <https://doi.org/10.1016/j.solener.2014.01.033>
- Tayari, N., & Nikpour, M. (2022). Investigation on Daylight Quality of Central Courtyard's Adjacent Rooms in Traditional Houses in Hot Dry Region of Iran: A Case Study Yazdanpanah House. *Iranian Journal of Energy and Environment*, 13(4), 320–332. <https://doi.org/10.5829/ijee.2022.13.04.01>
- Taylor, J. L., Lea, J., New, T. S., & Wales, S. (2008). *the Great Houses of Kolkata 1750-2006*.
- TERI 2006, Associate, P., Team, T., Seth, S., Fellow, A., Associate, P., Reviewer, T., Architect, P., Architects, A. B. L., Team, S., Kumar, D., Officer, A., Jha, R. K., & Nipane, V. (n.d.). *TERI. 2006*.
- Van der Straaten. (2021). Europe's evolution of atrium houses. *Thesis*.
- Vedhajanani, B., & Amirtham, L. R. (2023). Links Between Culture, Social Benefits and Courtyards: The Traditional and the Transformed Courtyard Houses of Kumbakonam, Tamil Nadu, India. *ISVS E-Journal*, 10(4), 24–37.

- Verma, L. A., & Bano, F. (2023). Socio-Environmental Sustainability of Traditional Courtyard Houses of Lucknow and Varanasi. *U.Porto Journal of Engineering*, 9(1), 72–103.  
[https://doi.org/10.24840/2183-6493\\_009-001\\_001438](https://doi.org/10.24840/2183-6493_009-001_001438)
- Widiastuti, I. (2019). *TYPOLOGY STUDY OF VERNACULAR COURTYARD-HOUSE IN KERALA , SOUTH*. December 2018. <https://doi.org/10.5614/sostek.itbj.2018.17.3.4>
- Yasmin, D. (2022). Dwelling Morphology of Courtyard Houses in Old Dhaka: A Study on Spatial Adaptations. *DUET Journal*, 8(1), 13–23.
- YU, N. (2002). *THE URBAN COURTYARD HOUSING FORM AS A RESPONSE TO HUMAN NEEDS, CULTURE AND ENVIRONMENT*.
- Zamani, Z., Heidari, S., & Hanachi, P. (2018). Reviewing the thermal and microclimatic function of courtyards. *Renewable and Sustainable Energy Reviews*, 93(March 2017), 580–595.  
<https://doi.org/10.1016/j.rser.2018.05.055>
- Zhang, D. (2020). Courtyard Houses around the World: A Cross-Cultural Analysis and Contemporary Relevance. *New Approaches in Contemporary Architecture and Urbanism*, May, 23–44. <https://doi.org/10.38027/n3iccaua316235>

## APPENDICES

### Appendices -A1: Questionnaire for users of courtyard and Non courtyard house

#### Questionnaire Survey

Research title: Assessing the impact of the courtyard in the housing typologies of low rise, medium density urban settlements.

Objective: **To validate the unanimity among the experts and end users regarding the importance of the courtyard concept and the need for its adoption in residential units.**

Dear Respondent,

I would be grateful if you could take part in the above titled study. The study is about the change and continuity in the Indian homes' layout and use (form & function), considering the courtyard-house concept in traditional and modern context. Data collected will only be used for this study and all information given will be kept confidential. Your anonymity will be also completely considered.

Thanks for participation

This questionnaire is part of a research project for doctorate in philosophy (Ph.D.).

#### SECTION A

##### I. GENERAL INFORMATION

Name: .....

Email id.....

Age: .....

Gender.....

Religion.....

Approx. size of House .....

Family type:

Joint

Nuclear

Type of Open space

Courtyard

Other open space(Front Lawn/Rear Lawn/Balcony

**SECTION B**

(Users' perceptions about the use of open spaces in home, please tick your answer)

**II. FUNCTIONAL PARAMETERS**

**1. How many Open space (suitable size) are there in your house.**

- One
- Two
- Three
- None

**2. For which purpose you use your open spaces?**

- Domestic Activities (Washing, Cloths drying etc.)
- Sitting and relaxing
- Storage
- Ornamentation (Plants and Decoration)

**3. How do you furnish your domestic open space?**

- Table & chairs
- Washing line
- Water feature & plants
- Bins or Household Utilities

**4. How the following spaces are connected with the open spaces of house**

Kitchen	Physically <input type="checkbox"/>	Visually <input type="checkbox"/>
Drawing Room	Physically <input type="checkbox"/>	Visually <input type="checkbox"/>
Living room	Physically <input type="checkbox"/>	Visually <input type="checkbox"/>
Bedroom	Physically <input type="checkbox"/>	Visually <input type="checkbox"/>

**5. Do the open areas of your house provide sufficient level of privacy?**

Yes No

**6. Do you feel that your home's layout maintains the required level of connection between the floors?**

Yes No

**7. Do you have proper space in your house for small family gatherings or functions (Like puja, Birthday celebration etc.**

Yes No

**8. Do you use your open space for daily household activities**

Yes No

### III. ENVIRONMENTAL PARAMETERS

9. Does the open space provide sufficient light to all the habitable spaces?  
Yes No
10. Do the open spaces of your house provide any kind of thermal comfort to the adjacent spaces?  
Yes No
11. Does the open space provide sufficient ventilation and air movement within the house?  
Yes No
12. Which is your most preferred time in the open space of your house?  
Morning Evening Noon Night
13. Which is your most uncomfortable time in open space of your house?  
Morning Evening Noon Night
14. In which season these open spaces creates maximum comfort.  
Summer Winter Monsoon
15. In which season these open spaces creates maximum discomfort.  
Summer Winter Monsoon
16. Do you feel that present houses need more mechanical devices (like fan or AC) for achieving comfort due to absence of central open spaces?  
Yes No

### IV. RELIGIOUS AND CULTURAL PARAMETERS

17. Does the courtyard possess any traditional, cultural or religious value?  
Yes No
18. Do you agree courtyard is the basic element of Vaastu in residential architecture ?  
Yes No

### V. PSYCHOLOGICAL PARAMETER

19. If given a choice, would you like reside in courtyard type house.  
Yes No
20. Do you agree that a well-designed courtyard(open to sky) affect the Psychological well-being of resident  
Yes No
21. Is the changing family pattern being the reason behind the non -popularity of courtyard houses?  
Yes No
22. Do the size and proportion of plot create hindrance in creating courtyards  
Yes No

**Appendices –A2: Questionnaire for Architects/Experts**

**Semi-structured interviews**

Research-title: **Assessing the impact of courtyard in the housing typologies of low rise, medium density urban settlements.**  
Objective: **To validate the unanimity among the experts regarding the importance of the courtyard concept and the need for its adoption in residential units.**

Dear Respondent,

I would be grateful if you could take part in the above titled study. The study is about the change and continuity in the Indian home’s layout and use (form & function), considering the courtyard-house concept in traditional and modern context.

This Semi-structured interview is part of a research project for doctorate in philosophy (Ph.D.).

Name:

Institution/Affiliation:

Designation:

Date:

**1. What would be your observations about ideal plot size and plot proportion for residential Unit for middle income group?**

- 50-100 Sqm
- 100-150 Sqm
- 150- 300 Sqm
- 300-500 Sqm

Explanation .....

**2. What would be your observations about ideal plot proportion (Width: length) for residential Unit for middle income group?**

- 1:2
- 1:3
- 1:1
- 2:1



Explanation .....

**3. Do you agree that plot-ratio influence the decision of a designer in choosing a Courtyard typology?**

.....

Explanation .....

**4. Does the culture of Indian families promote the courtyard typology?**

.....

Explanation .....

**5. Do the current building Bye-laws create hindrance in courtyard typology?**

.....

Explanation .....

**6. The Parameters like FAR, setback, GC, Height regulation are sufficient to achieve Climate responsive designs**

.....

Explanation.....

**7. What are main factors that are responsible for the disappearance of the courtyard from Indian Houses?**

- Client Choice
- Designers Choice
- Changing family structure
- Land scarcity and rigid Bye-laws

Explanation.....

**8. What are main principles that the Indian family often consider in making the design of a house?**

- Vaastu principle
- Functionality
- Sustainability
- Budget.

Explanation.....

### Frequency Table

1. Which is the most preferred plot size for residential development (For Middle income Group).

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid 50-100	5	13.9	13.9	13.9
100-150	11	30.6	30.6	44.4
150-300	17	47.2	47.2	91.7
300-500	3	8.3	8.3	100.0
Total	36	100.0	100.0	

2. Which is the most preferred proportion of plot for residential unit (i.e. Length: Breadth)

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid 1:2	28	77.8	77.8	77.8
1:3	3	8.3	8.3	86.1
1:1	2	5.6	5.6	91.7
2:1	3	8.3	8.3	100.0
Total	36	100.0	100.0	

3. The plot-ratio influence the decision of a designer in choosing a Courtyard typology

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Agree	15	41.7	41.7	41.7
Disagree	7	19.4	19.4	61.1
Strongly Agree	9	25.0	25.0	86.1
Strongly Disagree	5	13.9	13.9	100.0
Total	36	100.0	100.0	

4. The culture of Indian families promotes the courtyard typology.

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Agree	19	52.8	52.8	52.8
Disagree	7	19.4	19.4	72.2
Strongly Agree	8	22.2	22.2	94.4
Strongly Disagree	2	5.6	5.6	100.0
Total	36	100.0	100.0	

**5. The current building byelaws create hindrance in adopting courtyard typology.**

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Agree	16	44.4	44.4	44.4
Disagree	10	27.8	27.8	72.2
Strongly Agree	6	16.7	16.7	88.9
Strongly Disagree	4	11.1	11.1	100.0
Total	36	100.0	100.0	

**6. The Parameters like FAR and Setback is sufficient to achieve sustainable built form.**

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Agree	9	25.0	25.0	25.0
Disagree	15	41.7	41.7	66.7
Strongly Agree	1	2.8	2.8	69.4
Strongly Disagree	11	30.6	30.6	100.0
Total	36	100.0	100.0	

**3. Using a scale (4 = Most important and 1= Least Important). Please rate the following factors that Indian family often consider while making a house. [Vaastu Principles]**

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Least important	7	19.4	19.4	19.4
Second Least Important	5	13.9	13.9	33.3
Second Most Important	16	44.4	44.4	77.8
Most important	8	22.2	22.2	100.0
Total	36	100.0	100.0	

**3. Using a scale (4 = Most important and 1= Least Important). Please rate the following factors that Indian family often consider while making a house. [Functionality]**

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Least important	5	13.9	13.9	13.9
Second Least Important	12	33.3	33.3	47.2
Second Most Important	12	33.3	33.3	80.6
Most important	7	19.4	19.4	100.0
Total	36	100.0	100.0	

3. Using a scale (4 = Most important and 1= Least Important). Please rate the following factors that Indian family often consider while making a house. [Sustainability.]

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Least important	19	52.8	52.8	52.8
Second Least Important	13	36.1	36.1	88.9
Second Most Important	3	8.3	8.3	97.2
Most important	1	2.8	2.8	100.0
Total	36	100.0	100.0	

3. Using a scale (4 = Most important and 1= Least Important). Please rate the following factors that Indian family often consider while making a house. [Budget]

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Least important	5	13.9	13.9	13.9
Second Least Important	6	16.7	16.7	30.6
Second Most Important	5	13.9	13.9	44.4
Most important	20	55.6	55.6	100.0
Total	36	100.0	100.0	

4. Using a scale (4 = Most important and 1= Least Important).Please rate the following factors that are responsible for disappearance of courtyard from Indian Houses. [Client Choice]

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Least important	13	36.1	36.1	36.1
Second Least Important	8	22.2	22.2	58.3
Second Most Important	6	16.7	16.7	75.0
Most important	9	25.0	25.0	100.0
Total	36	100.0	100.0	

4. Using a scale (4 = Most important and 1= Least Important).Please rate the following factors that are responsible for disappearance of courtyard from Indian Houses. [Designer's Choice]

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Least important	7	19.4	19.4	19.4
Second Least Important	17	47.2	47.2	66.7
Second Most Important	10	27.8	27.8	94.4
Most important	2	5.6	5.6	100.0
Total	36	100.0	100.0	

4. Using a scale (4 = Most important and 1= Least Important).Please rate the following factors that are responsible for disappearance of courtyard from Indian Houses. [Changing families and lifestyle]

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Least important	13	36.1	36.1	36.1
Second Least Important	5	13.9	13.9	50.0
Second Most Important	10	27.8	27.8	77.8
Most important	8	22.2	22.2	100.0
Total	36	100.0	100.0	

4. Using a scale (4 = Most important and 1= Least Important).Please rate the following factors that are responsible for disappearance of courtyard from Indian Houses. [Land Scarcity and Rigid Bye-laws]

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid Least important	11	30.6	30.6	30.6
Second Least Important	4	11.1	11.1	41.7
Second Most Important	7	19.4	19.4	61.1
Most important	14	38.9	38.9	100.0
Total	36	100.0	100.0	

## Appendices –C1: Building Byelaws

### Annexure-2

Excerpt from Zoning Regulation Amaravati Capital City, 2016. (City: Amaravati)

Source: <https://crda.ap.gov.in/>

Appendix II

Typology	R1										R2					R3						
	D	SD	A	AP1	AP2	AP3	AP4	GD	AL		D	SD	A	AP	AL	D	SD	A	AP1	AP2	AP3	A
<b>Buildable area</b>																						
Minimum plot size (m2) *	100	100	100	300	500	2000	4000	4000	0	450	250	250	500	0	100	100	100	300	500	2000		
Cellars/Basements **	0	0	0	0	1	2	3	3	0	0	0	0	0	1	0	0	0	0	2	3		
Maximum Building coverage %	60	60	60	60	50	50	50	50	0	50	50	50	40	0	60	60	60	60	60	50		
Maximum FSI	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	0	1	1	1	1.2	0	1.75	1.75	1.75	1.75	2	2		
<b>Building type</b>																						
Maximum Building Height (m)	13	13	13	16	16	16	16	16	G	11	11	11	16	3	13	13	13	18	18	18		
Maximum Number of floors	G+3	G+3	G+3	G+4	G+4	G+4	G+4	G+4	G	G+2	G+2	G+2	G+4	G	G+3	G+3	G+3	G+5	G+5	G+5		
Maximum Floor to Floor height in Meters																						
Ground Floor	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	3	4.5	4.5	4.5	4.5	3	4.5	4.5	4.5	4.5	3	4.5		
Other Floors	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	0	3.6	3.6	3.6	3.6	0	3.6	3.6	3.6	3.6	0	3.6		
Minimum Floor to Floor height in Meters	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75		
<b>Minimum setback (m)</b>																						
<b>Above grade</b>																						
Front	2	2	2	3	3	5	5	TP	0	3	2	2	3	0	2	2	2	3	3	5		
Side 1	1	1	0	1	3	3	3	TP	1	2	2	0	2	1	1	2	0	2	3	3		
Side 2	1	0	0	1	3	3	3	TP	0	2	0	0	2	0	0	0	0	2	3	3		
Rear	1	1	1	2	3	3	3	TP	1	2	2	2	2	1	1	2	2	2	3	3		
Common	0	0	0	2	3	3	3	TP	0	0	0	0	2	0	0	0	0	2	3	3		
Corner	2	2	2	3	3	5	5	TP	0	3	2	2	3	0	1	2	2	3	3	5		
<b>Basement</b>																						
Front	0	0	0	0	3	3	3	3	0	0	0	0	3	0	0	0	0	0	3	3		
Side	0	0	0	0	1.5	3	3	3	0	0	0	0	1.5	0	0	0	0	0	1.5	3		
Rear	0	0	0	0	1.5	3	3	3	0	0	0	0	1.5	0	0	0	0	0	1.5	3		
Common	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Corner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
<b>Minimum Distance between block to block buildings within same plot</b>																						
Side	0	0	0	0	0	0	0	TP	0	2	2	2	2	0	1	2	2	2	3	3		

Table 5: Zoning Districts

Zone	Zone code	Zoning District
Residential	R1	Village Planning Zone
	R2	Low density zone
	R3	Medium to High density zone
	R4	High density zone

Source: (<https://urbanplanning.chd.gov.in/>)

4 RESIDENTIAL USE

4.1 Residential (PLOTTED)

Sr. No.	PARAMETERS	MARLA	ONE KANAL	TWO KANAL	ABOVE TWO KANAL
1	Set Backs	As per Zoning/ Frame Control			
2	Ground Coverage (max.)	65% + Upto 5%	50%	45%	35%
3	FAR (max.)	2.0	1.5	1.25	1.0
4	Plinth	Minimum 0.3m (1'-0")	Minimum 0.3m (1'-0") Maximum 1.2 (4'-0")		
5	Height (maximum)	Phase-I:10.06m(33'-0") Phase-II:9.83m(32'-3") Rear Court Yard: 3.35m (11'-0")From the plinth level.	Main building 10.67m (35'-0") & Rear Court Yard 3.35 m (11'-0") from 0.30m (1'-0") plinth height.		
6	No. of Storeys	3 (Three)			
7	Habitable Room	Min. Area 9.50 Sq. m (100 Sq. Ft.) with Min. Width 2.40 m (8'-0") & Min. Height 2.75m (9'-0") below the ceiling/ false ceiling or A.C. duct and below the beam 2.4m (8'-0")			
8	Kitchen	Min. Area 4.50 Sq. m (49 Sq. Ft.) with Min. Width 1.50 m(5'-0") & Min. Height 2.75 m (9'-0")			
9	Toilet	Min. Area 2.8 Sq. m (30 Sq. Ft.) with Min. Width 1.20 m (4'-0") & Min. Height 2.29 m (7'-6")			
10	WC & Powder room	Min. Area 15 Sq. Ft. & 20 sq. ft. with Min. Width 0.90 m (3'-0") & Min. Height 2.29m (7'-6")			
11	Bath	Min. Area 1.85 Sq. m (20 Sq. Ft.) with Min. Width 1.20 m(4'-0") & Min. Height 2.29 m (7'-6")			
12	Light & Ventilation	Minimum 1/8th of the floor area of the habitable space. Window/ Vent size in WC/ Bath/ Toilet shall be min. 0.3 Sq. m of the area with side not less than 0.30 m (1'-0").			
13	Ventilation Shaft	Minimum area 1.2 sq. m (13sq. ft.) with minimum width 0.90 m (3 ft.)			
14	Interior Courtyard For light & ventilation	Minimum area 9.0 sq. m with minimum 3.0 m width			
15	Verandah for light	Minimum width 1.8m (6'-0") and depth not more than 3.66 m (12'-0").			

**DEPARTMENT OF URBAN PLANNING CHANDIGARH ADMN.**

**NOTES:-**

- THE ZONING PARAMETERS BE SITE ORIGINAL HEIGHT OF THE BUILDING NO. OF BUILDINGS ON EACH SIDE, PROJECTIONS BEYOND LINE BOUNDARY WALL, GATE POSTS AND GATES, EXISTING PARKING ETC. MAY BE READ AS PER THE NOTIFIED CHANDIGARH BUILDING RULES SUBSEQUENTLY.
- THE PROVISIONS WRT. SOLAR PHOTO VOLTIC POWER, SOLAR WATER HEATING SYSTEM, RAIN WATER HARVESTING SYSTEM ETC. BE MADE AS PER THE NOTIFIED CHANDIGARH BUILDING RULES SUBSEQUENTLY.
- NO SITE WILL DENY DIRECT ACCESS OR EXIT FROM THE ROAD AND GREEN SPACE.
- THESE SHALL BE NO CHANGE IN THE FRONT BUILDING LINE AND FRAME CONTROL.
- IN MARLA HOLDERS MAIN BUILDING BLOCK SHALL BE OF 80% AND LEFT IN SINGLE STORY ZONE IS OPTIONAL ON RIGHT/LEFT SIDE OF THE ROAD. COUPONAGE AS PER THE DISCRETION OF THE OWNER AND AS PER BUILDING RULES. HOWEVER, NO SINGLE STORY ZONE WILL BE ALLOWED TOWARDS THE BOUNDARY WALL HAVING THE SIDE ROAD.
- NO FENCE, TANK AND ANY OTHER PERMANENT TEMPORARY STRUCTURE SHALL BE PERMITTED ABOVE THE 80% IMPERMEABLE TERRACE OF THE SINGLE STORY ZONE.
- NO DOWNSIDE/SUNSHADE SHALL BE ALLOWED IN THE SINGLE STORY ZONE BEYOND THE ZONED AREA.
- REFER SUB SECTOR ZONING PLAN FOR PLOTS OF SAME SIZE WITH RESPECT TO SETBACKS TO MAINTAIN THE UNDERSTANDING EFFECTIVE.
- IF ANY TYPE OF PLOT SIZE IS NOT INCLUDED IN THE ABOVE SIZE THE SAME SHALL BE DEALT SEPARATELY AND SEPARATE ZONING PLAN WILL BE PREPARED.

**LEGEND:**

- DOUBLE STOREY HEIGHT 30'-0" FROM EXIST PLINTH LEVEL (MARLA TYPE)
- DOUBLE STOREY HEIGHT 30'-0" FROM EXIST PLINTH LEVEL (KANAL TYPE)
- DOUBLE STOREY HEIGHT 30'-0" FROM EXIST PLINTH LEVEL (MARLA TYPE)
- DOUBLE STOREY HEIGHT 30'-0" FROM EXIST PLINTH LEVEL (KANAL TYPE)
- SINGLE STOREY HEIGHT 11'-0" FROM EXIST PLINTH LEVEL



**53. Size of plots.-** (1) Residential.

(i) Each plot shall have a minimum size and frontage corresponding to the type of development as given below :-

Type of Development (1)	Plot size (Sq. meters) (2)	Frontage (meters) (3)
Detached building	above 225	above 12
Semi-detached building	125-225	8 to 12
Row type building	50-225	4.5 to 12

(1) Front open spaces.

(a) Every Residential Building having height up to 12.5 meters, facing street shall have a front open space mentioned below and such open space shall form an integral part of the site:-

S. No. (1)	Width of street facing the plot (2)	Front open space Min. (3)
1.	up to 9.0 meters	3.0 meters
2.	More than 9.0 meters and up to 12 meters	3.6 meters
3.	More than 12.0 meters and up to 18 meters	4.5 meters
4.	Above 18 meters	6.0 meters

(2) Rear Open Space.

(a) Every Residential Building, having height up to 12.5 meters, shall have a Rear Open Space, as below :-

Sr. No. (1)	Plot area in Square meters (2)	Building height in meters (3)	Minimum Rear Open space in meters (4)
1.	Up to 40.00	10.00	Nil
2.	Above 40.00 and Up to 150.00	10.00	1.50
3.	Above 150 and up to 225.00	10.00 and above	2.50
4.	Above 225.00	10.00 and above	3.00



**10.7. सैटबेक:**

- (i) सैटबैक का निर्धारण भूखण्ड की बाउण्ड्री से होगा। भूखण्डों पर साईड व पीछे के सैटबेक तालिका-1 के अनुसार निर्धारित किये जावेंगे। समस्त भूखण्डों में अग्र सैटबेक योजनानुसार अन्यथा सड़क की चौड़ाई के आधार पर निम्न तालिकाओं के अनुसार रखे जावेंगे।

**तालिका-4  
सैटबैक निर्धारण**

तालिका-4.1 (सड़कों की चौड़ाई के अनुरूप अग्र सैटबैक का निर्धारण)	
सड़क की चौड़ाई	न्यूनतम अग्र सैटबैक
18 मीटर तक	3.0 मीटर
18 मी.से अधिक तथा 24 मी.तक	4.5 मीटर
24 मी.से अधिक तथा 30 मी. तक	6.0 मीटर

**तालिका-1**

नो भूखण्डों पर (आवासीय, वाणिज्यिक, संस्थागत )मवन निर्माण हेतु मानदण्ड

क्र.सं.	भूखण्ड का क्षेत्रफल	अधिकतम मू-आच्छादन	न्यूनतम सैट बेक्स (मी.)			अधिकतम ऊँचाई (मी.) (सड़क मार्गाधिकार के अनुसार)			मानक बी.ए. आर
			पार्श्व	पार्श्व	पीछे	सड़क मार्गाधिकार			
						9 मी.	12 मी.	18 मी.	
I(i)	90 व.मी. तक	सैटबेक्स क्षेत्र के अन्दर	---	---	---	9.0 (भूतल +2)	12.0 (भूतल +2)	15.0 (भूतल+ 2)	जो भी प्राप्त हो
(ii)	90 व.मी. से अधिक परन्तु 167 व.मी. तक	सैट बेक क्षेत्र के अन्दर	---	---	1.5	9.0 (भूतल +2)	15.0 (भूतल + 3)	15.0 (भूतल+ 3)	2.00
(iii)	167 व.मी. से अधिक परन्तु 225 व.मी. तक	सैट बेक क्षेत्र के अन्दर	---	---	2.0	9.0	15.0	18.0*	2.00
(iv)	225 व.मी. से अधिक परन्तु 350 व.मी. तक	सैट बेक क्षेत्र के अन्दर	3.0	---	3.0	12.0	15.0	18.0*	2.00
(v)	350 व.मी. से अधिक परन्तु 500 व.मी. तक	सैट बेक क्षेत्र के अन्दर	3.0	---	3.0	12.0	15.0	18.0*	2.00
(vi)	500 व.मी. से अधिक परन्तु 750 व.मी. तक	सैट बेक क्षेत्र के अन्दर	3.0	3.0	3.0	12.0	15.0	18.0*	2.00
(vii)	750 व.मी. से अधिक परन्तु	सैट बेक क्षेत्र के अन्दर	4.5	4.5	4.5	15.0	18.0	सड़क की चौड़ाई का 1.5 गुणा	2.00

Excerpt from Bhawan Nirman evam vikas Upvidhi 2008, UP. (City: Lucknow)

Source: <https://upavp.in/article/en/by-laws-map-approval>

### 3.4 सैट-बैक

- 3.4.1 आवासीय भवन भूखण्डीय विकास के अन्तर्गत आवासीय भवनों में अधिकतम तीन मंजिल निर्माण अनुमन्य होगा जिसकी अधिकतम ऊँचाई स्टिक्ट के साथ 12.5 मीटर तथा स्टिक्ट के बिना 10.5 मीटर होगी एवं सैट-बैक निम्नवत् होंगे :-

भूखण्ड का क्षेत्रफल (वर्ग मीटर)	सैट-बैक (मीटर)			
	अग्र भाग	पृष्ठ भाग	पार्श्व-1	पार्श्व-2
(क) रो-हाउसिंग				
50 तक	1.0	—	—	—
50 से अधिक 100 तक	1.5	1.5	—	—
100 से अधिक 150 तक	2.0	2.0	—	—
150 से अधिक 300 तक	3.0	3.0	—	—
(ख) सेमी-डिटेच्ड				
300 से अधिक 500 तक	4.5	4.5	3.0	—
(ग) डिटेच्ड				
500 से अधिक 1000 तक	6.0	6.0	3.0	1.5
1000 से अधिक 1500 तक	9.0	6.0	4.5	3.0
1500 से अधिक 2000 तक	9.0	6.0	6.0	6.0

- (1) स्टिक्ट फ्लोर 300 वर्ग मी0 या इससे अधिक क्षेत्रफल के भूखण्डों पर अनुमन्य होगा, परन्तु ऐसे भवनों में पीछे के सैट-बैक के 40 प्रतिशत भाग पर निर्माण अनमन्य नहीं होगा।

पृष्ठ 35/93

### 3.5 भू-आच्छादन एवं एफ.ए.आर.

3.5.1	भू-आच्छादन एवं एफ.ए.आर. के मानक	विभिन्न भू-उपयोगों हेतु भू-आच्छादन एवं एफ.ए.आर. के मानक निम्नवत् होंगे:-	
1.	भूखण्डीय विकास (आवासीय प्लॉट)		
		भू-आच्छादन (प्रतिशत)	
		एफ.ए.आर.	
	(क) निर्मित/विकसित क्षेत्र		
	• 100 वर्गमीटर तक	75	2.00
	• 101-300 वर्गमीटर तक	65	1.75
	• 301-500 वर्गमीटर तक	55	1.50
	• 501 से 2000 वर्गमीटर तक	45	1.25
	(ख) नए/अविकसित क्षेत्र		
	• 100 वर्गमीटर तक	65	2.00
	• 101-300 वर्गमीटर तक	60	1.75
	• 301-500 वर्गमीटर तक	55	1.50
	• 501 से 2000 वर्गमीटर तक	45	1.25

## Appendices –D1: Lucknow building byelaws recommendations

UP Building Bye-Laws 2008 (as amended 2011 and 2016)				
Clause No	Issues	Potential Outcome	Suggestion	Reference
Clause 3.4.1 Clause 3.5.1	Area within setback is always greater than permitted ground coverage for the respective plot size	Leads to confusion and prone to violation of ground coverage norms Capping of ground coverage leads to uneven building facades	Built to open ratio method should be adopted.	URDPFI, 2014 Architectural Controls, Chandigarh Building Rules 2017
Clause 1.2.31 Clause 1.2.32 Clause 1.2.33	Development control regulation based on three zones namely Constructed, Developed and undeveloped area,	Definition of these zones are very generalized in nature, hence leads to violation and confusion.	DCR should be based on typology of buildings or zones, Such as high density zone, low density zone etc.	Zoning regulation, Amravati MP Bhumi Vikas Adhiniyam
Clause 3.4.1 Clause 3.5.1	Setback, GC, FAR solely depends on Area of Plot	No consideration for the plot width and width of abutting road	Width of plot and width of abutting road should be taken into consideration for uniform street elevation However the method of built and open percentage will be more efficient in this after leaving the mandatory front setback. Narrow plots for compact row house development and broader plots for semi detached and detached type development	MP Bhumi Vikas Adhiniyam, URDPFI, 2014

Clause No	Issues	Potential Outcome	Suggestion	Reference
Clause 3.4.6	Exemption in setback	Exemption require maximum monitoring	The land left open as a consequence of the enforcement of the setback rule shall form part of the public street, Any Development /projection should not be allowed in front setback	Model Building Bye laws 2016
Clause 3.4.1	Rear setback	Rear set back violations showed a higher frequency than any other set backs . Generally, the rear of any building contained utility areas and citizens seem to consider rear setback requirements as a waste of space.	Minimum or no rear setback, it can be said that rear setback must be rethought to provide more flexibility to the designers for providing Interior open spaces(courtyard)	(Boob and Rao 2014) (Narayana 1996) (Byahut et al., 2020) URDPFI, 2014
Clause 3.4.1	10 % of Floor Area Width of interior open space as 3 m Min Area of interior space= 7.5 sq m	Prescriptive in nature not performance oriented, Location , orientation and geometry of house plays crucial role in daylight integration.	Courtyard Planning Built in software for daylight analysis for OBPAS (Pre DCR)	Day lighting, Teri

### **List of Publication**

**Title: Courtyard: A look at the relevance of courtyard space in contemporary houses**

Paper published in Civil Engineering and Architecture, Vol. 9, No. 7, pp. 2261-2272, 2021.

DOI:10.13189/cea.2021.090713

### **List of Conferences**

Paper presented in 3rd International Conference on  
Emerging Trends in Engineering and Technology

Title: Review of Building Regulation for Achieving Sustainable Development in Lucknow, India

Paper presentation in 2nd International Conference on  
Civil Engineering and Technology

Title: Conceptualizing Residential Open Space In Contemporary Houses