VISION, MISSION & QUALITY POLICY

VISION

- *To be globally recognized as an epitome of learning and innovation.*
- *Imparting multifaceted architectural education driven by social sensitivity and supported by state of the art of infrastructure.*

MISSION

- *To impart quality education that encourages students to be competent enough for best fit job roles.*
- *To provide faculty members with facilities to research, experiment and implement contemporary learning tools.*

QUALITY POLICY

" We, the Management, Faculty and staff of Aditya College of Architecture are committed to offer excellence in architectural education, by pledging to our core value of Agility, Innovation, Integrity our academic environment and state of the art facilities and infrastructure to our students, thereby ensuring mutual respect and trust for them.

We will work as a team and interact with the students in pro-active manner to achieve our institutional quality objectives and fulfill all academic , statutory and regulatory requirements to continually enhance the satisfaction of our students. "

ABOUT ACA

Aditya College of Architecture established in 2013 is affiliated to Mumbai University, India. Since its inception, the college has continuously been working towards a vision to take architectural education ahead of traditional curriculum and achieve higher goals in grooming better professionals every year. The primary objective of the school is to create 'global practices with local concerns' to achieve excellence in architectural design, practice and profession.

The campus has infrastructure comparable to the best in the world. An ideal environment for exploring new ideas that encourage creative and independent thinking of young minds. It also provides platform for promoting innovation and research for students and faculty. The pedagogy of the school is building professional capacity and cherished individual interest of the student.

With the vision that educating professional requires close coordination of industry and academic the institute encourages collaboration with eminent academicians and industry professions in the way of conducting workshops, seminars, and webinars in the present pandemic situation. The Institute has collaborated with Sri Lanka Institute of Architects by the way of exchange program and combine studios.

ADITYA COLLEGE OF ARCHITECTURE

ABOUT IDRC

This year Aditya College of Architecture (ACA) brings its 2nd International Design Research Conference (IDRC) with the theme 'Monadic Architecture', an attempt to derive at a plethora of design solutions using the concepts of modularity and self-similarity. Since the historic periods, the modularity involvement has gained extreme importance in the realm of architectural morphology of masses and spaces. Apart from being an economical and simplified approach, monadic designs come with the characteristics of easy prefabricated construction, simplified manufacturing, addition, and replacement thereby, leading to mass-production. This sustainable design approach also allows for incrementality and expansion, and hence turns cost-effective. Monadic architectural style is applicable at any scale from interior furniture design, facade, and fenestration designs to building spaces at any geographical context. The IDRC 2021 therefore endeavors to explore monadic or modular architectural design features, thereby contributing towards a sustainable built environment.

The IDRC conference intends to cover an array of topics that enables students, researchers, academicians, and practitioners, to express their thoughts, hypotheses and ideologies and demonstrate their designs through research and practice. It will also enable notable speakers to showcase their experience, expertise, and knowledge on the subject.

ABOUT IDRC

Theme:

Monadic Architecture

Sub-themes:

1. ***Monadic modules- relevance and application under architecture, urban planning, urban design, landscape and product design in contemporary times***
2. ***Modularity in architecture and planning***
3. ***Types and prototypes of the built and unbuilt***
4. ***Exploring geometry-space and form as units of measurement***
5. ***The play of fractals in monadic architecture***
6. ***Monadic modules for socio-culturally and/or climate responsive architecture***
7. ***Mitosis of modules-contribution to technology /structure/policy framework under architecture, urban planning, urban design, landscape and product design.***

Message From Founder Trustee

Shri Harishchandra Mishra

Founder Trustee & Chairman

A Leader is one who shows great perseverance, integrity, determination. They are the ones with the ability to guide and encourage others to achieve their goal. However, it is the traits of mental strength, high moral character, authority, and ability to find new solutions that forces others to look up to them.

Aditya College of Architecture (ACA) is fortunate to have such a leader. Our chairman, Shri Harishchandra Mishra, a leader who is proactive and driven by his passion for education. One that effectively takes his team along with him to scale the heights of success.

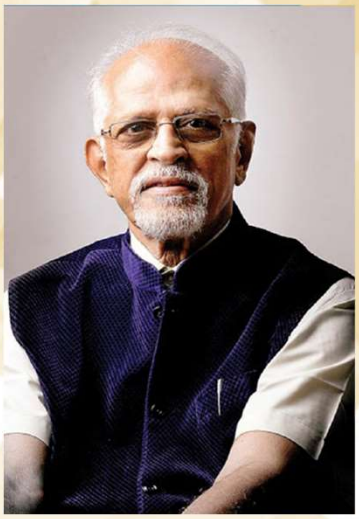
It gives me immense pleasure to see how Aditya College of Architecture has flourished with its abundant academic knowledge, immense industry exposure, and innovative strategies in the field of education and research.

I heartily congratulate Aditya College of Architecture for organizing the 2nd International Design Research Conference 2021 (IDRC) on the theme "Monadic Architecture.'' This year, IDRC aims to highlight the architectural need of the society by utilizing the concepts of fractals and modular features to derive at simple, sustainable, time-efficient, and cost-effective architectural design solutions.

We hope that IDRC 2021 will educate and nourish everyone with valuable message and insight. I wish all the prosperity and fortune to the institution and to the students who will take the baton ahead, to illuminate the world with their spark.

On behalf of Aditya College of Architecture, I wish International Design Research Conference 2021 a grand success. May our team succeed in transferring knowledge.

Message From Mentor



Ar. Gurunath Dalvi

Mentor & Advisor

As a Mentor of Aditya Collage of Architecture for last 9 years, I take great pride to keep on record that the college, after successfully organizing International Design Competition consecutively for last 7 years and launching the 1st International Design Research Conference in 2020, is majestically organizing 2nd International Design Research Conference on 18th December 2021.

The management, faculty and students deserve all praises and compliments for spending their enormous time and putting their efforts for the success of conference, in-spite of calamity of pandemic.

ACA is known for its vision and has been nurturing its students making them think out of the box. A plethora of themes for last all IDCs proves the truth. The theme selected for the 2nd IDRC 2021- "Monadic Architecture" is the record very apt for current global situation.

Understanding the need of the time, ACA came forward and shouldered the responsibility to bring all concerned together to deliberate on the design challenges mentioned under respective sub themes.

I hope that this year's conference will prove to be useful and derive at design solutions that are sustainable and humane by using modular design features, which can later be placed before the concerned authorities in State and Central government.

I wish the Conference a grand success.

Message From Principal

Ar. Rita Nayak

Principal

The concept of modularity has been with us for several years, yet 'monadic architecture' seems to be rarely ventured in the world of architecture. However, many architects and builder communities have worked and are working with this type of architectural designs, and hence, its most characteristic advantages are gradually permeating the public.

But what is monadic architecture? We can define it as design based on modules, elements that are equal. This differentiates them not only from traditional houses, but also from prefabricated ones, with which they share certain characteristics and achieve a spatial character that is human and sustainable.

The term 'Monadic' with its characteristics of modularity, fractalness, self-similarity, scaling and never-ending is represented in architecture as a formative idea and form generator. From cellular patterns to growing grains, the concept of 'monad' or modularity can imbibe chaos and complexity on one hand and rhythm and pattern on other hand in the realm of art, philosophy, and architecture. Architects, while designing using modularity, tend to use it aesthetically, creating decorative, simple, or complex patterns which can be easily perceived by the public. This has resulted in the use of modularity concept as well as monadic architectural features in designing attractive architectural masterpieces. The concept of self-similarity also allows for greater control of the construction process, easy manufacturing, replacing, thereby making the procedure safer and more convenient, as well as more precise and easier to replicate.

With unprecedented urbanization, there has been an increasing demand for architects to build cost-efficient structures. Monadic architecture can be utilized as a concept which revolves around assembling multiple prefabricated modules to create a volume of space. By joining similar elements together in various ways, modular architecture allows for more flexibilities in design and standardized repair, thereafter, reducing time and cost.

This year the IDRC 2021 platform with the theme of 'Monadic Architecture' reached out to students, academicians, subject experts, and professionals who are sensitive towards the need of sustainable and economically viable architecture. The abstracts presented in the compendium, elucidates the various fractal technologies and modular design strategies that can be employed in varying case-studies.

On behalf of ACA, I take immense pleasure in welcoming all to the 2nd IDRC event that aims to inspire architecture fraternity towards a socio-economically viable and environment-sensitive built-environment.

Message From IDRC Coordinator

Ar. Rasika Chodankar
Associate Professor

We here at ACA are proudly launching the 2nd International Design Research Conference (IDRC 2021), along with the constant success of our International Design Competition. It gives me an immense pleasure and I also feel honored to be a part of this venture while leading as well as working with a team of passionate and hard-working colleagues. For IDRC 2021, we decided to opt for a relevant and meaningful theme- Monadic Architecture. The concept of 'Monad' or modularity or self-similarity has been prominent since ages in the architecture realm, with an aim to derive at a plethora of simple design solutions.

The 2nd IDRC 2021 conference has reached out to international extends, where eminent architects from India, building scientists from Indonesia and other nations have been invited. We strongly appreciate our collaborations and associations with such industry stalwarts, whose work strongly sync with our theme at large.

Like last year (IDRC 2020), this year, we have received immense response from the architectural fraternity. We are thankful to the enthusiastic participants and to the esteemed review committee for their continuous effort and commitment. The plethora of topics selected by the researchers based on the sub-themes of the conference highlight the need, significance and sensitivity felt by the community about this concept. It strengthens our ideas to nurture the ideas within ourselves as mentors, for upcoming generations.

Modular architecture or "modularity in design" is a design approach that subdivides a system into smaller parts called modules or skids that can be independently created and then used in different systems. A modular system is characterized by functional partitioning into discrete scalable and reusable modules, rigorous use of well-defined modular interfaces, and making use of self-similar standards for interfaces.

The direct benefits of modular design are flexible in design and reduction in costs, while combining the advantages of standardization with that of customization. Through modularity, a plethora of designs can be achieved, which will be cost saving in design and construction. Thus, modularity is pushing out the productivity frontier in design creation. Within a modular system, the array of hypotheses underlays a reference frame with production control and scale purposes, that nonetheless enables variability in the outputs. Modularity of physical components is conceivable under a discrete aegis, which envisions a potential complexity achievable in the fashion of the discrete math of algorithms. Research in modularity in the context of the built environment has been following three main trends: (1) deepening on to the nature and/or features of module(s), from which a network of relations can evolve to create a range of shapes; (2) focusing on modular applications, i.e., in the engineering and assembly processes implied for modular structures to be brought about in real-life applications; (3) onto broader aspects of modular systematization. Further research should be executed on a synthesis of these concerns, as it deepens to the modular nature of the study object while addressing its applicability in varying fields.

The theme for IDRC 2021 conference 'Monadic Architecture' or modular architecture is to investigate modular design features to derive at innovative, simple, and sustainable design solutions.

Dr. Ahana Sarkar

Assistant Professor

Message From Publication In charge

Message From IDC Coordinator

Ar. Swati Ray
Associate Professor

Monadic Architecture is a term derived from the word 'Monad' which means a single unit. This year's IDC as the name suggests is based on the manifolding of prototype units to achieve a spatial character that is human as well as self-sustaining. When imaginatively formulated, Monads, can contribute algorithms that range from a single volume of space, scaling up to form the urban fabric of a city. As our cities continue to grow and expand rapidly, there has been an increasing demand for architects to build and design structures that provide more effective solutions. The benefits of modular design are universal, giving flexibility in design, reduction in costs and efficiency of time.

We at ACA believe that the time has come to introduce Monadic architecture in the contemporary domain as an undeniable answer to meet some the rural and urban building needs.

This year's IDC 2021 was an attempt to inculcate this need of the future and encourage young minds to embrace this method of design evolution.

The Competition brief involved the conceptualization of a singular unit and its replication to resolve a pertinent issue of the participant's home country. We received several entries across five continents addressing serious issues like refugee housing, mid income housing and rural education.

We do hope that through this platform we have been able to inspire young minds towards a more socio-economically responsible built environment.

About Our Reviewers

Dr. Shilpa Sharma holds a doctorate from RTM Nagpur University for her research on the ranga mandaps of Hindu temples of Karnataka. She has also been the national winner of the prestigious IIA Awards for Excellence in Architecture in 2018, in the category for Research for her paper, Architectural Strategies used in Hindu Temples to Emphasize Sacredness.

She is an Associate Professor, Mumbai University at the IES COA and heads the Humanities Dept., and has been the Coordinator, M.Arch. in Constr. Mgmt.

She has been involved in teaching since she graduated with a First Class from the Academy of Architecture. Along the way she took a sabbatical to pursue pottery in Delhi and was also involved with research for INTACH, Delhi. This led to an interest in environmental behavior and eventually her doctoral studies.

Dr. Shilpa Sharma

IES College of Architecture, Mumbai

Dr. Priya Choudhary is an architect-planner and is currently working as Professor and Head of the Urban Design Department at Smt. Manoramabai Mundle College of Architecture, Nagpur. She accomplished Ph.D. from Visveswaraya National Institute of Technology, Nagpur under the guidance of Dr. V.S. Adane in 2014. During doctoral research, she was awarded Fulbright Nehru Doctoral and Professional Research Fellowship and had been to the University of California, Berkeley in 2011.

She has been actively involved in conducting Teachers' Training programs in collaboration with NIASA by the Council of Architecture, New Delhi in and outside India. She is impaneled by the Council of Architecture for research assignments.

She has vast experience in the field and has worked on many architectural designs and planning of Institutional, residential, commercial projects in and around Nagpur in the last 20 years.

Dr. Priya Choudhary

Smt. Manoramabai Mundle College of Architecture, Nagpur

Ar. Rita Nayak
Principal

IDRC TEAM

Ar. Rasika Chodankar
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Ar. Samreen Khanam

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Ar. Disha Barik

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Ar. Manali Rane

Ar. Arundhati Nagargoje

Er. Soham Chowdhary

ADITYA COLLEGE OF ARCHITECTURE

TABLE OF CONTENTS : RESEARCH PAPER

TABLE OF CONTENTS : RESEARCH PAPER (IDRC WORKSHOP)

THE AESTHETIC APPRECIATION OF SNAKES: AS A LANDSCAPE ARCHITECTURAL STRATEGY TO MITIGATE HUMAN - SNAKE CONFLICT IN SRI LANKA

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ABSTRACT:

Sri Lanka has been identified as a hotspot for snakes which provides habitats for approximately 105 snake species with 50% endemicity. Yet they are the least appreciated vertebrates that are victims of negative values and ideas which lead to the humans-snakes conflict. The objectives of the study were; Studying co-relationship of people's attitude towards snakes, knowledge level, and metaphoric perspectives of snakes: Developing a landscape architectural strategy to mitigate human-snake conflict by applying those findings and Yuriko Saito's and Allen Carlson's theories of aesthetic appreciation. The data collection occurred from July to August 2020 and consisted of an online questionnaire that applied to 185 study participants according to their knowledge levels. A literature survey was conducted to examine the main factors of Aesthetic appreciation theory named Animal ethics, Positive aesthetics, and Rewilding, and to study the role of landscape architects in mitigating human-snake conflict. From the findings, I confirmed that; The lack of knowledge and the metaphorical perception of snakes are the reasons for creating human-snake conflict; The role of Landscape architects is important when finding solutions for the conflict; The main factors of Aesthetic appreciation theory called Animal ethics, Positive aesthetics, and Rewilding can be used as a landscape architectural strategy to mitigate the conflict.

KEYWORDS:

Human-snake conflict, Aesthetic appreciation, Animal ethics, Positive aesthetics, Rewilding

1. INTRODUCTION

Being a tropical island with diverse habitats which are preferable to snakes is a leading factor for rich snake fauna in Sri Lanka. Sri Lanka is home to 105 snake species and high diversity encompasses 11 families: Acrochordidae, Boidae, Colubridae, Cylindrophiidae, Elapidae, Gerrhopilidae, Homalopsidae, Pythonidae, Typhlopidae, Uropeltidae, Viperidae. 50 of them are endemic to Sri Lanka and that's the main reason for the conservation of snake fauna in Sri Lanka.

Sri Lanka has the highest snake species density than the other fauna species such as mammals, fishes, and birds. But birds, mammals, and fishes are more privileged and protected because they are more socially accepted than snakes. Therefore it is easier to protect and conserve the aesthetically pleasant species than less socially appreciated species such as snakes. The existence of a large number of myths, legends, and misconceptions resulting from the direct interpretation of local folklore is mainly responsible for negative attitudes towards snakes. As a result, they are among the least appreciated fauna in the animal kingdom due to fear and lack of knowledge about snakes (Kellert, 1982). The lack of knowledge results in snake deaths and risk of snake bites, which leads to a human-snakes conflict and conflicts lead to alarming changes in the perception of snakes among people like loss of appreciation, negative attitude towards snakes, and in extreme cases might lead to the killing of the snakes whether they are venomous or non-venomous. Such negative changes in people's perception of snakes, harmfully affect the natural fabric of co-existence. Snakes are suffering from common threats like deforestation, leading to habitat loss, habitat degradation, man-made forest fires, the use of agrochemicals, road killings, and domestic animals predators (Jayatissa, 2012).

Snakes are useful for humans and the environment because some toxins and venoms produced by them are useful to medicine. Snakes play an important role in our ecosystem by maintaining a balance to the food web. When the aesthetic appreciation of snakes comes as a research topic, recent work in aesthetics / aesthetic appreciation has brought welcome attention to the beauty of nature and animals, but the aesthetic appreciation of snakes remains rarely discussed. Therefore it is important to discuss the topic and develop a landscape architectural strategy to mitigate human – snake conflict in Sri Lanka based on aesthetic appreciation.

2. AIM

The aims and the objectives of the research are: Applying the theories of aesthetic appreciation of nature by Yuriko Saito and Allen Carlson, to the aesthetic appreciation of snakes: Study the co-relationships between scientific and common knowledge about snakes, metaphoric perspectives of snakes, and people's attitude towards snakes to examine the theories and discover specific concepts within the theory: Discover the main factors that are in the theory of aesthetic appreciation to develop a landscape architectural strategy to mitigate the human-snake conflict.

3. LITERATURE REVIEW

The literature review was conducted by applying the same arguments in "Theories of aesthetic appreciation of nature" propounded by Allen Carlson and Yuriko Saito, since snakes are also a part of nature.

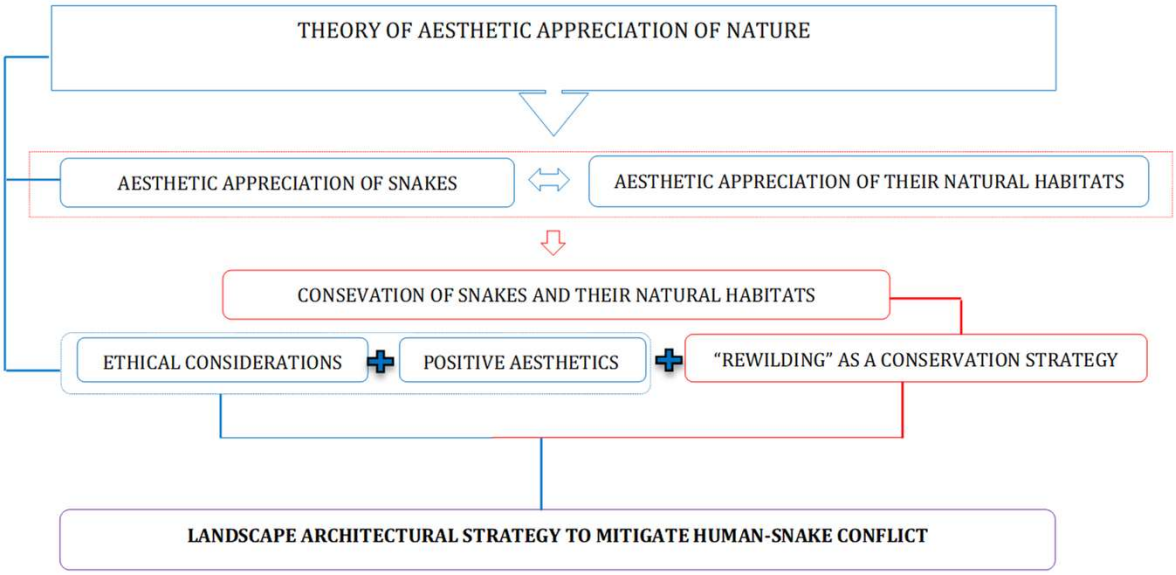


Figure 1: Theoretical framework for the study

3.1 Allen Carlson's theory of appreciation of nature

Allen Carlson claims that we have to have common sense or scientific knowledge to aesthetically appreciate nature. He claims we can aesthetically appreciate nature only when we understand it and only the natural science provides the framework for it.

"If to aesthetically appreciate art we must have knowledge of aesthetic traditions and styles within those traditions, to aesthetically appreciate nature we must have knowledge of different environments. In the way in which the art critic and the art historian are well equipped to aesthetically appreciate art, the naturalist and ecologist are well equipped to aesthetically appreciate nature" (Carlson, 1979, pp. 267-275).

According to Carlson, our aesthetic judgments can be varied according to the category which artist categorized the particular object in the artwork. Carlson clarifies it by applying Kendal Walton's theory for categories of art. According to Walton (1970), since there is no accurate procedure to define correct categories for artworks; we can use four considerations to decide correct categories. They are;

I. Relatively a large number of standard features for the category;

II. Whether a work can be more interesting or aesthetically pleasing under the category;

III. Intentions of the artists;

IV. The condition of society in which a work was produced.

Since natural objects are not our creations, they don't have any intention or a social condition. Therefore intention of artists and social condition have major role in defining the correct category. According to Carlson (2013), when we see wilderness of the virgin nature from ecological and scientific perspective / under the ecological and scientific category we have to admit that wilderness is the true representation of the natural environments and it is aesthetically good. Therefore wilderness consider as one of the positive aesthetics. The positive aesthetics means the scientific understanding has an ability to change our appreciation of nature in positive way. For example Darwin's research changed the view of nature and evolution as Carlson explains. Carlson (2013) explains that natural science helps us to identify the origin, functions, of the nature and it helps to avoid misconceptions of nature that created by artworks which put the particular natural object in a wrong category.

3.2 Yuriko Saito's Theory of appreciation of nature

Saito (1998) affirms that in order to aesthetically appreciate nature, we must appreciate nature as it is and any natural component has its own biological character to play and has its own way which independent of metaphoric perceptions made by people.

Therefore, in order to deeply appreciate nature, we should listen to nature's story, not ours. Gonzalez (2017) contended that Saito also insists that we should not limit nature to its visual aspect and we should appreciate nature with all our sensations. Therefore appreciating snakes in a zoo or snake farm is multisensory than appreciating them in photographs or films. But the problem is we can't appreciate them as they are in a maintained captive in enclosures which designs by humans. According to Saito, animals show their identical characteristics through their natural behaviour in their natural habitats. The imprisoned and manufactured space of zoos makes it unsuitable for animals to perform freely (Gonzalez, 2017).

3.3 Metaphorical perception of snakes

Leddy (2012) claims that when we creatively see something in art, we see it in terms of a category to which it really does not belong. We can identify those seeing as metaphorical perceptions. Carlson (2013) claims that two sociological factors have limited us from appreciating nature as it really is. Those factors are religious and picturesque representations of aesthetic formalism.

When people use "serpent/snake" as a metaphor, applied to humans and by this metaphorical sense of "snake", most of the time they mean an illogical evil creature driven by revenge. But, when we scientifically observe the behaviour of snakes, we understand that they don't bite to seek revenge but only for self-defence and most of the snakes in the country are non-venomous. The real nature of snakes does not match this metaphorical aspect of evil creatures. To see snakes as evil or dark creatures can be creative but cover the reality. When people consider that snakes are evil or dark creatures, they will be less likely to appreciate and protect them. The current hatred for snakes is the reason for massively killed them in many countries, has its sources in this distorted perception of snakes originated in our culture that has nothing to do with their real behaviour.

In Hinduism, most of the time snake stands for all the evil and demonical nature in the world. For example when we consider the story of Krishna and the snake called Khaliya. Khaliya was a poison-ous snake with his hundred and ten hoods who vomiting poisons to the Yamuna River. The snake around the god Sivas' neck represents that Shiva controls fear and death and the snake symbolizes fear and death. In Greek mythology of the Gorgons were serpent-women whose gazes would turn people to stone. The serpent in Genesis was a snake that symbolises Satan.

Davis (2012) claims that a superficial appreciation of animals can be important. In most cultures, people consider cobra as a sacred animal, therefore people avoid killing cobras and some people even worship them. Some legends, and symbols in the Buddhist culture represents superficial version of snake which valuable for protect snakes. For example, there is a story that the Naga king Muchalinda shielded the Buddha from getting wet in the rain. The legend of the Buddha's visit to Nagadeepa, to settle the dispute between two Naga kings called, Chulodara, Mahodara who were serpent worshippers. The snake on the ancient Guard Stones in Sri Lanka represents the guardian of wealth and harbinger of prosperity. Another example is the Naga Raksha or the Snake Demon. According to Morner (2009), Raksha transformed into poisonous snakes, which captured their enemies and made them slaves. Now the Raksha masks are used in a lot of festivals, cultural dances, and healing or spiritual purposes and are also sold to the tourist trade and institutions for display in Sri Lanka.

The pictorial representation of the Lord Vishnu resting on the snake king Shesha symbolizes the en-ergy and that shows the superficial appreciation of snakes in Hinduism. Mansa Devi is a Hindu goddess of snakes worshipped mainly for the prevention and cure of snakebite and for fertility and prosperity. She is depicted as a goddess sitting on a lotus, covered with or standing upon snakes.

Brandy (2014) affirms that some symbolism of animals may be suitable and relevant because they represent the similar characters and behaviour of those animals. For example, the Chulavamsa refers to performing surgery on a snake by king Buddhadasa, which symbolizes the compassion towards snakes in early people and traditional knowledge of veterinary surgeries. The logo of the WHO consists of a snake that coiling round and symbolizes medicine and the medical profession. It originates from the myth of Asclepius, who was honoured by the ancient Greeks as a god of healing and whose cult involved the use of snakes. Currently, some snake venom has been used in medicine. Therefore this representation shows the true qualities of snakes.

4. RESEARCH METHODOLOGY

The aim of the study is to examine the co-relationships between: scientific/common knowledge, metaphoric perception of snakes, and attitude towards snakes which I identified from literature survey to discover the main factors for developing landscape architectural strategy.

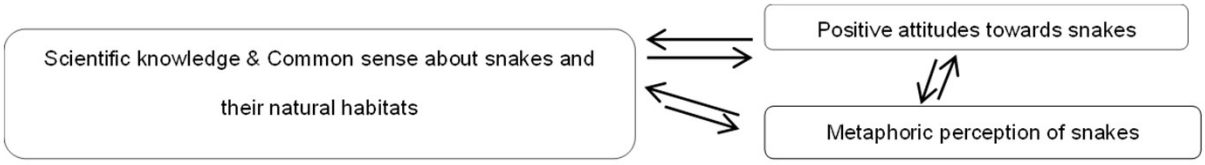


Figure 2: The aim of the study

I conducted a pre designed and pre tested online questionnaire that made up of a combination of closed and open ended questions and lasted 5-10 minutes. The data collection occurred from July 2020 to August 2020. This was an online survey that consisted sets of questions regarding attitudes, knowledge, practices, beliefs and ideas for conservation of snakes. The sample size of the study was 185 and the participants for the survey were selected through Judgment sampling and random sampling methods. The goal of the judgment sampling method in the study was select the people with higher knowledge of snakes than general public which was compulsory for completing the study successfully. The goal of the random sampling in this study is to get a sample of people that is representative of the larger population. The expected outcome of the sampling was selecting the participants with variation of knowledge levels.

5. ANALYSIS & DISCUSSION

This chapter analyses and discusses the data that collected through an online questionnaire and the literature survey to develop the conclusion of the study.

5.1 Correlation of knowledge level (scientific knowledge & common knowledge) and attitude towards snakes:

For analyzing the common knowledge, scientific knowledge, and people's attitudes towards snakes, I asked separate questions and finally discussed the correlation between knowledge level and the attitude towards the snake.

5.1.1 Common Knowledge of study participants

To assess the common knowledge regarding snakes I asked two questions (see figure 3, 4). There were 8 false statements in the first question based on myths and 4 false statements about immediate treatments after a snake bite. I only considered the false answers and I gave -1 point to each wrong answer.

Figure 3: Results of the question, "Please select each of the following statements with which you agree."

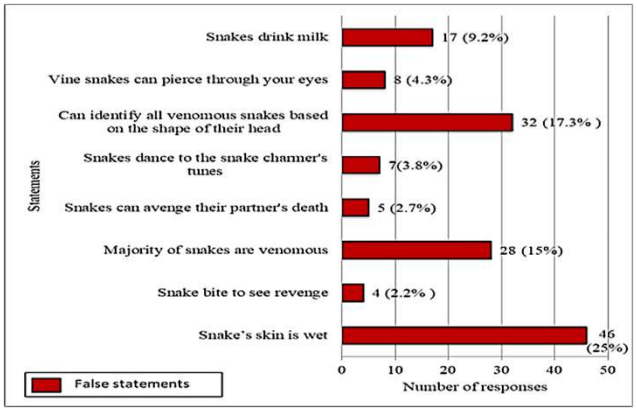
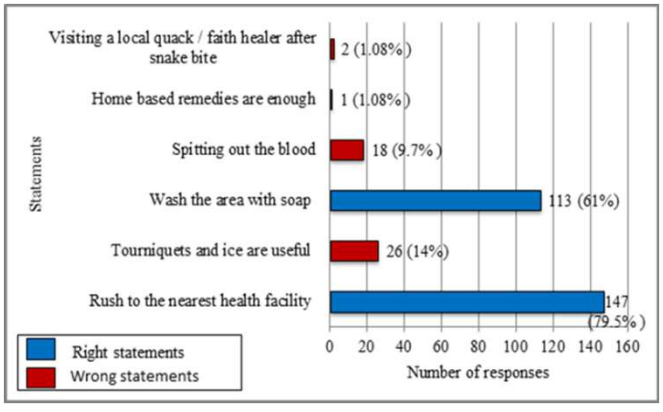


Figure 4: Results of the question, "If you get bitten by a snake?"



5.1.2 Scientific Knowledge of study participants:

To assess the scientific knowledge regarding species identification and venomosity of snakes, I asked two questions of snakes and gathered data (see table 1, 2).

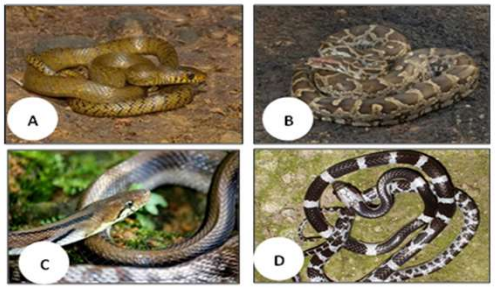


Figure 5: Images for question of snake identification

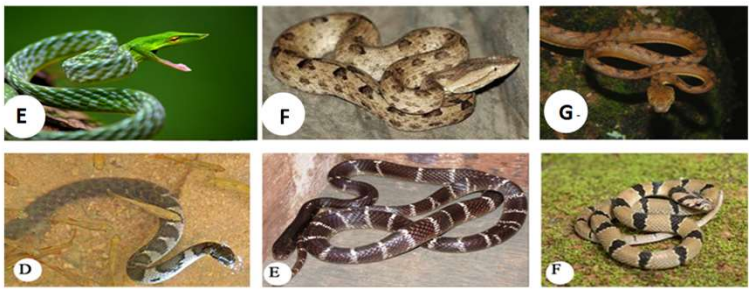


Figure 6: Images for question of snake identity and venomosity

One was to assess the knowledge of identification of the snake by their names (local/scientific/common names) with images of snakes (see figure 5) and another one was to assess the knowledge of identification of the venomosity of the snakes with images of snakes (see figure 6). I gave +1 point to correct identification and there were 10 identifications.

Table 1: Distribution of study participants according to knowledge regarding identification of snakes by their names

	Correct Name of the species	**Image identified correctly – N (%)**	**Image identified incorrectly – N (%)**
A	Common Rat snake – Ptyas mucosa	98 (53.0)	87 (47.0)
B	Indian Rock Python – Python molurus	116 (63.0)	69 (37.0)
C	Trinket snake – Coelognathus Helena	46 (25.0)	139 (75.0)
D	Common Bridal snake – Dryocalamus nympha	49 (26.5)	136 (73.5)

Table 2: Distribution of study participants according to knowledge regarding identification of the snakes by their venomosity

	Correct Name of the species	**Venomosity**	**Identified correctly- N (%)**	**Identified incorrectly- N (%)**
E	Green vine snake – Ahaetulla nasuta	Mildly	96 (51.9)	89 (48.1)
F	Merrem's Hump nosed viper – Hypnale hypnale	Moderate	87 (47)	98 (53)
G	Beddome's Cat snake – Boiga beddmomei	Mildly	68 (36.8)	117 (63.2)
H	Boulenger's Keelback – Fowlea asperrimus	Non-	71 (38.4)	114 (61.6)
I	Common Krait - Bungursu caeruleus	Highly	134 (72.4)	51 (27.6)
J	Common Kukri snake – Oligodon arnensis	Non-	65 (35.1)	120 (64.9)

5.1.3 Study participants' attitude towards snakes:

To assess the attitude towards the snake of study participants, I asked and got results from four questions (see figure 7, 8, 9, 10).

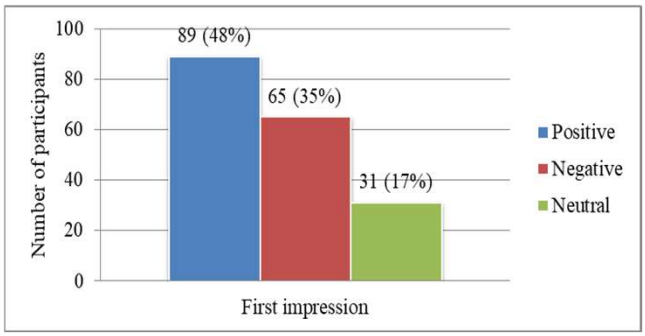


Figure 7: Results of the question, "When snakes are broached as a subject matter, how you feel?"

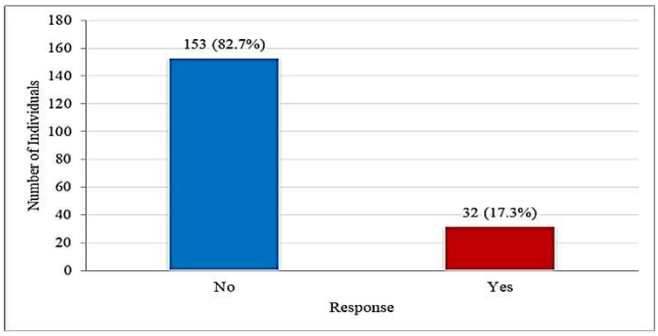


Figure 8: Results of the question, "Do you feel uncomfortable when you seeing these photos of snakes?"

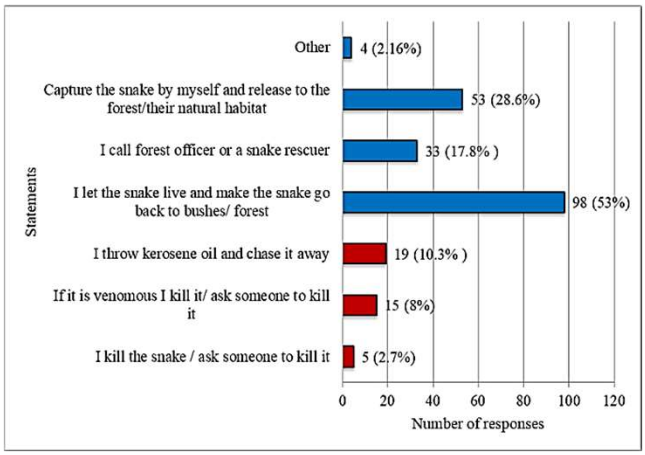


Figure 9: Results of the question, "What action would you take if you encountered the snakes in your yard or home?"

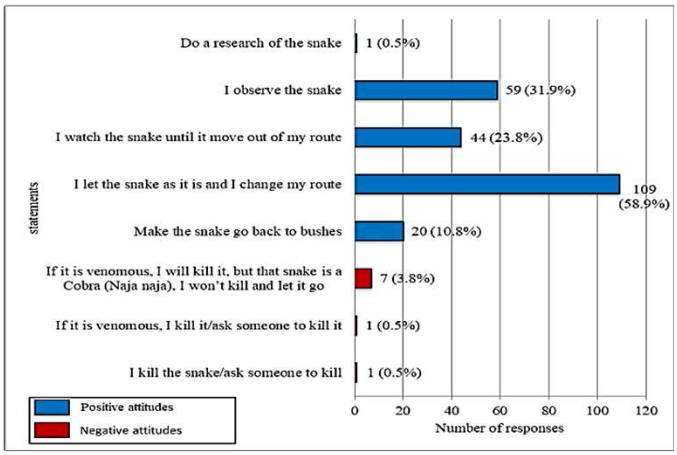


Figure 10: Results of the question, "What action would you take if you encountered the snakes in the wild?"

By considering all the answers given by each participant for all four questions, I assumed their attitudes as a positive or negative (see Table 3).

Table 3: Study participants' attitude towards snakes

Knowledge level	Total individuals in each level - N (%)	Negative attitudes - N (%)	Positive attitudes - N (%)
Low (-4 to 0)	43 (23.24)	30 (69.8)	13 (30.2)
Average (1 to 5)	87 (47.03)	31 (35.6)	56 (64.4)
High (6 to 10)	55 (29.73)	0 (0)	55 (100)

5.1.4 Discussion about the correlation between knowledge level and attitude of study participants:

The study shows that the study participants in the low knowledge level had a higher percentage of negative attitudes than the study participants on average knowledge level. The major finding of the study was, the study participants who were in the high knowledge level showed 0 (0%) of negative attitudes. This proves the Allen Carlson's and Yuriko Saito's theory that in order to appreciate snakes people should have a scientific and common knowledge of snakes.

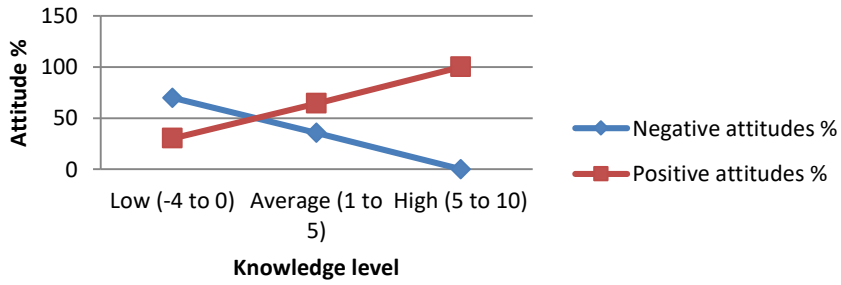


Figure 11: Correlation between knowledge level and attitude of study participants

5.2 Discussion of the correlation between the knowledge level and metaphoric perspectives:

In order to assess the metaphoric perceptions and its influence towards appreciation of snakes, I asked 2 questions based on myths, legends, and symbols regarding snakes I got below results (see figure 12, 13).

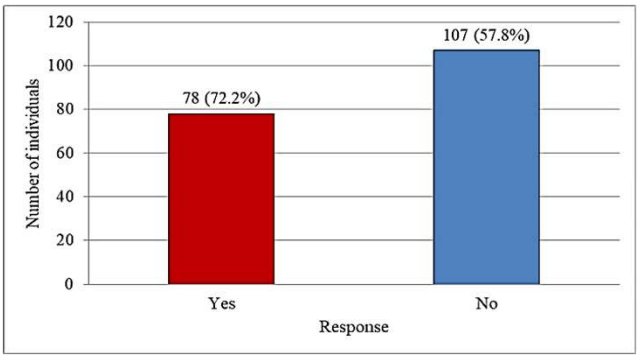


Figure 12: Results of the question, "Do you think your perception of snakes influenced by these legends, myths, and symbols?"

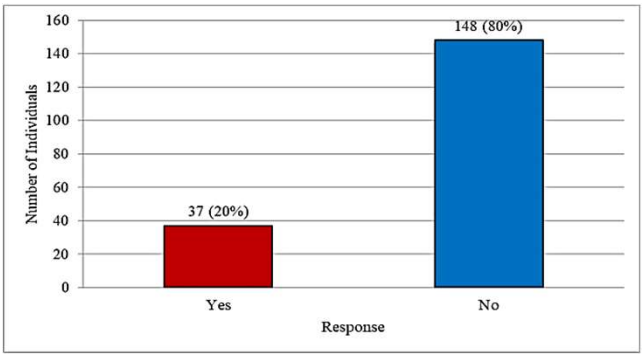


Figure 13: Results of the question, "Do you consider "Cobra" as sacred?"

To assess the metaphoric influence, I combined all the results that I got from the above two questions and the results were, out of 185 participants, 78 (42.16%) had been influenced by metaphoric representations, while 87 (47.02%) hadn't been influenced by those. When I compare with the knowledge levels which each participant got, the results were participants who got low marks (-4 to 0) were highly influenced by metaphoric representations and the influence was decreased when the knowledge level was high (see table 4 and figure 14).

Table 4: Knowledge levels according to the metaphoric influence

Knowledge level	Total individuals in each levels - N (%)	Influenced by metaphor - N (%)	Not Influenced by metaphor - N (%)
Low (-4 to 0)	43 (23.24)	23 (53.49)	20 (46.51)
Average (1 to 5)	87 (47.03)	44 (50.57)	43(49.43)
High (6 to 10)	**55 (29.73)**	**11 (20.00)**	**44 (80.00)**

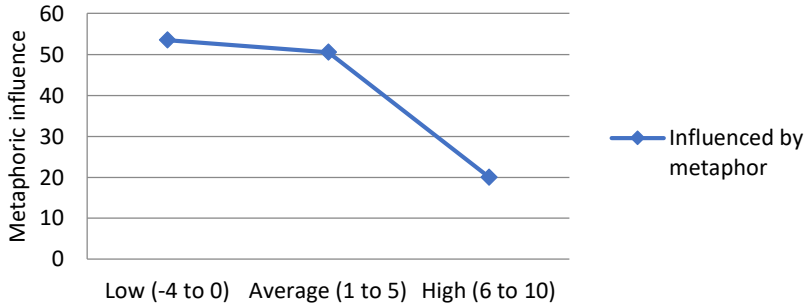


Figure 14: Correlation between knowledge level and metaphoric influence of study participants

5.3 Discussion of the correlation between knowledge levels, metaphoric influence and the negative attitude:

People with high knowledge level (marks above 6) shows 0% negative attitude towards snakes and they are the least influenced group by metaphoric perceptions. This shows the even people who knowledgeable about snake could be influenced by metaphors and because their scientific/common knowledge of snakes or the superficial qualities that snake metaphor represented, they shows 0% negative attitudes towards snakes or they aesthetically appreciate snakes. According to the Carlson (2000), science provides us knowledge about nature and it helps to clarify the correct categories of the object. Even the people with metaphoric perceptions, can appreciate snakes as it is when they got the scientific knowledge about snakes.

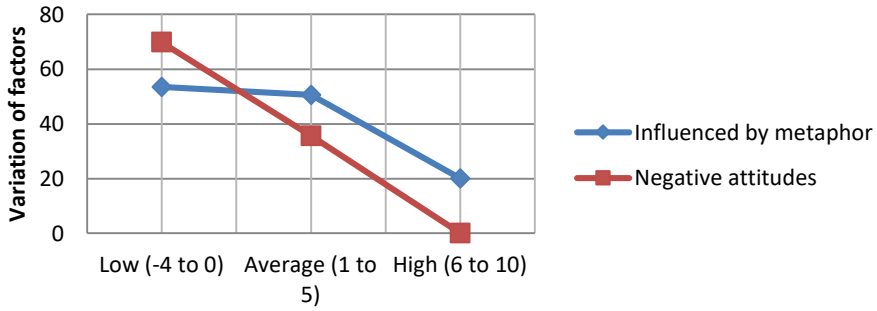


Figure 15: Correlation between knowledge level and metaphoric influence of study participants

5.4 Where can we appreciate the aesthetic qualities of snakes: in zoos / snake farms or in their natural habitats?

Majority of participants said that they would go to the forests because it's the best way to observe their true behaviour. 23.2% of people said that they would go to the zoos or snake farms to observe them (see figure 16), because some snake species are venomous and zoos and snake farms provide safety and clear viewing condition to observe snakes. In this section, I discuss both arguments according to the aesthetic appreciation theories by Yuriko Saito and Allen Carlson.

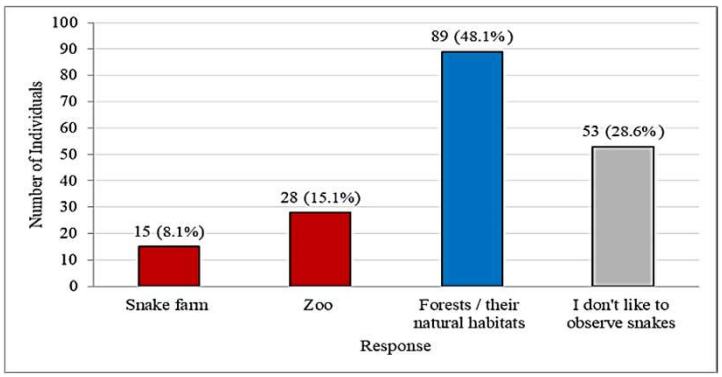


Figure 16: Results of the question, "If you like to experience/observe snakes and their natural behavior, what do you prefer?"

According to Saito (1998), if we want to observe snakes as it is and appreciate it seriously and deeply, we must observe it in its natural habitat and we should always experience nature with all our sensations not only limited to its visual appearance. In zoos we can see snakes, hear the noises that they create, smell them, and can even touch them. Therefore appreciating snakes in a zoo could be a multisensory experience.

However, the zoos are maintained captives that are designed by humans and it appears that they're more autonomous in their behaviour, thus we can't observe their true behaviour in zoos or snake farms. The artistic characteristics of snakes such as their colour, form, and also the behavioural patterns, all evolved overages in specific environments. When we remove a snake from its natural environment, we only have a fragment, not a complete animal (Gonzalez, 2017).

According to Saito (1998), to aesthetically appreciate animals, we must understand the specific characteristics of that species. Animals show their natural behaviour and in their natural habitats. The confined and unnatural space of zoos makes it undesirable for snakes to act naturally because their enclosures are ruled by humans. For example, zoos deny animals the chance of hunting their foods and prevent predation. Therefore the best way to appreciate the aesthetic qualities of snakes seriously and deeply is only in their natural habitats.

5.5 Landscape architectural strategy to mitigate human – snake conflict

According to the above analyses and discussion I developed the Landscape Architectural strategy that aim to mitigate human - snake conflict which consist with 3 factors: Ethical considerations, Positive aesthetics and "Rewilding" as a conservation strategy.

Figure 17: Main 3 factors of Landscape Architectural strategy that aim to mitigate human – snake conflict

5.5.1 Ethical considerations

According to Carlson (2008), aesthetics and animal ethics can strengthen each other and they should work together to preserve nature. Therefore when developing a landscape strategy to mitigate human- snake conflict, ethical considerations should part of it as below.

- When designing a space for appreciating snakes that aim to mitigate snake- human conflict, a landscape architect must have had a deep understanding and scientific knowledge of the snakes and their habitats.
- According findings, it's proved that without the scientific and the common knowledge people can't appreciate snakes aesthetically. The designer's main intention should be to give scientific or common knowledge through the design.
- In order to appreciate snakes, we have to appreciate their natural environment also. Therefore we have to use a conservation strategy to conserve both snakes and their natural habitats.
- When promoting superficial qualities, people go far away from the truth and it's ethically wrong. Therefore it is better to promote Positive aesthetics rather than superficial appreciations to appreciate snakes.

5.5.2 Positive aesthetics

Science can change people's appreciation of nature. For example, Darwin's research changed the view of nature, as Carlson (2013) explains.

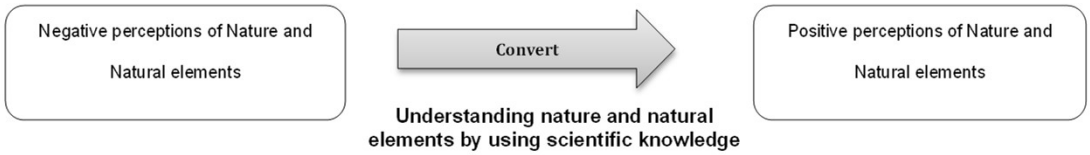


Figure 18: Positive aesthetics

Some examples for positive aesthetics are, Origin and evolutional story of snakes and the environment; External body qualities of snakes; Colours, textures, forms in their natural habitats; Natural behaviour of snakes; Their role in balancing ecological equilibrium, and wilderness.

5.5.2 Rewilding as a conservation strategy

"But rewilding, unlike conservation, has no fixed objective: it is driven not by human management but by natural processes. There is no point at which it can be said to have arrived. Rewilding of the kind that interests me does not seek to control the natural world, to re-create a particular ecosystem or landscape, but – having brought back some of the missing species – to allow it to find its own way" (Monbiot, G., 2014, p.83).

Snakes or any kind of wild animal has an unbreakable bond with their natural habitats. The conservation strategies should focus on conservation snakes in their habitats and with their habitats. Wilderness has positive aesthetics because it provides self-sustainable ecosystem where we can observe the true nature of the environment. Snakes are keystone species that maintain the ecological equilibrium by ensuring stable relationships throughout their food chain. Therefore conservation snakes are important to the whole ecosystem and rewilding conservation strategy can be used to conserve snakes and their natural habitats.

6. CONCLUSION

Since Sri Lanka has the highest species density of snakes than the other mammal species, high snake richness in the world, and high endemicity, there should be a proper appreciation and proper strategy for the conservation of snakes. But not only in Sri Lanka but also around the world, snakes are among the least appreciated species which exposure to the negative attitude of people. In this research, I proved that the lack of knowledge is the problem for creating human-snake conflict, and metaphorical perception of snakes based on legends, myths, and symbols is also a reason to create a negative perception towards snakes.

When aesthetic appreciation of snakes comes to the relation with ethics, there is a direct connection between a superficial appreciation of snakes and morally wrong behavior towards them. Therefore rather than promoting metaphors with superficial qualities it is better to promote the positive aesthetics based on science, such as origin and the evolutional story of snakes and the environment, external body qualities of snakes, natural habitats/wilderness, natural behavior of snakes, and their role in balancing ecological equilibrium. It is impossible to appreciate snakes through artificial installations like zoos/snake farms and we can only appreciate them in their natural habitats. Therefore the conservation strategies should focus on the conservation of snakes in their habitats and with their habitats. The quality of wilderness has positive aesthetics because it provides a self-sustainable ecosystem where we can observe the true nature of the environment. Therefore to conserve snakes and their habitats, the best conservation strategy is rewilding.

In conclusion, when finding solutions for human-snake conflict or human-wildlife conflicts, the role of Landscape architects is important. Animal ethics, positive aesthetics, and rewilding are the main qualities and factors in the concept of "the aesthetic appreciation" that can be used as a landscape architectural strategy to mitigate human-snake conflict.

REFERENCES:

1. Brady, E., 2014., Aesthetic Value and Wild Animals: *Environmental Aesthetics*. New York: Fordham University Press, pp.195.
2. Carlson, A. (2013). Environmental aesthetics: *The Routledge companion to aesthetics*. New York: Routledge, pp. 507-520.
3. Carlson, A., 1979., Appreciation and the natural environment: *The Journal of Aesthetics and Art Criticism*, 37(3), pp.267-275.
4. Carlson, A., & Lintott, S., 2008., Nature, aesthetics, and environmentalism: *From beauty to duty*. Columbia University Press.
5. Davis, S., 2012., The Artful Species: *Aesthetics, Art, and Evolution*. Oxford: Oxford University Press, pp.23.
6. Jayatissa, L. P., 2012., Present Status of Mangroves in Sri Lanka: *The National Red List*, pp.197-199.
7. Kellert, S.R., 1982., *Public attitudes toward critical wildlife and natural habitat issues*. US Department of the Interior, Fish and Wildlife Service.
8. Leddy, T., 2012., Aesthetization, Artification, and Aquariums: *Contemporary Aesthetics*, pp.6.
9. Monbiot, G., 2014., Feral*: Rewilding the land, the sea, and human life*. Chicago: University of Chicago Press, pp.10-83.
10. Morner, P., 2009, December 18., *Naga Raksha is the mirror of the soul.* Retrieved from http://www.infolanka.com/
11. Saito, Y., 1998., Appreciating Nature on Its Own Terms: *Environmental Ethics,* pp.135-149.
12. Gonzalez, M.T., 2017., The Aesthetic Appreciation of Animals in Zoological Parks: *Contemporary aesthetics*, pp.15.
13. Walton, K. L., 1970., Categories of art: *The philosophical review*, pp. 334-367.

READING NEED BASED CHANGES IN MORPHOLOGY IN SETTLEMENTS OF DELHI: MAPPING THE BUILT AND THE UNBUILT

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ABSTRACT:

Unprecedented urbanization experienced by Delhi typically provokes discussion on its altering morphology. In some areas single storied buildings has been converted to a multi storied structure, hundreds of commercial areas defy the Master Plan guidelines, changes in urban tissues have happened etc. Hence, an attempt has been made to read the morphology of purposefully selected settlements of Delhi. The article seeks to uncover the network changes that exist between 'the built' and 'the unbuilt' across the relevant scales of settlements based on quantitative and qualitative attributes of urban morphology. This is an evidence-based study in which varied cases are selected to study the changes in urban morphology vis a vis changes in Building structures, Land uses and Urban tissue. The analysis of this study will be drawn upon by fieldwork that will be carried out in the spaces of few selected settlements. The fieldwork would employee two important urban research methodologies in parallel. Based on observation, "Ground Truthing method" and ''Ethnographic method'' will be used to study the spatiality of the above selected settlements and it would be interpreted from an urbanist's point of view. Finally, in a concluding section, after collaborative documentation the authors will discuss aspects of morphology resulting in hybrid spatiality and altered building structures. The research would attempt to expose various forms of activity, both conscious and unconscious, that change the morphology of these settlements.

KEYWORDS: Constructs, Fabric, Urban Morphology and Urbanization

INTRODUCTION / BACKGROUND

Discussion of the emerging changes in morphology in various settlements in Delhi typically provokes critical comments focused either on the incompetence of the urban planners in drafting, designing basically envisioning the masterplan by predicting urban growth or incompetence of the implementing agencies i.e., weak judiciary. Departing from both these perspectives, this paper seeks to investigate hybrid settlements in the city of Delhi, from the lens of transforming morphologies[1]. The research has exposed various forms of activity, both conscious and unconscious, that change the morphology of various formal and informal settlements in Delhi.

Here, the building prototypes and the land uses along with the built fabric have evolved to accommodate a new landscape which is evolved out of the needs of the inhabitants and various network exchanges happening in the settlement. Under mutually beneficial and negotiable conditions, the city dwellers have modified habitat resulting in altered morphologies. The research seeks to uncover the various methods to read these changes in the morphology and identify constructs for conducting the same process. Collation of identified constructs focusing on the case of Delhi has been done in order to evoke discussion/future research on identifying parameters of morphology.

AIM / PURPOSE

The objective of the paper is to dissect the mechanism of need-based morphological changes of various formal (authorised) as well as informal (also unauthorised areas) settlements through additive layering and analysing various nuances of existence. An understanding of the relationship between dwelling and building in the design of cities, in conjunction with the environmental, social, political, and intellectual environments at the time of their planning and thereafter has been documented too.

LITERATURE REVIEW

Urban Morphology has been a topic of detailed research and study, various authors have talked about urban morphology in a direct or an indirect way. The word ''morphology'' was coined by botanist Goethein the year 1790.Goethe's studies in botany revealed to him certain common patterns in the development and modifications of natural forms. The name he gave to this new manner of inquiry was morphology. His definition of morphology was derived from anatomy of leaf and the proteus it has that keeps changing its patterns. (ZEMPLÉN, 2017)

In the year 1929, Ernest W. Burgess while studying Chicago's morphology, came up with a model for hypothetical pattern of urban growth based on the idea that land values are highest in the centre of a town or city indicating market forces as one of the major factors for shaping city's morphology. Hoyt Model on the other hand suggests, few activities grow in the form of sectors which radiates out along the main travel links. Activities in a sector are the same throughout the sector because of the purpose/function it serves. Land use within each sector would remain the same because like attracts like. Transportation route from hereon was considered one of the major parameters of discerning morphology. In theories related to urban morphology- cities are formulated by four intrinsic entities: 'buildings and their complementary/associated open spaces, plots, or lots. (Moudon, 1997). On the other hand in the Indian context, Manzoor Alam has attempted a new approach in his studies of the twin cities(Hyderabad-Secunderabad) through these western urban morphology models. (Alam, 1965)

Urban morphology approaches human settlements as generally unconscious products that emerge over long periods, through the accrual of successive generations of building activity. This leaves traces that serve to structure subsequent building activity and provide opportunities and constraints for city-building processes, such as land subdivision, infrastructure development, or building construction. Articulating and analysing the logic of these traces is the central question of urban morphology. Roger Trancik discusses three major theories of urban spatial design and urban mythology which can guide analysis of the above mentioned city building processes. The theories are Figure and Ground theory, linkage theory and place theory. One of the most significant theories suggesting 'history' of a place as an indicator of morphology is place theory. It operates upon structured systems of human needs and usage. In essence, place theory within spatial designs is "understanding the cultural and human characteristics of physical space." If we consider space as being a void bounded by urban mass with the potential to link people and spaces, it only becomes a place "when it is given a contextual meaning derived from cultural or regional content.'' (Trancik, 1943)The above stated theories are indicative in nature and do not highlight coherent measures of formation of cities. However, they give a clue of elements such as urban mass, open spaces (figure ground theory) transportation network (linkage theory) and ecology and the overall context(place theory) shaping/altering morphologies.

Table 1: Evolution of Urban Morphology, Source: author

1790	Goethe	Identified common patterns in the development and modifications of natural forms. The name he gave to this new manner of inquiry was 'morphology'. His definition of morphology was derived from anatomy of leaf and the proteus it has that keeps changing its patterns.
1899	Camillo Sitte	used a morphological understanding of the urban fabric to formulate principles for urban design, or 'city planning according to artistic principles.
1929	Ernest W. Burgess	While studying Chicago's morphology, he came up with a model for hypothetical pattern of urban growth based on the idea that land values are highest in the centre of a town or city.
1933	Le Corbusier	castigated traditional urban fabrics and proposed his own modernist solutions.
1939	Hoyt model	suggested that few activities grow in the form of sectors which radiates out along the main travel links. Activities in a sector are the same throughout the sector because of the purpose/function it serves. Land use within each sector would remain the same because like attracts like.
1945	Harris and Edward L. Ullman	Based on the structure of Chicago Harris and Ullman argued that a city might start with a single central business district (CBD), but over the time the activities scatter and gets modified. The scattered activities attract people from surrounding areas and act as smaller nuclei. These small nuclei gain importance and grow and start influencing the growth of activities around them.
1961	Jane Jacobs	appreciated traditional townscapes once more for their urban qualities
1962	John E. Brush	Brush wrote a book on 'The Morphology of Indian Cities' explaining four types of cities in India depending on their morphology: Indigenous cities Anglicized port cities Two-node cities Planned cities
1965	Manzoor Alam	In his book-Hyderabad-Secunderabad: Twin Cities, A Study in Urban Geography he evolved a model to account for urban growth and structure in Hyderabad. His model is clearly related to Western urban morphology models, especially to the concentric zone, but it does attempt to formulate, however, a new approach. He did intend to offer his model as a universal exemplar for South Asian cities.
1970	Arthur E. Smailes	He endorsed the idea that morphology of an area can be understood in terms of description of the area, its nature, its relative disposition and social interdependence which also constitutes a major component of geographical analysis of an urban area.
1970	RL Singh (Father of Modern Geography)	According to him the term 'morphology' includes the various internal forms and structural patterns and characteristics of a spatial unit. In brief, urban morphology is the distribution of different functions in a city.

James Vance	He claimed that morphology of the city i.e., its physical form and structure has the power to influence the culture, society, and the day-to-day lives of inhabitants. Vance has explained the significance of the "morphogenesis" of the city in Western civilization.
Nikos Salingaros	He created a new school of urban morphology based on morphogenesis and emergence and provided with computational analysis for the same, taking forward Alexander's work. Salinger's writings helped to introduce two key concepts in urban morphology, fractals and networks.

In 1970, another contribution in the seminal text of Geography by Arthur E. Smailes was marked significant due to the suggestive qualitative indicator of urban morphology it had. All facets of urban geography are discussed in the book including the core, integuments, population structure, land-use patterns, enclaves, and town structure. Population mobility and the continual crisscross circulation of populations within and between town and region are seen as important forces affecting the internal geography of towns. (Smailes, 1966)

Table2: Recent studies in Urban Morphology, Source: author

1990	Urban Morphology Research Group	The study of the physical (or built) fabric of urban form, and the people and processes shaping it.
1995	Smailes	Urban morphology-is not merely two dimensional in scope. On the contrary, it is through the special importance which the third dimension assumes in the urban scene that much of its distinctiveness and variety arise
2000	Michael Batty	He gave mathematical modelling to quantify urban morphology.
2001	Whitehand	Global structure develops from local processes They analyse cities as a complex rule-based model, where rules applied to small scales are similarly applicable to a larger scale (fractal). Models can then be used as a prediction tool for growth or changes in urban form
2005	Cowan	The study of urban form.
2005	Mayer	Morphology literally means form-lore, or knowledge of the for-what is the essence of that form; does certain logic in spatial composition apply, certain structuring principles
2005	Larkhem	Approach to conceptualising the complexity of physical form. Understanding the physical complexities of various scales, from individual buildings, plots, street blocks, and the street patterns that make up the structure of towns helps us to understand the ways in which towns have grown and developed.
2006	Gauthier and Gilliland	First, there are studies that are aimed at providing explanations or developing explanatory frameworks or both (i.e., cognitive contributions); and secondly, there are studies aimed at determining the modalities according to which the city should be planned or built in the future (i.e., normative contributions)
2012	Serge Salat	He formed various Morphological indicators for assessing the sustainability of cities such as the human size of the city, its ability to create wealth, the connection and accessibility of the city, its diversity, its density, bioclimatic urbanism, the place of nature and the resiliency of the city.

Above studies give various factors (qualitative and quantitative) of urban morphology that can be used as indicators while mapping built and unbuilt layers of a settlement.

RESEARCH METHODOLOGY

Two step approaches

The analysis of this study will be drawn upon by fieldwork that will be carried out in the spaces of the selected settlements in the city of Delhi. The fieldwork employee two important urban research methodologies in parallel. Based on observation, "Ground Truthing method" and ''ethnographic method'' has been used to study the spatiality of the above selected settlements and it would be interpreted from an urbanist's point of view to understand the on-ground situation developing an idea of the built and unbuilt layers. By inter-referencing mixed data (Google maps, historical maps, archival records, observation of interstitial space by walking and making field notes, photography, and critical drawing), mapping of the most salient and hybrid features of these spaces would be done. The mapping is later enhanced by ethnographic method, the space is examined from the point of view of its residents and users. This approach will rely on interviews, mapping participant trajectories, photo-ethnography, and scratch notes. Finally, in a concluding section, after collaborative documentation the authors have discussed aspects of morphology resulting in hybrid spatiality and altered building structures. The research has attempted to expose various forms of activity, both conscious and unconscious, that change the morphology of these settlements.

Ground Truthing method

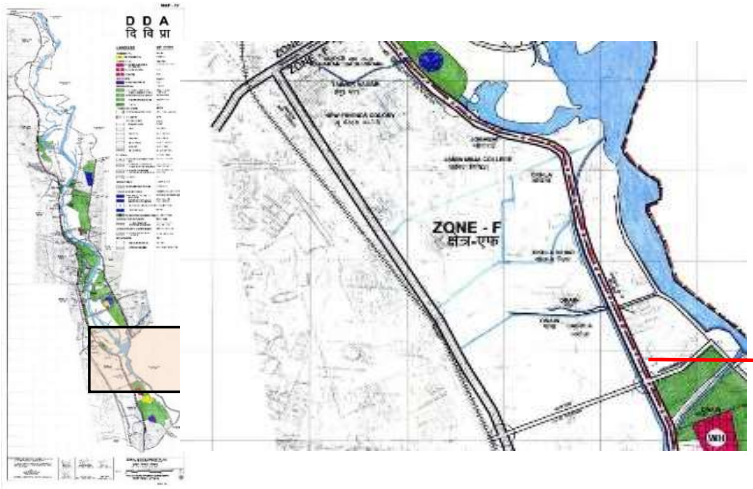
By inter-referencing mixed data (Google maps, historical maps, archival records, observation of interstitial space by walking and making field notes, photography, and critical drawing), mapping of the most salient and hybrid features of these spaces has been done.

Ethnographic method

The mapping has been enhanced by ethnographic method, the space is examined from the point of view of its residents and users. This approach relies on interviews, mapping participant trajectories, photo-ethnography, and scratch notes.

Various cases (pilot projects) which are a good mix of formal-informal and new-old settlements of Delhi such as **Lala Lajpat Rai Market, Shahjahanabad, Shaheen Bagh, Sarita Vihar and Jasola Vihar** have been chosen purposefully and an attempt has been made to read their existing and changing morphologies through mapping the built and the unbuilt.

Case of Shaheen Bagh



Shaheen bagh holding a population of 1.5-2 lakh area) in land use plan of zone O

Fig1: Location of Shaheen Bagh in Delhi, Source-Masterplan (2001) of Delhi

The Khasra map(archival map) was retrieved from the Revenue Department of Delhi which was prepared before the Delhi Land (Restrictions on Transfer) Act, 1972.

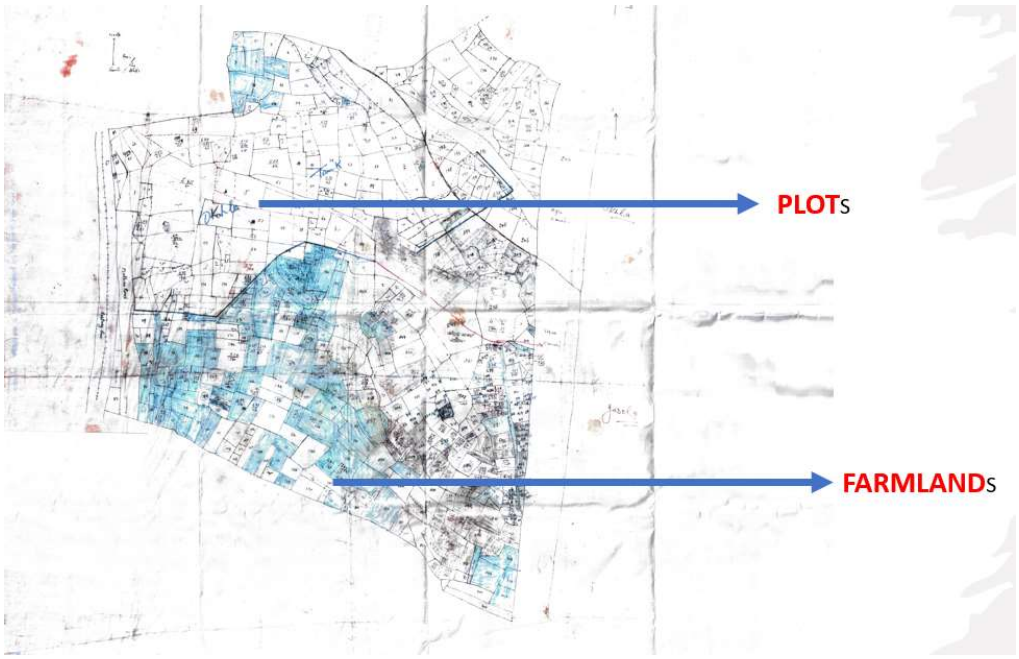


Fig2: Khasra map showing area of Shaheen Bagh, Jasola Vihar and Jasola Vilage in Delhi, Source-Retrieved from the Patwari of Jasola Village(Revenue Department)

All the plots which were vacant, and farmlands were marked in different colors, as they were the only visible layers of built and unbuilt on the khasra map. Later, this would be overlapped with the google earth map (showing present scenario) to identify land use and urban tissue/fabric related morphological changes. This exercise helped in capturing multiple transformations that were a resultant of land acquisition acts in Delhi. The residents were also interviewed later, to gather information on the process. The residents in the age group of 65-70 could shed some light through cognitive memory and also object memory on the conversion of farmlands into 3-4 storey buildings that later became the new source of occupation of the farmers. In the case of Jasola Village, due to the negotiations between developers and landowners there-the morphology of the interstitial spaces were transformed completely. These hybrid spatialities in the settlement may be seen as a resultant of these negotiations only. The hybrid urban reality created has the potential to develop into a new spatiality hence there is a need to alter the way we perceive the development of masterplans of such settlements in Delhi by rethinking upon them.

Fig3: Marked form determinants and greens of Shaheen Bagh Source-author

OLD SETTLEMENT V/S NEW SETTLEMENT

Fig4: Marked new and old settlements around Shaheen Bagh area Source-google earth

This mapping was done to identify the conflict areas where a layer of built has come upon the existing greens of Southeast Delhi, Zone F and vice versa.

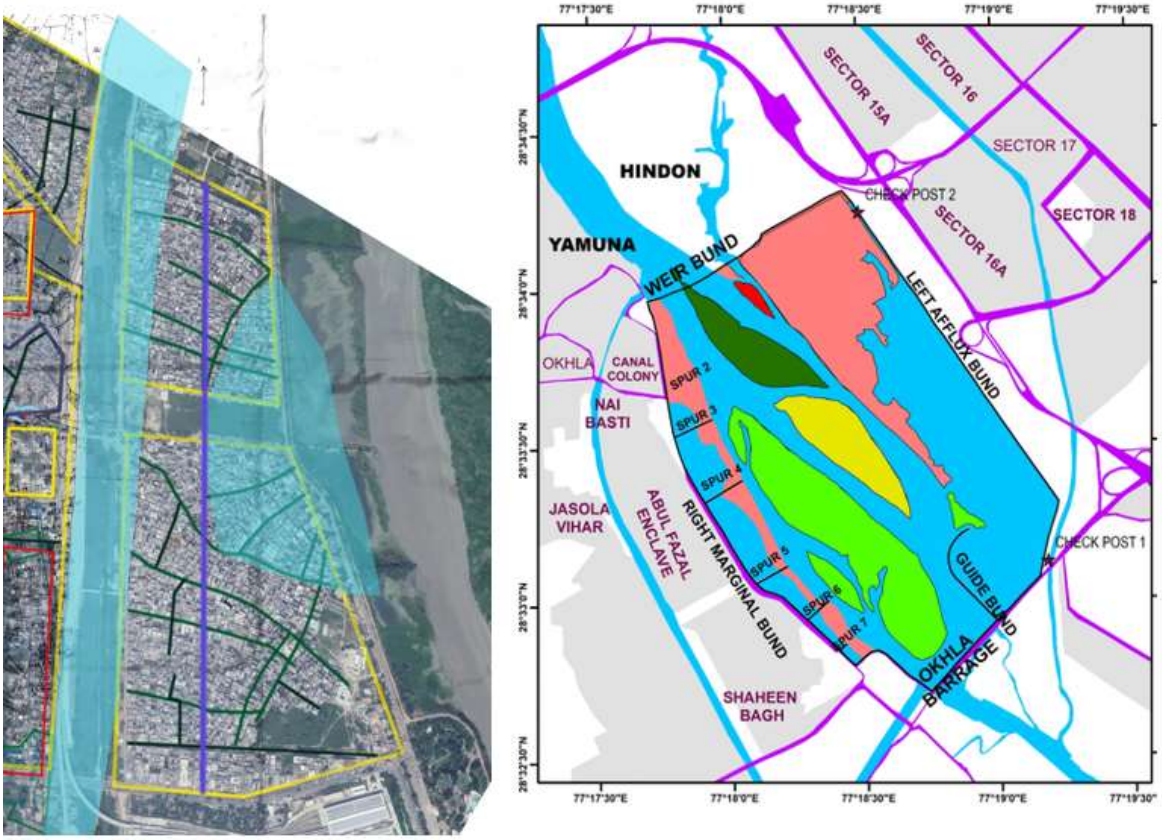


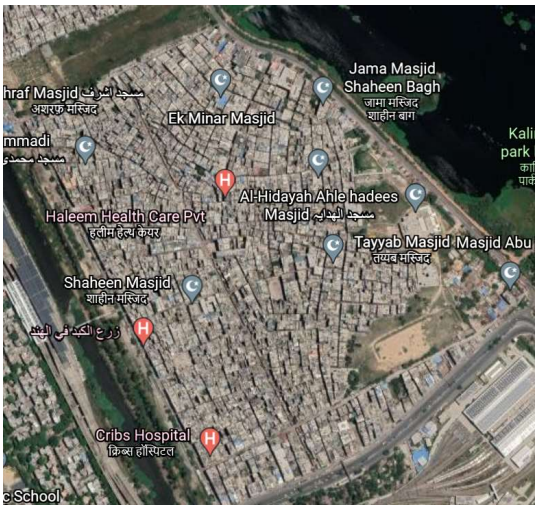
Fig5: Morphology of Shaheen Bagh area Source- Hydrological characteristics and flood plain vegetation of human impacted wetlands: a case study from Okhla Bird Sanctuary, National Capital Region, New Delhi, India (Research Gate) by Upma Manral

This mapping was done to identify the conflict areas where a layer of built has come upon the existing greens of Southeast Delhi, Zone F and vice versa. Form determinants found were Agra canal, Railway line and drains which followed the street pattern. Very little research has to date been done around the these physicalities of any settlement acting as the major form determinants.

OBSERVATIONS

Spurs/Streets major streets are a resultant of the Yamuna's water accumulation. - result of 8 number,7 number (pulia) in the entrance of Shaheen Bagh. The settlement pattern is ovular/circular despite of being straight and chances are it is derived from hierarchy of streets , shape of water and sand beds that has generated the bulging streets. Above morphological patterns are only read through archival mapping inter referenced with google earth map of the same chunk. Secondly, the high tension line came before the settlement, settlement wasn't built under it. A very clear distinction by a major street (central spine) is visible on the current google earth map. Currently, this central spine has been commercialized(bazaar) and has turned into a regular market for Shaheen Bagh and adjacent area(precinct of Okhla) with a weekly vegetable bazar.

Major reserved greens have Apollo and Okhla STP now. This was discussed with a few residents also, who pointed out this change complaining about the lost greens in their vicinity. Possibility is Government could not acquire agricultural land, preferred developing land with reserved greens.



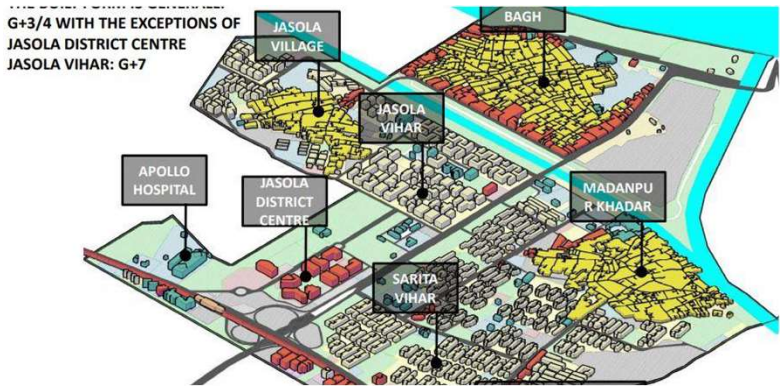


Fig5: Current scenario of central spine slowly getting commercialized, Source- Exploring Co-existence of Formal and Informal Settlements: A case of Jasola Vihar and Shaheen Bagh (Research Gate authors Samreen Sultan and Anshul Abbasi)

Commercial (Showrooms/food outlets) occurring on periphery of Shaheen Bagh has also been documented which was observed while conducting reconnaissance survey of the site. On being asked the residents informed the belt of branded showrooms has come up due to the realization of the need of branded items in nearby areas as it was projected from the growing dependency on nearby malls in Noida. The area started developing to accommodate showrooms and restaurants in the peripheral area abutting the main arterial road with busy traffic through out the day hence increasing their sale.

This also changed the layer of built(a different fabric with altered heights)contrasting the regular household fabric of the settlement of Shaheen Bagh with similar plot sizes.

Fig6: Changing land use mapped and clicked in the peripheral road of Shaheen Bagh, Source- Author

It is evident that the residents had been preparing themselves for such a transformation, and with time they had developed a collective/individual capacity to benefit from market speculation also. Old residents stared selling their plots on the periphery to builders. On the one hand, they were thus partly able to control the terms and timing of the traffic flow, thus moderating the commodification process to reflect their own interests.

On the other, they have been able to enter fractional partnerships with private developers to guarantee them a lifetime of monetary returns. Many of them have thus succeeded in turning the sale of their lands into a profit-making mechanism that has left them and their family better off than before. And in doing so they smoothly transformed themselves into capitalist agents and re-wove their family and community bonds into functioning networks that comprised new roles and responsibilities.

Fig7: Current scenario of central spine and peripheral road-slowly getting commercialised in Shaheen Bagh,

Source- Clicked by author

CASE OF SARITA VIHAR AND JASOLA VIHAR

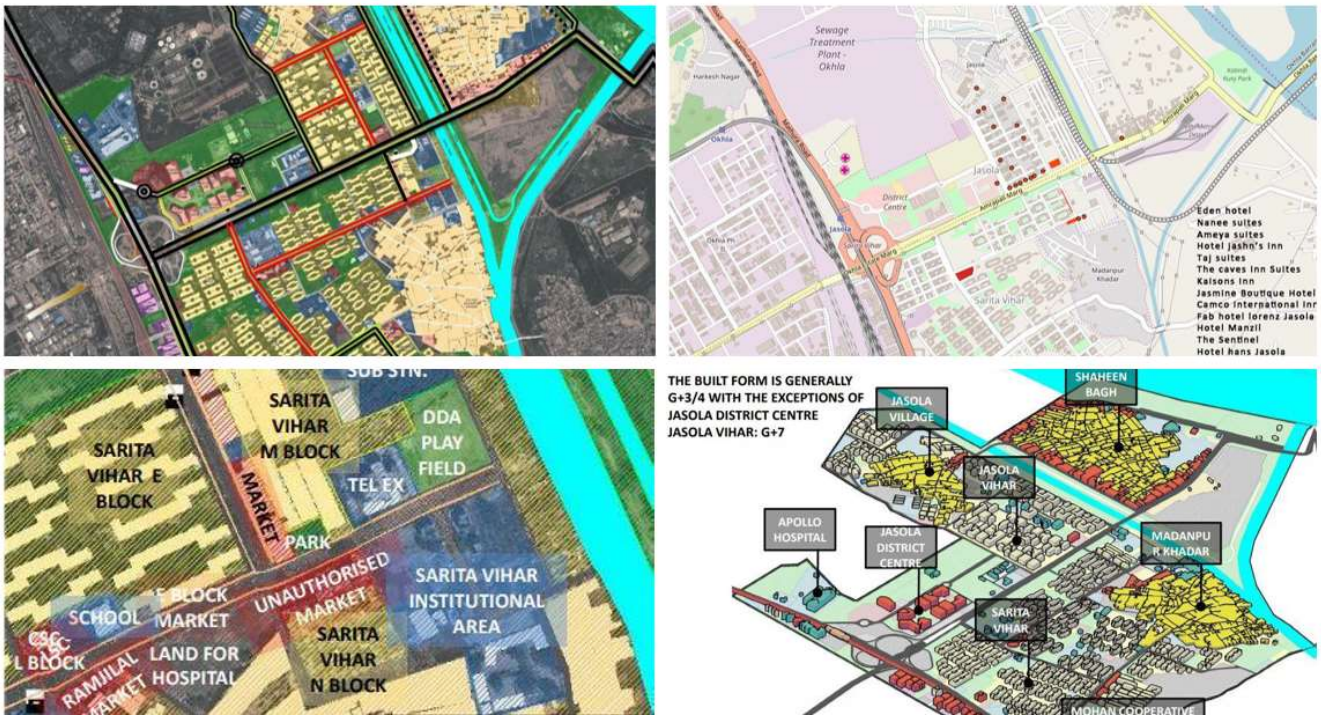


Fig8: Case of Sarita Vihar and Jasola Vihar (markets and suites coming in), Source- Dissertation on Effect of Medical tourism on local settlements by Avikarsh Bhatnagar(M.Arch, Urban Regeneration(Jamia)

OBSERVATIONS

Morphology of an area is very much guided by real estate forces and as such should have been a prime consideration for the designation of density patterns and building heights proposed in Masterplan. Some areas are shown in Masterplan as low-density area but are gradually getting converted into high density areas in an unauthorised manner. Also, there have been instances where residential areas get converted into commercial uses due to real estate forces nearby.

In the case of Sarita Vihar a new maket has come up in the planned colony by DDA out of the daily needs of people. Also, an interesting morphological pattern of building up of new suites is observed in the outskirts of Jasola vihar(area in proximity with Apollo hospital).All this is a consequence of growing medical tourism in the city, a network exchanged that was not realised by the planners while developing the masterplan. Also, in areas designated as residential- new chemist shops have been opened to support the foreigners staying in the area to visit Apollo hospital.

Changing heights in Authorised settlements of Jasola Vihar

Fig9: Case of Jasola Vihar (Illegal construction on terrace)

Fig10: Case of Jasola Vihar (Illegal construction on terrace) Source: Author

Fig11: Case of Jasola Vihar (Illegal construction at dead end of the society) Source: Author

Large scale unauthorised development of low-income workers has been observed in the planned colony of DDA flats, Jasola Vihar. The development of temporary shelters of the domestic workers shows lack of space(servant quarters) in the designed colony by DDA. Further, other needs of groceries shops, press wala, vegetable shops etc. were also not realised that resulted in development of illegal construction in a planned colony. This is a result of lack of understanding of socio-economic parameters of the population in evolving morphology of the city which eventually masterplan fails to address.

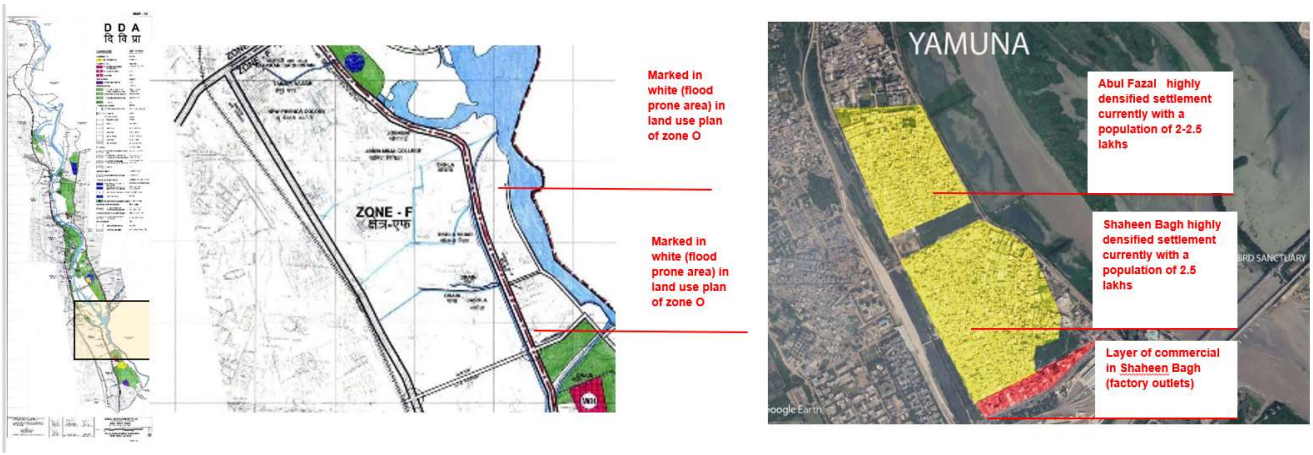


Fig12: Case of unauthorised informal settlements on the floodplain Source: Delhi MPD

Unauthorized settlements holding a population of 2-2.5 lakh each have emerged on the floodplains of Yamuna marked in white in Masterplan. The masterplan of Delhi (even the latest draft of 2041) is still silent about this discrepancy that has happened overtime due to the unrealized need of housing and error in projecting the population growth.

Case of Shahjahanabad

Ground Reality-Existing Land use of Zone A (walled city) showing red(commercial) penetration in the residential fabric of Shahjahanabad.

Fig13: Zonal Development Plan of Zone A(walled city) showing red(commercial) only along Chandni Chowk road and Asaf Ali Marg. Source: Delhi MPD

The land use studies of walled city of Shahjahanabad indicate large scale changes in land use character of area wherein residential land use has been unauthorizedly converted into commercial use. Zonal development plan does not recognize these changes and show the entire area as residential except the strip along Asaf Ali Road and Chandni Chowk as commercial. Interstitial spaces such as streets, markets, and city commons may provide a stage to unravel everyday socio-spatial co-mingling, where diverse actors manoeuvre via intricate operations to claim their rights to space. Hence, the change in land use has come out of the need of people and their activities.

Case of Lala Lajpat Rai Market

The masterplan for Delhi suggests the single storey character of the market shall be retained, however the market is already three storied high. The masterplan does not suggest how it proposes to convert the three storeyed structure back to single storey. This is an example of lack of understanding of the forces that guide the morphology of a place thus leading to a proposal that remains unimplemented in the last 40 years.

Fig14: Current scenario in Lala Lajpat Rai Market, Source: author

The masterplan for Delhi suggests a certain height in the market of Delhi shall be retained, however the market have already grown taller. The masterplan does not suggest how it proposes to fix the FAR of such areas considering the changing socio-economic patterns. This is an example of lack of understanding of the forces that guide the morphology thus leading to difficulty in reading the morphology.

CONCLUSION

Following parameters of reading morphology were derived through the above case studies to read morphology of any settlement. Planners have not been able to gauge these parameters and thus there are various anomalies in the masterplans they come up with. Yet no significant research from the authorities has been able to map the evident morphological change in a systemic/methodical manner for various settlements in Delhi.

FINDINGS/ ANALYSIS &INFERENCE

The derived parameters (shown below in Table3) if dealt with in detail shall help planners decide the level of intervention and controls to be introduced in formal and informal settlements.

Table 3: Parameter selection matrix for reading morphology, Source: author

Physical	Non-Physical
Land use including mix land use.	Density
Plot size	population
Building heights	Income groups of population
Floor area ratio	Occupation pattern
Parking Lots	Workers participation rate
street pattern/road pattern	Migration Component
railway network	Literacy rate
open spaces	Birth and Mortality rate
water bodies	Sex ratio/ child sex ratio
Landmarks and heritage buildings	Average household size
	Land values
	Urban Ecology (concept of invasion and succession)
	Inclusiveness

The research findings in the form of parameters derived can help develop holistic maps of the built and unbuilt layers in any settlement's map which can in turn help develop the local area plan and the overall masterplan of any city judiciously. Moreover, it would help create an additional/suggestive list of stakeholders of varying disciplines who are required to be a part of master planning process to draft local area plans and masterplans.

Moreover, above study of various pilot cases reveal a method that can be developed of 'Additive Layering' based on the layers of Economy, Social Life, Infrastructure, Environment and Ecology. These aspects trigger a change in the morphology of any settlement at so many levels. Below, is a graphic produced by author to kick start a discussion on each of these aspects resulting in discrete morphologies.

Fig15: Additive layering derived from the cases of Delhi with altered morphologies, Source: author

The above image summarizes the significant layers on which morphology can be traced and later mapped reflecting the built and unbuilt fabric of any settlement. Other physicalities of a settlement -factors such as public service provision, hazard mitigation, housing, alleyways, setbacks, drainage and water connection, economy activities, provision of electricity, sanitation, public private interface and governance can also be analyzed to read its morphology. This includes a study on types, materials, uses, design, placement, quality, F.A.R, service coverage etc.

This research also creates a ripple effect in the discussions concerning quality of life in various settlement for one can attempt to comprehend the various nuances of existence that were talked about in an implicit and explicit way. The graphic below has been created by author which is are indicative in nature and defines the future scope of research.

Fig16: Nuances of Existence derived from the cases of Delhi with altered morphologies, Source: author

Further research can be carried on aspects entailing mapping and details of food exchanges(in the form of network diagram), quality of life, equitable societies and an attempt can be made to empiricalise various qualitative factors which can only be depicted through mapping such as historical context, festivals, religious scenario and social practices.

REFERENCES:

1. Samreen, S. ,2021., Exploring Co-existence of Formal and Informal Settlements: A case of Jasola Vihar and Shaheen Bagh, pp. 138-142.
2. Upma, M, 2012 Hydrological characteristics and flood plain vegetation of human impacted wetlands: a case study from Okhla Bird Sanctuary, National Capital Region, New Delhi
3. A. H. Maslow, 1943., A Theory of Human Motivation, Originally Published in Psychological Review, 50, pp. 370-396.
4. Irshad, Q, 2017 Measuring social interaction in housing typologies: the case of Delhi published in Dakam's International Architecture Studies Meeting, pp.266-27.
5. Alam, M, 1965 Hyderabad-Secunderabad, twin cities; A study in urban geography published in Allied Publishers, pp.150-54.
6. Roger T., 1943, Finding published in Lost Space: Theories of Urban Design published in John Wiley and Sons, Inc
7. Arthur E., 1966, The Geography of towns published in Bombay, New York, Allied Publishers.

Journals

1. Moudon, A,1997, Urban morphology as an emerging interdisciplinary field published in Urban morphology journal 1997,
2. Zemplen G, 2017, Structure and Advancement in Goethe's Morphology published in University of Toronto Press

Websites

1. Delhi zonal development plans from https://dda.org.in/
2. Tissue/Fabric mapping from https://earth.google.com/web/

COMPARING DIVERSITY IN AN OLD CITY WITH ITS NEW CITY: A CASE OF SHAHJAHANABAD AND NEW DELHI

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ABSTRACT:

More than half of the world's inhabitants live in cities. Yet, why do some cities seem more vibrant and livelier than others? To acknowledge this, we should understand the facts that makes the cities vibrant and diverse. The existing belief in city planning has been replaced by diversity. Are planned districts natural homes to diversity like organically evolved historic cities or is it just a coincidence?

Ultimately people want their cities to be great places to live and work. Throughout history, comparative analysis of cities has been one of the eminent sources of insight into the characteristics of the lifestyle of city dwellers. The aim of this study is to analyse and find the diverse city among a historic city (Shahjahanabad) and its new city (New Delhi), both born in similar context. Furthermore, to find the strategies to be adopted while planning a new city aiding the city to sustain and prosper on its own.

Different types of supporting diversities in cities were identified and the comparison is done based on the diversity conditions outlined by Jane Jacobs. For the comparison, the significance of time spread is taken into account for both cities.

Comparing the different aspects of diversity in terms of functioning in Chandni Chowk of Shahjahanabad (historic city) and Kirti nagar of New Delhi (new city), it was found that the old city of Shahjahanabad breed more diversity in different ways that impact neighbourhoods and social life. Thus, proving the hypothesis that "old cities are more diverse and vibrant than new cities".

KEYWORDS: city diversity; old city; new city; Shahjahanabad; New Delhi.

1.1 INTRODUCTION

Diversity is said to be found, if in a group or community, there are people having different ideologies and culture. A person's social and personal development have a major effect on the diversity of the environment he or she lives in. Living in a diverse environment increases the creativity and productivity as it caters to learning as well as growing with and from each other. A creative and much brighter generation is produced due to the exchange of ideologies between people.

City diversity is one of the variables that have played a big social role for the economic growth of cities. A diverse environment increases productivity and creativity, adding to the profits and further improving the lives of employees and workers.

Shahjahanabad and New Delhi go hand in hand like the two faces of the same coin. They are two zones of the same state with no boundary defining them. Old Delhi still portrays the old Shahjahanabad with small lanes and joint families. It contains a lot of historic tourist attractions oozing Mughal architecture, making it the soul of Delhi. The most famous and oldest market in India, Chandni Chowk is in Old Delhi. It is still bustling with people.

New Delhi articulates a different story from Shahjahanabad with high rise buildings, metro corridors and structures standing as testaments to the British reign. It is truly a metropolitan city with all amenities and luxuries. The city was affected by both industrialization and modernization. It is India's political and administrative centre. A very contrasting difference can be noticed in the lifestyle and area of the two cities.

It is important to analyse the growth of diversity among cities of Shahjahanabad and New Delhi in order to breed various functions into the city and consequently enhancing globalization.

1.2 AIM

To study and compare aspects of diversity in terms of functioning in a historic city (Shahjahanabad) with that of a new city (New Delhi) with respect to Jane Jacobs criterias for city diversity.

1.3 OBJECTIVES

- To study the different types of supporting diversity and conditions for city diversity outlined by Jane Jacobs in her book "The Death and Life of Great American Cities".
- To understand diversity by comparing parts of Shahjahanabad and New Delhi placed in similar context, that impacts neighborhoods and social life based on diversity criterias.
- To understand if the rapid conversion of cities to cement-dominated urban centers in New Delhi is causing great losses in diversity in terms of functioning

- To analyse conditions of diversity in Shahjahanabad and New Delhi based on criterias outlined by Jane Jacobs for city diversity.
- To develop new design concepts from the characteristics of the diverse city.

1.4 RESEARCH METHODOLOGY

The study begins with identifying the different types of supporting diversities in cities. It then focuses on understanding the conditions for diversity in cities put forward by Jane Jacobs and the need for these conditions which generate diversity in an urban district. The case study taken into account is to study the differences between an organically evolved parent city (Shahjahanabad) and its new planned city (New Delhi) to understand which is more dynamic and diverse in its function, both cities placed in similar context to accurately conduct the study. A detailed case study of localities of Chandni Chowk and Kirti Nagar (mainly common areas) in both cities such as residential neighbourhoods, markets etc is done. The methods of data collection used are:

- Primary sources: questionnaires (for people residing in the site), interviews, by observation, and collection of data directly from the site.
- Secondary sources: reports, records, newspapers, documents.

A comparative study of both cities (Chandni Chowk and Kirti Nagar) is done based on the diversity conditions outlined by Jane Jacobs. For the comparison, the significance of time spread is taken into account for both cities.

Further, analyzing various aspects missing in the new city and understand the features that contribute to diversity in historic city cores so that some aspects can be implemented in new cities.

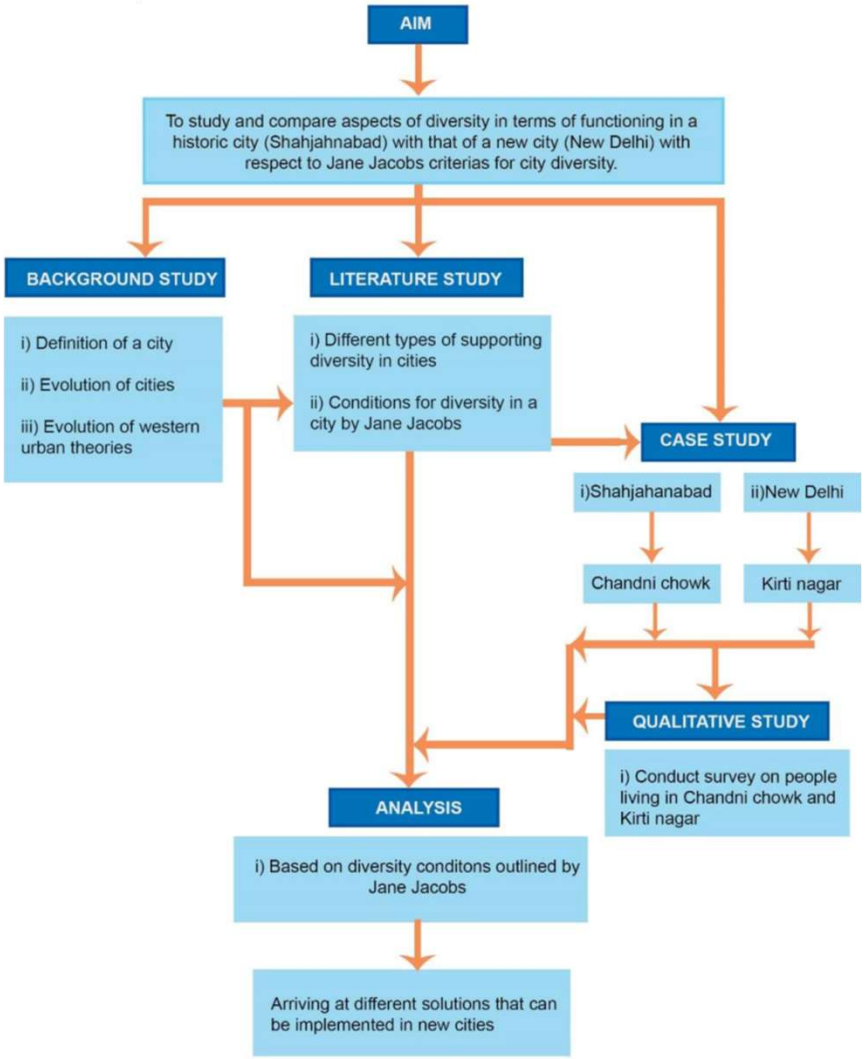

Figure 1: Methodology chart; Source: Author generated

2. LITERATURE STUDY

Historic cities are reflections of their respective cities. They depict the cultural character and standard of the urban life, serving as foundation to modern urban growth. They are the backbone to local and regional economies.

present era, new cities are being foreign to their old parent city, abandoning its identity. Cities are constructed with hopes of increasing country's economic growth.

2.1 DIFFERENT TYPES OF SUPPORTING DIVERSITY

As places where people come together for labour, to enjoy and dwell, cities promote and profit from diversity. Besides they foster and strengthen a variety of cultural, social and economic activities. Even though ethnic groups, faiths and races are associated with the term diversity, there are more diversities besides population diversity which incorporate people. Two additional options include industrial diversity, defined by the amount and scale of various industries in the city, and neighbourhood diversity, determined by the mixed use and situation of land-use patterns. Industrial diversity refers to the variety of economic activities that reflect differences in economic structure. (Malizia & Ke, 1993). Cities thrive socially and economically when different types of diversities coexist.

2.2 CONDITIONS FOR CITY DIVERSITY

Jane Jacobs' made numerous findings, one of which is the significance of diversity and a mixture of uses for cities to sustain on their own. It is a fact that cities naturally sow the seeds of diversity and profusely produce new enterprises and ideas of all kinds, but this does not mean that they unconsciously produce diversity solely by surviving. Furthermore, they are natural economic homes of immense numbers and ranges of small enterprises. Several spots stay alive and busy, while the rest stand dead. This ubiquitous principle is the need of cities for a most intricate and close-grained diversity of uses that give each other constant mutual support, both economically and socially. The components of this diversity can differ enormously, but they must supplement each other in certain concrete ways. (Jacobs, 1960)

Jane Jacobs put forward four essential conditions for cities to generate diversity in abundance throughout:

1. The district, and indeed as many of its internal parts as possible, must serve more than one primary function; preferably more than two. These must ensure the presence of people who go outdoors on different schedules and are in the place for different purposes, but who are able to use many facilities in common.
2. Most blocks must be short.
3. The district must mingle buildings that vary in age and condition, including a good proportion of old ones so that they vary in the economic yield they must produce.
4. There must be a sufficiently dense concentration of people, for whatever purposes they may be there.

Together, these four conditions create powerful and potential economic line-up of uses.

3. LIVE CASE STUDY

3.1 INTRODUCTION

Delhi is one among the oldest and constantly colonized cities all around the world. Countless civilizations have laid their roots in its rich soil throughout history, creating an amalgam of cultures that is communicated most puissantly in the architecture of the whole city. It was the contrasting characteristics between the two cities of New Delhi and Shahjahanabad that led to the commencement of this research. Both the cities are placed in a similar context, overlooking the Yamuna River without any formal boundary between them. Yet, they can be easily distinguished. The two cities are compared to study the contrasting characteristics between a planned city and its organically developed historic parent city and to acknowledge the more dynamic and diverse one in terms of functioning.

3.2 SHAHJAHANABAD

3.2.1 HISTORY

Shahjahanabad is a city that has endured the passage of time and growth. Delhi as we know today was formed by the integration of seven historic cities. One among these was Shahjahanabad. Until now, Shahjahanabad keeps up with a vibrant and diverse population and a throbbing economy. Built by Shah Jahan in 1639, it was one of the grandest capitals of its time.

With time and ensuring political upheavals; the city fell prey to neglect, consequently degenerating the quality of life it once provided. With the British siege, "Shahjahanabad" became the "Old city" of Delhi and the focus shifted to the newer settlements further southwest. A shift of land use from predominantly residential to trade and commerce can be observed, establishing Old Delhi as one of Asia's largest wholesale markets. Further increase in population and deteriorating infrastructure have created slum-like conditions in the city.

However, despite years of plunder and neglect, its magnificent scale is breath taking. Apart from the grandeur of what remains of its architectural splendour, the city also showcases an array of traditional art, craft, beliefs and practices. Various layers of markets, food stalls, and cultural stops make it an everlasting fete. The rich culture, bustling markets, fascinating and intricate monuments and a beautiful built-in heritage has all the possibilities to attract international tourists to Shahjahanabad.

3.2.2 PLANNING

The city was designed for 60,000 population which is spread over 569 hectares enclosing a wall punctured with seven major gates from which radiated highways to all parts of his empire. As per Indian 'Vaastu Shastra' (Architecture) is perceived to have influenced its settlement geometry as a bow and arrow shaped semi elliptical city. City was planned on man macrocosm analogies (Datmann, 1969); Spine as Chandni Chowk, Ribs as streets, Head as fort, Heart as Jama Masjid, Organs as Sarai (Rest House) and Wall as skin. (Dutta & Dutta, 2012)

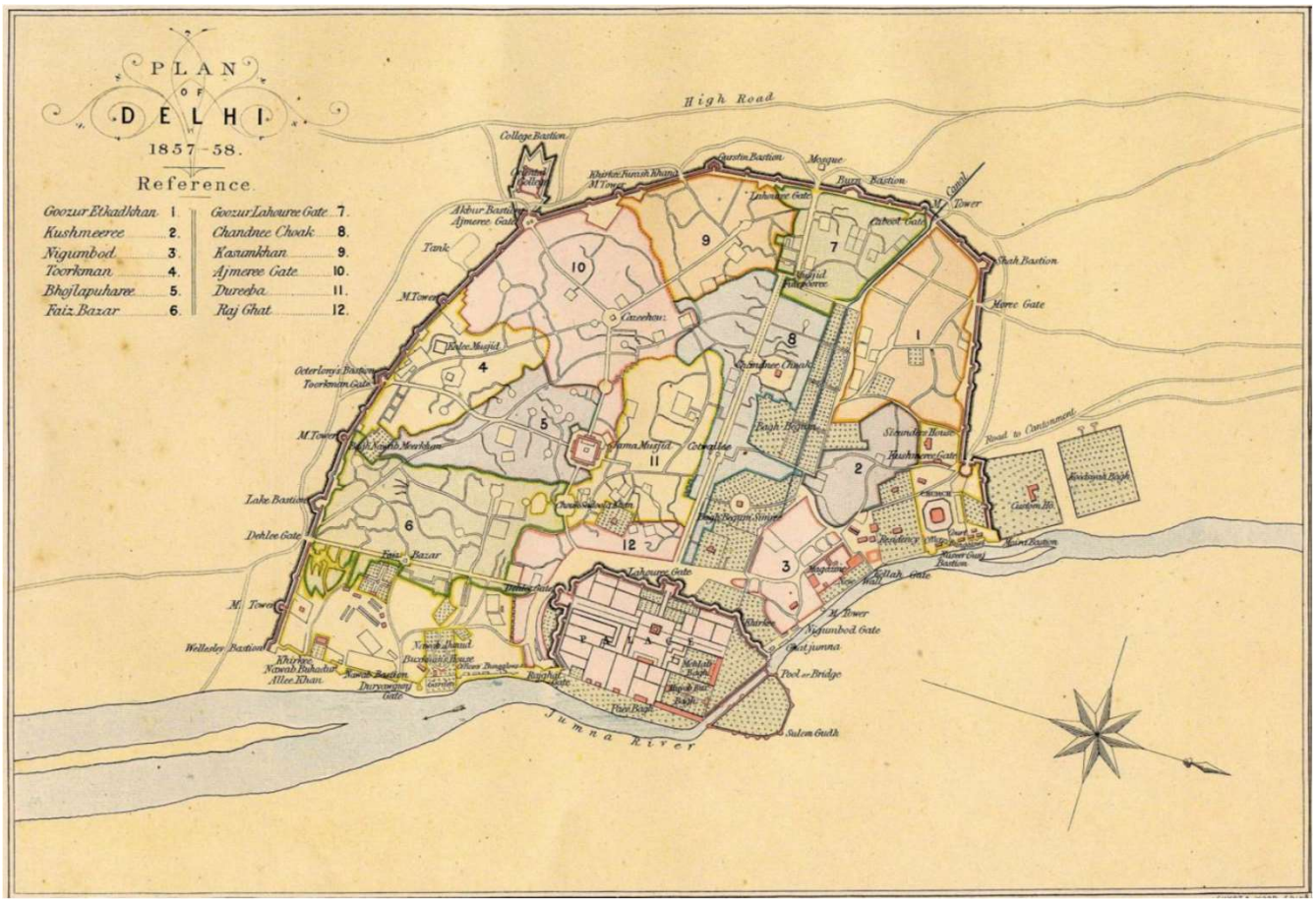

Figure 2: Shahjahanabad before the rebellion of 1857; Map Source: Guyot, & Wood. (1860). Plan of Delhi 1875-58

Framing the city lie the red fort and the Jama masjid, parallel to one another on a straight-line running east and west. The central axis from Lahori gate was called Chandni Chowk, housing over 1500 shops. This makes a detour at the Fatehpuri masjid.

The rich culture, bustling markets, fascinating and intricate monuments and beautiful built-in heritage has all the possibilities to attract international tourist to Shahjahanabad. The traditional City of Shahjahanabad, part of which is a core of the business district, is prone to commercialization, particularly with improved accessibility due to the MRTS. (The Delhi Development Authority, 2010)

3.3 NEW DELHI

3.3.1 HISTORY

Built in 1911 by British architects Sir Edward Lutyens and Sir Herbert Baker, when the capital was shifted from Calcutta to New Delhi due to the partition of Calcutta. Located south west to Shahjahanabad, it was visualized to be a city of automobiles and wider roads and city as an “Anglo Indian Rome” which will reflect the might, glory and vastness of the British empire. The Connaught Place gave life to the new city and it gradually grew into the largest commercial capital in northern India.

3.3.2 PLANNING

Lutyens designed New Delhi, inspired from the Garden City Movement by Ebenezer Howard. The city was built completely alien to the parent city in a rectangular grid format with streets crossing at right angles, extensive green open spaces and wide vistas unlike the winding streets of Shahjahanabad. Initially, the city had streets crossing each other a right angle, similar to the plan of New York city. Later, considering the heavy dust storms that sweep away landscapes, he followed hexagonal grid similar to that of the plan of Rome, Paris and Washington with roundabout edges and trees.

The plan can be viewed in two parts - a rectangular grid or main central axis that has the monumental government buildings and the hexagonal layout that focuses on the local and residential aspects of the city. The central axis called the Rajpath, also known as the king’s way runs through the layout of the new city with several avenues and streets radiating from it. It was designed as a path that linked the Viceroy’s palace now the Rashtrapathi Bhavan at the west end to the west end to India Gate at the east end of the axis. To give more importance to the British, the Viceroy’s palace was built higher than Jama Masjid. They used a mixture of Greek and Mughal architecture. The hexagonal pattern links major governmental, commercial and recreational activities with residential areas. (Jain, 2010)

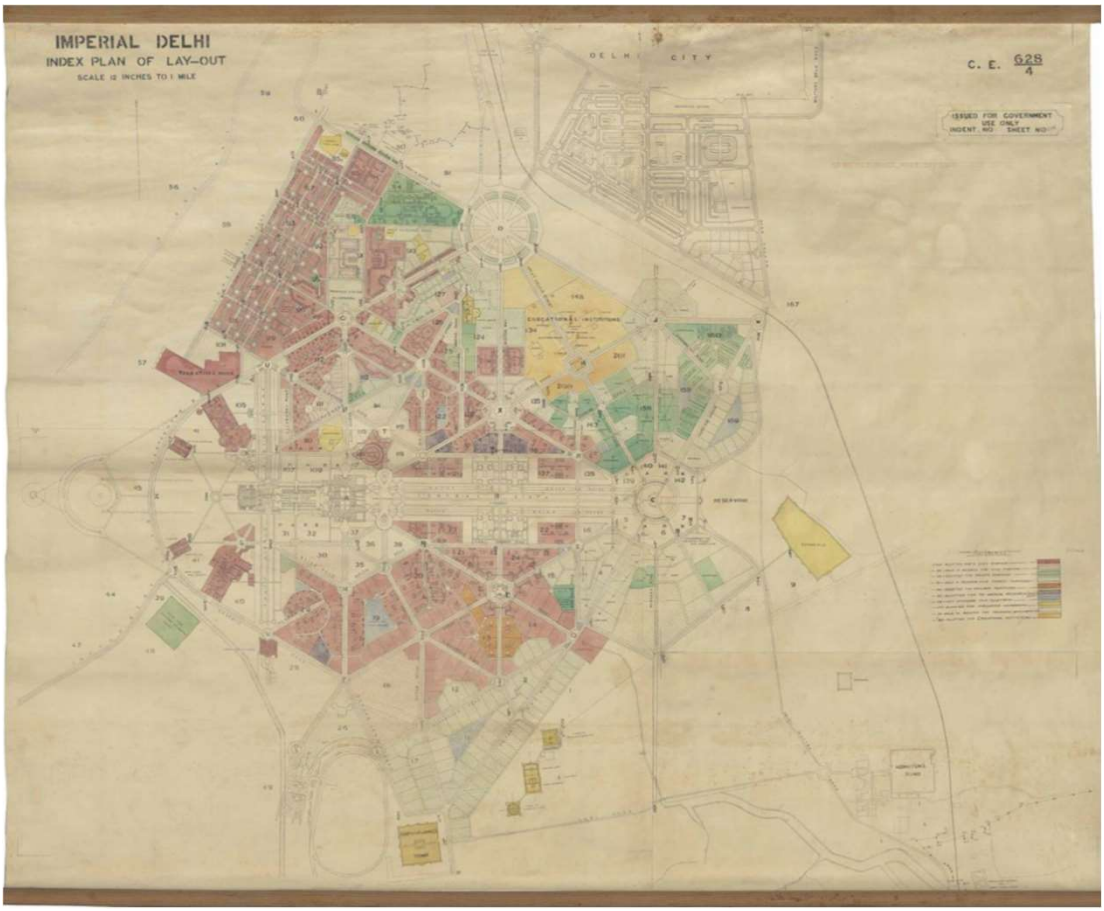

Figure 3: Plan of Lutyens Delhi; Map Source: Archive of Albert Edward Peter Griessen (1875 – 1935) – New Delhi, 1913-1922

3.4 CHANDNI CHOWK

Located nearby to the Old Delhi railway station, it is the oldest market in Shahjahanabad which remained a bustling market throughout Mughal, colonial and post-independence India. It was designed by Jahanara begum, Shah Jahan's eldest daughter. Down the street she got this huge caravanserai built that was considered to be the most beautiful structure outside the fortress until its demolition in 1857. She builds the beautiful chowk in front of it which had a channel of water running down in the middle and when it came to the chowk or square it became a pool in the middle of the road which was later replaced by a clock tower. Due to the construction of Town Hall, Queens Garden and Nai Sarak, gradually water stopped flowing into the pool and thus The Chandni Chowk eventually ceased to exist. (Liddle, 2011)

Figure 4: Chandni chowk in 1850; Map source: (1850). Thomas Kraft Map of New Delhi

Chandni Chowk at present includes both sides of road starting from Red Fort to Fatehpuri Masjid, but earlier this avenue was divided into three sections by two squares: Urdu bazar (Lahori gate to chowk Kotwali), Johri bazar (chowk Kotwali to Chandni Chowk) and Fatehpuri bazar (Chandni Chowk to Fatehpuri masjid).

The market is a witness to various incidents of historical importance throughout the years and the market started to disintegrate but, the partition had a bigger impact on the identity of Chandni Chowk. As a result of the partition, Chandni Chowk had a tremendous change in its population. Different parts of Shahjahanabad saw several changes with the inundation of refugees as divergent and unfamiliar practices and cultures came into being. Countless establishments in the market have been brought to being by refugees who resumed their lives and commerce once they moved to Shahjahanabad.

Over the time, Chandni Chowk turned into a highly chaotic and complex street with vehicles competing for right of way with pedestrians. Thus, the Shahjahanabad Redevelopment Corporation (SRDC) started the Chandni Chowk Redevelopment Project with a vision to bring back its glory through pedestrianization, with the 1.3 km stretch between Red Fort and the Fatehpuri masjid being turned into a car free zone. A vehicular traffic restriction will be extended on the road for 12 hours, from 9 am to 9 pm. Only non-motorized transport (NMVs) such as cycle rickshaws will be allowed to ply in a dedicated corridor. Hopefully the revamp will bring more business visitors and tourists and to bridge the gap between old and new residents of the city.

3.5 KIRTI NAGAR

Kirti Nagar is primarily a housing colony for refuges. The work centre consists Kirti nagar industrial area and furniture market. Kirti nagar furniture market is a major furniture market in Delhi with some very high-end stores on the main road and smaller ones inside in the gullies.

Commercial zone: The nearby district is the Rajouri Garden, an in-demand retail area, consisting of the principal market, Nehru market and numerous shopping centres such as TDI Mall, Moments mall, TDI Paragon mall, Shoppers Stop, City Square, West Gate mall, and Paradise mall.

Residential Zone: The area was occupied by migrants from west Punjab and gradually turned out to be mixed community. The refuges were attracted to this area due to the economic opportunities the place offered. High-density low-rise development is seen here.

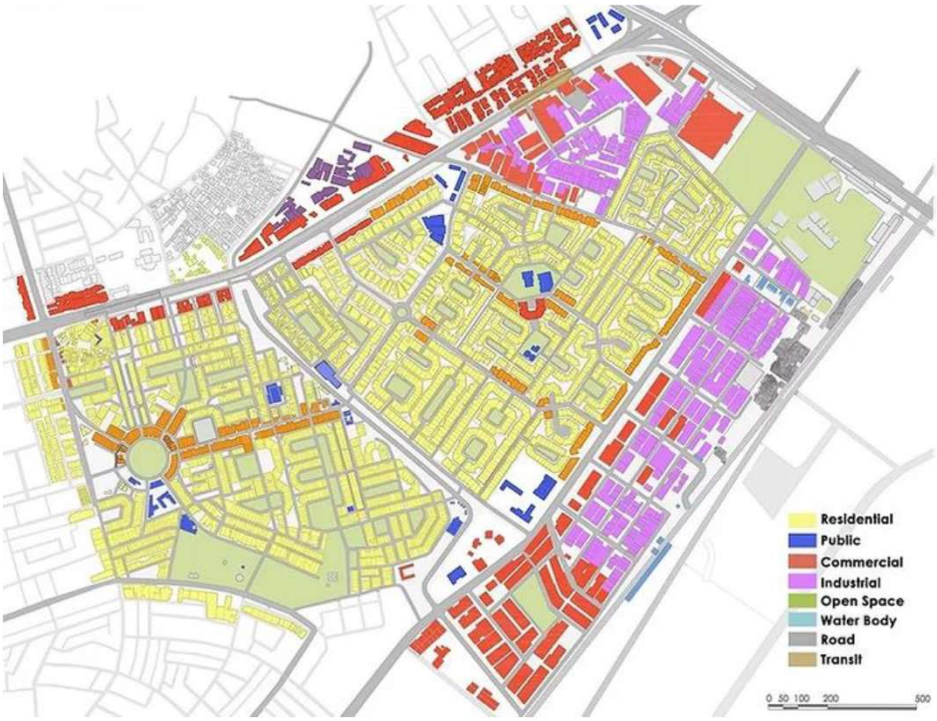

Figure 5: Built use map of Kirti Nagar; Map Source: Delhi master plan 2021

Industrial zone: The Kirti nagar industrial area is one of the major employment centres of the zone contributing employment around 2/5 of the total work force of the zone, occupying an important place in the occupational structure.

Furniture and timber market: greater degree of the immigrants who settled here were involved in carpentry and was the amin reason for proliferation of the furniture market in this area.

4. ANALYSIS

The diversity criterions delineated by Jane Jacobs is used for comparative analysis.

4.1 MIXED PRIMARY USE

Condition 1: “The district, and indeed as many of its internal parts as possible, must serve more than one primary function; preferably more than two. These must ensure the presence of people who go outdoors on different schedules and are in the place for different purposes, but who are able to use many facilities in common.”

For districts to be prosperous, people ought to be there at various periods. This is time considered on a small scale, hour by hour through the day. (Jacobs, 1960) People are necessary in the close precinct in streets for multiple reasons, otherwise these will be utilized occasionally. For analyzing the first condition of mixed primary use, different activities at various time period are taken into consideration.

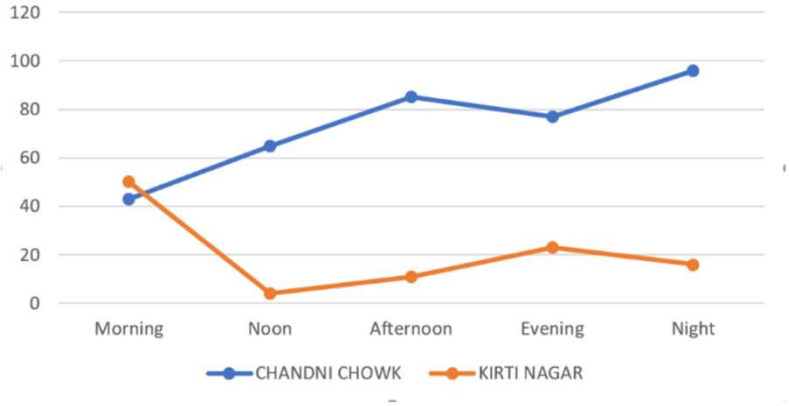

Figure 6: Graph depicting percentage of people during different time spread in Chandni Chowk and Kirti Nagar; Source: Author generated

At lunchtime, the employees from the amazing array of local manufacturers and enterprises provides support to all the local dining spots, eateries and most of the other commerce. The streets of Chandni Chowk are most active during night and midday. 65% of these activities are commercial and 15% are residential and the rest comprises of religious and street vending activities. Thus, Chandni Chowk serves more than one primary function. The people are provided with a variety of options and uses. The area becomes significant as people are available on the street at all time spreads of the day for various reasons.

If Chandni Chowk's commerce dies, the residents would suffer a significant loss. The district being a historical tourist attraction, attracts international tourists in addition to the local residents or local workers. This leads to an increase in living standards of people residing in this area as the shops and establishments gets exposed to a wider range of crowd.

Kirti nagar, unlike Chandni Chowk, is separated into three zones: residential, industrial and commercial. The residential area of Kirti nagar is considered in order to know the importance of neighbourhood diversity. In the residential neighbourhood, there are hardly any commercial and institutional structures.

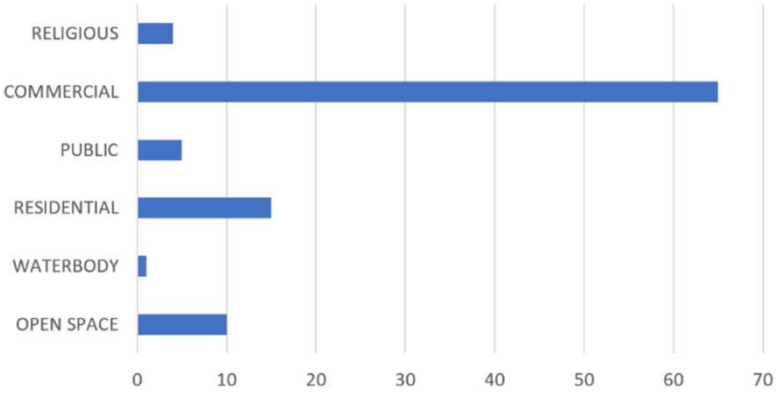

Figure 7: Graph depicting percentage of different activities in Chandni Chowk; Source: Author generated

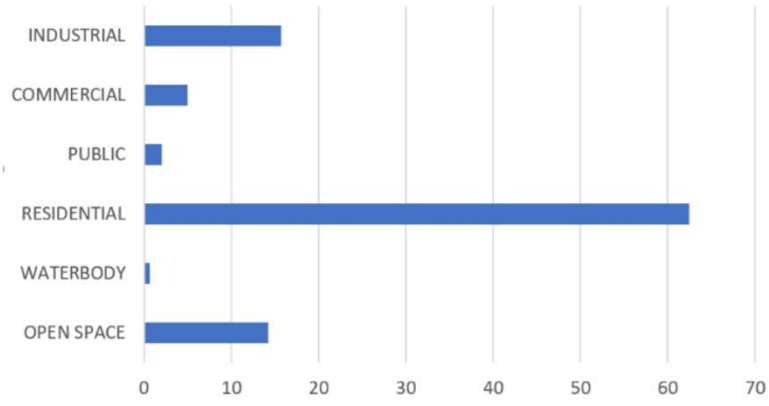

Figure 8: Graph depicting percentage of different activities in Kirti Nagar; Source: Author generated

Kirti Nagar serves only one primary function: residential. Other secondary functions should assist the primary function in order for the district to be diverse and alive. The secondary functions in Kirti nagar are insufficient to sustain the residential functions. The residents of Kirti nagar are experiencing extreme time unbalance. A reasonable number of people strike the district early in the morning to use the institutions, making the early hours lively. As the district is mostly residential, the inhabitants leave for work outside the district, leaving the streets deserted. This brings a stark contrast between the mob scene during lunch and monotony is seen at other times in the commercial areas. Later, in the evenings, after work hours, a small crowd begins to emerge. Till then the shops go dead. On weekends, the residents venture outside the district for leisure. As a result, the neighbourhood becomes bleak and barren. The recreational space is insufficient for the entire community to sustain. The open space is only utilised by people in the immediate neighbourhood.

4.2 Small Blocks

Condition 2: "Most blocks must be short; that is, streets and opportunities to turn corners must be frequent."

In Chandni Chowk, the blocks are short allowing continuous street use. These streets between the blocks are not isolated and they tend to mix and intermingle. Thus, at each and every turn, spots are generated, where activity may begin, places to dine, place for street vendors to set up etc. Every turn leads to more active places. Thus, the streets are public places rather than conduits of traffic.

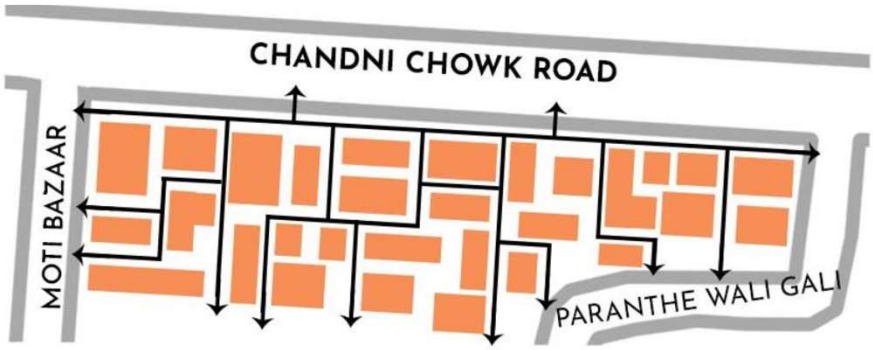

Figure 9:Chandni Chowk Street plan; Source: Author generated

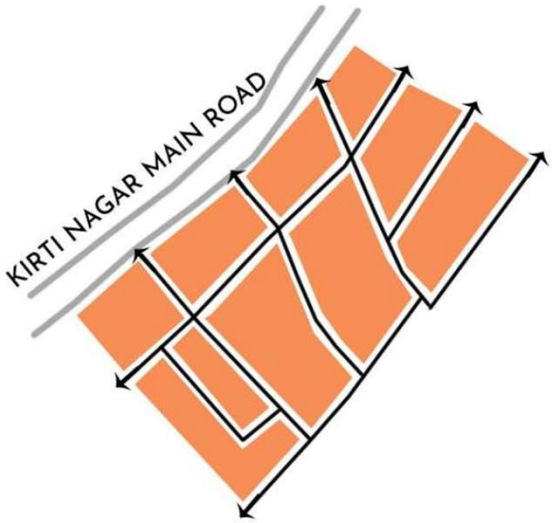

Figure 10: Map of commercial district at Kirti Nagar Main Road; Source: Author generated

Figure 11: Map of block C Kirti Nagar residential zone; Source: Author generated

These commercial stores in Kirti nagar have grown monotonous with continuous and identical streets with prevailing commercial approach. The monotony of the streets causes people to become bored. The streets are isolated and there is lack of mixed use. Within the streets there are no pause points. People in the neighbourhood for similar primary purpose (commercial activity) do not interact. This limits the creation of interactive hotspots and city cross-use.

The blocks in this residential zone are too lengthy. As their streets are too different and secluded, a person utilising access 1 would not once encounter a person using access 2. They would only interact at a specific intersection if the person walked in the direction of access 2. If not the odds of them interacting are little to none.

The neighbourhoods can breed diversity by establishing spots that benefit economically. This can be achieved by providing an additional street across the block. Thus, we can conclude that for city to be diverse it is important to have short blocks which creates repetitive arrangement of streets.

4.3 Aged Buildings

Condition 3: "The district must mingle buildings that vary in age and condition, including a good proportion of old ones."

The mingling of high yield, middle yield and low yield enterprises in Chandni Chowk created a thriving diversity. Old structures made the district active, due to the rich past linked to these historic structures in Chandni Chowk. A progressive mix of structures of various periods and typologies emerged as some of the old ones were eventually substituted by new ones.

In January 2021, this gateway fell down and now it has been raised to the ground. The sense of desolation and loss of a way of life in Shahjahanabad is always seen when passing through. Few historic but abandoned buildings are turned into small business space, contributing a new life to the building and the whole neighbourhood. As long as the city districts have liveliness and are accountable for people's requirements, changes will constantly occur.

In Kirti nagar, only high yielding enterprises are observed. This has lowered the area's vitality. Cities need old buildings so badly it is probably impossible for vigorous streets and districts to grow without them. (Jacobs, 1960)

Shahjahanabad has its own fair share of old structures. In fact, it's far too much. Majority of it should be removed. The ones that are deteriorating and can no longer sustain themselves must be removed as they will become the remains of the bygone era. A fine mixture of old buildings must persist. This is necessary as economic worth of new structures can be substituted unlike that of old ones which are made by time.

Figure 12: Gateway at Chandni Chowk; Source: Author generated

5. INFERENCE

Historic cities are diverse in nature. Thus, it is critical to understand the characteristics that lead to diversity in historic city centres so that some of these can be recreated in future cities. New cities lack diversity in population and functions as they are only used by a particular group of people.

	CHANDNI CHOWK	KIRTI NAGAR
CONDITION 1 mixed primary use	Supports more than one primary function making it lively and active throughout the day.	Supports only one primary function, there is no pockets of spaces to support any activity other than residential making it more desolate in nature.
CONDITION 2 small blocks	Short blocks making the streets public places with growth in every corner.	Long blocks creating monotonous and isolated streets with no mixed use.
CONDITION 3 aged buildings	Mixture of buildings of many ages and types contributing a new life to the building and the whole neighbourhood.	Only high yielding enterprises are seen reducing the vitality of the place.

Table 1: Comparative analysis table; Source: Author generated

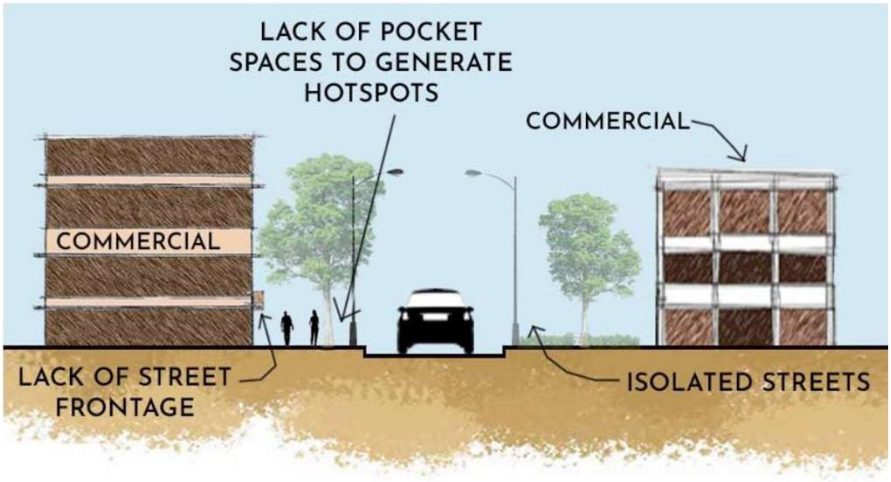

Figure 13: Street section of Kirti Nagar; Source: Author generated

Kirti nagar is saturated with residents, with no pockets of open areas to sustain any activity other than residential.
The activity and magnitude of the mixed-use development used should differ depending on the particular conditions of each neighbourhood. Such approaches will aid in bettering the standard of living in the city, increase accessibility and encourage public transportation. The concept can be implemented by increasing the supply of housing in mixed use environment allowing more opportunities for people to live and work in the area. While planning for diversity through mixed-use development approach can serve to increase the exuberance of a communities and a city, it has its own challenges and drawbacks too. In the early phases of execution, mixed-use development may be detrimental to the community. Opposition generally emerges when the community disagrees to such changes.
Thus, mixed-use development is widely useful, but it can have several consequences, based on its incorporation. Mixed-use development approaches that fuel diversity are a critical concern as this shape the city.

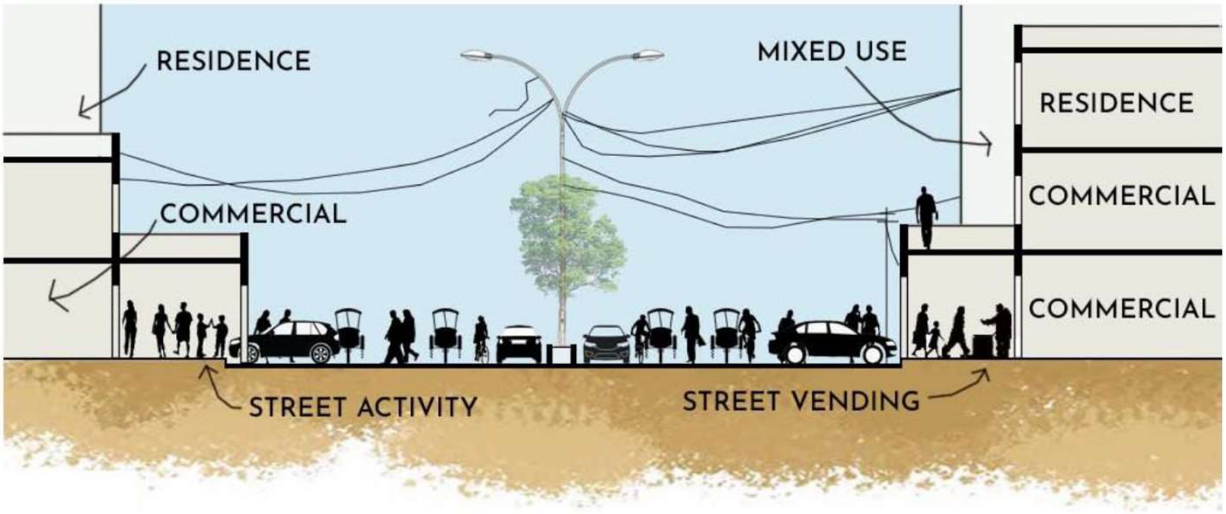

Figure 14: Street section of Chandni Chowk; Source: Author generated

The historic city of Shahjahanabad is more diverse in nature but has its own share of problems. Therefore, it is reasonable to assume that the various districts of Old Delhi have become indigenous and artistic havens whereas New Delhi has further become uniformly upscale and placid.

6. CONCLUSION

Comparing the different aspects of diversity in terms of functioning in Chandni Chowk of Shahjahanabad (historic city) and Kirti nagar of New Delhi (new city), it was found that the old city of Shahjahanabad breed more diversity in different ways that impact neighbourhoods and social life. Thus, proving the hypothesis that "old cities are more diverse and vibrant than new cities".

In the current era, to obtain global city status, two trends are being followed. One that supports diversity and the other to destroy it. From the study it is understood that the new city of New Delhi misses a lot of aspects such as presence of mixed primary use, frequent activity generators etc., which are present in the old city of Shahjahanabad which makes it more diverse. Incorporating mixed use development strategies and pocket spaces to support activities in the new city can bring back and infuse a new life to the city without losing its identity.

8. REFERENCES:

1. Blake, S. P., 1991. *Shahjahanabad The Sovereign City in Mughal India 1639 - 1739.*. Cambridge: Cambridge University Press.
2. Chenoy, S. M., 1998. *Shahjahanabad, a city of Delhi, 1638-1857.* New Delhi: Munshiram Maoharlal.
3. Dutta, B. K. & Dutta, S. B., 2012. Regeneration of Heritage Urban Space of Delhi, Shahjahanabad, the Walled City.
4. Fanshawe, H. C., 2010. *Delhi Past and Present.* New Delhi: Low Price Publications.
5. Hearn, G. R., 1906. *The Seven Cities of Delhi.*
6. Jacobs, J., 1960. *The Death and Life of Great American Cities.* London: n.d.
7. Jain, A. K., 2010. *Lutyens Delhi.*
8. Lange, A., 2012. *Writing About Architecture: Mastering the Language of Buildings and Cities.* New York: Princeton Architectural Press.
9. Liddle, S., 2011. *Delhi 14 : Historic walks.* Chennai: Westland.
10. Malizia, E. E. & Ke, S., 1993. THE INFLUENCE OF ECONOMIC DIVERSITY ON UNEMPLOYMENT AND STABILITY. *Journal of Regional Science,* 33(2), pp. 221-235.
11. Ottaviano, I. P. & Peri, G., 2005. The Economic Value of cultural diversity. *Journal of Economic Geography 6,* 6(1), pp. 9-44.
12. The Delhi Development Authority, 2010. *Delhi master plan 2021.*

ARCHITECTURAL PSYCHOLOGY OF WORKPLACE DESIGN-

ANALYSING THE IMPACT OF SPATIAL CONFIGURATION ON EMPLOYEE PRODUCTIVITY

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ABSTRACT:

People in today's world spend more than three quarters of their time in a day, indoors. It is vital for us to understand how these built spaces affect the health, wellbeing, cognitive capacities and emotions of its users. The focus of this research is on the impact of work environments on user psychology.The main aim is to study the effects of workplace architecture on the behavioural traits of its employees, and to arrive at specific design strategies, that shall improve employee performance and organizational profit. The methodology followed is the factor-based analysis of spatial configurations and their influence on employee productivity, by means of a modular evaluation tool, i.e. space syntax. Space syntax is the predominant mode of quantitative assessment used, to study how each spatial module affects employee output in an open-plan workplace. Simulations are generated via DepthMapX, a software tool. Qualitative modes such as user surveys and literature studies are utilized to statistically record aspects responsible for employee perceptions and distractions at workplaces. Three common types of workplaces were analysed i.e. open-plan, activity-based and hot-desking. Comparing the three case studies, it could be concluded that activity-based workplaces were more successful in enhancing employee performance. Open-plan layout analysed in this paper was hypothetically altered into an activity-based configuration. As per simulations generated via space-syntax, altered activity-based layout offered better results in comparison with the existing open-plan. A flow chart is tabulated on the basis of these findings, to highlight various design strategies that may be adopted to improve productivity.

KEYWORDS*: Health, Well-being, Employee productivity, Spatial configuration, Space Syntax*

1. INTRODUCTION

Office spaces do more than just accommodate its users; they also shape the *psychological framework* that affects the motivation levels and career satisfaction of their employees. Often, planning of workplaces may be efficient in terms of space utilization and aesthetic aspects, but fails to consider factors that influence employee psychology which in turn, has high impacts on their performances and work-life balance. Statistics from around the globe, says that staff expense, which includes their remuneration, benefits, medical needs etc. attribute to around 90% of the organizational operation costs (World Green Building Council, 2014). This not only implies that, it is the responsibility of the organization to provide a work environment that caters to the needs and well-being of its employees, but also indicates that, the operational profit of the organization itself lies in the same, i.e. in providing a healthy work environment. Employees who are more content with their work environment are more likely to generate better work outcomes, according to several studies. Thus, *user satisfaction* is the key indicator of performance – it can be the driving factor in the overall economic development of any organization.

1.1 AIM / PURPOSE

To study the effects of work environments on the psychological and behavioural traits of its employees and to arrive at design guidelines, to create comfortable and healthy office spaces; that shall improve employee performance and overall productivity. This involves, understanding the behavioural traits of the employees that gets affected when in a work environment, and analysing the architectural parameters that bring about this effect.

1.2 RESEARCH METHODOLOGY

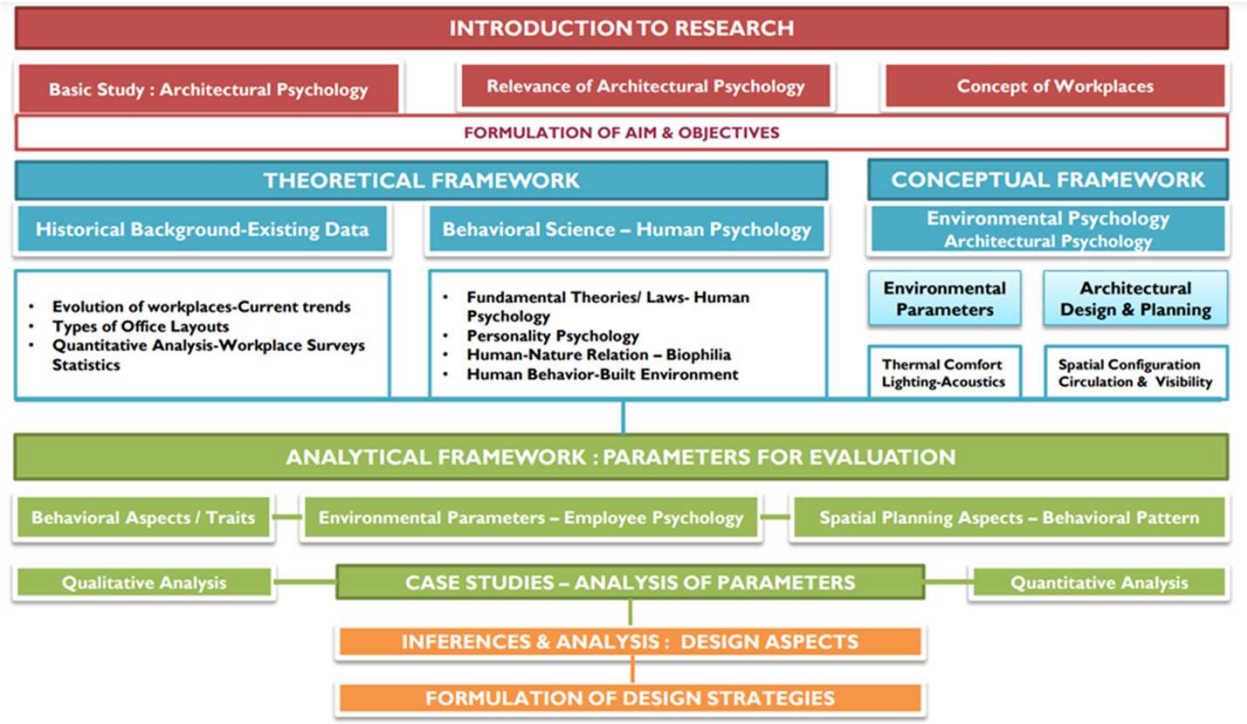


Figure 1 : Research Methodology Flow Chart; Source: Author

2. ARCHITECTURAL VARIABLES IN WORKPLACE PSYCHOLOGY

With the completion of secondary study; from various literature sources, it could be concluded that there are three major parameters in workplace design, that influence employee productivity; discussed as below.

2.1. Behavioural aspects in Environmental Psychology of workplaces

- *Perceived job satisfaction* –User satisfaction varies based on *spatial planning*. One such example is *hot-desking* wherein employees reported a lack of personalization in their workspaces. *Hence, it* was concluded to be a main criterion of evaluation, to be considered in the subsequent live case study.
- *Territoriality & Sense of belonging* - Territoriality in a workplace is related to two factors, namely privacy and collaboration. This was concluded to be another criterion to be analysed with respect to the spatial configuration and employee perception, via space syntax analysis and questionnaire surveys respectively.
- *Privacy & Security* - Privacy in a workplace is of two types - *psychological* and *architectural privacy*; these can be achieved in three levels –ability of the user to limit access to their workstations, ability to limit the amount of distractions and, the ability to mingle and collaborate with fellow colleagues.
- *Degree of Collaboration & Ease of interaction* – The significance of break-out zones and other collaboration areas in workplaces were to be analysed. Employee interviews were chosen to be the analysis tool.

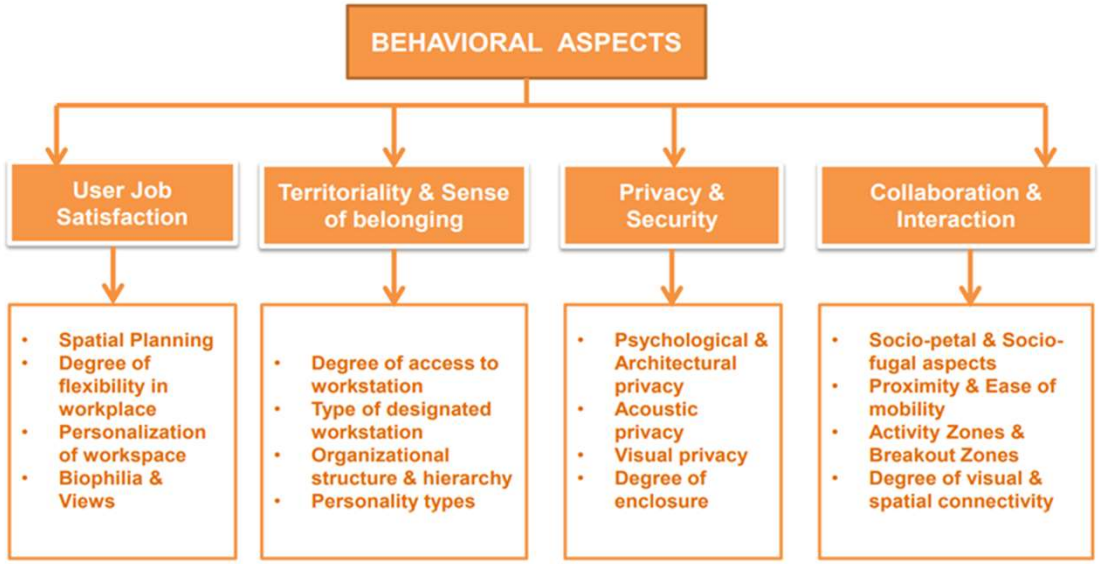


Figure 2 : Behavioural Aspects & its Parameters; Source: Author

2.2 Environmental Parameters & Employee psychology

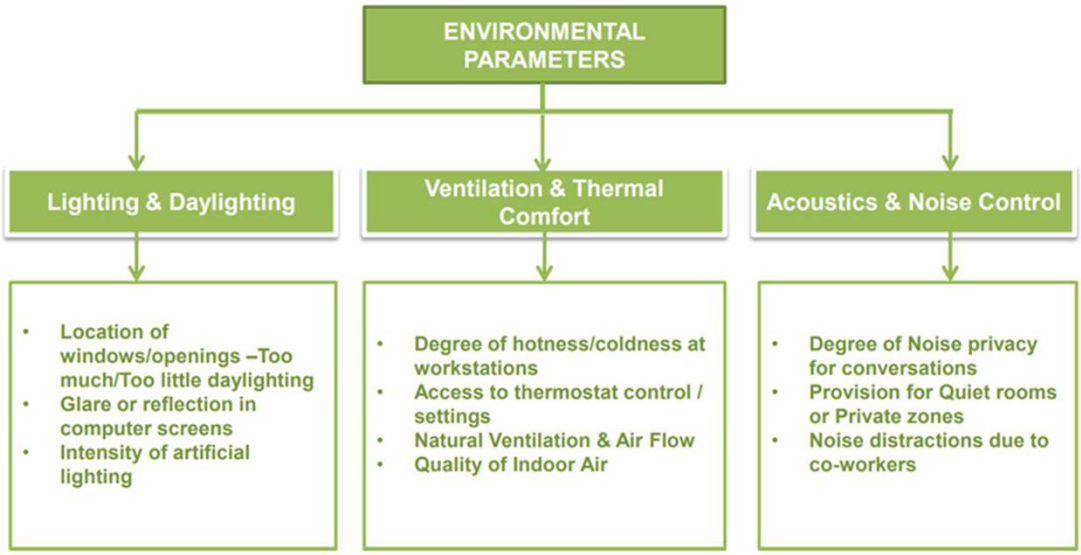


Figure 3 : Environmental Aspects & its parameters; Source: Author

2.3 Spatial Configurations & Employee-Behavioural pattern

- **Degree of Openness –** This is one of the causes behind why open-plan office layouts are heavily criticised. Environmental stresses (including being exposed to 'irrelevant sound', the lack of 'visual privacy' and a reduced ability to control one's own personal space), as well as the risk of various infections, the types of jobs done and group dynamics are all reasons, suggestive of the negative impacts of an open plan layout and its high degree of openness (Bodin Danielsson, Chungkham, Wulff and Westerlund, 2014).
- **Circulation, Mobility & Proximity -** It is important to bring about active movement in workplaces, as the employees, who spend too much time in front of their screens, tend to lose concentration and alertness. Greater mobility allows employees to mingle more, aiding in face-to-face communication, thus workplaces are to be planned such that they encourage human communication (Clements-Croome, 2017).

- **Visibility & Accessibility** - Physical barriers such as high partitions or cubicles, improperly positioned columns, file storages that block the lines of sight, are few of the aspects that must be gravely considered while planning the spatial layout. Nevertheless, the extent of visibility has to be carefully planned such that it does not affect the visual privacy and confidentiality required by the employees.

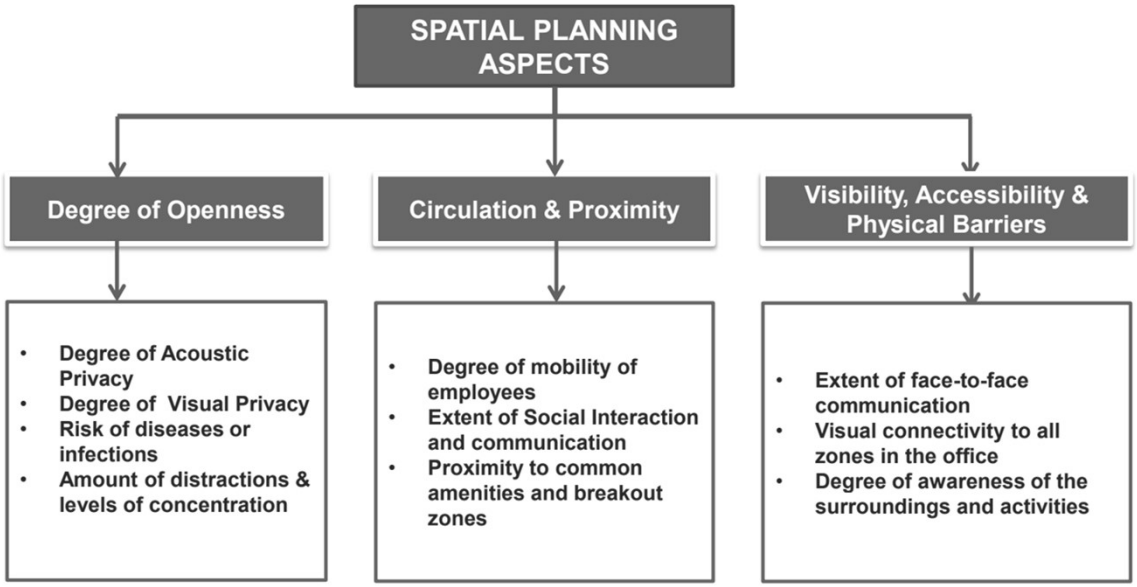


Figure 4 : Spatial planning aspects & its parameters; Source: Author

3. ANALYSING THE PSYCHOLOGICAL EFFECTS OF VARIOUS SPATIAL CONFIGURATIONS OF WORKPLACES; THROUGH CASE STUDIES

3.1 Open Plan layout: A case of an IT office space in Cyber Park ,Kochi, Kerala (Live Case Study)

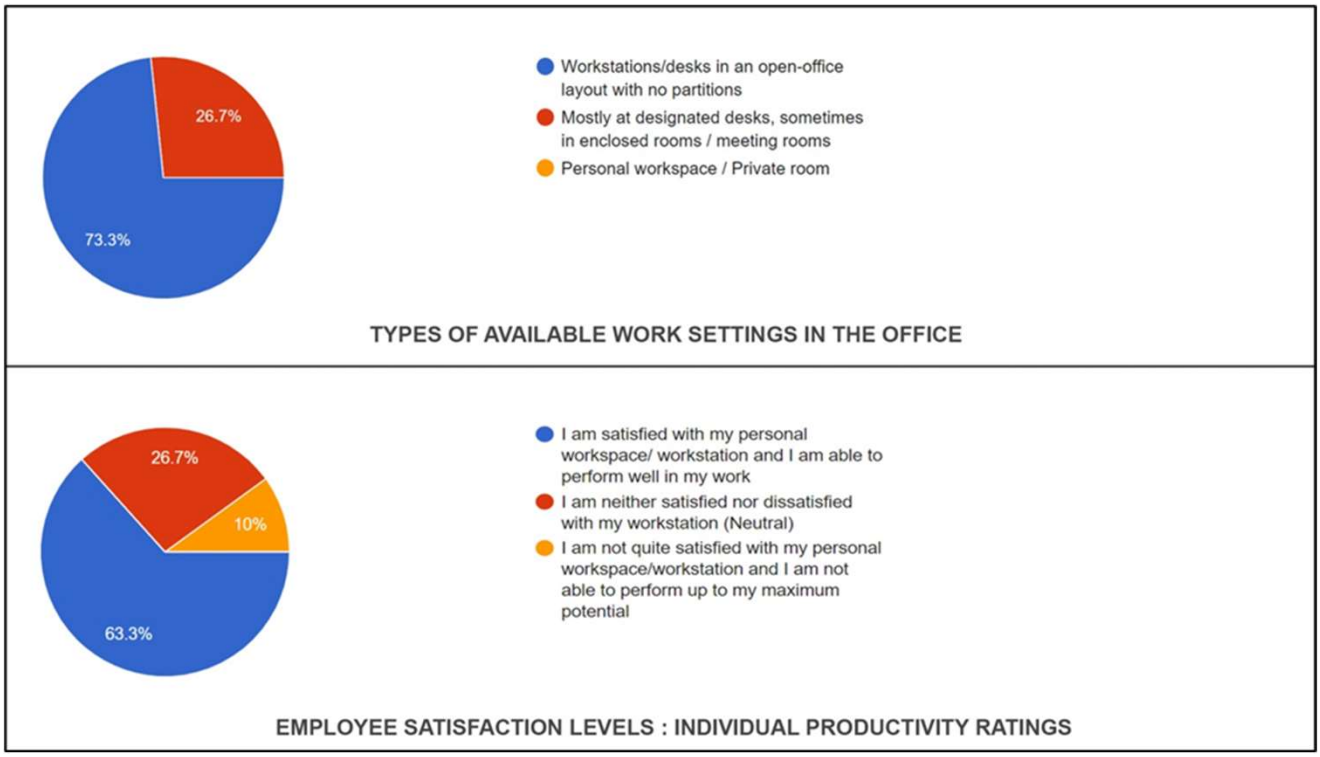
A questionnaire survey was conducted among 30 employees in this workplace to assess their satisfaction levels and the issues faced with respect to spatial planning; live interviews were also conducted as part of the study.

1. **Behavioural responses of employees-** As per interview reports, 65% of the employees conveyed that open office facilitated collaborations and is comfortable to work in, whereas 35% of the employees expressed a need for a more flexible work environment with hot-desking and casual seating spaces, as it was exhausting to sit at the same workstations; throughout the entire day, reducing their work efficiency. Employees reported that workstations felt less territorial i.e. they were often distracted as people frequently pass by their workstations.

2. **Environmental parameters and its impact–** Employees reported lack of day lighting; in cases where ample amount of sunlight entered into the workplace, there were issues of glare on computer screens. Thermal discomfort was the major cause of distraction and lack of attention in task completion. Majority of the employees seated in designated workstations reported the lack of acoustic privacy being distracted by co-worker discussions; while others were distracted by exterior noise

3. **Spatial configuration & Employee performance** - As per interviews, most of the employees reported lack of conversational privacy during phone calls. Employees experienced lethargy, being restricted to their workstations, due to lack of mobility and breakout spaces. They also reported lack of visual connectivity due to physical barriers (columns, shelves etc.); and lack of connection between work zones.

Given below, is the compilation of the results obtained from employee questionnaire surveys, wherein the employees were asked about the impact of each individual variable (concluded from the initial literature reviews) on their individual performances, and overall satisfaction levels at their work environments.



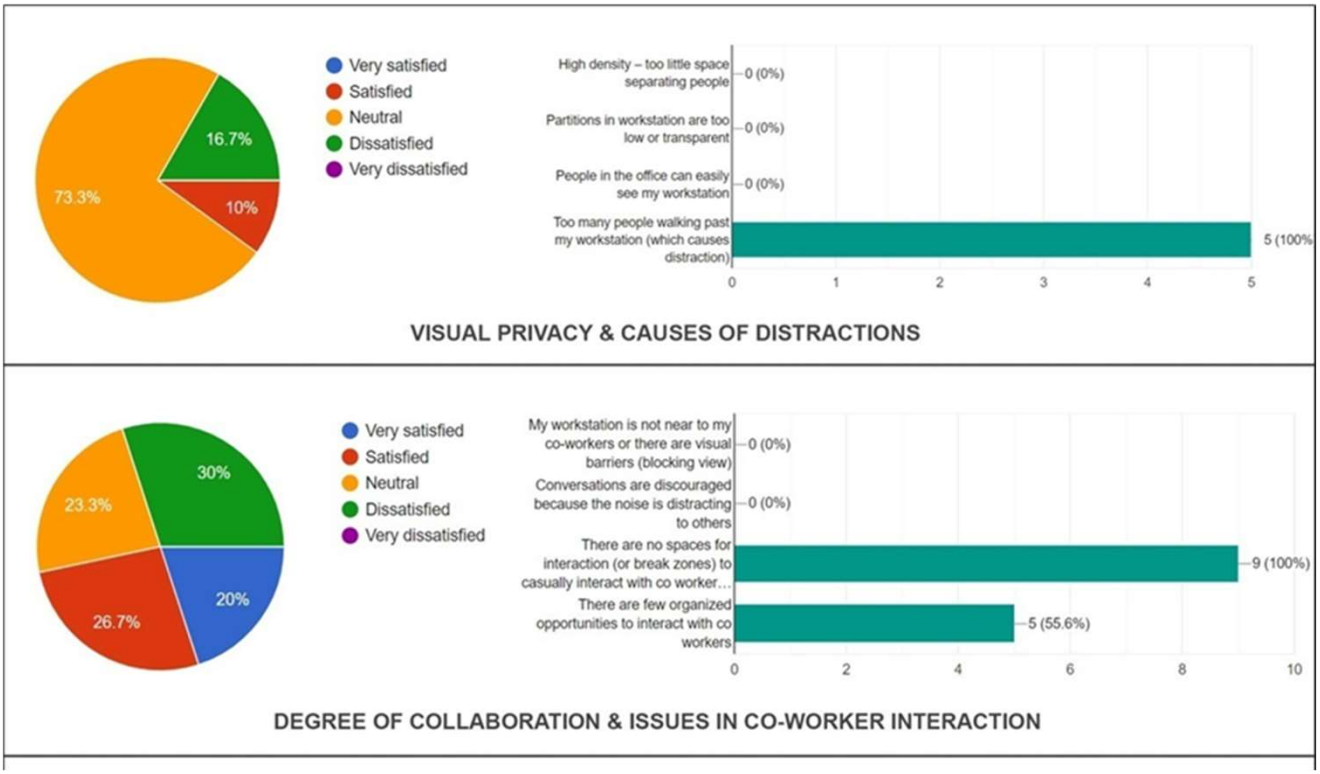
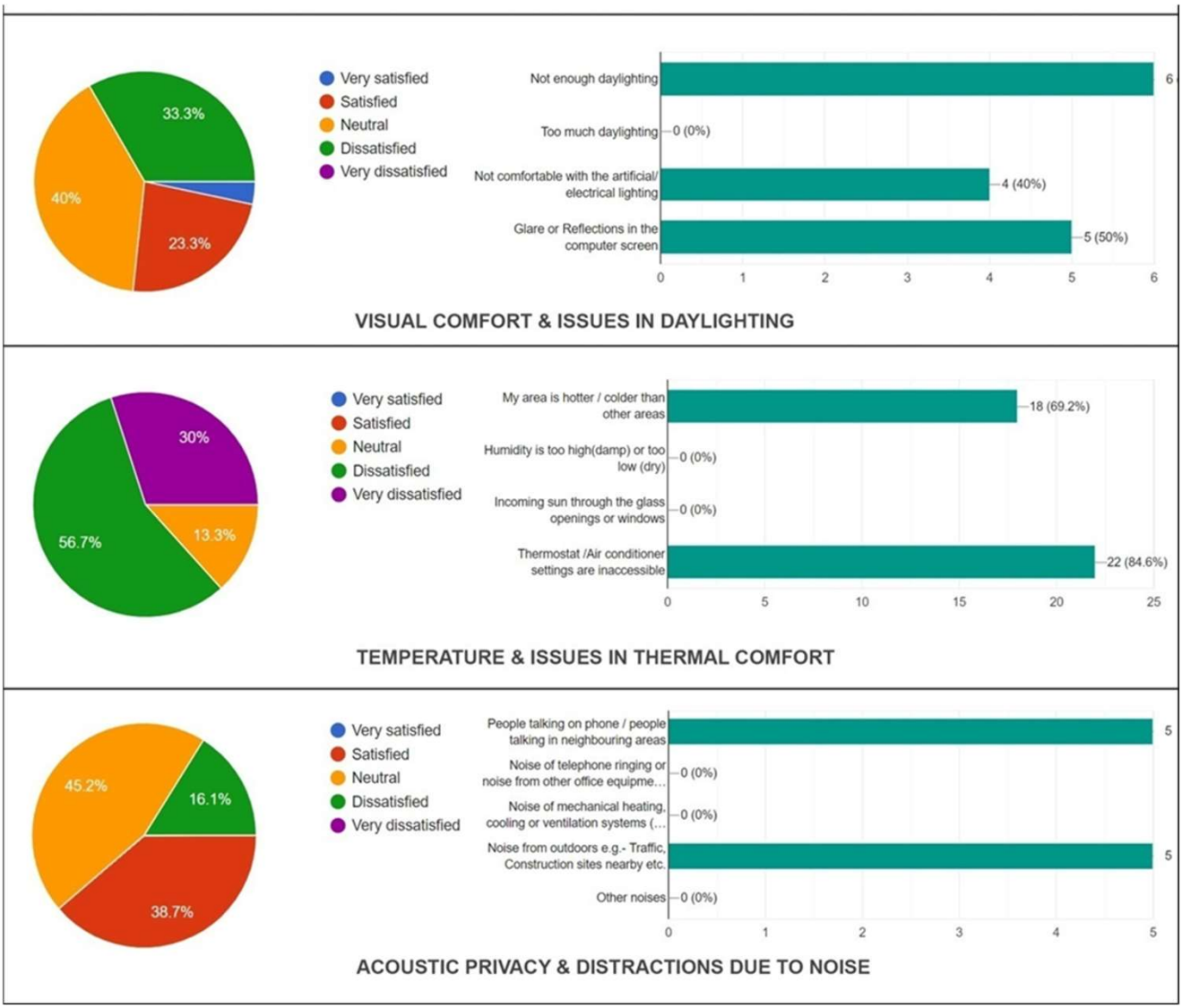


Figure 5 : Questionnaire Survey Statistics - Result Analysis from Live case study; Source: Author



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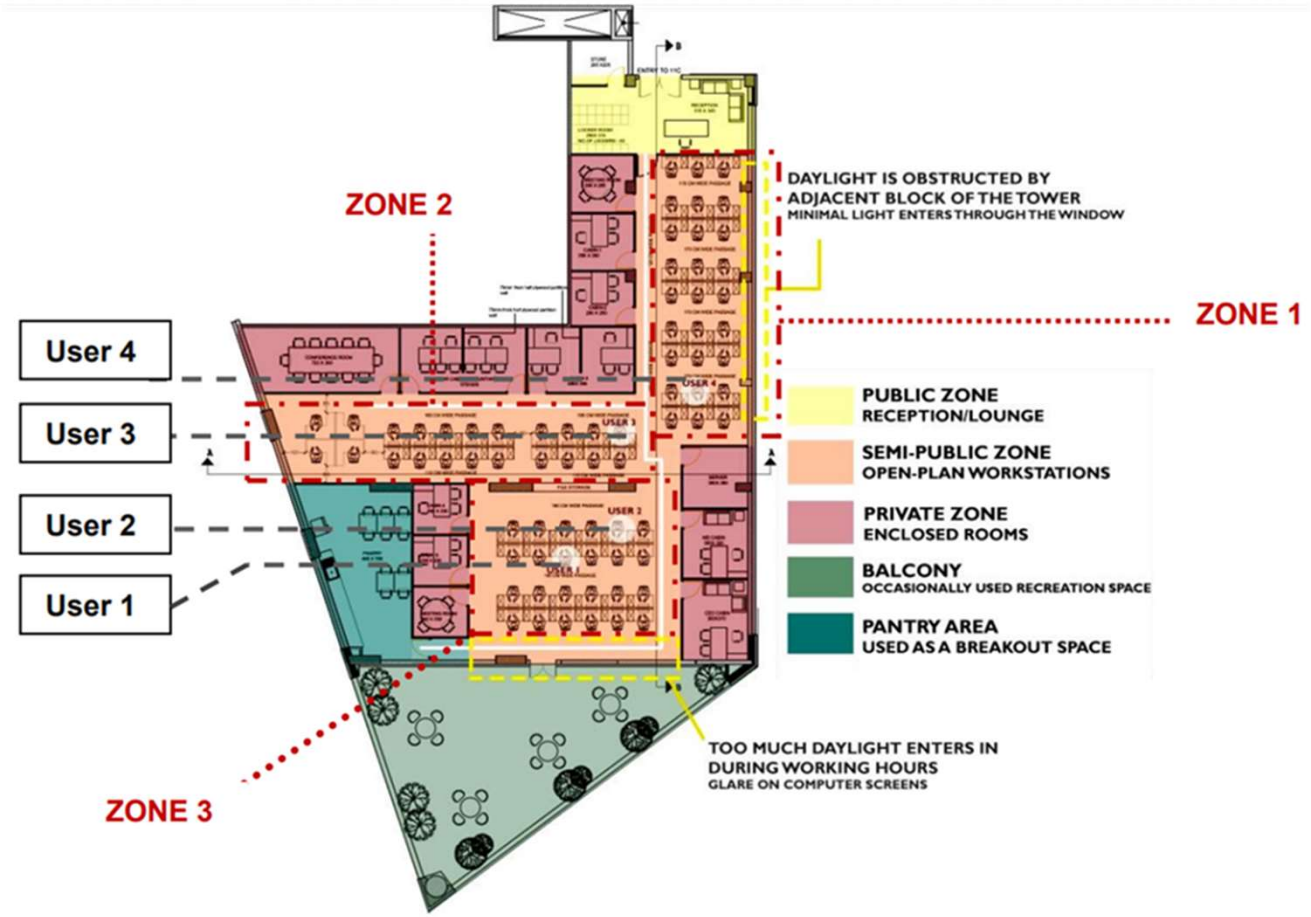


Figure 6 : Floor Plan- Configuration of Work Zones; Source: IT Office Kochi, Pvt Ltd.

3.2 Analysis of Open-plan spatial configuration & its Inter-relationship with Employee Behavioural pattern – Using Space Syntax Method

Although surveys were conducted among the employees to understand their response towards the workplace, it was also important to quantitatively understand the inter-relation of this response with the spatial planning. Space Syntax method (scientific approach used to decipher spatial formations and its effect on human behaviour) was thus, used for analysis of spatial configuration. Simulations for the floor plan were carried out using the software DepthMapX. Spatial planning aspects such as visibility were analyzed using VGA (Visibility Graph Analysis) and Isovist maps. Aspects such as circulation and accessibility within the workplace were analyzed using Axial maps and Angular step depth graphs. Space syntax segregates the entire workplace into various spatial modules to generate a simulation graph. Each module is of dimensions 0.75 metres by 0.75 metres.

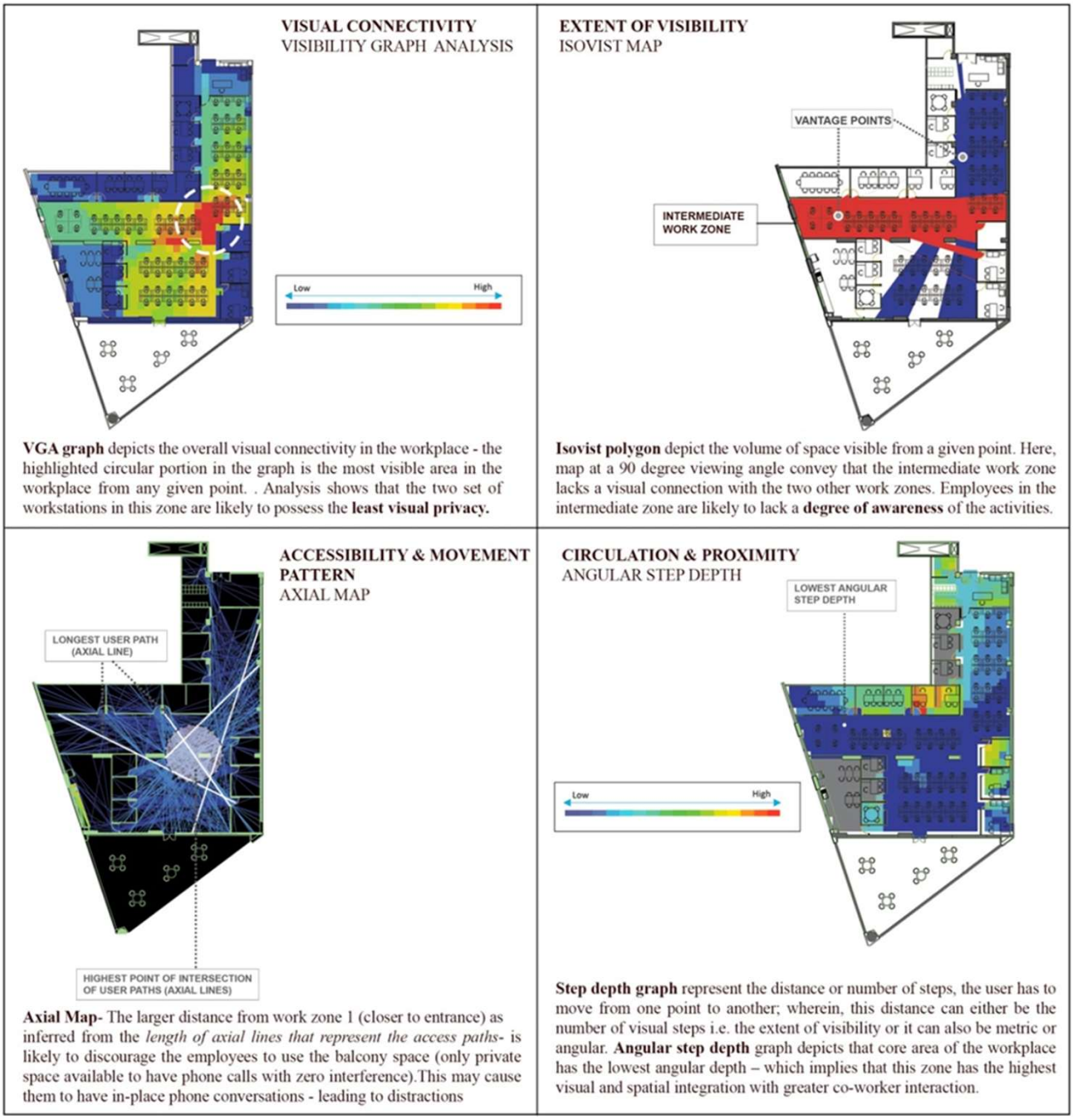


Figure 7 : Space Syntax Analysis using DepthMapX - Simulation graphs generated to analyse spatial configurations based on architectural variables of workplaces; Source: Author

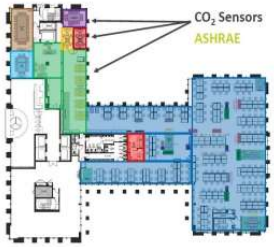
3.3 Spatial Analysis using Space Syntax & Employee Survey Statistics (Live Case Study)

Table 1: Comparative Study - Spatial configuration analysis & Employee Survey Statistics; Source: Author

ARCHITECTURAL VARIABLES (WORKPLACE PSYCHOLOGY)	SPACE SYNTAX ANALYSIS - TOOLS (SPATIAL CONFIGURATION)	SURVEY STATISTICS (EMPLOYEE RESPONSE TO SPATIAL LAYOUT)
VISIBILITY & CO-WORKER INTERACTION	**VGA**- As per the graph, the green portions (Work Zones 1 & 2) receive only moderate visibility towards other work zones. Hence, extents of interaction of employees in these zones are likely to be limited. **ISOVISTS** – Work zone 1 has only partial visibility towards work zone 3 and no visibility towards zone 2, causing lack of communication.	As per survey statistics, 30% of the employees were dissatisfied with the level of collaboration and only 10% were completely satisfied with the visual privacy. Employees along zone 1 of the workplace (entrance) reported a lack of visual connectivity with the central work core and to the main meeting spaces hence, they were less aware of the activities going on.
CIRCULATION, MOVEMENT PATTERN & ACCESSIBILITY	**AXIAL MAPS-** Highlighted circular portion in map is the most frequently traversed space in the workplace. Employees seated in this zone, experienced significant lack of work and personal privacy. **STEP DEPTH GRAPH** – Highest angular depth and least spatially integrated are private cubicles – hence, highest degree of privacy.	User 3 reported lack of visual privacy, being at a location which is an intersection of two common paths, being traversed frequently. User 4 and other employees in Zone 1, closer to entrance reported difficulty to have in-place conversations / phone calls- balcony is not at close proximity, hence the inconvenience.

3.4 Correlation between Spatial planning & Employee performance : A comparative analysis of three different spatial configurations ; Open-plan, Activity-based & Hotdesking - Through case studies

Table 2 : Comparative Analysis of case studies; Source: Author

Research Domains User Psychology	Live Case Study *Prevalent AI, Kochi* **(Open-Plan layout)**	Literature Case Study 1 *Arup HQ, Melbourne* ***(Activity-based layout)***	Literature Case Study 2 *Cundall HQ, London* ***(Hot-desking layout)***
Behavioural Aspects			
Floor Plan & Spatial Layout	 *Open Plan Layout*	 *Activity-Based workspace*	 *Hot-desking (fit-out)*

Research Domains User Psychology	**Live Case Study** *Prevalent AI, Kochi* **(Open-Plan layout)**	**Literature Case Study 1** *Arup HQ, Melbourne* ***(Activity-based layout)***	**Literature Case Study 2** *Cundall HQ, London* ***(Hot-desking layout)***
Behavioural Aspects			
User Satisfaction	-Low flexibility in work environment -Moderate degree of personalization (shared workstation) -No plantscaping	-High flexibility in work environment -Degree of personalization is in control of users ;can choose work setting -Biophilic design	-High flexibility due to hot-desking -Degree of personalization is considerably low -Plantscaping; high user satisfaction
Territoriality & **Sense of belonging**	-Maintains organizational hierarchy (private rooms) -Lack of quiet zones for focused working	-Territoriality can be controlled by users -Organizational hierarchy maintained -Quiet zones and diverse work settings available to users	-Lack of territoriality due to hot-desking; sharing of the workspaces -Quiet zones are located outside the central work core
Privacy & Security	-Lack of conversational privacy -Less visual privacy	- High privacy due to sound mapping -High visual privacy; green buffer& zoning	-Moderate visual privacy via green buffers and plant screens or dividers
Collaboration & Interaction	-Moderate interaction -Lack of visual connectivity at specific work zones -Lack of breakout zones except pantry	-High interaction due to socially active cores; bump+spark interactions -Variety of breakout space/activity zones	-High work interaction ;due to hot desking -Breakout spaces other than pantry ; located away from the work zones
Worker **Performance & Productivity**	-Moderate satisfaction in the work performance -Users suggest scope for improvements	-High satisfaction;92.5% employees satisfied as per survey statistics	-Higher productivity 50% reduction in absenteeism & 27% reduction in staff turnover
Environmental Aspects in Planning			
Day lighting & Lighting	-Less day lighting (closed blinds during daytime to avoid glare) -Glare on computer screen (near window) -Discomfort due to artificial spotlights	-High amount of day lighting due to full length windows -Artificial lighting programmed to mimic circadian rhythm: higher efficiency in work	-High amount of day lighting through openings & reflective materials on interior surfaces -Filters harsh direct sunlight via green walls on the south

Environmental Aspects in Planning			
Ventilation & Thermal Comfort	-Centralised air conditioning system for ventilation –Thermal discomfort & distraction ; lack of temperature control -Moderate air quality	-Temperature gradient across floors; activity based working allows users to choose work setting -High air quality; Biophilia & materials	-Thermal mapping to ensure optimum temperature for all employees -High IAQ ;use of zero VOC materials and plantscaping
Acoustics & Noise control	-Less acoustic privacy except in enclosed rooms -Distractions at workstations	-High acoustic privacy due to task based acoustic mapping & activity-based concept in planning	-Moderate acoustic privacy as meeting spaces zoned away from central work core ;plant buffers incorporated
Spatial Configuration & Planning			
Degree of Openness & Enclosure	-Lack of work & personal privacy -Lack of visual privacy mainly along common passages causing distractions	-High work & personal privacy brought about by voids/atriums and intermediate levels in planning; optimum level of openness	-Moderate work privacy; visual buffers- segregating work zones -Better acoustic privacy as meeting spaces zoned away from work core
Circulation **Proximity &** **Mobility**	-Less active movement causing lethargy in users -Not proximal to breakout zones	-Higher active movement across workplace via open staircases -Intermediate breakout spaces closer to work zones	-Moderate active movement via ;ergonomic stand-up desks -Proximal to break out zones; visually separated from core
Visibility, **Accessibility** **& Physical Barriers**	-Extent of face to face communication is high in the central work zones but reduced in the sub work zones -Decreased visual connectivity due to physical barriers such as columns or walls -Low degree of awareness of surroundings due to barriers between work zones	-High degree of visibility between various work zones except from private workspaces -High visual connectivity towards collaborative core -High degree of awareness of surroundings due to seamless connection of the workplace via solid-void hierarchy and mezzanines	-High degree of face to face communication -Moderate visual connectivity due to open plan but segregated by intermediate plant buffers ;no view towards meeting zones -High degree of awareness; plant screens act as partial zoning

4. INFERENCES FROM CASE STUDIES

Based on the comparative case study analysis, the following design aspects to enhance employee productivity could be inferred, as discussed below –

4.1. Spatial Planning to enhance Employee Perception

- **User Satisfaction through diversity & flexibility** - As per studies, it could be inferred that employees in an activity-based work environment achieved highest levels of satisfaction as it provided a diverse variety of work settings. Biophilic approach in design i.e. plant scaping has also proved to bring about drastic improvements in work efficiency and job satisfaction.
- **Increasing Territoriality & Personalization -** Design of workstations must take personalization into consideration. Personalization in an open plan layout can be improved by providing 1ft high partitions in the workspace, on all the three sides of the workstation. A neighbourhood concept shall be applied in planning, to bring about a sense of belonging in employees.
- **Greater Work & Personal Privacy -** The challenge is to achieve an optimum level of privacy which is determined by the degree of transparency; several design aspects that can be considered to allow for privacy; while also not blocking communication between the co-workers, is through indoor landscaping using green buffers & plant screens. Another design strategy is; allowing optimum transparency through careful planning of solid-void hierarchy in the initial stages of the design.
- **Enhancing Collaboration & Co-working -** Interactive cores are to be planned at strategic locations within the workplace to increase collaboration. Breakout spaces shall be designed as ambient places for relaxation; with casual seating areas; not as rigid and regimental spaces. It can even be designed along vertical modes of circulation, for e.g. main staircase where people pass along most of the time and tend to bump into each other, resulting in interactions.

4.2. Environmental Considerations in Planning

- **Improving Day lighting and Visual Comfort** - In order to avoid direct sunrays but also to let in maximum daylight into the interiors, clerestory windows shall be provided if possible. Another design aspect that may be adopted is the planning of atriums or skylights within the workplace so as to improve overall day lighting while also controlling issues related to glare on computer screens.
- **Better Temperature control & Thermal comfort** - In most cases, centralised air conditioning systems have been proved to be the major cause of thermal discomfort. An effective design solution can be the use of mixed-mode ventilation; planning of the workplace in the initial stages, from this perspective, has to be followed by thermal mapping of various work settings and incorporating natural ventilation into as many work zones as possible.
- **Careful Selection of Materials and Finishes** –The use of reflective surfaces can considerably increase the amount of day lighting in the interiors without causing glare on computer screens. Use of zero VOC (Volatile organic compounds) materials or finishes for furniture and other interior surfaces; enhances the air quality.
- **Enhancing Acoustic privacy via sound mapping-** Design process in the early stages may use sound mapping to resolve the issue; through the clear differentiation or zoning of work settings from the most noisy to the most quiet zones. Use of green buffers such as plant screens or vertical garden walls; especially in meeting spaces or collaborative cores of the office can significantly reduce noise.

4.3 Spatial Planning & Configuration

- **Optimum Degree of Openness -** Planning of the workplace should be such that this degree of openness is optimum; with adequate transparency and connectivity between the different work zones so as to encourage collaboration and interaction between the co-workers; while also maintaining the required levels of acoustic and visual privacy.
- **Effective Circulation and higher Mobility -** Circulation within work zones is to be planned with care, as this decides the pattern of encounter of the users; which further impacts their interaction. Proximity of the central work-zone to breakout spaces must be considered during planning i.e. it is always preferred to provide intermediate breakout spaces in close vicinity, apart from the main active core, such that employees can take short breaks in between their stressful working hours.
- **Enhancing Visibility & Accessibility** - Face to face communication depends upon the planning of the workplace; this should be such that it allows clear lines of sight between almost all the work zones, except for the most private spaces of the office.

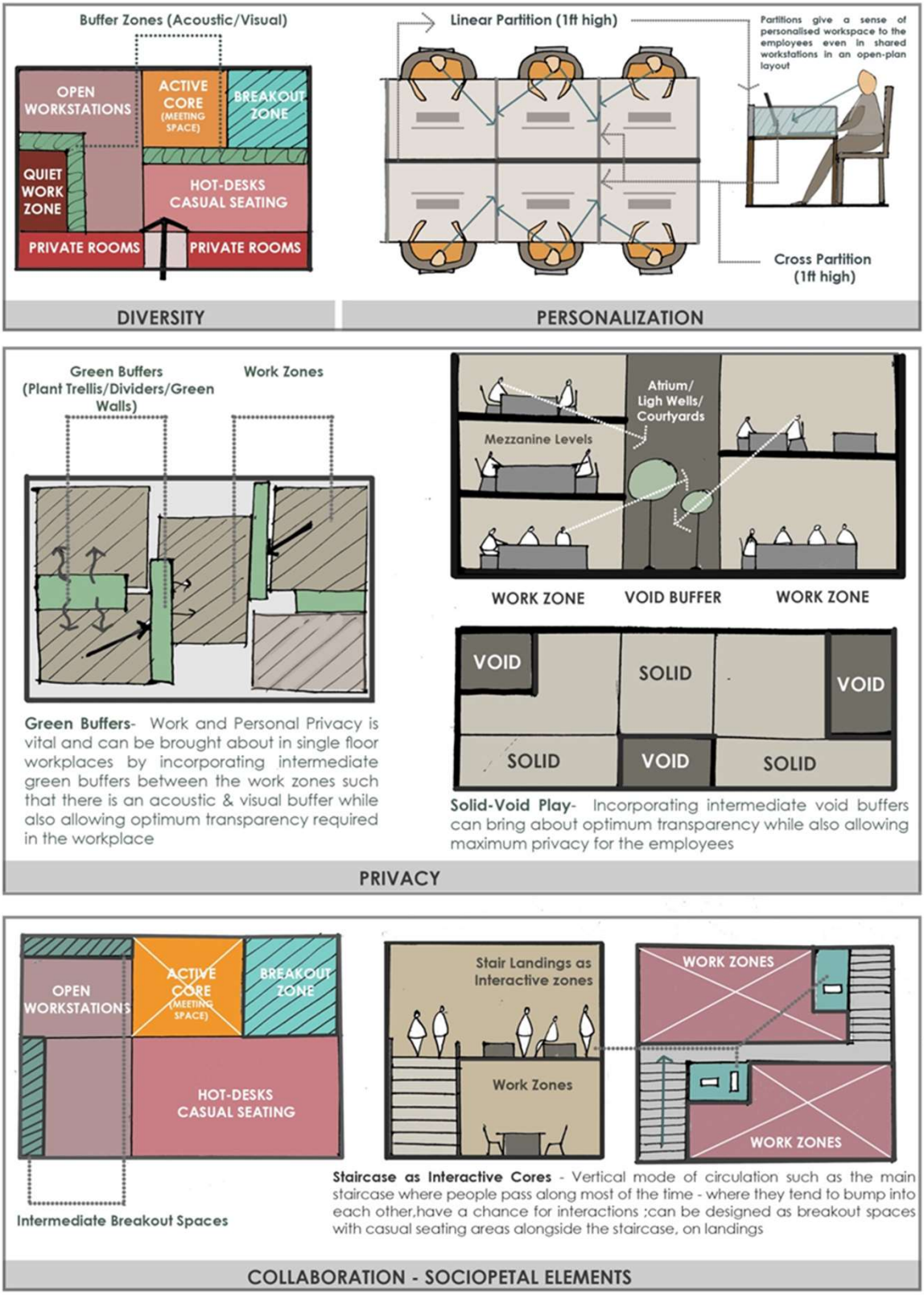


Figure 8 : Behavioural Aspects in Workplace Planning (Design strategies); Source: Author

5. FINDINGS : TOWARDS A PRODUCTIVE WORKPLACE

The proposed flow diagram below elaborates on design strategies that may be adopted towards developing a productive workplace. It also gives further insight into the design aspects that influence individual factors (staff turnover, revenue etc.) that define organizational productivity.

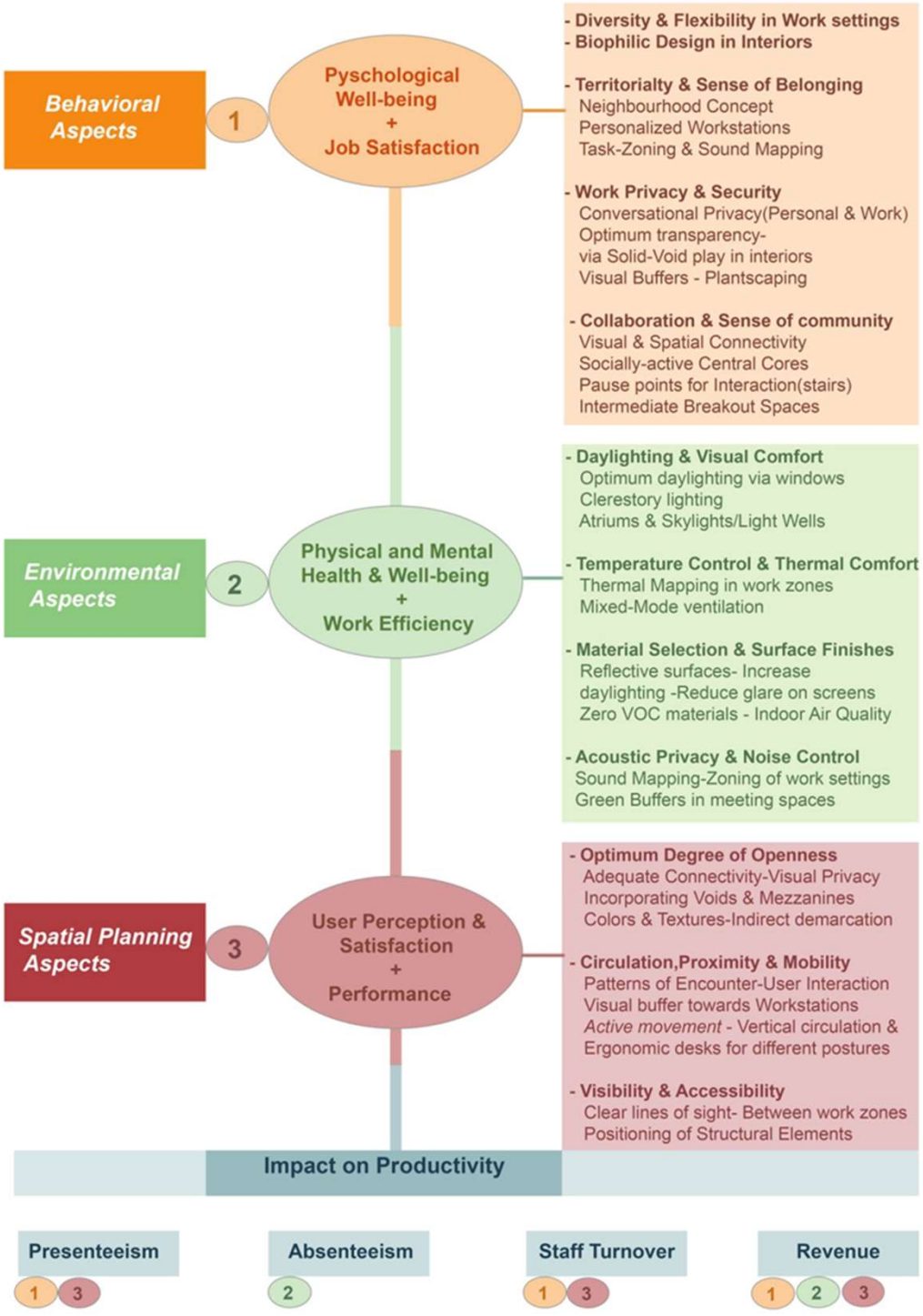


Figure 9 : Proposed Flow Diagram: Design strategies to boost Employee Productivity & Financial Outcomes;

Source: Author

A process flow chart is also proposed with an insight as to how the process of execution of a user-centric workplace can be implemented by architects or designers.

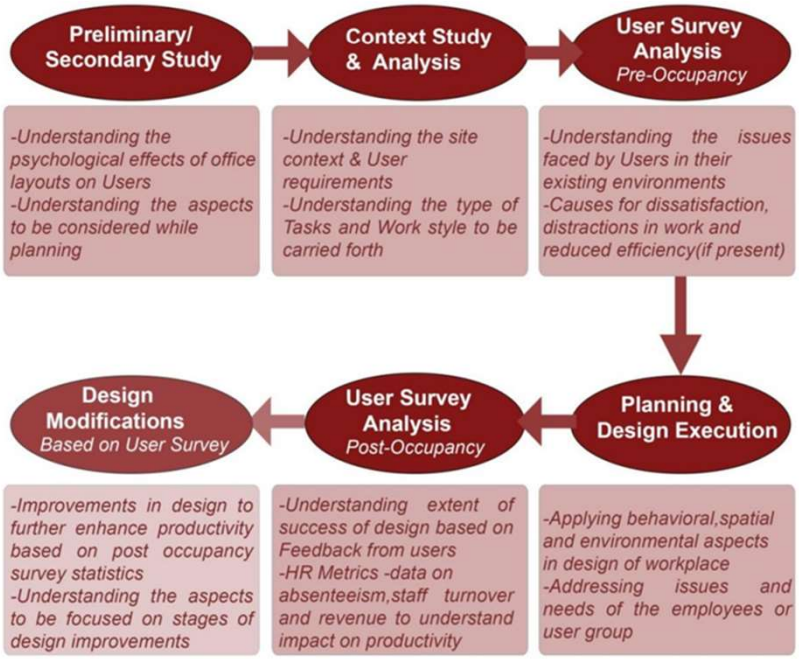


Figure 10: - Proposed Research Model: Guidelines for the design & execution of a productive workplace; Source: Author

6. FINDINGS BASED ON SPACE SYNTAX ANALYSIS OF AN OPEN-PLAN SPATIAL CONFIGURATION; USING DEPTHMAPX

Based on the initial inferences and findings, the open-plan workplace that was previously studied by means of employee survey statistics and space syntax methods is further critically analysed .The open plan spatial configuration is therefore hypothetically altered or re-designed into an activity based workplace. Activity-based workspace was concluded to be a better option as compared to open-plan or hot-desking.

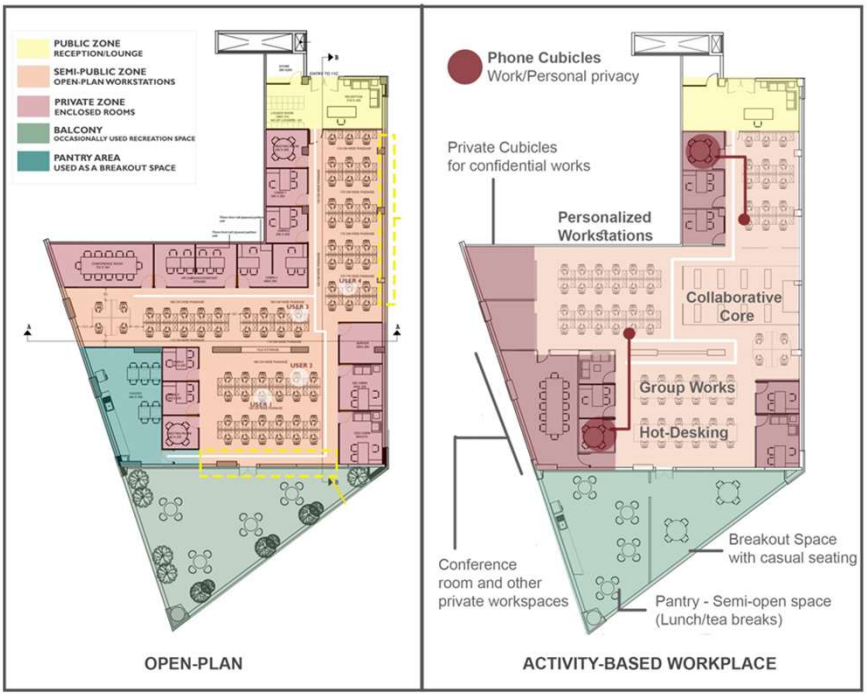


Figure 11: (a) Open-plan layout –Existing (b) ABW planning- Modified spatial configuration; Source: Author

6.1 COMPARATIVE ANALYSIS OF SPATIAL CONFIGURATIONS: OPEN-PLAN (EXISTING) AND ACTIVITY-BASED WORKPLACE PLANNING (PROPOSED) USING SPACE SYNTAX TOOLS

Analysis is carried out into the above mentioned layouts and the spatial configuration is further analysed through space syntax technique to conclude with a set of design strategies that shall be incorporated in the planning of any workplace. A comparative analysis of an open-plan layout and modified activity-based spatial configuration of the same workplace is performed. Visibility analysis graphs (VGA) and Isovist maps were generated to analyse the advantages of activity-based workplace over open-plan layouts.

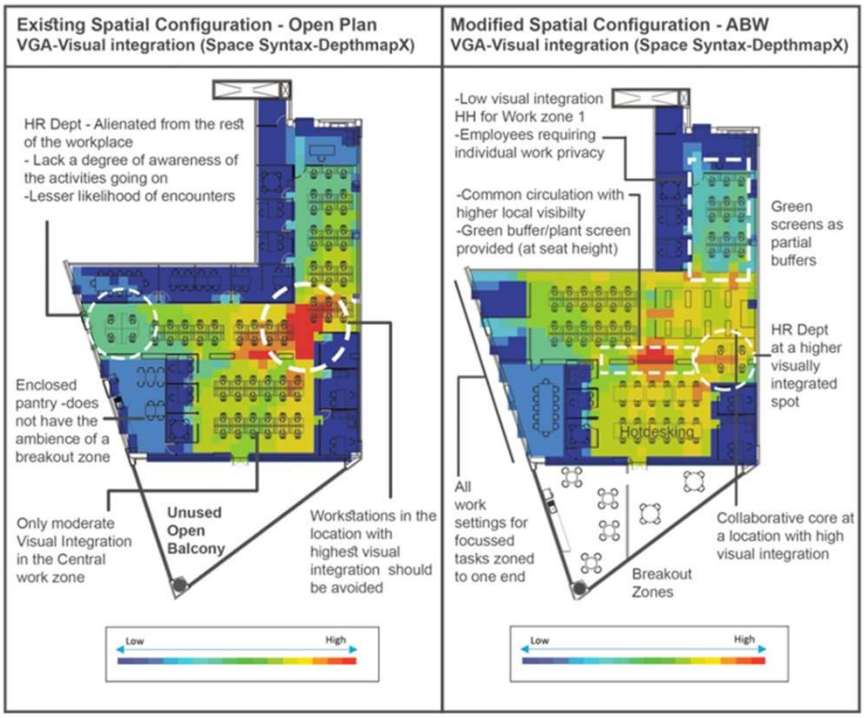


Figure 12: (a) VGA: Open-plan layout - Existing (b) VGA: ABW planning – Proposed; Source: Author

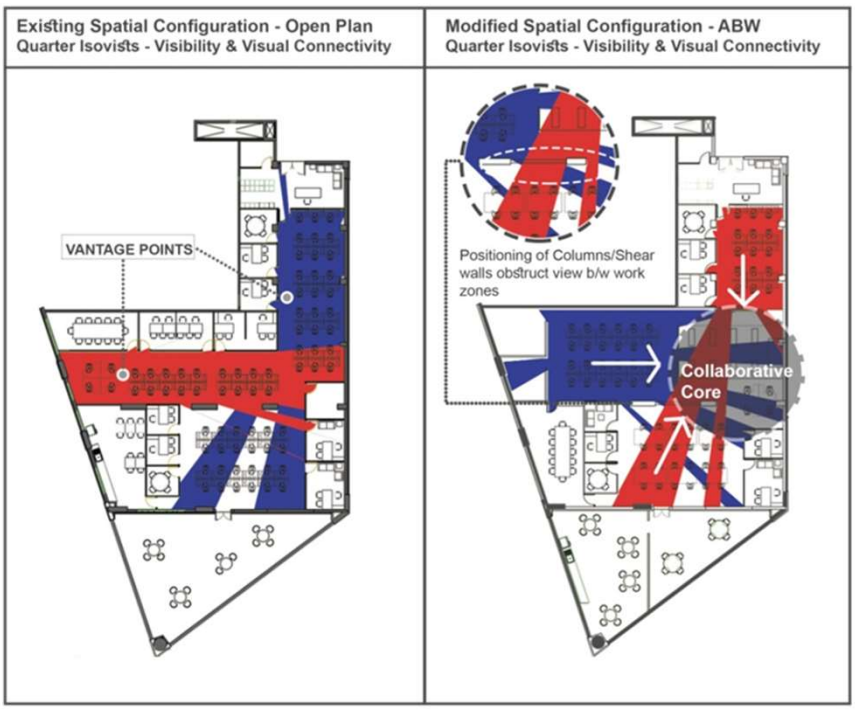


Figure 13: (a) Isovists: Open-plan layout – Existing (b) Isovists: ABW planning- Proposed; Source: Author

6.2 DESIGN STRATEGIES TO BE INCORPORATED IN SPATIAL CONFIGURATION TO ENHANCE EMPLOYEE PRODUCTIVITY (BASED ON SPACE SYNTAX RESULT ANALYSIS)

1. High levels of global spatial integration so as to allow free movement of employees across the workplace – while segregating the common passages from work zones so as to avoid possible distractions in tasks.
2. Careful planning of the encounter pattern of employees with a greater proportion of visually integrated spaces to enhance likelihood of interactions.
3. Low visual and spatial integration in spaces allocated for focused tasks or research-based works by employees. Moderate to high integration is preferred in collaborative work zones that are provided for group discussions, meetings, brainstorming sessions etc.
4. Incorporating catalysts in well integrated zones in the workplace to enhance movement, face-to-face communications and social interactions etc. Incorporating intermediate breakout spaces or informal meeting spaces for impromptu discussions in areas zoned slightly away from the main active work core.
5. Higher local visibility to be incorporated while planning the common circulation paths in the workplace - to enhance the degree of awareness of activities going on among employees. Common circulation paths should not affect the work and visual privacy of the employees.
6. Segregated spaces for phone conversations (work or personal) – in the form of cubicles/semi-open kiosks etc within the work zones. These shall be planned in locations with low visual and spatial integration. Axial paths or distances towards these cubicles or segregated spaces should be planned such that, they are optimum from all work zones or individual workstations.
7. Indirect spatial demarcations by means of wall colours, textures, material palette etc., and variations in furniture layout or specific pattern in configuration of workstations can enable easy identification of different work zones for the new employees in a workplace – enhancing their sense of comfort, making them feel at ease.

7. CONCLUSION

The ongoing trend of open plan adopted in most workplaces, without actually understanding its impact on employee well-being and performance efficiency is an aspect of grave concern. A workplace can be productive only if its design incorporates behavioural and environmental aspects; in the early stages of planning. Hence, spatial planning plays a key role and must be able to accommodate all personality types into the workplace, as there is no “one size fits all” concept and each workspace has to be tailored to suit the needs and working style of its employees.

REFERENCES:

1. World Green Building Council, 2014. *Health, Well-Being & Productivity In Offices*. WGBC.
2. Bodin Danielsson, C., Chungkham, H., Wulff, C. and Westerlund, H., 2014. Office design's impact on sick leave rates. *Ergonomics*, 57(2), pp.139-147.
3. Clements-Croome, D., 2017. *Creating The Productive Workplace*. 3rd ed. London: Taylor & Francis.
4. Vischer, J., 2007. The Concept of Workplace Performance and its Value to Managers. *California Management Review*, 49(2), pp.62-79.
5. Oseland, N., 2009. The impact of psychological needs on office design. *Journal of Corporate Real Estate*, 11(4), pp.244-254.
6. Milne, R., Fallick, S. and Hakky, D., 2017. *The Effect Of Individualized Work Settings On Productivity And Well-Being*. New York: Perkins Eastman.
7. Shand, J., 2019. *Arup’S Melbourne Workplace Awarded Platinum WELL Certification*. [online] Arup.com. Available at: <https://www.arup.com/news-and-events/arups-melbourne-workplace-awarded-platinum-well-certification> [Accessed 2nd January 2021].
8. Vischer, J., 2008. Towards an Environmental Psychology of Workspace: How People are Affected by Environments for Work. *Architectural Science Review*, 51(2), pp.97-108.
9. Colenberg, S., Jylhä, T. and Arkesteijn, M., 2020. The relationship between interior office space and employee health and well-being – a literature review. *Building Research & Information*, 49(3), pp.352-366.

AN EXPLORATION OF CO-WORKING SPACE AS AN OFFICE SPACE TYPOLOGY WITH SPECIAL REFERENCE TO COLOMBO

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ABSTRACT

In the modern developing world, new designs and techniques have been implemented to upgrade the standards and quality of the designs. There are diverse building types, and office buildings are a major type of them. Co-working spaces are the trending development of office spaces. The employee is the individual who is most affected by the working environment's physical, psychological, and social conditions. Based on worker satisfaction and prevailing concerns, this study evaluates the effects overtime of a construction trend that was introduced to the industry recently. The main aim of the study is to understand the elementary aspects affecting user satisfaction and to explore the relationships between worker satisfaction and the physical work environment. The literature review is conducted based on the employee satisfaction theories. The research analysis is studied using three different co-working spaces in the Colombo commercial urban area.

The field investigations were conducted using a questionnaire survey with an equal number of employers in each place based on their level of satisfaction within the working space and comfort ability with the architectural factors of the particular working space from the perspective of their satisfaction levels with their physical environment. The research explored the qualities of most employer satisfied co-working space from selected three case studies. The study's findings showed the connection between co-working space, design factors and employer satisfaction, where some oppressive influences were found to affect employee satisfaction positively. According to the results it was initiated, Visual link with nature, thermal comfort, and adequate lighting levels are the most contested reasons in the Sri Lankan context for an employee to be satisfied within a working space. By applying these theoretical principles and findings in the construction industry, the effectiveness of co-working users could be increased.

Further research may be performed by comparing the design factors of many case studies where the effect of design factors on the workplace is investigated. It suggests moving this survey and in cooperating additional number of participants, which will provide more reliable feedback.

KEYWORDS – co-working space, working environment, employer, satisfaction

1. DEFINING CO- WORKING AND WORKING SPACE

1.1 INTRODUCTION TO CO – WORKING SPACES

The co-working idea has contributed to the growth and popularity of collaborative workspaces. However, little is understood about where co-working users are situated and what they prefer in sri lanka. This research explores user expectations for co-working spaces.

Several business shifts have led to new ways of working, such as the sharing economy, the growing need for flexibility, and the increasing use of public spaces as workspaces. A multi-tenant office can be represented as a building that offers working space and a number of shared amenities to multiple organizations.

The amount of co-working spaces has been increasing continually over the past few years. Co-working spaces are dynamic, stimulating, and cost-efficient workspaces where people from different backgrounds can collaborate, learn from each other and develop innovative solutions. Their success stems from a changing attitude towards work,' namely self-employed people and other individual professionals are increasingly searching for a workplace outside their home because they feel depressed while at home and want a better perspective between their work and personal life.

Co-working spaces – These types of work spaces include “the membership-based office spaces where a multitude of workers are brought together to fulfill the goal of the organization within a shared community (Duverge, 2016).

A lot of freelancers, remote employees, and other sorts of independent professionals are trained to do co-working jobs. Based on a study conducted by Harvard Business Review, it was found that high quality of work is reached by co-workers as opposed to daily office workers.

Co-working is a collaborative workplace where people can work in different places, which have meeting and break out spaces. Circles represent small businesses and startups as a place to obtain work experience. Co-working spaces can vary from month to month walk-away to one-year tenancies.

1.1.1 CLARIFICATION OF THE WORD "CO-WORK SPACE."

According to Butler and Kiera on their works well with others paper, Co-working arrangements in which staff from different firms share an office room allowing cost savings and flexibility through the use of similar facilities, such as appliances, and custodial, receptionist and, and even in some cases, refreshments and package acceptance services. It is suitable for independent researchers, mobile workers, and people who do their work in the classroom. Co-working has also been shown to alleviate feelings of depression and job-related alienation for people who work remotely. Some co-working spaces allow paid memberships.

1.1.2 CONCEPTS OF CO-WORKING SPACES

This co-working big idea is based upon "open interactive space" architectural concepts and is symbolic of the internet era. Typically individual workers, contractors, freelancers, and developers chose to work from home in solitude and also expecting was that they had a sense of human contact. At the stage of meeting a client or a college best option for them is to use a place like a restaurant or coffee shop. Co-working gathers people who work individually but who share values and search out the potential of working in a collective room filled by colleges and inspiring people.

Entrepreneurs in co-working spaces share the same workplace but have access to a wide variety of resources based on their involvement. This model is ideal for entrepreneurs who want to have a more comfortable office and do not want to waste a lot of time on administrative activities and spend money on their own space, buying furniture, and interior designing. Co-workers can rent desks to their own reserved room or that they can use for an agreed time.

1.1.3 CHARACTERISTICS OF CO WORKING SPACE

The world is especially search about co-working, particularly with regards to how it is transforming the work climate for the better. The manager of the co-working space is trying to create a productive and sustainable space that will be usable. Hallman claims that we cannot really truly understand society but that there are certain fundamental absolutes of community.

In order to build a community within the co-working room, a person needs to take an active role in sharing relevant information outside of it. "Employers work closely with the community architects serve" It seems, in part, to be a sustainability issue within the urban environment. Society needs to be fulfilled in more than the virtual space, but also the environment. "It needs to be sustainable, but one that does not consume the community as the space getting used for years." "Co-working space holders providing more space within existing space," says Hillman.

This kind of space is used for freelancing, software design and development, and all other kinds of online professions. It is favored by co-workers because it offers the most creative atmosphere.

Features	Importance (out of 5)
Physical environment	4.5
Community gathering	4.3
Collaborative Environment	4.1
Location	4.0
Networking Opportunity areas	3.9
Excellent Co-working areas	3.7
Meeting Spaces	3.7
Quiet Spaces	3.4
Security	3.2
24 Hr. Access abilities	3.1
Event spaces	2.9
Privacy	2.8
Personalized Space (own desk)	2.6

Table 1: Importance of office features:

Source: data taken by (https://www.sciencedirect.com/science/article/pii/S1877705811029894)

1.2 WORKER SATISFACTION IN A WORKING SPACE

1.2.1 INTRODUCTION TO WORKER SATISFACTION

Job satisfaction is a well-described term that is studied by many researchers and is characterized and used differently. According to the popular scholars Greenberg and Baron in their book' Behaviors in Organizations', job satisfaction is "a feeling that can create a positive or negative effect toward one's roles and responsibilities at work" and "added that it is necessary to explain the concept of job satisfaction as there is no particular way to satisfy all workers in the workplace." (Greenberg & Baron, 2008)

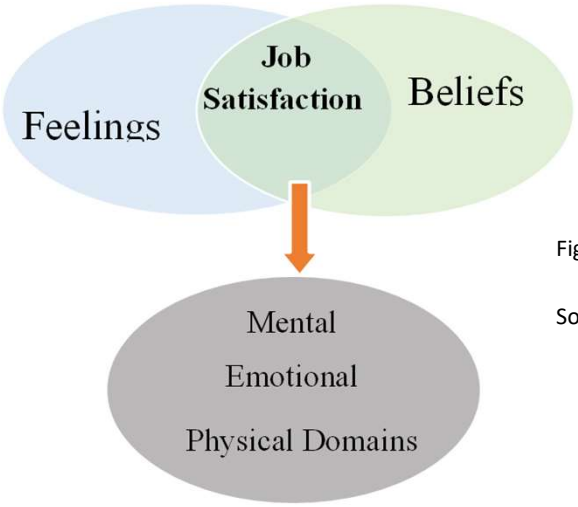


Figure 1: Concept of Job satisfaction defined by George and Jones

Source: Author's own figure

Furthermore, there are meanings given to the term 'Job Satisfaction' by several scholars where George and Jones (2005) have mentioned as this meaning is the combination of feelings and beliefs, which include the mental, emotional, and physical realms.

This can be further articulated as "a worker's psychological response to different aspects of job satisfaction resulting in finding pleasure, comfort, motivation, rewards, self-development, and multiple beneficial opportunities, high expression mobility, acknowledgment and evaluation done on a performance model with economic value as a recompense" (Robbins & Judge, 2007)

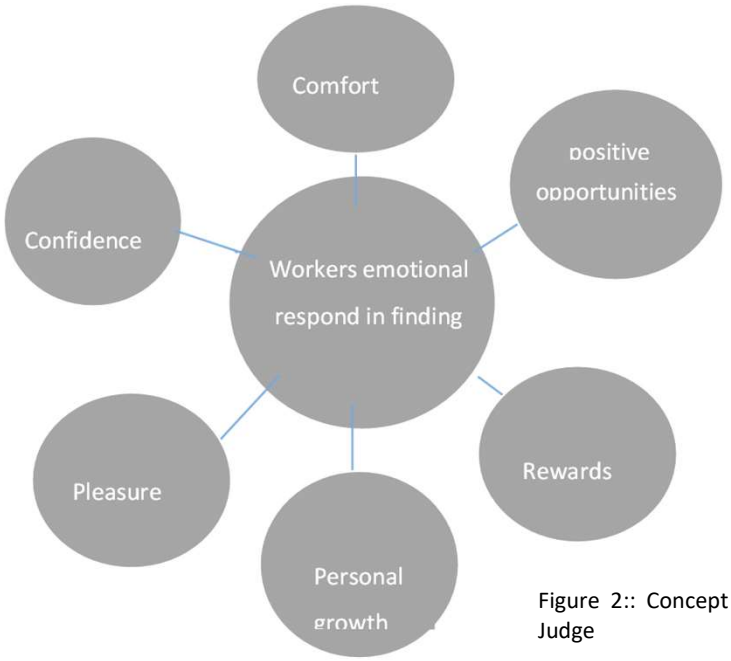


Figure 2:: Concept of Job satisfaction defined by Robbins and Judge

Source: Author's own figure

Hirschfield (2000) said, "Perceived satisfaction of employees is how people feel about the nature of the task performance themselves, whereas perceived extrinsic job satisfaction is how people are feeling about the nature of the work environment that is external to the job tasks or work itself" (Mohammed & Eleswed, 2013)

There are many meanings of work satisfaction on the market. Some describe it as the optimistic emotional level achieved by the employee when the employee gets a job assessment (Locke, 1976)

Employment satisfaction refers to the level of satisfaction and pleasure people have in their careers. Positive feelings about the job suggest workplace satisfaction. It is also believed that a negative or unfavorable attitude suggests work dissatisfaction (Aziri, 2011).

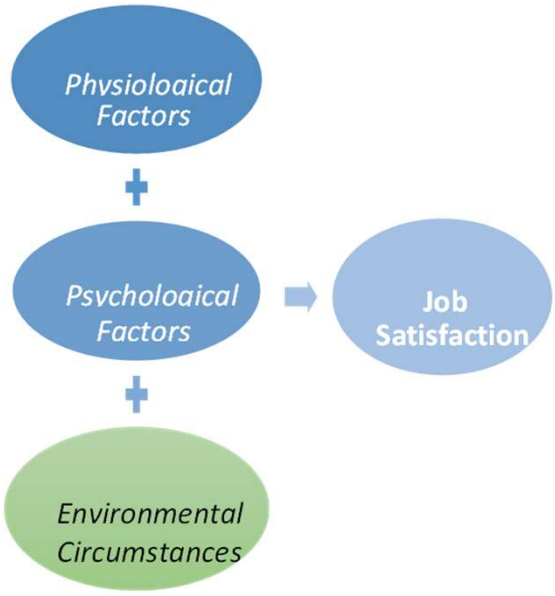


Figure 3:: Concept of Job satisfaction defined by Hoppock in 1935

Source: authors own figure

1.2.2 THEORIES OF WORKER SATISFACTION OF JOB ARE EXPLORED IN LITERATURE.

The theory is a vast body of mutually dependent concepts and principles that provide order to or impart coherence to a significant amount of evidence. (Weihrich, Harold, & Willoughby, 1999). Job satisfaction theories would be discussed in relation to theories that describe human motives.

These explanations of quality of work life are the fundamental theories used to describe and understand the principles. Most of these hypotheses were built through academic research, which always commitment to providing empirical evidence over the long term.

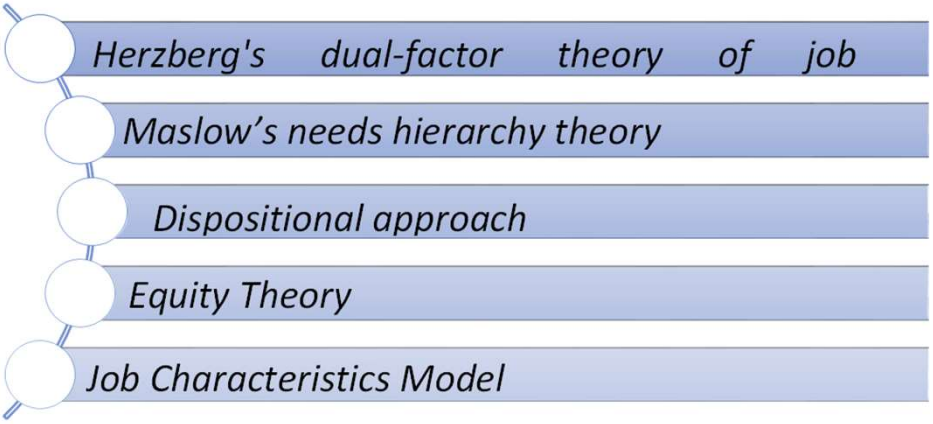


Figure 4: Basic Theories of Job Satisfaction

Source: Job satisfaction theories: Traceability to employee performance in organizations

1.2.3 THE RELATION BETWEEN EMPLOYEE SATISFACTION AND WORK ENVIRONMENT CHARACTERISTICS.

A healthy work environment helps improve employee satisfaction. Job climate plays a number of roles in physical and emotional well-being. Well-being A quality work environment is fundamental to support labor effectively and efficiently. Numerous studies investigating the relationship between job satisfaction and success have proven to be successful.

It was found that there was a clear association between a worker's happiness and the working environment. It affects the motivation of everyone through its degree. In the workplace, productiveness is dependent on the number of people and the productivity of the people.

The effectiveness of a work environment is critical in increasing worker satisfaction, which would increase productivity and boost an organization's overall performance. Based on a study published in the East African Journal of Public Health, it was found that providing a positive work environment motivates employees to conduct day to day work more efficiently, resulting in better utilization of the employees' expertise (Agbozo, Owusu, Hoedoafia, & Atakorah, 2017).

Figure 5: Factors that impact on the job satisfaction

Source: https://www.google.com/search?q=Factors+that+impact+on+the+job+satisfaction

2. RESEARCH DESIGN (METHODOLOGY)

2.1 DATA COLLECTION METHODS WITH REFERENCE TO LITERATURE.

Data collection method of the research is a questioner survey. It is a qualitative survey method. And it is an online survey the possible way to get the study done during the pandemic situation. Because of the pandemic situation online media is the preferable way to contact employees of selected co-working space.

The data was obtained using previous scholarly studies into job satisfaction and workplace climate. Primary research techniques built by academics have been used in these case studies to research practical issues over a long time. Those previous survey methods were further modified as per the requirements of this research area.

In the research questionnaires were used based on five categories for the study.

- 1st set of questions reveal the worker's personal information, which will be considered in measuring the satisfaction levels, which indirectly may help for the research's expected findings.
- 2nd set of questions were set regarding the satisfaction levels of their personal growth and the career development of their occupation, which might indicate their attitude towards their job. These questions helped to understand their interest in the job irrespective of the environmental condition.
- 3rd section looks at the preference of the employees' collaboration ideas with other employees.
- 4th set of questions were prepared to rate their own productivity and quality of work based on the work allocated for them where it helps to reveal and compare the satisfaction levels and productivity of work.
- 5th the most important section of the questionnaire is questioned the employees idea on various architectural factors of the building the employees working.

The explanations that generated the study on work satisfaction and job results are used to interpret the data collected and also to define the methods of data collection. The analysis and research experimentation recommendations that were generated as the recommendations of the academics were employed in this investigation, research that had been used by them for a long time.

2.2 BACKGROUND OF THE CASE STUDY

The idea of selecting case studies was to select three different case studies from Colombo commercial area with three different architectural categories with differentiate hierarchy, organization, interior exterior connection, indoor outdoor views, material usage, comfort levels.

2.2.1 CASE STUDY ONE – PARKLAND BUILDING, COLOMBO

Parkland building is a newly build commercial use building in Colombo commercial area by Archt. Sunil Gunawardhane. It provides spaces for monthly, daily and hourly payments as all other co- working areas provided. Parkland is having an eye catching colonial view from outside.

Figure 6: exterior of parkland office building, Colombo

Source: https://www.google.com/search?q=parkland+building

Figure 7: a co-working place of parkland, Colombo

Source: https://www.regus.com/en-gb/sri-lanka/colombo/parkland-building-4135

Author got questioner filled by 20 participates currently working in parkland building who were the members of parkland co working space.

2.2.2 CASE STUDY TWO – COLOMBO COOPERATIVE CO- WORKING SPACE

The second case study is Located in bambalapitiya area. It got the views of Indian Ocean and Colombo city to the co-working spaces. And consist with interior greenery and mainly timber textured interior.

Figure 8: exterior view from inside of Colombo co-operative
Source: https://www.colombocoop.com/mission

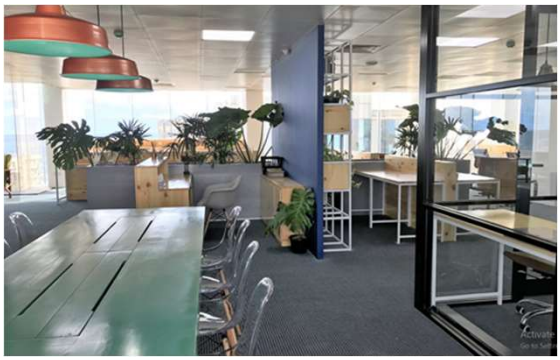


Figure 9: greenery interior of Colombo co-operative
Source: https://www.colombocoop.com/mission

From the all three case studies this is the study with interior greenery. Author get 20 questionnaires filled with Colombo co-operative co-workers.

2.2.3 CASE STUDY THREE – CO-NNECT, SHANGRI-LA COLOMBO

This case study is a part of the Shangri-La hotel Colombo. It is the luxurious (according to the rates) co-working space among all three. Considering the surround environment interior consist with replication patters of the nature in the co-working spaces. The walls, floor, roof, partition, furniture and all accessories got the natural material textures.
The questioners got in this place are with currently working and mainly previously worked employees. Due to high rates co-nnect co working space is rented only for exclusive meetings according to the feedbacks author got. There is 20 participants participated to the questioner.

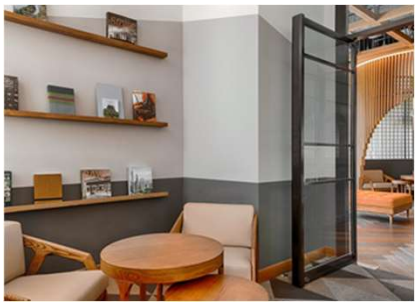


Figure 10: timber usage of interior in co-nnect
Source: https://ww w.co-nnect.info

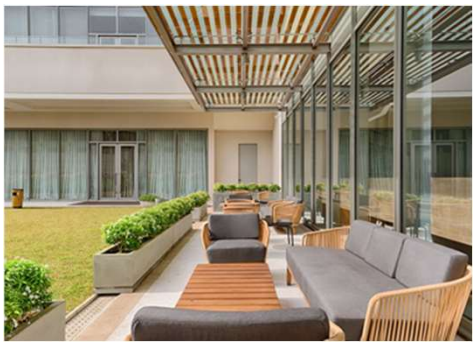


Figure 11: green exterior of co-nnect

Source: https://www. co-nnect.info/nnect

Figure 13: meeting room with green, timber and stone replication of co-nnect

Source: https://www.co-nnect.info/

3. DATA ANALYSIS

3.1 THE PROCESS OF DATA ANALYSIS

Analyzing the process of the data of the research paper is shown in the diagram below, which reveals the methodology used to study the hypothesis. The final conclusion was made by examining the statistically significant research results in accordance with this process.

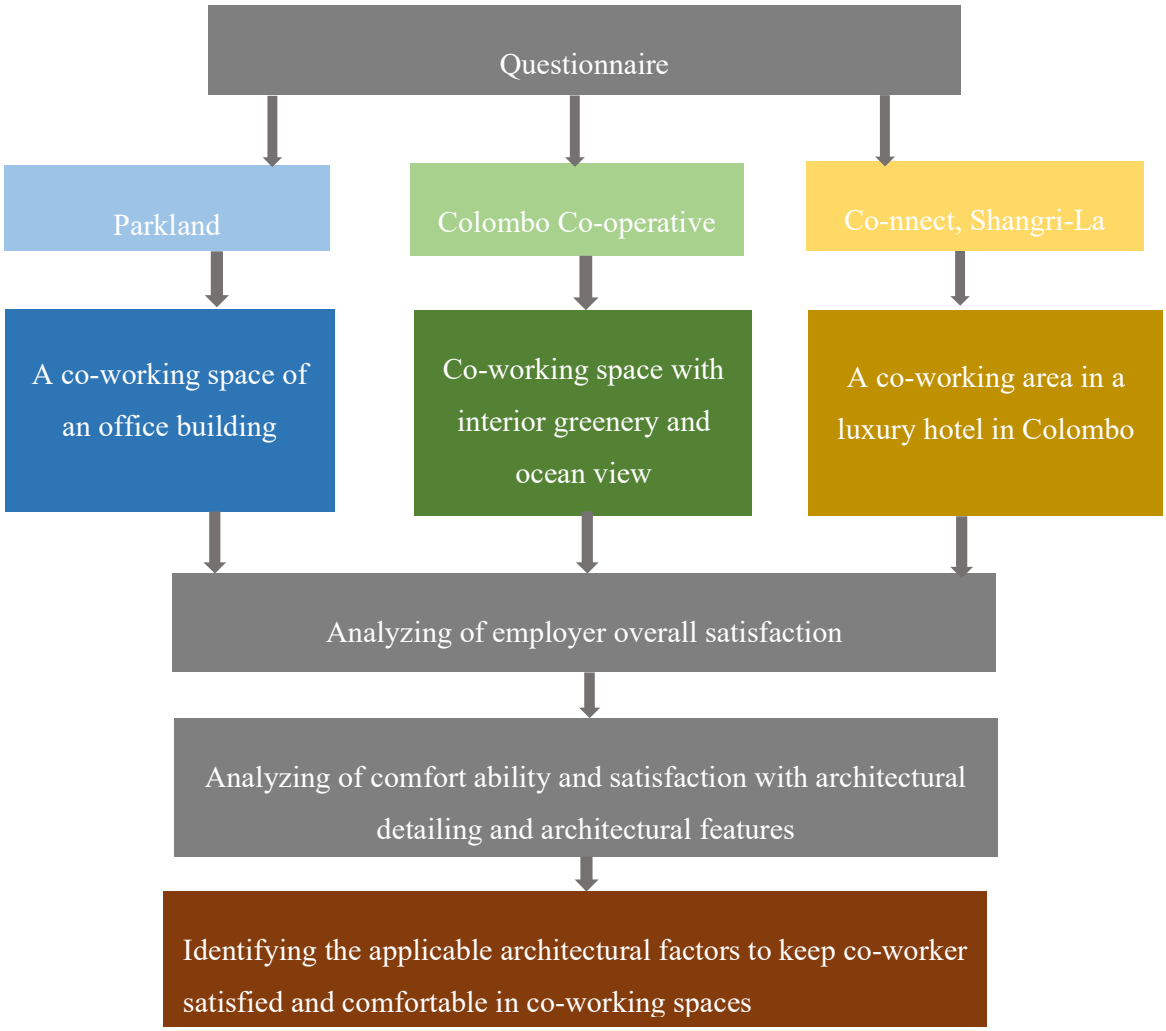


Figure 14: data analyzing process

Source: Authors own figure

3.2 ANALYSIS OF THE DESIGN AND ENVIRONMENTAL FEATURES OF THE CO-WORKING SPACE

The 1st set of questions which reveal the worker's personal information, comparatively most of employers in Co-nnect co-working space, booked the particular space only for their meetings with someone. The reason for this can be the high rates of the Co-nnect co-working space.

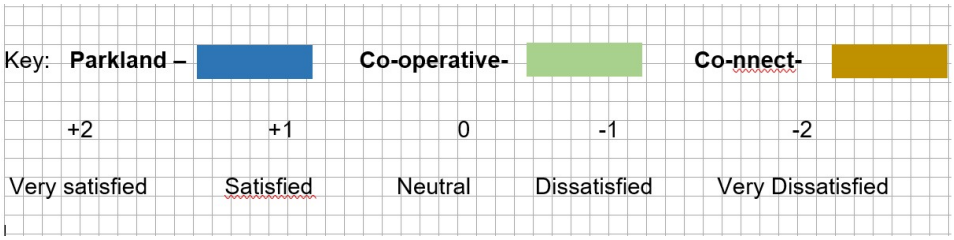
With the 2nd set of questions regarding the satisfaction levels of their personal growth and the career development of their occupation, there is no any dissatisfied employee in any of the co- working area. Each of them was satisfied with their work in particular co-working space. This equally factor of all 3 co-working spaces impact positively to analyze the rest of the questioner.

In the 3rd section looks at the preference of the employees' collaboration ideas with other employee's results were varying among the employers but equally distributed among the all three co- working spaces.

In the 4th set of questions were prepared to rate their own productivity and quality of work ; averagely all employees stay productive according to their ideas in all three co-working spaces. And there is little high rate can be seen in co-nnect co-working space. According to the general personal data of co-working spaces co-nnect space is mostly used for meeting clients and mainly for one or two hours. So it is obvious to be productive in that two hours of working.

All above set of questions shows equal results which is impact positively to analyze the satisfaction levels of design factors.

Below are the results of questions asked about how the working environment will have an effect on the employee satisfaction level where this should be one of the significant sections of the entire questionnaire the (5th set of questions). The below chart prepared by the given answers by co-workers of selected co-working spaces.



Design factor effect on employees satisfaction	+2	+1	0	-1	-2
Q1- Space planning	3	6	9	2	0
	7	10	3	0	0
	8	12	2	0	0
Q2- Exterior view from the space	0	0	6	9	5
	13	7	0	0	0
	15	5	0	0	0
Q3-Natural ventilation and freshness	0	0	4	11	5
	0	6	5	5	4
	0	9	7	4	0
Q4- Availability of daylight and adequate illumination	4	8	6	2	0
	11	7	2	0	0
	13	5	2	0	0
Q5- Cleanliness and ease of maintenance	17	3	0	0	0
	12	8	0	0	0
	18	2	0	0	0
Q6- Indoor plants and landscaping	0	0	0	17	3
	19	1	0	0	0
	14	4	2	0	0

Q7- Privacy and noise level	5	9	6	0	0
	9	7	6	0	0
	14	8	0	0	0
Q8- Safety and security	16	4	0	0	0
	17	3	0	0	0
Q9- Pleasant color scheme	14	6	0	0	0
	19	1	0	0	0
	20	0	0	0	0
Q10- Presence of coordinated art objects	0	6	10	6	0
	17	3	0	0	0
	18	2	0	0	0

Table 2: design factor effect on employee satisfaction

Source: authors own table (data taken from survey)

The comments get in the comment section are as bellows,

Parkland,

1. Employers were satisfied if they got more greenery to inside of the building
2. Need some artifacts or some art objects to view in free time.
3. Interesting to have a coffee bar at right near by the working area.
4. The exterior look of colonial features at parkland is interesting and asked for that features in inside of the building also.

Co-operative,

1. Satisfied with what they got in their working environment.
2. Satisfies with the ocean view
3. Satisfied with the greenery inside the building

Co-nnect,

1. Satisfied with the homely environment.
2. An office space should be feel free and safe to work
3. Interesting how timber and stone patterns going inside of the building.
4. Feel free to stay with the friendly staff and they were so helpful.

Comparatively the parkland co-working space which is in an office building architectural factors satisfaction is less than other two spaces.

According to the analysis of the satisfaction level of the employees the highest rate of satisfied with the co-operative building. So according to the data analysis co-operative co-working space which is with ocean view is the satisfied working space of all according to the questioner survey.

CONCLUSION AND RECOMMENDATION

According to the primary field investigation done on understanding the co-working employer satisfaction levels, the final study outcomes revealed that the prototypical co-working space design trends could affect co-worker satisfaction levels of employees related to their physical work environment.

Most of employers were respondents were satisfied with their working environment, largely because of the well manipulated design factors and friendly atmosphere the organization offers. Some design factors affect the other designs with the responses from the individuals. Noise levels of the space, Visual association with nature, art object presentation, and access to the green area are the important factors that make a difference in the quality between the three case studies. As co-working space has become a trend in the country, this has had a major effect on human behavioral patterns. The majority of the buildings in urban contexts are built to have a direct impact on human health and well-being and based on the research findings, it is recommended to keep a connection with nature and relaxing features as same as maintaining the safety and health well-being of employers.

In future research, it is proposed that studies examine how the physical factors could contribute to worker dissatisfaction and how those factors can be minimized in building design. There are different explanations for worker satisfaction and dissatisfaction. Job satisfaction can also be considered one of the most significant aspects affecting an employer's satisfaction phase of life.

LIST OF REFERENCE

1. Agbozo, G., Owusu, I., Hoedoafia, M., & Atakorah, Y. (2017). The Effect of Work Environment on Job Satisfaction: Evidence from the Banking Sector in Ghana. *Journal of Human Resource Management* - Volume 5, Issue 1, 12-18.
2. Aziri, B. (2011). Job Satisfaction, a Literature Review. *Management Research and Practice*, *3*(1), 77–90.
3. Beacham, K., & Barrington, S. (2007). CallMinder™ - The development of BT's new telephone answering service. *BT Technology Journal*, *25*(3–4), 143–150. https://doi.org/10.1007/s10550-007-0069-6
4. Cooper, C. (2006). Wellbeing at work. *Bmj*, *333*(7580), s219.2-s221. https://doi.org/10.1136/bmj.333.7580.s219-a
5. Department of Census and Statistics. (2004). *Computer Literacy Statistics 2017, Sri Lanka*. *2017*, 1–4. http://www.statistics.gov.lk/education/ComputerLiteracy/ComputerLiteracy-2017Q1-Q2-final.pdf
6. Design Guidance: Office Space. (2003). *History*, *September*.
7. Duverge, G. (2016, JANUARY 13). Ofce Space: Evaluating 5 Types of Office Environments. Retrieved from BUSINESS ADMINISTRATION AND MANAGEMENT: HTTP://WWW.TUW.EDU/BLOG/CONTENT/BUSINESS
8. Ergin, D. (2014). *How to Create a Co-Working Space Handbook*.
9. Gilbert, J. P. (2004). Construction Office Design with Systematic Layout Planning. *2nd World Conference on POM 15th Annual POM Conference Cancun, Mexico*.
10. George, J.M., & Jones, G.R. (2008). Understanding and managing Organizational Behavior (Fifth Edition). *Upper Saddle River: New Jersey, Pearson Prentice Hall.*
11. Greenberg, J. & Baron, R.A. (2008). Behaviours in Organizations.
12. Hirschfield,R. (2000). Work centrality and work alienation.
13. Hoppock, R. (1935). *Job Satisfaction,*. New York: Harper and Brothers.
14. Haynes, B., Suckley, L., & Nunnington, N. (2017). Workplace productivity and office type: An evaluation of office occupier differences based on age and gender. In *Journal of Corporate Real Estate* (Vol. 19, Issue 2). https://doi.org/10.1108/JCRE-11-2016-0037
15. Javed, M., Balouch, R., & Hassan, F. (2014). Determinants of Job Satisfaction and its impact on Employee performance and turnover intentions. *International Journal of Learning and Development*, *4*(2). https://doi.org/10.5296/ijld.v4i2.6094
16. Lee, X., Yang, B., & Li, W. (2017). The influence factors of job satisfaction and its relationship with turnover intention: Taking early-career employees as an example. *Anales de Psicología*, *33*(3), 697. https://doi.org/10.6018/analesps.33.3.238551
17. Locke, E. (1976). The nature and causes of job satisfaction. . In M. D. Dunnette, *Handbook of industrial and organizational psychology* (p. 1300). Skokie, IL: Rand McNally.
18. Mohammed, F., & Eleswed, M. (2013). Job satisfaction definition, Factors Affecting Job Satisfaction, and Significance. *International Journal of Business, Humanities and Technology* , 43.

MODULAR ARCHITECTURE- CHANGING THE PERSPECTIVE OF LIVING

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ABSTRACT:

We all know that India is a developing country. It is the fifth-largest economy in the world, with a GDP of $2.87 trillion in 2019, more than 4% higher than in 2018. Although the economy is growing, orphan children is still a major challenge for India. Orphan are also one of the most neglected classes in India by the people of India and also the government of India. The numbers of orphanages are very less as compared to the number of orphan children in India. Also, many orphan homes are not even capable of fulfilling the basic needs of these children. Taking these things into account and to alleviate their suffering we can provide solutions to improvise the space quality for their better living which will be capable of fulfilling their basic needs of hygiene, some privacy. In India modular architecture is in practice nowadays because of its advantages. Major cities of India have been already reached at their limits. Because of this it became very difficult to store raw material on sites. In such situations modular architecture is playing very important role as it doesn't need any storage space for raw materials also it is economical and requires low maintenance. After reading research paper and case studies on modular architecture I found that, modular architecture will be the best for this orphan home.

KEYWORDS: Orphanage, Modular architecture, Container housing.

INTRODUCTION

India is known to be a developing country. We are daily achieving milestones in different fields like education, research and technology, agriculture, construction, transportation, and many more facets. But yet we are not succeeded in dealing with the "orphan children's" issue. Every day it is getting bigger and bigger. Some private foundations and NGOs are taking initiative but they also have some limitations. Also, there is a very bad response from the government. (2) Because of the lack of surveys carried out by the Indian government for these children. (2) Many orphan children don't have their registration in government files. (2) According to United Nations Children's Fund (UNICEF), India has 29.6 million orphaned and abandoned. (3) SOS Children Village conducted a study in 2011 and concluded that the former category equals 4% of India's child population. (3) Out of this 29.6 million (the numbers could be much higher than this) very fewer children reach orphanages because there is little infrastructure for these orphan children. (3) One in five districts in the country does not have even a single orphanage, and the majority of districts don't have the minimum three orphanages needed (one for children less than 6 years of age and one each for boys and girls of 6-18 years respectively). (2) The main problem is because of the small number of infrastructures for orphans.

To deal with this issue modular architecture can be the solution. As we know nowadays by taking the help of modular architecture we can convert shipping containers into houses, offices, mobile toilets, etc. Shipping containers are generally used in international cargo transport. They are made up of metal sheets and steel posts. These materials get treated in factories in such a way that they shouldn't get affected by extreme weather. As many times these containers are transported through ships so it becomes very important to keep them safe from foreign decaying agents like moisture, bacteria, and harsh weather because they carry expensive cargoes in them like cars, poisonous chemicals, medicines, etc. From the external side, these containers get treated with paints containing phosphorus and chromium in them, and from the inner side, they are insulated by an insulating material to keep the goods safe from harsh weather. After using these containers for 10 -12 years owners send them to the crushing yard. Without sending them to the crushing yard we can utilize them in the habitable space for the orphans.

AIM - Use of modular construction as an economical solution for social issues.

OBJECTIVES

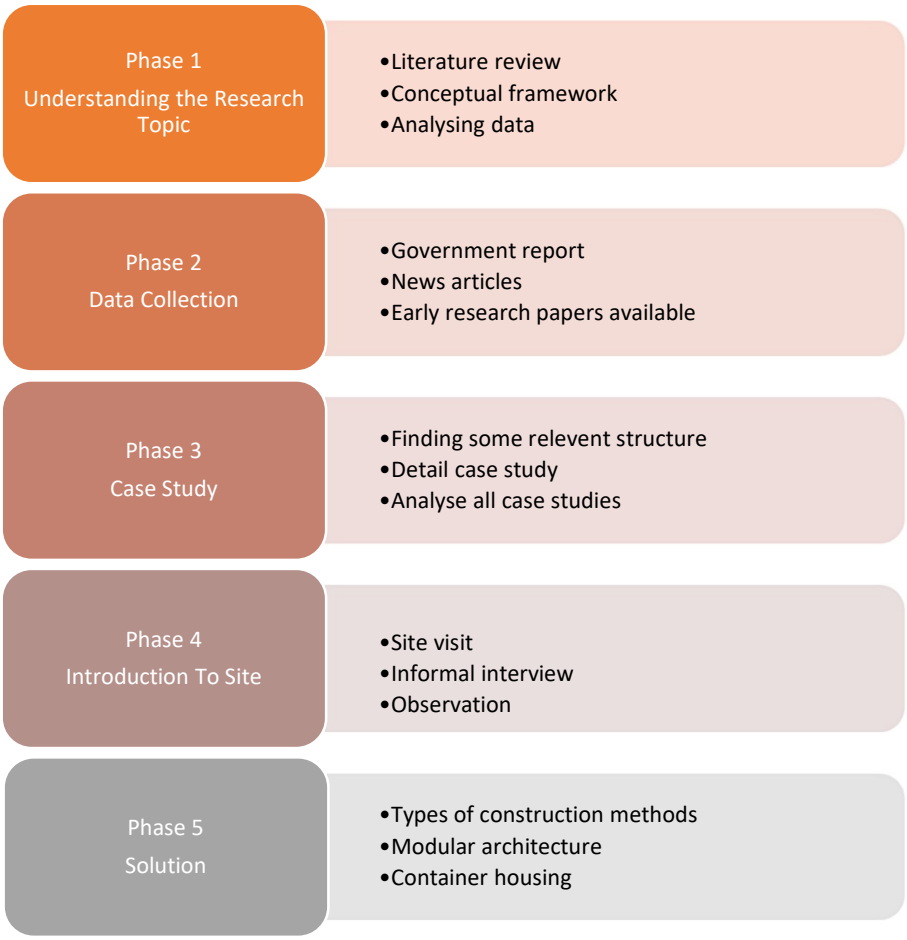
The objectives of this study are – a) Analysing the space-related problems in day to day life of orphan children. b) Providing solutions to improvise space quality which will fulfil their basic needs. c) The solution to be economical, with low maintenance, and with future expansion possibilities.

SCOPE AND LIMITATIONS

The study has been carried out on understanding daily problems faced by the orphan children. Also, study of modular architecture has been done. The advantage and disadvantages of modular architecture are discussed.

Attempt of alleviating the suffering of orphans through designing a good habitable space by the help of modular construction has been done. There are a lot of situations where we can use modular architecture because of its characteristics.
The study is limited to container housing which is a part of modular architecture. Only one type of modular architecture is explored.

METHODOLOGY



Phase 1:
In phase 1 study of literature has been done referring various research papers.

Phase 2:
In phase 2 study of reports published by government bodies and some news articles has been studied.

Phase 3:
In phase 3 case studies of two foreign structures has been done to understand the construction process of modular architecture.

Phase 4:
In phase 4 live proposal of site has been studied. Some discussion done with orphan children and the caretaker. Observation has been noted after discussion.

Phase 5:
In phase 5 comparison of different construction method has been done. After comparison of all construction methods most efficient method of modular architecture for the given proposal is justified.

CASE STUDY

1. CITE A DOCK (STUDENT RESIDENCE)

Location – Le Havre (France). (4)

Architect – Cattani Architects. (4)

The architect Cattani said the thoughts that accompanied her work. “How do I prevent students, prospective tenants, from feeling them put in the box? (4) Compelling needs have arisen. (4) Necessary to conceive of a lightweight, transparent, and certainly not solid. (4) Hence the idea of independent living, to avoid the stacking effect”. (4)

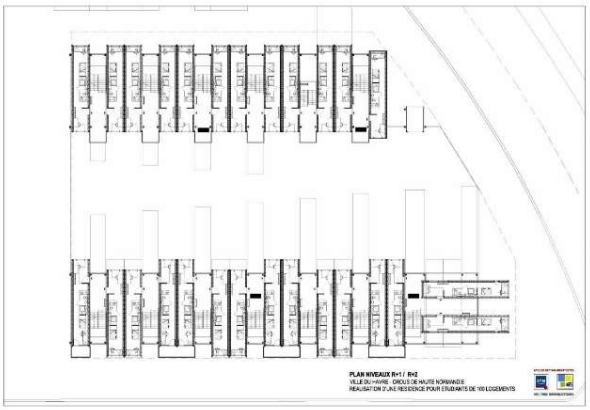
This residential complex was made by mounting 100 containers on a metal structure, where each staircase serves two stacked sets of apartments, with a total of four floors in height (ground floor + 3), this gave rise to a total of 100 apartments of 24 square meters each.

Site plan

Ground floor plan

To avoid stacking of containers, a metal frame that acts as structural support to the old container was introduced, which allowed staggering of the units, and created new space for walkways, patios, and balconies.

The first level was raised from the ground. In this way, the units here can enjoy the same privacy afforded to units on the upper floors.



Upper Floors Plan

To ensure maximum heat and sound insulation, the walls of the container adjacent to the outside and those that divide the different units have been coated with firewalls in reinforced concrete 40cm wide, and come within layers of rubber to dampen vibrations.

The external facade is designed by the combination of the old “boxes” that have been kept undulating, repainted in metallic grey.

Inside, the designers chose white walls and wooden furniture. Each studio has a bathroom, and kitchen.

2. DORTHEAVEJ RESIDENCE

Architect – Bjarke ingles group.

Date – 2018.

Location – Copenhagen, Denmark.

Cost - 9,800,000 $

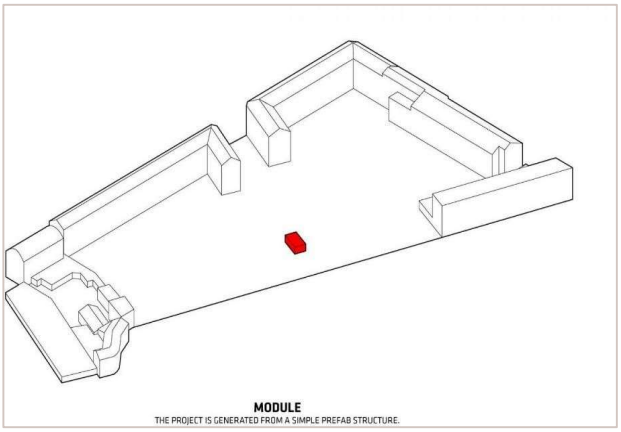
Typology – Block courtyard

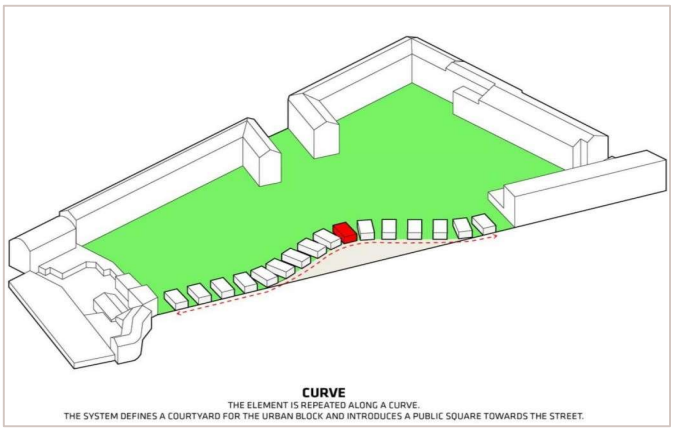
Number of units – 66 units, 5 levels, 73,194 sq. ft, 11.5 ft. ceilings

Private outdoor space – 42 % / unit

Density – 16.5 Units / acre

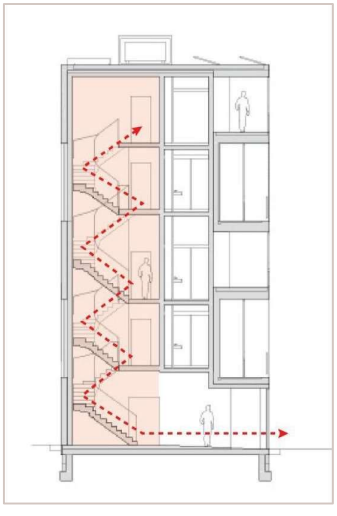
The concept was “Homes for all”. The Dortheavej provides affordable housing and public place in an urban environment while simultaneously keeping pedestrian passageways open and the adjacent courtyard untouched.





Site and context – The Dortheavej are located in the lowest income neighbourhood of Copenhagen, the 5-story building wind through the area characterized by car repair shops, storage, and industrial buildings from the 1930s–50s. The modules are stacked to achieve the height of the surrounding industrial buildings; however, the modular stacking allows each apartment to have an open terrace for fresh air and healthy living. The curve of the building pulls away from the street to offer a public courtyard for residents, visitors, and surrounding community members.

Circulation - Circulation through the building is achieved through stacked return stairs serving two units on each floor. On the first floor, doors open both towards the street and to the courtyard allowing a straight path from the street to the courtyard through the unit.



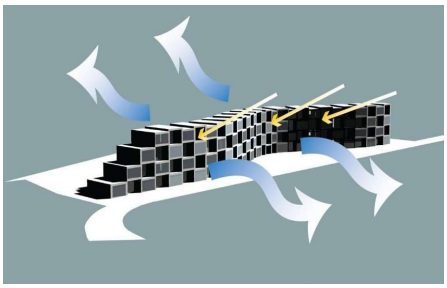
Stair cores on the courtyard of the building provide access to two units on each floor on the upper levels.

Public vs private - The curve of the building creates space for a public plaza on the street and a more private green courtyard on the opposite side. Residents pass through circulation cores are shared by two units on each floor, then through a more private terrace, finally to the bedrooms and bathrooms spaces.

Unit analysis - The modular units are used to produce multiple unit types on each floor. On the first floor, studios and 1-bed units are alternated around circulation spaces while on the second floor two types of 2-bedroom apartments fit together like a puzzle throughout the building. Transitional unit types on the end and in the center are the result of the curving plan and stair-stepped nature of the west side of the building.

Materials - The southern portion of the apartments is fronted with floor-to-ceiling glazing and alternating balconies, affording access to natural ventilation, light, and exterior views. The northern façade is designed to convey a repetition of solid and void configurations. The structure is created from modular construction with modest materials, allowing the formation of generous living spaces at both the urban and residential scales. (5)

Natural light and ventilation - Expansive floor-to-ceiling windows in each unit allow daylight into the units, further affording outward views to the courtyard and the surrounding neighborhood. The offset, stacked modular system creates space between the modules, allowing each apartment to have own terrace and access to fresh air and sunlight.



CONCLUSION:

After studying these two case studies it is observed that

1. Both structures are made in low cost and in short time frame.
2. Both structures are for residential purpose.
3. The arrangement of shipping containers has been done in such a way that every room will get ample of sunlight and ventilation.
4. By taking climate into consideration they provided insulation from inside and outside also.
5. Services are worked out very efficiently in both structures.
6. We can relate both case studies with the orphanage issue.
7. Climate of Lasalgaon is moderate though it falls up to 3 degree Celsius to 4 degree Celsius. So, these case studies will be helpful for designing modular structure in Lasalgaon.
8. Terrain of both structures is flat land there are no contours in site which is similar to the site located in Lasalgaon.

By taking help of modular architecture we can turn scrap into a good habitable space for the needy one.

SITE STUDY

INTRODUCTION -

Location – Lasalgaon, Nashik.

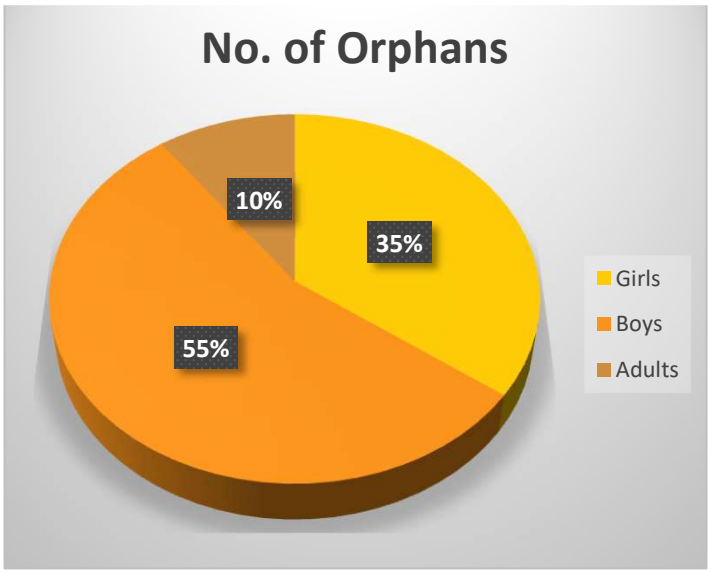
Managing authority – Shree Janardhan Maharaj Sansthan, Lasalgaon.

The site is located on the outskirts of the city. It is surrounded by farmlands. The total area of the site is around 2500 M^2 out of which only 50% area is used for construction. The site has 4 zones 1) Guest residence and office 2) Caretaker residence 3) Residential block for children's and common gathering area 4) Kitchen, storeroom, and utility area.

Site Photographs - Google Map

PEOPLE

This orphanage consists of one caretaker family, around 90 orphan children's and 4-5 adults. From a 6-month-old child to 26-year-old girls and boys are there.



Demographic data of orphan children in India –

- India – In India there are around 20 million orphan children. (6)
- Maharashtra – Around 10,000 to 15,000 orphan children are in Maharashtra. (7)
- Number of orphan homes in Nashik district –
  - ❖ Trimbakeshwar – 01
  - ❖ Nashik – 15
  - ❖ Lasalgaon – 01
  - ❖ Malegaon - 02

From the above number of orphan children and the number of orphanages in whole Nashik district, it is found that orphanage at Lasalgaon is the only orphan house in whole Niphad taluka. This orphanage is parenting more than 90 children from all over the Niphad taluka. It is at the centre of Nashik and Malegaon.

STRUCTURE

Load bearing construction method is used here. The structure only has a ground floor. The guest room and caretaker block are load-bearing. These rooms are covered with asbestos roofing sheets. Common gathering space and children's blocks are covered by metal sheets from all sides. There is no insulation treatment given to these metal sheets. In summer, the inner room temperature of children's blocks increases. Talking about the safety measures so no such things are taken into consideration for children's block. The structure is not that strong to absorb heavy wind loads and shocks from the ground.

ISSUES OBSERVED

While discussing with the caretaker and children (above 10 years) present there, some major issues were noted down.

Discussion with a caretaker -

1. There are no measures taken for the safety and security of children. The orphanage is located in open land. There is no fencing provided around the building so anyone can directly able to access in children's room.
2. Also, there are only two blocks provided for children's out of which one is for girls and another one is for boys. The main issue that comes here is privacy. 55 boys live in one common hall which leads to bullying or other such things.

Discussion with Children -

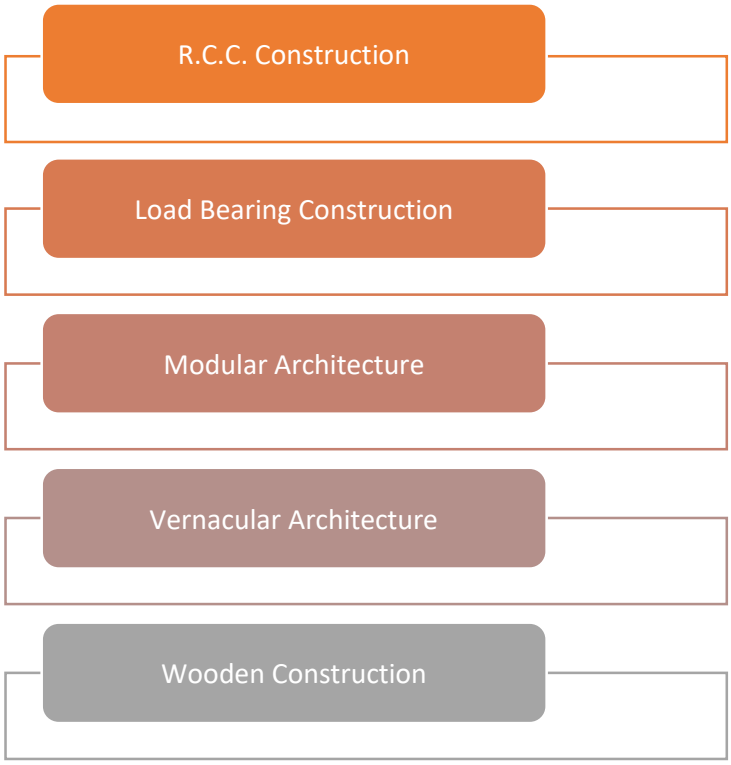
1. No storage space is provided for children to keep their clothes and other things. Because of this, the room becomes messy.
2. As the rooms are covered by metal sheets and have fewer openings, they seem very dull and dark in day time also. You can't feel fresh there. This thing directly impacts the children's minds which makes them lazy and less productive.
3. There is a storage room where all things are stored like ration required, clothes and other things of children's and utensils required to make food. Everything is kept in one room.

FUTURE PERSPECTIVE

After analysing the issues which were noted during the site study. It is observed that the present orphanage structure is not good for children. Because of, low strength of the structure and low quality of material used for construction. To make that structure safer and more comfortable for children there, new construction techniques were studied keeping the future needs of children in mind.

1. TYPES OF CONSTRUCTION

To design a good space having good strength as well as comfort, the most important thing is a selection of good construction methods by keeping the financial aspect in front. Nowadays, a lot of construction methods are available. Some of them are –



Comparison of R.C.C construction and Modular construction –

SR. NO	Comparison points	R.C.C. Construction	Modular Construction	Wooden Construction	Load Bearing Construction
1.	Foundation	Required	Required	Required	Required
2.	Labour cost for whole construction	Maximum	Minimum	Maximum	Maximum
3.	Speed of construction	Slow	Fast	Medium	Slow
4.	Weathering treatment	Not required	Required	Required	Not required
5.	Mobility	No	Yes	Yes	No
6.	Durability of structure	Good	Good	Good	Good
7.	Space for raw material storage	Required	Not required	Required	Required
8.	Strength of structure	Maximum	Maximum	Maximum	Minimum
9.	Earth quake resistance	Yes	Yes	No	No
10.	Quality control during construction	No	Yes	No	No
11.	Reuse of waste material in construction	No	Yes	No	No
12.	Economical	No	Yes	No	No
13.	Reusability	No	Yes	No	No
14.	Design flexibility	No	Yes	No	No

After studying all these methods, it is found that modular construction will be a more suitable method for new orphanage buildings, because of its characteristics. R.C.C Construction and load-bearing construction require more time than modular construction, they also need big foundation work, a greater number of laborers, and storage space for raw materials as compared to modular construction. Vernacular and wooden construction also have limitations.

2. MODULAR ARCHITECTURE

Modular architecture deals with designing a module according to the need and repeating that module number of times to build a structure. Modular architecture is in trend nowadays. It has many advantages over other construction methods.

TYPES

a) Pre-cast construction – In pre-cast construction, the whole module or the parts of the module are manufactured in the factory and transported to the site. After transporting them on site they assemble there and get placed in the specified position.

Container housing comes under the pre-cast construction as the whole module gets modified in the factory and then transported to the site.

a) Cast-in-situ Construction – In cast-in-situ type, the whole manufacturing plant gets set on site. And all modules get manufactured their only.

This method saves transportation costs.

ADVANTAGES

a) Fast in construction.

b) Reduced cost (through supply chain management, economies of scale, reduction of waste, and working in a controlled environment)

c) Extendibility.

d) As all parts of the module are made in factories so there is no chance of impurity in construction that increases the strength and durability of the structure.

e) It is flexible in design. You can easily shift it to the other places where u need fast construction or have an emergency. Also, if u want to fix it permanently u can fix it.

f) Many times, the material used in modular construction is taken from used objects like shipping containers. In this case, we are saving the container from going into the crushing yard and also helping the earth by reducing the carbon footprint required in manufacturing new material.

g) The potential to de-construct for re-location, re-use, or re-sale.

h) Reduced labor costs.

i) Reduced disruption, noise, and waste.

j) Reduced need for on-site storage plant and other equipment.

DISADVANTAGES

a) It needs heavy cranes to place different modules.

b) Transportation cost is high.

c) Limitation in size and shape of the module.

d) Poor aesthetic quality.

3) SELECTION OF MATERIAL

Used shipping containers will be the best solution for this issue. They are available at a low price. As old/second-hand shipping containers will be going to use here, the energy required in manufacturing new construction material for this building will be saved. Also, the carbon footprint generated during the manufacturing of new construction material will be reduced by using old shipping containers. All these things will be going to help mother earth in her healing process.

The price of one fully developed unit having size 14-15 M^2 is around 1 – 1.2 lakhs. If the same is done in R.C.C construction then it will cost around 1.9 to 2 Lakhs for only constructing the same area (All Market rates are taken from India mart. The Rates are not the latest). And the carbon footprint, construction time, labor costs are other points to consider in R.C.C construction.

Different sizes of shipping containers available in market are (the dimensions are in the format of length x width x height and all sizes are in meter) – 3 x 2.44 x 2.59, 6 x 2.44 x 2.59, 12 x 2.44 x 2.59, 6 x 2.44 x 2.89, 12 x 2.44 x 2.89, 12.57 x 2.5 x 3.

FINDINGS/ ANALYSIS & INFERENCE

Case studies studied here are from two different locations. The first one is from Le Havre, France, and the second one is from Copenhagen, Denmark. Designed by two different architectural firms. But the thing which is similar in them is the construction method. The construction method used in the first case study is container housing which is one of the types of modular construction. In the second case study, they designed concrete modules which have sizes similar to the shipping containers. Both structures have multiple floors and are designed for residential purposes. In both structures, insulation is done from inside and outside by using materials like concrete, wood, and layers of rubber to dampen the vibrations. Sufficient openings are provided for light and ventilation. Interior layouts are designed in such a way that u can't even feel you are living in a small metal box. They used modular construction because of some of the reasons like they had less time for construction, availability of used shipping containers near the site, and low budget. With the help of modular construction, a metal box going in the crushing yard can be converted into a good habitable space for the needy ones.

CONCLUSION

Modular designs can be the better solution to deal with the problems like poverty, long time taking construction, the site having no scope for storage of raw material, and carbon footprint of the structure. These all will be possible because of the good characteristics of modular architecture. In this modern world, we expect everything should be fast. To live with this, we need to update our old construction methods to a modular architecture. As it is fast in construction. There are many examples available of constructing a whole high-rise building in 2-3 days by taking the help of modular architecture. Also, nowadays because of random development in cities like Mumbai. It doesn't get possible to store raw material needed for construction on site. By considering all these points, it seems that modular construction will be the future of "Making India".

REFERENCES:

1. "World Development Indicators". World Bank. Accessed Dec. 23, 2020.
2. "Orphans of India". Times of India. Oct. 2, 2019.
3. "Business Standard". Oct.30, 2018.
4. "Cite A Docks Student Housing by Cattani Architects". https://www.contemporist.com. Sep. 30, 2010.
5. "Homes for All - Dortheavej Residence / Bjarke Ingels Group". Arch Daily. Oct. 08, 2018.
6. "About 20m kids in India orphan". https://www.hindustantimes.com/delhi/about-20m-kids-in-india-orphans-study/story-CM5xsW91McYBjQ3WLhh6MO.html. Jul. 27, 2011.
7. "The reports of the committee for analysing data of mapping and review exercise of child care institutions under the juvenile justice". https://wcd.nic.in/sites/default/files/CIF%20Report%201_0_0.pdf. Sep. 06, 2018.
8. "Modular Buildings". https://www.designingbuildings.co.uk. Sep. 29, 2021.
9. "Shipping Container Dimensions". https://www.scf.com.au. Oct. 6, 2020.

A COMPARATIVE THERMAL ANALYSIS OF COOL ROOFS IN HOT-HUMID CLIMATE

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ABSTRACT

The absorption of solar radiation by roof contributes to the heat island effect while making the indoor thermally uncomfortable. Most of the studies on building thermal performance focus on the walling material and insulation and the cool roof technology as part of the solution is not well established in Indian Context. The main aim of this study is to assess cool roofs and its thermal performance in buildings in hot-humid climate. Numerical comparative analysis is carried out to evaluate the thermal performance of four types of roofs namely tiled cool roof (Roof A), White elastomeric-coated roof (Roof B), green roof (Roof C) and a bare roof (Roof D).. The thermal analysis is conducted for the 21st of summer months on an average hourly basis. Findings revealed that the different cool roof materials has an effect on the heat transfer on the building envelope and the results obtained indicates that the performance of this passive technique for cooling the indoor environment of a building is largely dependent on the climate and construction morphology. Cool roofs have greater energy savings than conventional, heavily insulated roofs. The comparative analysis indicates that the percentage heat gain for Roof C is 18.5% on the building envelope, which remains constant throughout the summer months and is considered the most effective solution to reduce the cooling load of the building in hot-humid climate.

KEYWORDS : Cool Roofs; Environmental impact; Green Building; Green roofs; Thermal performance.

INTRODUCTION

In a hot tropical climate like India, there exists a yearlong cooling requirement in many parts of the country. Enhanced thermal performance with better indoor air quality and low energy consumption becomes a great challenge. Urban Heat Island (UHI) affects the inhabitants by increasing the energy consumption in buildings. Conventional building envelopes are insufficient to mitigate heat gain in the summer. Building roofs have an essential role of transferring heat into buildings. Since roofs are exposed to direct solar radiation during the day, exposing maximum surface area, roofs act as paths of heat gain into the interior spaces.

One of the most extensively adopted ways for reducing building heating and cooling loads is by increasing the thermal insulation of the external components, particularly the roofs. However, while high thermal insulation can help reduce energy consumption in the winter, it can also cause overheating in the summer, which can have negative impact on the indoor thermal comfort. It is understood that excessive envelope insulation reduces the effectiveness of passive techniques commonly used in the summer. One of the best passive strategy to mitigate UHI by offsetting CO2 emissions, improving indoor air temperature and human comfort is through cool roofs, which considerably reduces electricity demand for space cooling in conditioned buildings (Levinson, 2005). This study aims to assess four types of cool roofs, namely tiled cool roof (Roof A), white elastomeric-coated roof (Roof B), green roof (Roof C) and a bare roof (Roof D) through a numerical comparative analysis to determine the building thermal performance. With very less studies related to cool roofs in India, the work is an attempt to fill-in the gap.

Many studies have investigated the significant impact of cool roofs on indoor thermal comfort. Gagliano (2015) Investigated and conducted a multi-criteria comparison of ten cool roof scenarios globally with and without the thermal Insulation. This study revealed that the thermal behavior of insulated roofs has better energy performance. However, increasing the insulation did not provide significant effect in terms of energy savings but had a negative impact on the UHI effect and thermal stress.

An analysis of environmental impacts and estimated energy savings of various coated cool roofs in an office building was performed by Anand (2014). The impact of ambient temperature on the heat transfer rate of the building envelope was demonstrated through a numerical comparative analysis. The study also indicated that cool roof application on building resulted in increased comfort level by not depending solely on the air-conditioning systems.

Algarni (2019) investigated the effects of cool roof on residential buildings in hot-dry climate of Saudi Arabia. This study also estimated the cooling and heating requirement for the selected 13 locations. There was a reduction of annual energy consumption by 110.3 and 181.9 kWh/m^2 by using passive cool roof technology.

The effect of cool roofs on the thermal performance and energy efficiency of a school building in Athens, Greece was studied by Stavrakakis (2016). “Ceiling fans with no cooling systems” (existing condition) and “air-conditioning split units with no ventilation systems” were the two summer-conditioning scenarios investigated. This study demonstrated that the building block under the cool roof reduces the energy demand for ventilation by at least 25%, with a 3% increase in comfort during working hours.

In Egypt's hot, dry climate, Dabaieh (2015) estimated the energy-cooling load required to meet human comfort requirements. When compared to the base scenario of a normal non-insulated flat roof in a typical Cairo residential residence, using a vault roof with high albedo coating reduces discomfort hours by 53% and saves 826 kWh during the summer.

Guidelines for better functioning of cool roofs in combination with thermal insulation is given by Piselli (2019) taking the climate context as well as other critical building boundary conditions into account. This study also recommends the optimum envelope configuration with varying climatic conditions. It stated that when designing the roof assembly, thermal insulation have to be selected on the basis of thermo-physical characteristics of the roof coating. Furthermore, the building energy efficiency was more vulnerable to roof solar reflectance variance.

A hot and humid city like Chennai has discomfort period throughout the year extensively during summer months called as overheated period. Building roofs are the largest component of the structure that receives maximum solar radiation during the day exposing maximum surface area. Roofs act as paths of heat gain into the interior spaces. Bare roofs, which are typically composed of concrete, have a tendency to absorb more heat, which raise the indoor temperature of the building, resulting in increased demand of air conditioning systems. However, heat gain through the roof into the building can be minimized with the use of cool roof technology. This reduction in heat gain will also help in lowering the indoor temperature to maintain thermal comfort.

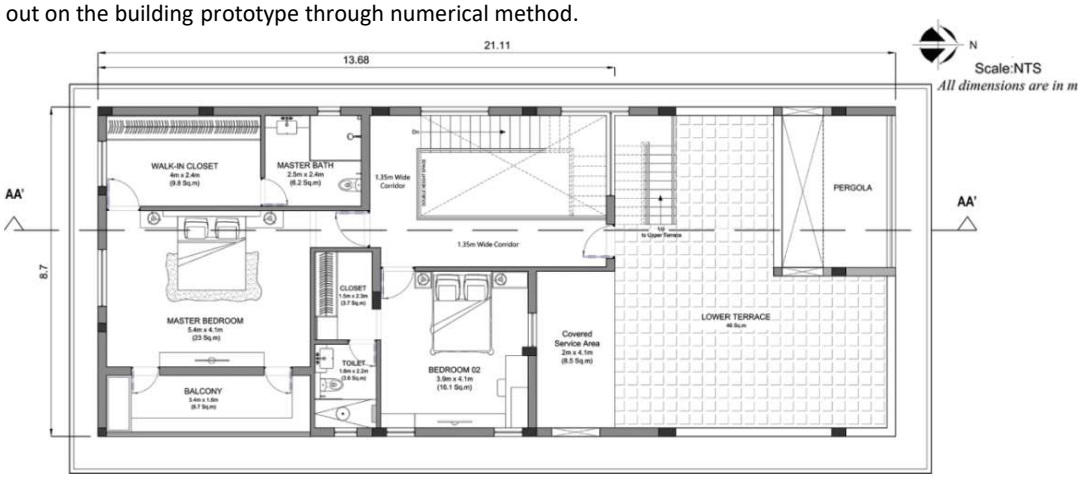
Based on the previous studies it is inferred that thermal performance and energy savings are highly dependent on a variety of factors, including the environment, roof type, solar reflectivity usually ($r > 0.6$) for cool roofs, thermal emissivity($0.8< \varepsilon < 0.9$) and the type of building. The present study deals with three different cool roof materials which are more commonly available in Indian markets. Thermal analysis for the same will be carried out to understand better energy performance in buildings. The relationship between ambient temperature and heat transfer through the roofing system will also be studied in the analysis to maintain thermal comfort in the buildings.

MATERIALS AND METHODS

Study Area

The study building is a two-story residential building with a cool tile roof located in the hot and humid climate of Chennai, India (Latitude: 13°05'33.5"N Longitude: 80°11'15.0"E). The urban fabric comprises of low-rise residential buildings with minimum contribution to the shading. Summer temperature can reach up to 38.5°C in the city due to heat island effect with the mean temperature of 28.5°C. The annual average relative humidity is 69.8% and average wind speed in Chennai is 8 m/s predominantly from SW and NE directions. Maximum solar radiation in Chennai is received in April and minimum in December. The direct normal radiation is higher in April, May and June with the mean value of 275 W/m^2 per hr. Since Chennai has hot and humid climate most of the year, it has overheated period due to higher solar heat gain and low relative humidity.

A two-story residential building model is selected because roof properties have a major impact on the floor below it. The exposed horizontal surface of the 2nd floor (i.e. Upper Terrace level) of area 106.5 m^2 is covered with ceramic based cool tiles. Figure 1 shows the floor plan and section of the building along with the detail of the cool roof. Table 1 shows the thermo-physical properties of the building envelope such as external and internal walls are of 0.23m and 0.115m thick brick masonry cement plastered on both sides and finish with paint. Story height is 3.3m and the window wall ratio is 9.44% for the selected floor of the building. Furthermore, the building has air-conditioning system that operates during heated period (March 1st– June 31st) at a set-point temperature of 20 °C and 30°C during cooling period (December 1st – January 31st). The air exchange rate for the selected floor is minimum 3.4 ACH, which meets the recommended level as per NBC for the habitable spaces in residence. The ventilation heat flow rate for the selected floor sums to 613.5W is calculated using **Qv =qv x ΔT**. Assessment of various cool roofing materials will be carried out on the building prototype through numerical method.



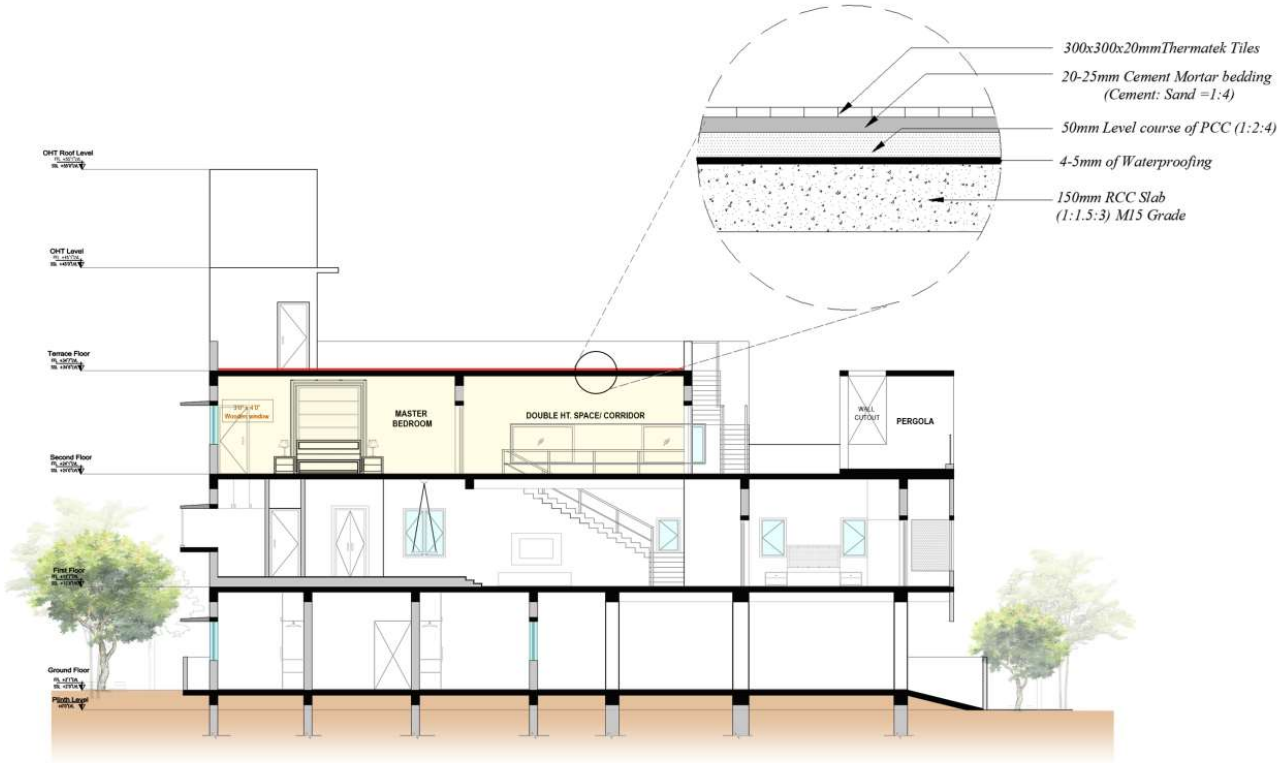


Figure 1 Floor plan and Section and detail of cool roof in case building

S.no	Envelope Components	Quantity (nos.)	Material	Physical and thermal properties		
				Thickness (m)	Surface Area (m2)	Conductivity (W/m-K)
1	External Walls	6	Brick	0.23	127.8	0.72
			Plaster	0.115	127.8	0.73
2	Internal Walls	9	Brick	0.23	85.95	0.72
			Plaster	0.115	85.95	0.73
3	Window	7	Glass	0.006	12	0.96
4	Door	8	Teak Wood	0.035	14	0.15
5	Roof	1	Flat- Tiled cool roof	0.318	106.5	1.32

Table 1 Thermo-Physical properties of building envelope

METHODOLOGY

A Comparative thermal analysis is performed through numerical method to analyze the impact of different cool roofing materials that are typically available in the Indian markets. The calculations are based on the total amount of heat gain through bare roof as well as through cool roofs. Solar reflectance (ρ) and thermal emittance (ε) are fundamental parameters in evaluating any surface material, particularly important for cool surfaces that determine their performance and degradation with aging Table 2. Both the properties are measured from 0 to 1 means higher the value, cooler the roof. This study focuses on the application of three different cool roofing materials such as ceramic based cool tiles (present in the existing case), white elastomeric coating and green roofs. The study is conducted on an average hourly basis for the selected building during the summer months of April, May, and June.

Roof Type	Solar Reflectance (ρ)	Emissivity (ε)	SRI (%)
Roof A	0.73	0.93	90.7
Roof B	0.75	0.79	90.6
Roof C	0.2	0.95	100
Roof D	0.1	0.96	21

Table 2 Radiation properties of investigated roofs

NUMERICAL METHOD TO CALCULATE HEAT TRANSFER IN BUILDING

The heat transfer in any building is calculated numerically using the mathematical relationship of heat transfer, which is given as

$$Q = U \times A \times \Delta T,$$

Where "Q" is the heat transfer in Watts, "U" is the overall heat transfer coefficient and "A" is the total roof area (106.5m^2), and "$\Delta T = To - Ti$" is the temperature difference between outside and inside air temperature. Since the study is not carried out through experiment, Ti values cannot be determined. Alternative method to calculate heat gain through opaque elements is given by the formula

$$Q = U \times A \times (G \times \alpha - E) \times Rso,$$

Where "G" is global horizontal radiation, "α" is absorbance value, "E" is radiation emission and "R_{so}" is outside surface resistance. In order to determine the thermal comfort conditions for each case, comfortable temperature "T_c" intervals were adopted. According to *ASHRAE 55-2004 for naturally ventilated buildings is* given as

$$T_c = 17.9 + 0.31 * T_o$$

The four roof conditions considered are

i. ***Roof A*** - **tiled cool roof**

ii. ***Roof B*** - **white elastomeric coated cool roof**

iii. ***Roof C*** - **green roof**

iv. ***Roof D***- **bare roof**.

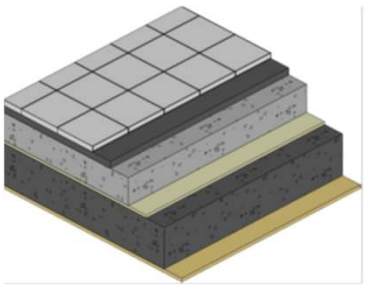
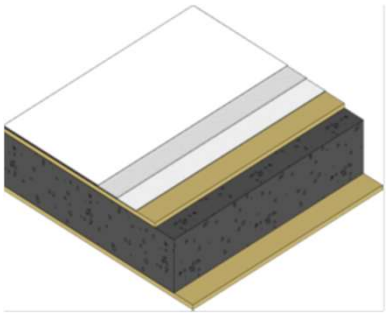
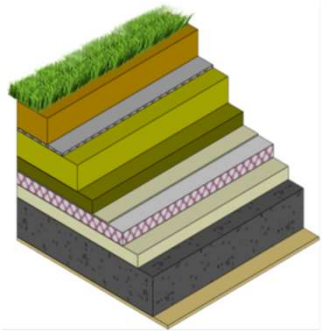
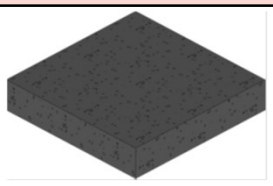
Tiled Cool Roof (Roof A)				
Envelope Configuration	**Thickness (mm)**	**Thermal Resistance (m²K/W)**	**U- Value (W/m²K)**	
Plaster (Light weight)	12.7	0.07	1.32	
RCC slab	150	0.11		
Permeable Felt/ Water Proofing	4 to 5	0.01		
PCC (1:2:4)	50	0.19		
Cement Mortar bedding	25	0.06		
Ceramic based Thermatek tiles (Heat Resistant Tile)	20	0.11		
Total	318.7	0.75		
Total R value includes Outside + Inside Air film **Materials which are not readily available in Opaque 3.0 are created using thermal properties taken from IES, Introduction to Architecture Science, ECBC & Thermatek brochure**				

Table 3 Construction details of various roof assemblies

Tiled Cool Roof (Roof B)				
Envelope Configuration	**Thickness (mm)**	**Thermal Resistance (m²K/W)**	**U- Value (W/m²K)**	
Plaster (Light weight)	12.7	0.07	**2.13**	
RCC slab	150	0.11		
Plaster (Light weight)	12.7	0.07		
Base Coat of White paint	1	0		
First Reflective Coat over the base coat	1	0.01		
Final Reflective Coat :Thin ploymer-silicon based water repellent transparent film	1	0.01		
Total	182.4	0.75		
Total R value includes Outside + Inside Air film **Materials which are not readily available in Opaque 3.0 are created using thermal properties taken from manufacture's manual**				

Tiled Cool Roof (Roof C)				
Envelope Configuration	**Thickness (mm)**	**Thermal Resistance (m²K/W)**	**U- Value (W/m²K)**	
Plaster (Light weight)	12.7	0.07	**0.61**	
RCC slab	150	0.11		
Moisture barrier	50	0.22		
Thermal Insulation	50	0.5		
Waterproofing / Permeable felt	5	0.01		
Root Barrier	50	0.26		
Drainage Layer	100	0.11		
Filter Layer	10	0.05		
Soil Layer Vegetation	100	0.1		
Total	527.7	1.63		
Total R value includes Outside + Inside Air film **Material thermal properties are taken Gagliano (2015)**				

Tiled Cool Roof (Roof D)				
Envelope Configuration	**Thickness (mm)**	**Thermal Resistance (m²K/W)**	**U- Value (W/m²K)**	
RCC slab	150	0.11	**2.13**	
Total	150	0.31		
Total R value includes Outside + Inside Air film				

RESULTS AND DISCUSSION

THERMAL BEHAVIOR OF THE SELECTED ROOF ASSEMBLIES

Figure 2 shows the heat transfer as well as variation in T_c and T_{amb} for the selected building with time during the month of April. From the figure, we can observe that heat transfer through the roofs display an increasing trend until 12:00 hours thereafter showing a decreasing trend. During the month of April, the heat transfer through Roof D i.e., bare roof shows the maximum at 12:00 hours when the ambient temperature is 34.6°C, which in turn raises the indoor temperature of habitable spaces. Also, the heat gain percentage of different cool roof materials on 21st of April at 12:00 hours when the ambient temperature is maximum is 38.46% for Roof A, 52.56% for Roof B and 17.94% for Roof C as compared to 100% for Roof D.

From the above analysis for the month of April, we can infer that Roof C is found to be more effective in terms of energy savings and thus maintaining the indoor comfort temperature.

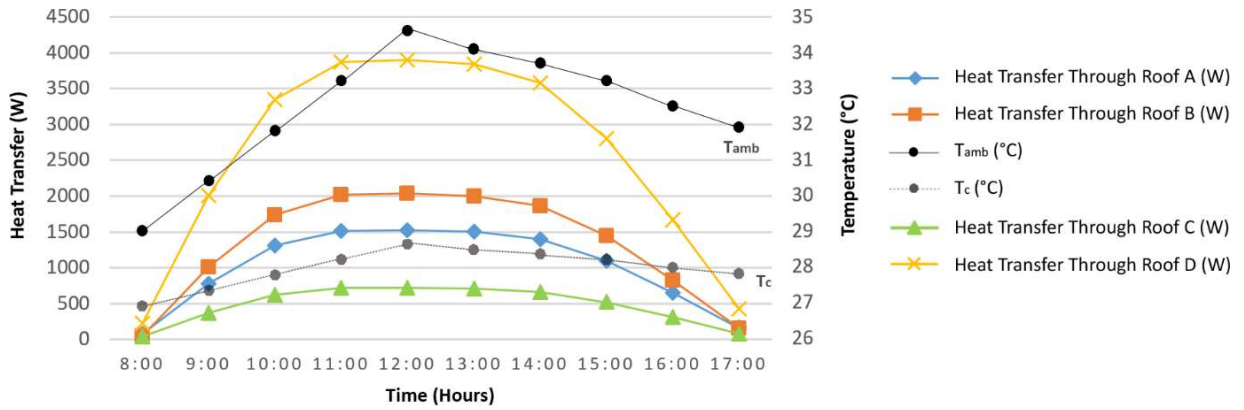


Figure 2 Heat transfer rates of roof assemblies during April

Figure 3 shows the heat transfer with T_c and T_{amb} for the month of May. From the figure, we can observe that heat transfer through cool roofs Roof A, B, C and heat transfer through the Roof D, all display a steadily increasing trend until 12:00 hours thereafter showing a decreasing trend. This is because the direct normal radiation is high when the sun is at higher altitude. Specifically, the thermal behavior of roofing system has a significant impact on peak load and energy cooling demand in conditioned buildings also the indoor thermal comfort in non-conditioned buildings.

During the month of May, the heat transfer through Roof D i.e bare roof shows the maximum at 12:00 hours when the ambient temperature is 37.2°C, which in turn raises the indoor temperature of habitable spaces. The heat gain % of different cool roof materials on 21st of May at 12:00 hours when the ambient temperature is maximum is about 39.4% for Roof A, 52.6% or Roof B and 17.1% for Roof C. This indicates that green roofs (Roof C) with moderately insulated is most effective method for reducing energy consumption in buildings while maintaining the indoor thermal comfort. It can also be seen that the heat gain inside during May follows the same trend as April.

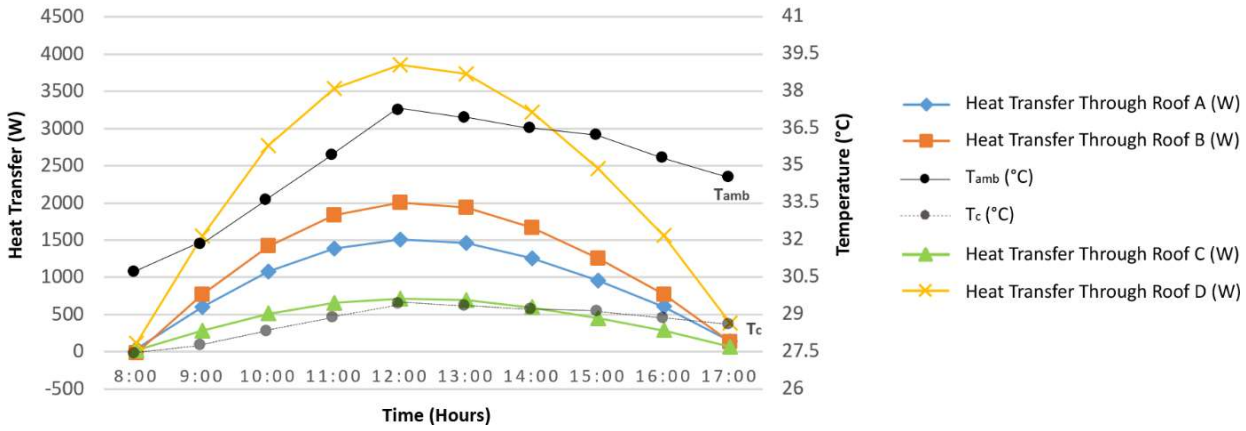


Figure 3 Heat transfer rates of roof assemblies during May

Figure 4 shows the difference in heat transfer and variation in T_c and T_{amb} with time during the month of June. Heat transfer through cool roofs Roof A, B, C and heat transfer through the Roof D, all display an increasing trend between 13:00 and 14:00 hours thereafter showing a decreasing trend.

During the month of June, the heat transfer through Roof D shows the maximum at 13:00 and 14:00 hours when the ambient temperature is 36.7°C and 37.3°C respectively. Although the ambient temperature is maximum at 15:00 hours, the heat transfer is less by the roof assemblies because of less global horizontal radiation. The change in ambient temperature also raises the indoor temperature of habitable spaces making them thermally uncomfortable.

The negative heat transfer of Roof B is due the outside temperature at 8:00 hours during the month of June is lower than the room temperature, which should be kept at 27.5°C. The heat gain % of different cool roof materials on 21st of June at 13:00 and 14:00 hours when the ambient temperature is maximum is about 40% for Roof A, 50% or Roof B and 16.6% for Roof C. The impact of ambient temperature on the Roofs A, B, C is less as compared to the Roof D because cool roof coatings help to reduce the heat transfer rate, thus maintaining the temperature of the roof assembly as well as indoor thermal comfort.

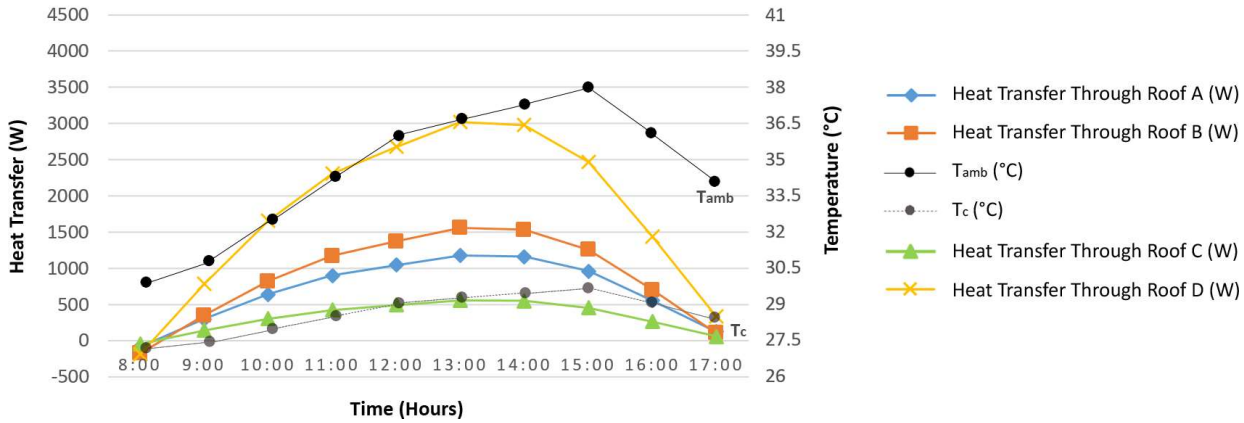


Figure 4 Heat transfer rates of roof assemblies during June

The outcomes from the above comparative analysis demonstrates how the thermal energy performance of cool roofs, are able to minimize the energy demand of residential buildings and alleviate the roof's surface temperature, which has an impact on the UHI effect. The variation in ambient temperature and solar reflectance greatly influence the heat transfer in the buildings (Y. Anand, 2014). Several reviews in the literature support the findings. From the findings, it is found that Roof A seems to be moderately effective with a maximum percentage heat gain of 50% in the month of June. Roof B seems to be less effective with a maximum percentage heat gain of 52.6% at 12:00 hours in the month of May. This is because thermal emissivity of Roof B is 0.79, which is less compared to Roof A and Roof C. The percentage heat gain for Roof C (Green Roof) is 17.9% which remains almost constant in all the months. Therefore, green roof absorbs a large amount of solar radiation to fulfil the biological functions of the plants, so less heat flux is transmitted to the indoor environment. The green roofs also act as an insulation preventing the indoors from heating up.

CONCLUSION

Findings revealed that the cool roofs have positive impact on a building's energy and thermal performance. This study attempts to create to assess the potentials of cool roofs in reducing indoor air temperature and lowering building energy consumption and CO2 emissions. In this view, roof configuration characterized by two parameters that affects the thermal performance of the building envelope were taken into account, i.e. solar reflectance ($r > 0.6$) for cool roofs, and thermal emittance ($0.8 < \varepsilon < 0.9$). Roof D in particular had a higher heat gain than the cool roofs A, B, C. because of the high solar reflectance of the materials. Cool roofs provide a passive cooling effect that reduces the cooling demand in the buildings. However, due to weathering and soiling, the solar reflectance of a cool roof can decrease with time. Hence, the effectiveness of green roofs depends on many other variables. The following are the outcomes from the study.

a) Roof A i.e. tiled cool roof seems to be moderately effective with a maximum heat gain of 41.2% in the month of June. In addition, when combined with cool mortar will greatly improve the energy performance in the building.

b) Roof B i.e. white elastomeric coated roof seems to be less effective with a maximum heat gain of 50% with an ambient temperature of 37.2°C at 12:00 hours in the month of May.

c) Roof C i.e. green roofs has confirmed the best performance in the summer months with the consistent result owing to the influence of vegetation shade and evapotranspiration, as well as the reduction in heat transmission

offered by insulation of the soil. Furthermore, the thickness of the thermal insulation has no effect on thermal performance of the Roof C in summer. The maximum heat gain for Roof C is 17.9% with an ambient temperature of 37.2°C at 12:00 hours in the month of April and May respectively.

d) Roof D i.e. bare roof has the maximum heat transfer in the buildings. Several literature studies suggests that bare roof can produce nearly the same energy needs as Roof A, B, and C during the cooling period, but only if at least twice as much insulation is used in such higher-performing solutions to achieve optimal performance.

At 8.00 in the month of June, the outside temperature is lower than the indoor temperature leading to a negative heat transfer from outside to inside i.e -80.4 W for roof A, -171.76W for roof B, -35.4W for roof C and -184.41W for Roof D (Figure 4). This means insulation or cool roofs are beneficial during the summer months of April and May throughout the day and night. In the month of June it is beneficial from 9.00 am till 5.00 p.m. During the other months, when the outdoor temperature is lesser that the month of June, the cool roofs may be beneficial for lesser hours. This is contrary to the general understanding that cool roofs and insulation are beneficial throughout the year in the hot-humid climate of Chennai. Nevertheless, cool roofs are an environmentally responsive solution for a sustainable and green building.

REFERENCES

1. Algarni, S. (2019). Potential for cooling load reduction in residential buildings using cool roofs in the harsh climate of Saudi Arabia. *Energy and Environment*.
2. Gagliano A.*, M. D. (2015). A multi-criteria methodology for comparing the energy and environmental behavior of cool, green and traditional roofs. *Building and Environment 90 (2015) 71e81*.
3. Dabaieh, M. W. (2015). Reducing cooling demands in a hot dry climate: A simulation study for non-insulated passive cool roof thermal performance in residential buildings. *Energy and Buildings*.
4. E. Bozonnet∗, M. D. (2011). Cool roofs impact on building thermal response: A French case study. *Energy and Buildings*.
5. Green, A. L. (2020). Above-roof air temperature effects on HVAC and cool roof performance: Experiments and development of a predictive model. *Energy and Buildings*.
6. Guo, R. G. (2020). Optimization of cool roof and night ventilation in office buildings:a case study in Xiamen, China. *Renewable Energy*.
7. Hernández-Pérez, I. X.-M.-C.-G.-L. (2018). Experimental thermal evaluation of building roofs with conventional and reflective coatings. *Energy and Buildings*.
8. Piselli, C. P. (2019). Cool Roof Impact on Building Energy Need: The Role of Thermal Insulation with Varying Climate Conditions. *Energies*.
9. Ronnen Levinson*, H. A. (2005). Inclusion of cool roofs in nonresidential Title 24 prescriptive. *Energy Policy 33 (2005) 151–170*.
10. Stavrakakis, G. A. (2016). Experimental and numerical assessment of cool-roof impact on thermal and energy performance of a School building, Athens, Greece. *Energy and Buildings*.
11. Y. Anand, 1. A. (2014). Comparative Thermal Analysis of Different Cool Roof Materials for Minimizing Building Energy Consumption. *Journal of Engineering*.

MODULARITY IN ARCHITECTURE AND PLANNING-

HOW MODULAR ARCHITECTURE CAN REVOLUTIONIZE INDIAN ARCHITECTURE AND BY DEFAULT THE LARGER SOCIETY

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ABSTRACT:

Modular architecture or "modularity in design" is a design approach that subdivides a system into smaller parts called modules or skids that can be independently created and then used in different systems. A modular system is characterized by functional partitioning into discrete scalable and reusable modules, rigorous use of well-defined modular interfaces, and making use of industry standards for interfaces. With the onset of the Modern Movement in architecture, industrialization, mass production and standardization principles came to the fore. Modular architecture is the result of this thinking wherein creativity has been replaced by the prospect of standardized mass production of buildings at a faster rate and lower cost. Having said that modular architecture is yet to charm its way into third world countries like India, Sri Lanka, Pakistan, Bangladesh. Yet the increasing population, space crunch and depriving economic conditions means this kind of architecture might very well be a revolutionary concept in such developing countries. In this paper we explore the origin of modular architecture, the challenges this kind of practise may face in the future, the scope of such ready-made objectsfrom the point of view of developing countries specifically focused in India. We speak about already existing examples in other developing countries and also contemplate on whether this type of computerized form of buildings can jeopardize the traditional creativity of Indian architecture and shed some light on the economic effects this new dimension of architecture can bring about In India.

KEYWORDS: Modular architecture, Prefabricated construction, monads, rural architecture,urban architecture.

INTRODUCTION / BACKGROUND

The capabilities of modular architecture will be highlighted in this study, which include quick construction and lower embodied energy due to the assembly line approach of building construction. We'll also talk about how the qualities of prefabricated building might aid in the development of infrastructure in a developing country like India. It will attempt to explain how a new type of modular architecture might be produced that is regionally specific and not monotonous.

AIM / PURPOSE

- To study the role of modular construction in developing countries like India
- Trying to determine via qualitative analysis which section of the country requires this form of construction more.

WHAT IS MODULAR ARCHITECTURE?

Since Henry Ford used the production line to assemble the Ford T model in 1913, the construction industry has been searching for the optimization of resources through the standardization of constructive methods and its components.

Architecture generated by these procedures is what we call modular architecture.

Architecture in which the number of functions is approximately similar to the number of components, where usually the interactions (as well as the interfaces) between components are relatively simple, and where each module is intended to be the main (often the only) responsible for providing a given function or sub-function of the product.

A BRIEF HISTORY

Modular architecture originated back in the 1600s when a colonial American fisherman who had just moved back from England, wanted to build a home for himself using the trusted English construction method. As a solution, he decided to ship a disassembled home by boat across the Atlantic Ocean.

Although modular construction gained prominence during the American Gold Rush in the 1800s due to the demand for a quick housing solution, it wasn't until the end of the 19th century that the demand for modular homes that the demand for modular homes really started gaining prominence.

E.F. Hodgson established a manufacturing business in Dover, Massachusetts in 1897, taking advantage of the rapidly rising American population. The E.F Hodgson Company created a catalogue that they used to sell modular homes all throughout the country. Sears, Roebuck and Montgomery Ward soon followed in their footsteps and sold hundreds of thousands of modular homes over the next few decades.

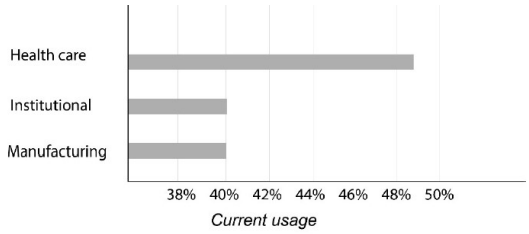
MODULAR ARCHITECTURE IN THE 21ST CENTURY

The craze for tiny spaces and the modern space crunch problem has given modular constructions a fresh lease on life in recent years. People are finding out how modular homes can be environmentally and financially beneficial on a regular basis. Modular buildings have a less environmental footprint and can be built to last and have a distinct personality. You can now buy a modular home for a fraction of the cost of one built on-site, and you may customise practically every feature of it.

New technology, such as better construction cranes, has enabled modular buildings to be created in larger, taller, and more varied configurations. Units can be delivered across the country and assembled on-site in only a few days. In fact, in a feat that may not seem possible, Chinese company Broad Group has sped up the usual one-year time frame for constructing a 10-floor building to just 29 hours. According to the company, the building, erected in the central city of Changsha, was the world's fastest construction for a building of this size.

MODULAR ARCHITECTURE IN INDIA

India's infrastructure demand is at an all-time high. The government is taking significant steps to improve infrastructure in order to meet the demands of an ever-increasing population. In a country that is already congested due to its high population, we now need to build mass housing to house 900 million additional people by 2050, which equates to 856 new houses built every hour for the next 30 years (assuming a four-person occupancy in each house), not to mention schools, colleges, hospitals, and other institutional buildings.



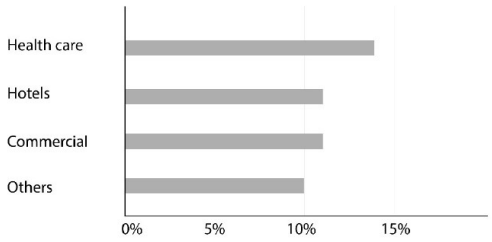


Figure 1: Future Scope

Demand in the top seven cities alone is expected to rise by 32% year on year in 2019. As the government looks to accelerate infrastructure growth in India, it has approved Real Estate Investment Trust (REIT) to help investors come forward to invest in the Indian real estate market, creating a Rs. 1.25 trillion (US $ 19.65 billion) opportunity in the Indian market over the coming years. The sheer scale of this massive project is ground-breaking, and it necessitates an equally ground-breaking solution in order to achieve the required scale of construction in order to meet the construction market's demand efficiently.

THE MOST EFFICIENT AND EFFECTIVE SOLUTION IN THIS CASE IS MODULAR CONSTRUCTION.

Modular construction, without a doubt, has the advantage of speed. When properly planned, it can cut the time required to build per unit of structure by half. Where traditional methods of construction could only produce 200 houses, modular construction could produce 300 houses. This, in turn, reduces labour costs while also lowering overheads due to idle time of workers on the job site, allowing construction to be completed in stages. In traditional construction, the ceiling cannot be built before the walls, and the walls cannot be built until the floor is completed. All of this work can be completed concurrently thanks to modular construction, which saves time, labour, and money.

Both advantages, faster delivery and lower cost, are the foundation of success in the Indian market, and both are efficiently met by the use of modular construction.

IS MODULARITY A NOVEL CONCEPT IN INDIA?

It would be wrong to say that modular architecture is a concept developed in the west. In practically every section of the country, there is unique evidence of modularity to be found in vernacular architecture. Traditional architecture in India's north-eastern states is primarily made of natural, renewable materials such as bamboo, mud, grass, straw, cane leaves, and so on. They normally construct the basic framework of the house out of bamboo frames and then add bamboo or straw weaved inlays as partitions. The stilt portions of these houses are formed by tying bamboo diagonal bracings over bamboo supports. Horizontal members are strung across the bamboo supports with jute ropes and dowel and Tenon joints to build the structure above. The space beneath the stilt is frequently used to store a canoe for use in the event of a flood. The stilt buildings are usually built to protect against strong monsoons and flash floods.

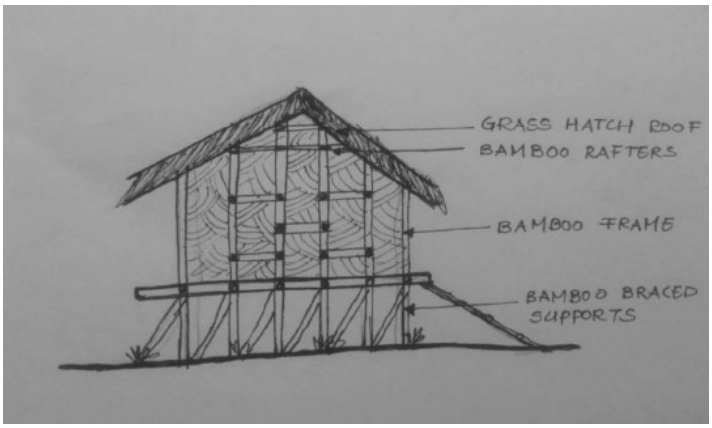


Figure 2: Illustration of typical Assamese house, using prefabricated wall panels

Figure 3: Joinery detail of bamboo members (dowel & Tenon joint)

Figure 4: Typical wall with weaved bamboo infill and mud plaster over

Because the bamboo weaved inlays are placed as prefabricated wall parts to the previous bamboo structural frame, this style of building might be considered modular, or panelized. Mud plaster is frequently used to cover these inlays, mostly for insulation and to prevent infiltration.

CASE STUDY

Modular architecture is a pretty novel concept in the realms of Indian Architecture. That being said, there have been some pretty interesting projects whose core concept has been based in modular architecture. One such example is the Vijayawada Garden Estate, designed by Penda China under the commission of Pooja Crafted Homes. The Lego-like modular skyscraper is designed with customizable prefab elements.

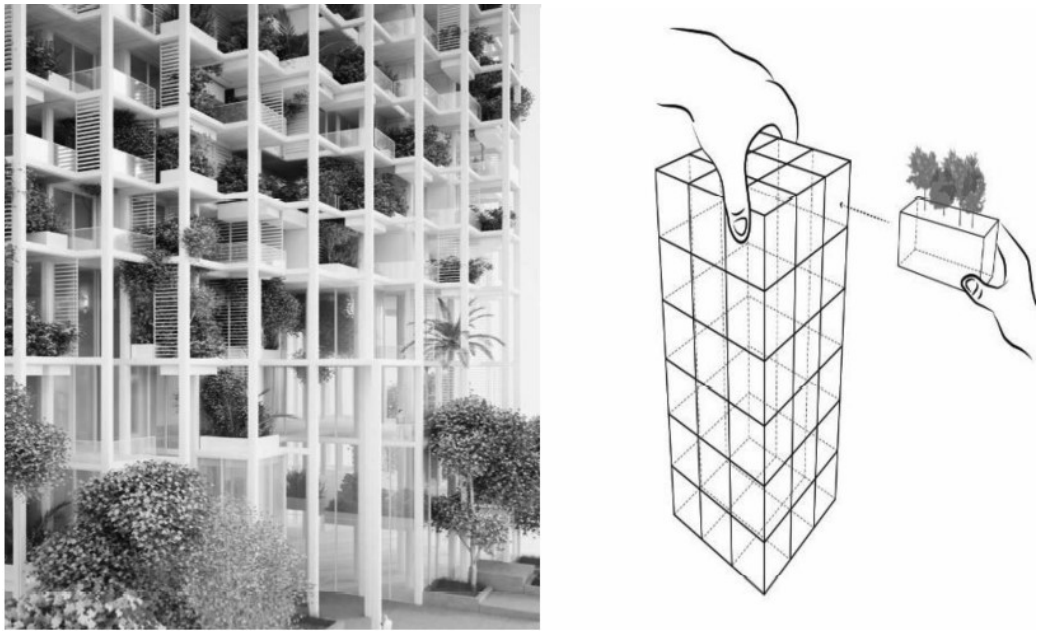


Figure 5: Vijayawada Garden Estate

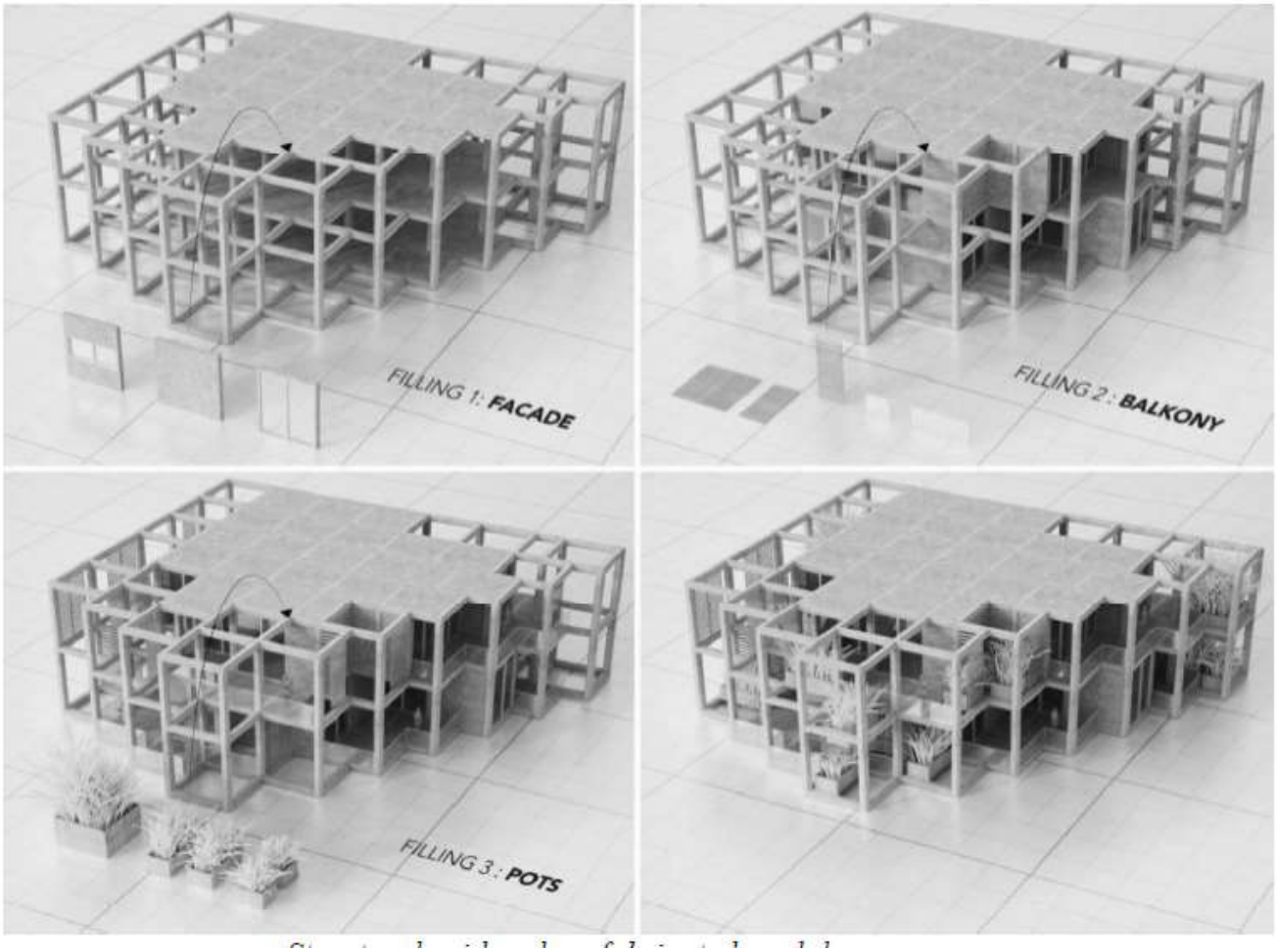


Figure 6: Structural grid and prefabricated modules

The architects devised a framework that can be filled with the desired configuration and then installed into the structure after being manufactured off-site. The structural grid and the infrastructure were chosen as the sole permanent aspects of the building by the architects. The usage of prefabricated modules allows for complete customization of all other components like different types of flooring, façade elements and internal organization as per the owner's wish. The terraces will be overgrown with plants that will be irrigated with rainwater. Natural ventilation will be facilitated by the optimal module arrangement, while the plants will aid to keep fresh air and the high-natural rise's aspect.

"In a time of mass production and a certain conformity in the construction industry, we try to use modern construction techniques to rescue a level of individuality for the residents of a tower. A type of individuality that you would have when building your own home," commented Penda architects.

Scope

Modular architecture has already gained acceptance in large parts of the world, especially the developing countries. Its economic and sustainable usage has helped it to quickly become a popular housing method. Modular building systems are progressively gaining traction in India, with a growing number of builders and construction businesses using the concept.

Prefabricated modular buildings currently account for only 1% of India's $100 billion real estate sector. Developers anticipate that its popularity will rise as a result of the prolonged decline in residential real estate, which has seen inventories reach all-time highs. The reason for this is that prefabrication allows for a considerably speedier completion of projects, lowering total expenses. According to experts, if a house project takes a year to build using traditional methods, it only takes 5 to 6 months to finish using modular construction, assuming the scale is the same.

In India, the government has set a goal of providing housing for all by 2022, which will necessitate the construction of 30 million low-cost residences as well as 98 smart cities. Both of these concepts are intended to give the modular system a boost. Furthermore, the government's move in late 2014 to relax prior criteria for 100 percent foreign direct investment in real estate has accelerated the use of modular technologies.

ADVANTAGES & DISADVANTAGES OF OFFSITE MODULAR CONSTRUCTION IN INDIA

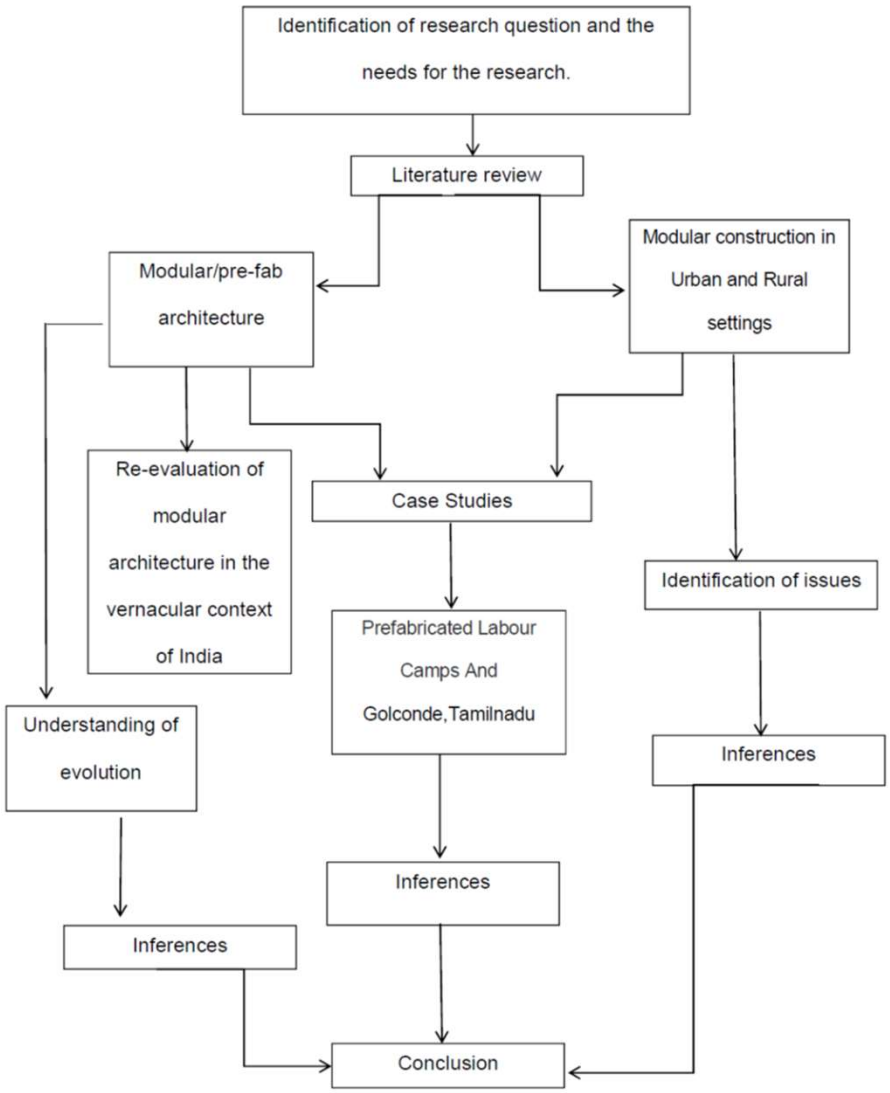
Advantages	Disadvantages
Reduced cost: Offsite building reduces the cost of construction, manpower, materials, water usage, and labour by a large amount, making it cost-effective.	**Project Planning:** It necessitates extensive planning and engineering prior to the start of the project. Additionally, because of the intricacy of module design, more thought and preparation is required when incorporating diverse components within a module, as well as when modules are lifted, transported to the final project site, set on the foundation, and linked to form the building.
Environmentally friendly: Because much of the building is finished in a controlled setting inside a factory, waste generated during construction	**High Initial Cost and Site Constraints:** Setting up appropriate machinery to run a modular manufacturing plant requires a significant amount of initial expenditure. New construction processes may be challenging in locations
can be managed considerably more effectively.	where labour is cheap. A restriction is the scarcity of competent and experienced individuals, such as designers and engineers, off-site construction consultants, suppliers, and contractors with sufficient competence with modular systems.
Strong structure: Compared to traditional construction, the components that make up a building are more factory created and more robust.	**Reduced Adaptability to Changes in Design:** Other interdependent actions are carried out simultaneously after the design has been accepted, therefore the design cannot be changed.

Shorter construction time: Construction time is reduced since offsite modular buildings are driven by technology rather than traditional construction methods.	**Transportation Issues:** Moving the modules a long distance can be difficult. Late transmission permissions for large components can result in time delays.
Consistent quality: The sub-assemblies of the structure have a consistent quality since they are manufactured in a controlled environment and to established specifications.	**Job Cuts:** A large part of the daily wage workers or migrant labourers relies on the construction industry as their earning source. Prefabricated industry made structure will result in lesser man-power requirement which can lead to severe job losses which will have a detrimental effect on the economy.
Better labour management: Compared to traditional construction methods, offsite construction technology requires less manpower. This aids in tackling the construction industry's most pressing problem: a scarcity of competent labour.	

RESEARCH METHODOLOGY

India as a country has seen its demographic being divided into the urban and rural population. India is yet to be hit the tidal wave, which is pre-fabricated architecture. The construction industry is yet to get out of the inertia of traditional architecture. However, modularity is not a new concept for India. There are distinct traces of modularity which being showcased in the vernacular architecture of almost all parts of the country. Whether modular construction has a better scope at the urban or rural level is the point of contemplation of this research.

This paper performs a quantitative and qualitative analysis of modular construction in urban and rural settings from the point of view of the Indian market.



WHY MODULAR CONSTRUCTION SHOULD BE INTRODUCED IN URBAN INDIA?

While we have talked about the general pros and cons of Modular construction, we look at its positive effect exclusively on an urban level.

- **Improved air quality:** Because the modular structure is built in a factory-controlled environment with dry materials, there is no risk of significant amounts of moisture being trapped in the new structure.

  This can solve the problem of air pollution to a large extent that metropolitan cities like Delhi grapple with on a daily basis.

  Building construction is a major source of air pollution.

- **Cater to the urban poor:** Not everyone in urban India can afford to build a house especially migrant workers who come to big cities looking for work. Hence we see an increase in people making the streets their home. The government, too under its urban housing scheme has taken measures to ensure basic housing for everyone. Modular architecture in its sustainable and economic way can be the perfect solution.

- **Skilled labour and management:** Modular construction being a technologically advanced form of building construction will require engineers, labourers etc. skilled in this form of construction. There are higher chances of finding such people in the urban area.

- **Decreasing housing cost:** Owning a house is a distant dream of many owing to the soaring real estate prices in cities and even mid-tier towns. The economic the method of modular architecture will not only be successful in providing more houses at a lower cost, it will bring down the real estate prices too.

Here we will look at an example of a modular building which exists in urban settings.

PREFABRICATED LABOR CAMP

Guiding Principles and Construction: Angath Exterior & Interior is a distinguished organization engaged for **Prefabricated Labour Camps manufacturer** in India. These Prefab Labour Camps are manufacture and installed on sites where Construction/Mining projects are run on a temporary basic. The prefab labour camps can be shift to other sites easily. The offered camps are available in Delhi, Lucknow, Bhopal, Raipur, Guwahati, Gurgaon etc. **Prefabricated Labour Camps** are designed with the help of supreme quality material and modular technology in compliance with set industrial standards. The offered camps are made available in various specifications for clients to choose, form. Clients can avail these camps at market leading prices. The offered range is precisely designed by the team of expert engineers and hard-working members of our company.

Figure 7: Prefabricated Labour Camps

Features Of Prefabricated Labour Camps:

* Strong construction

* Durability and High strength

* Non corrosive

* Minimal maintenance

* Application-specific design

* All weather proof

* Scratch resistant

Conclusion: Prefabricated housings are an economic and sustainable way to provide living space for migrant workers or the urban poor. They can be easily dismantled and shifted and is a viable choice for temporary as well as permanent housing.

WHY MODULAR CONSTRUCTION SHOULD BE INTRODUCED IN RURAL INDIA?

With a larger part of the Indian population residing below the below poverty level, occupying the rural belts of the country, modular construction can benefit the housing scene of these areas.

- The government of India is determined in its effort to build permanent pucca houses for all citizens. The Pradhan Mantri Awas Yojana Gramin (PMAG) is an initiative of the Government of ndia which aims at providing affordable housing with some of the basic amenities to the rural poor by the year 2022. The scheme was first launched on 1 June 2015. Using off-site modular construction methods can be an economic and sustainable way to provide housing under this scheme.
- Since the rural areas are often devastated by extreme climatic conditions, like floods, cyclones rendering the population homeless, using modular methods can result in a faster construction process resulting in strong structures which can last generations.
- In the villages, there is a dearth of skilled labourers, engineers, architects etc. This leads to unplanned buildings which often do not meet the design goals. Prefabricated factory made modules can improve the quality and design.

Here we will look at an **example of a modular building which exists in rural settings.**

GOLCONDE, PONDICHERRY, TAMIL NADU

Introduction: The Aurobindo Ashram in Pondicherry, Tamil Nadu, built Golconde as a residential dormitory. This is the country's first attempt at modular building. It was one of the most advanced buildings of its day, in terms of construction methods and techniques, and it was constructed in one of the country's most remote locations. Golconde is an ideal case study for examining the possibilities and risks of prefabricated buildings in a suburban/rural setting. It may provide insight into how modular design might be made viable in non-industrialized locations, particularly villages.

Figure 8: Outer façade of Golconde, Tamil Nadu

Figure 9: Interior and exterior facades showcasing modularity

Guiding Principles and Construction: With the most insecure of materials, the structure was mostly completed by inexperienced volunteers and ashram members. Almost every fitting, on the other hand, is pre-fabricated. The construction of the structure began in October of 1938. It took nearly a decade to finish. It was designed by Antonin Raymond, a French architect. Although Raymond had planned for a six-month construction schedule, this did not take into consideration Sri Aurobindo's intention to shield the peaceful ashram setting from the noise of commercial development. This is one of the main reasons why the construction of a pre-fabricated structure takes almost a decade.

The building's impeccably kept materials include a reinforced concrete basic structure, bowed concrete shell roof, and polished Cuddapah (a native slate) floor. Precast curved tiles cover the top of the modular RCC shell roof, which features a ventilated air space over the deck.

Each room is exactly the same size, measuring 4mX5.5mX3.5m h. The teak wood sliding doors that separate these rooms from the corridors are designed to enable air to move through while maintaining privacy. The precast concrete panels that divide the rooms are used as dividers. The north and south facades are also beamed with precast, operable concrete louvres that ensure consistent air circulation.

The stairwells were also cast off-site and installed while the building was being built.

Inference: Modular building is associated with a high level of industrial involvement and infrastructure investment. The Golconda, on the other hand, shows that this is not the case. It was constructed in an environment that was practically hostile to prefabricated construction, especially in 1938. This structure paves the way for prefabricated/modular architecture in rural and suburban regions.

FINDINGS/ ANALYSIS & INFERENCE

Looking at these examples and analysis, we can say that both the urban and rural areas of India require modular construction by virtue of its economic, sustainable, advanced construction techniques. By implementing modularity amidst the already existing construction methodology, all sections of the people across this country can be benefitted.

CONCLUSION

Modular architecture has its positive and negative effects. While the positive aspects have been discussed at length, the negative effects, especially its effect on the economy cannot be neglected. The government needs to take baby steps in allowing implementation of this modern building technology, regulating foreign investments, and supplementing the job losses in some way or the other. Once these issues are duly dealt with, modular, more specifically prefabricated construction has the power to usher in a new era in the Indian housing and construction space.

REFERENCES:

1. ALEXANDER, Christopher. 1959. Perception and Modular Co-ordination.Pp. 425-429 in Journal of the Royal Institute of British Architects 66.
2. Prefabrication and Modularization: Increasing Productivity in the Construction Industry, National institute of Standards and Technology, Smart Market Report.
3. S. Alonso-Zandari and Arman Hashemi,"Prefabrication In The UK Housing Construction Industry," in 5th International Conference on Zero Energy Mass Customised Housing - ZEMCH 2016, 20th - 23rd December 2016, Kuala Lumpur, Malaysia, pp. 347-360, 2016.
4. E. M. Generalovaa, V.P. Generalova and A. A. Kuzbetsovaa, Modular Buildings in Modern Construction," In Procedia Engineering, vol. 153, pp. 167 172, 2016.
5. https://www.masterbuilder.co.in/architectural-designing-modularbuildings-modular-houses-part/
6. https://aceupdate.com/2018/03/06/prefabrication-the-future-ofconstruction-in-india/
7. https://www.routledge.com/The-Future-of-Modular-Architecture/Wallance/p/book/9780367467227

MODULAR ARCHITECTURE: TECHNOLOGY OF THE FUTURE

Modularity In Architecture and Planning

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ABSTRACT:

Traditional building is gradually being displaced by modern design approaches, precision engineering, and exceptionally high-quality standards. Modular architecture, although it is nearly the polar opposite of traditional buildings, it represents a novel way to design flexibility. Even though modular architecture has been around for a long time, it appears to be a one-of-a-kind advert in the field of architecture. There has always been a tension between originality and feasibility in design as a form-giving activity, given that design is fundamentally the turning of ideas into tangible objects. Creative thought is freed from excessive dimensional restrictions if the traits of modular procedures are exploited early in the design process to encourage the shape for further adjustment. Many architects and notable builders have worked with this type of construction, and it appears that its most defining aspects are slowly gaining popularity among the general public. Modularity has been applied to a wide range of fields and is always seen as a balance of conflicting forces, such as independence and interdependence, standardization and customization, fixed module and flexible design, and so on. The research technique used in this study was a combination of historical and analytical assessment with case studies as a phenomenon in a realistic context. This research paper aims to understand the contextual patterns that make modular thinking significant. Also discussed is how modular design has become a popular trend in the construction industry.

KEYWORDS: Mass production, Integral Architecture, Tangible, Patterns

INTRODUCTION / BACKGROUND

According to current industry statistics, India's estimated urban housing shortfall is 18.8 million people and expanding. The country's construction industry has not kept up with the nation's rising city's increasing housing needs. For the vast majority of Indian people, a decent, cost-effective home remains a utopian dream. Globalization trends are inclusive, encompassing every object and action conducted around the planet. To tackle this, the Indian Urban Ministry has proposed several projects, including Housing for All by 2022, Affordable Housing, and Smart Cities, some of which would constitute the construction of over 30 million dwellings and closer to 98 smart cities, respectively. India requires revolutionary and innovative building and planning approaches to help build new houses at least three times faster than the conventional traditional manner to complete this massive task within the specified schedule. Modular architecture is the most pioneering and fastest mode for construction in the current scenario.

Modular architecture, often known as design durability, can be dismantled into smaller components. These would then be fabricated individually and used in other schemes. The functional segmentation of a modular system into isolated, scalable, and reusable modules defines it. And even the adoption of industry standards for interfaces and the strict use of well-defined modular interfaces. The number of functions in this architecture is roughly proportional to the number of components, component interactions are usually simple, and each module intends to be the primary provider of a particular function or sub-function of the product. Because there are fewer and acknowledged ties with other modules, separate groups can work independently on their development. An integral architecture organization necessitates a high level of group participation and coordination. We can classify an organization's information as integral architecture when different physical blocks serve the same function. The modular architecture is envisioned as a collection of modules, components, and subsystems that perform a specified use. Modular construction is a way of building a structure off-site, in a controlled industrial setting, using the same materials and following the same codes and standards as conventional buildings, but in half the time. Buildings are constructed up of modules that, when assembled on-site, reflect the same architectural purpose and standards as the most advanced site-built building – all without sacrificing quality. Modularity has three goals: the first has a lot to do with the construction flexibility and vertical and horizontal extensions. Second, even if it exhibits an expansion due to the growth in spatial needs, its design language maintains general consistency. Third, these components can be changed into long-term structures to satisfy future needs when they are no longer needed.

Figure 1 (Arch20, n.d.)

THE ORIGIN OF MODULAR DESIGN

Many people believe that modular construction started in the twentieth century, although it dates back further. Over the last three centuries, modular building has evolved and developed. Continue reading to find out more about the modular construction industry's history. Modular structures have been around since the 1600s. A colonial American fisherman who had recently emigrated from England and desired a home built with trusted English construction methods gave birth to one of the first known modular dwellings. The solution was to ship a deconstructed home across the Atlantic Ocean aboard a boat. As the United States pushed westward in the 1800s, modular construction became increasingly popular. Mining towns grew in popularity during the California Gold Rush, necessitating a speedy housing solution. Before being shipped to California, 500 preassembled homes were constructed in New York. However, it wasn't until the late 1800s that demand for modular homes began to increase. In 1897, E.F. Hodgson founded a manufacturing company in Dover, Massachusetts, capitalizing on the rapidly growing American population. The E.F Hodgson Company created a catalog that they used to sell modular homes throughout the country. It became even easier to manufacture modular homes at a price that many more people could afford after Henry Ford established the assembly line in 1913. After World War II, when the United States faced a housing shortage as soldiers returned home and began families, the modular building provided quick, low-cost housing options to accommodate a new generation of Americans. Modular buildings have provided innovative and cost-effective solutions. The modular building industry grew from residences to commercial projects in the years after that. Modular construction's advantages became clear: it was quick, cost-effective, and infinitely configurable. Mobile houses and leisure vehicles were used by converting classrooms and mobile offices across the country. The typical modular restaurant, readily recognizable by its long, narrow shape, first appeared on the East Coast, specifically in New Jersey. Customers wanted more modern-looking modular buildings with complicated construction and facilities in the 1960s. Modular buildings are used by schools, firms, hospitals, and other industries to expand their available space.

Modular structures gained popularity after famed architect Frank Lloyd Wright commended them for their adaptability. Advances in technology and design, and a wide range of materials, led to new uses for modular buildings across the country in the latter half of the twentieth century. The tiny house craze has given modular constructions a fresh lease on life in recent years. People are finding how modular homes can be environmentally and financially beneficial regularly. Modular buildings have a less environmental footprint and can be built to last and have a distinct personality. You can now buy a modular home for a fraction of the cost of one built on-site, and you may customize practically every feature of it. Modular buildings could now be constructed in taller and more diversified designs thanks to advancements in technology such as improved construction cranes. Units can be delivered across the country and assembled on-site in only a few days. In 2003, McDonald's restaurant created a world-record-breaking 13 hours. We should expect an increasing number of people and enterprises to embrace modular buildings for houses, offices, businesses, and other purposes in the future.

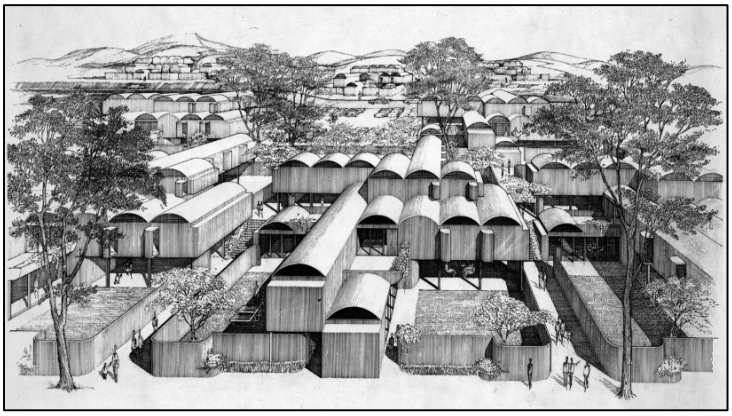

Figure 2 (Marcos Gasc, GKV Architects, n.d.) g

CHALLENGES OF MODULAR ARCHITECTURE?

The modular architecture is built on the interconnection of modules to construct a specific structure. Modular homes, unlike traditional buildings, are typically assembled outside of their final location. It further distinguishes them from both conventional and prefabricated constructions, although they share some similarities with both. The modules are constructed independently and transported to their final destination in the same manner. It allows for better building control away from extreme weather and other potential deterioration making the technology safer and more convenient to use precisely and easier to inspect and monitor. Modular construction is a type of off-site construction in which a building's components, or modules, are built in a factory and then transported to the construction site for assembly. The most well-known example of this kind of construction is bathroom pods, the usual form of construction in many residential and hospitality buildings. In recent years, the construction industry has observed an escalation in the practice of modular construction, which comprises constructing as much of a structure as attainable off-site before bringing it to its final place.

A typical volumetric project would consist of a complete room, including a bathroom, a portion of the corridor, and possibly some external finishing. Modularity refers to options of the same module in numerous configurations, allowing for a wide range of designs without specific component types. This modularity has various benefits, including lower capital requirements and cost savings. Modularity is highly useful when the project's scale and scope are relatively large. It is a realistic and cost-effective alternative in such situations. Modularity allows creating numerous designs while keeping development costs low and saving money on design and construction. As a result, you'll see that modularity is pushing the productivity frontier in design creation further out. On the other side, if there are many similar modules, modularity may result in exorbitant expenditures due to over-design, poor performance, and a loss of design identity.

Prefabrication/modularization, which has been around for decades, is undergoing a revival as new technology, such as BIM, enables better assembly and exact design of modular components. Changes in design, such as the rise of ecologically conscious design, have also enhanced the possibility of permanent modular structures. Furthermore, as a result of construction techniques and a desire to build for less, prefabrication and modular construction have grown in popularity. Although the trend toward more off-site building has been slowly increasing for years, the recession and new technologies may accelerate its adoption. Reduced construction interest burden and associated time savings due to a shortened construction timeline result in a higher financial return. As well as decreased production hard cost from repeatable and higher efficiency construction methods, streamlined construction process, reduced material waste, and improved construction quality are all potential benefits.

Modular building projects require design completion at an earlier stage than traditional construction. It's because the design must account for manufacturing and assembly, whereas traditional designs are far more fluid and are frequently completed only after the building has started on site. As the supply chain expands, this appears to have positive and negative implications for modular construction. However, if the environment forces a change in design, it may be seen as overly rigid and costly to change. As planning authorities become more mindful of our social impact and ensure that our global growth is sustainable, this has never been a more crucial factor for building projects. As a result, using renewable resources and lowering carbon emissions are critical factors for any construction project. Although both construction methods can employ renewable resources, modular construction produces less waste and higher-performing buildings. Modular building projects, on the other hand, tend to produce lower levels of carbon emissions. Workforces are often smaller, with fewer workers traveling to the job site and less fuel-powered heavy machinery, all of which contribute significantly to carbon emissions.

TYPES OF MODULAR CONSTRUCTION

Modular construction is a type of construction in which structures are built off-site in factories under stringent quality control while adhering to the same building laws and standards as traditional methods. These structures are constructed in modules or small components that are delivered to the job site and assembled. Modular construction is gaining popularity because of its speed, cost-effectiveness, and efficiency. Permanent and temporary modular buildings are the two most common forms.

Figure 3 (Triumph, n.d.)

Permanent Modular Construction: Permanent Modular Construction (PMC) is a unique, sustainable execution program that utilizes onsite, lean manufacturing technologies to prefabricate single or multi-story whole building systems in deliverable module pieces. In contrast to projects that only use site-built construction, PMC modules can be integrated into site-built projects. It may be given in less time as a turn-key solution with MEP, fixtures, and interior finishes, resulting in reduced waste and greater quality control. According to a recent study, modular construction is a cost-effective technique poised to help the construction industry thrive.

Temporary Modular Construction: A partially or fully completed building that complies with applicable standards or state regulations is known as Temporary Modular Construction. It is constructed in a building production factory using a modular construction method. Relocatable buildings are designed to be reused or repurposed several times and transferred to new construction locations. They are used for schools, construction site offices, medical clinics, sales centres, and any other application where a movable structure may suit a temporary space requirement. These architectures provide quick delivery, mobility, low-cost reconfiguration, faster depreciation schedules, and adaptability. Instead of being permanently affixed to real estate movable buildings are built to meet the manufacturer's installation specifications and local building codes. When speed, temporary space, and the ability to relocate are necessary, these structures are essential.

Figure 4 (Triumph, n.d.)

IS MODULAR CONSTRUCTION COST EFFECTIVE?

Modular construction can save money, but it isn't its main advantage. The main advantage of modular construction is that it saves time and provides a quicker return on investment. Because modular building allows for industrialized assembly and site preparation simultaneously, the time reduces for completing a project. The factory-built modules are often ready to be placed by the time the site is ready (foundation, plumbing installed, etc.). A modularly constructed hotel, for example, may open its doors and begin producing money 30 to 50 percent faster than a traditionally constructed hotel. It is a very adaptable architecture that enables personalization. It's versatile, allowing it to be used in both permanent and temporary installations, as well as reaching out to isolated locations where traditional housing isn't possible. Because its structural structure allows for the addition, replacement, and removal of standard units and the application of any finish, it provides for customization. The features of the buildings and modular homes also allow it to reduce its ecological footprint in two ways. For starters, while much depends on the materials and resources used, wood, for example, is environmentally friendly and 100 percent recyclable, and it produces less waste in a shorter period. Second, because the prefabricated sections are geometrically correct and fit perfectly together, the structures become more energy-efficient, resulting in energy savings in terms of heating and cooling. It's also worth noting that adding water recycling or renewable energy systems during the construction process is simple. There is no reason why ecological architectures can't be developed in a modern style using today's technology and resources. The product's quality is totally under control, and it passes all certification standards because it is built in a controlled environment and according to conventional norms. Because high-quality materials capable of lasting transportation are employed, you can get constructions with excellent geometric correctness and enormous strength. Finally, the systematization and industrialization of the methods and the environment in which the process is carried out aids in lowering production time in comparison to a traditional building and, as a result, reduces costs.

The cost of modular construction is impacted by automation in which machinery and robotics are used to automate some human jobs. As a result, fewer construction teams can function at a higher level of productivity than a traditional building. Automatic machinery's capabilities are only going to get better with time. Overruns and delays are much less frequent because there are fewer risk variables that influence costs. Fewer people and contractors on the construction site manage fixed unit costs to reduce rework and variations. Due to lower contractor overheads, modular offers high cost and time certainty than traditional. Expenses can be reduced to enhance workmanship quality and rework with increased control of the manufacturing process in industrial settings and precise engineering. Modular construction provides significantly higher quality and lower rework costs in comparison to traditional construction. As a result, the costly and time-consuming process of correcting design flaws and production quality issues can be delt on a construction site. However, several factors raise the cost of modular building compared to traditional construction. The expenditure of the facility and manufacturing facility for offsite construction is exceedingly expensive to build and maintain. If the client has their facility or outsources manufacturing to third-party providers, it reflects in the expenses. Mobility and logistics must be taken into account because offsite-built components need to be delivered and assembled on site. These expenses might be substantial depending on the distance between the site and the manufacturing facility. The transportation restrictions for the vehicles while commuting with the components. Acquiring funding is more challenging in the case of modular construction because it often has a higher interest rate. Banks are afraid of the higher bankruptcy risk associated with modular construction due to the market players' lack of experience.

This is projected to improve over time as operators develop a track record of long-term operations, giving lenders more confidence. Expenses of materials can be more costly for modular structures because autonomous machinery necessitates a better level of materials. Similarly, factory-built buildings must resist transit and assembly a greater number of materials are utilized than in conventional construction, making it more expensive.

Seville Cruise Terminal Phase 2

A significant challenge in modular construction is the Seville Cruise Terminal Phase 2 by architect Buró 4, Hombre de Piedra Arquitectos. Ports and cities have one thing in common: they are constantly changing. Port buildings should be able to alter over time without resorting to improvisation to meet the problems posed by that interaction. One approach could be to provide a modular industrial architecture that emphasizes the port's unique characteristics while still providing the architectural quality essential for proper urban integration. The Port of Seville required a modern cruise terminal that was modern, accessible, and compact. It would also allow it to gradually react to increasing passenger traffic and opportunities for urban/port areas near the Las Delicias Dock. The Seville Port Authority's cruise ship terminal intends to be a sustainable modular structure that takes advantage of the construction possibilities given by recycled shipping containers. Construction took place in two stages. The first was in 2013 with several of the repurposed containers. The building work on-site could only last 15 days, which is the maximum interval between two cruises docking. The Seville Port upgraded its facilities in the second phase was completed in 2016, and increased the number of modules from 508 square meters on the ground floor to 891 square meters. The upper level is accessible, bringing the passenger greeting room's total surface space to 1,096 square meters. The building's morphology consists of a series of high-cube containers organized in a row, with standard containers atop them that serve as skylights. The result is an open space with a rhythmic sequence of lights and shadows, regular and double ceiling heights, and corrugated sheet metal walls that disclose the structure while also providing an artistic aspect and a location to accommodate all forms of activity. The building's bioclimatic analysis also allowed for more comfortable rooms to be built and energy savings that improved the structure's sustainability. In the upper half of the double spaces, the air is hotter. Windows were located at the east and west ends of the skylights to allow prevailing winds to easily pass through the buildings, eliminating heat from the higher levels.

Figure 5 (ArchDaily, 2020)

Phoenix Court, Bristol, UK

Phoenix Court provides students in Bristol with different room configuration rooms in 2–6-bedroom with studios with a higher standard. An onsite laundry, bike storage, a common room, and in-room internet access were all included in the project. Phoenix Court is Europe's highest self-supporting modular building and groundbreaking among an 11-story construction to use only cold-rolled steel modules. Majorly the studios and units were delivered to the job site with FF&E, kitchens, and white goods with vertical heat systems. The site location is at the end of a busy freeway in central Bristol and has transportation challenges. Integration of modular construction with steel or concrete frameworks to achieve space planning flexibility in instances where the dimensional limits of modular systems would otherwise be prohibitive. Installation of modules for designing a podium or platform construction can be using modular technology. It enables the construction of an open area for retail or commercial use with underground parking. Support beams should align with module walls, and columns are arranged in a 20-to-26-foot grid. In the United Kingdom, a 24-foot column grid was deemed ideal for parking on the ground floor or basement level since it allows for three parking places. 6 to 10 floors of modules sit on top of a 2-story steel-framed platform in this 12-story dormitory and commercial structure in Bristol, England.

Figure 6 (Harper, n.d.)

The 400-bedroom modules have an external width of 9 feet, and about 100 of them are linked in pairs to create larger studios with two rooms. The width of the kitchen modules is 12 feet, with four braced steel cores providing stability to some modules. A double passageway construction for life safety concerns allows a cluster of five rooms to be integrated into one compartment. The braced steel cores offer stability, and a maximum of 5 modules are positioned to reduce forces in the core connections. The structure has rain screen cladding, a lightweight system in which the modules support the cladding's self-weight. The module already includes the airtight and weathertight layers with the majority of the insulation.

CONCLUSION

Life has changed in recent years, with changes designed to accommodate pandemic and post-pandemic existence. It's now time to rethink architecture as well. With a growing lack of competent personnel as more retire without being replaced, and a broader absence on the horizon, depending on this workforce for new projects creates gaps and raises concerns. Modular building is the answer. In a word, modular construction comprises the use of factory-made modules that are brought to and erected on construction sites. This technology enables faster and more efficient operations with less trained workers because the modules are not cast on-site. Modular construction can help architects and cities to solve challenges during pandemics and the early aftermath of pandemics. Modular construction necessitates fewer skilled workers and workers in general, allowing projects that might otherwise fall short of safety criteria to move forward. People in charge of these projects will save money by using modular construction. Expanding without disrupting the activities of healthcare facilities is especially critical during a pandemic. The movability of the modules is another virtue of modular structure related to the Coronavirus. Such modules produce advanced for hospital use, delivered to the location where they are most needed, and then moved to another space or stored.

Modular construction, even for larger projects, provides advantages that the existing method cannot match. Modular construction is the most practical, inexpensive, and efficient option because of its superior cost-performance and high positive affect rate. When working with modular construction, it's crucial to understand the building codes and module-specific constraints. The challenge is to overcome with some creativity and ingenuity, and the cost, construction time, and the result will be well worth the work spent planning. Modular buildings have a lengthy history, but it's evident that they're not going away anytime soon. They'll be around for a long time, thanks to increased demand. They are beneficial because they have always provided refuge for millions of individuals who would otherwise be unable to afford a home or build well-equipped medical facilities. Modular building has some intrinsic environmental benefits to the other advantages it brings, such as efficiency and affordability. Compared to other construction methods, modular construction produces fewer pollutants, wastes less raw materials, and has a lower environmental effect. As we move toward a more environmentally conscious culture, the benefits of the modular building stand out in comparison to alternative cost-effective construction solutions that frequently harm the environment and do not match the same quality standards.

BIBLIOGRAPHY

1. Advice Manufacturing, n.d. *Embodiment Design: Modular Design and Product Architecture.* [Online]
   Available at: http://www.advice-manufacturing.com/Modular-Design.html
   [Accessed 3 Nov 2021].

2. AGI, n.d. *Modular architecture, why should it be chosen?.* [Online]
   Available at: http://www.agi-architects.com/blog/en/modular-architecture-chosen/
   [Accessed 3 Nov 2021].

3. Arch20, n.d. *Modular Architecture: When Beauty and Efficiency Meet.* [Online]
   Available at: https://www.arch2o.com/language-modular-architecture/
   [Accessed 2 Nov 2021].

4. ArchDaily, 2018. *CitizenM Bowery / Concrete + Stephen B. Jacobs Group.* [Online]
   Available at: https://www.archdaily.com/905600/citizenm-bowery-concrete-plus-stephen-b-jacobs-group
   [Accessed 5 Nov 2021].

5. ArchDaily, 2020. *Seville Cruise Terminal Phase 2 / Hombre de Piedra Arquitectos + Buró 4.* [Online]
   Available at: https://www.archdaily.com/945750/seville-cruise-terminal-phase-2-hombre-de-piedra-arquitectos-plus-buro-4
   [Accessed 4 Nov 2021].

6. Astrachan, I.-D., 2020. *Modular Construction as a Post COVID-19 Design Alternative.* [Online]
   Available at: https://www.buildingenclosureonline.com/articles/89199-modular-construction-as-a-post-covid-19-design-alternative
   [Accessed 5 Nov 2021]

7. Cao, L., 2020. *Why Choose Modular Construction?.* [Online]
Available at: https://www.archdaily.com/949219/why-choose-modular-construction
[Accessed 3 Nov 2021].

8. Harper, D., n.d. *Buildings on Bond Street South, Bristol.* [Online]
Available at: https://www.geograph.org.uk/photo/4537456
[Accessed 4 Nov 2021].

9. IGI Global, n.d. *What is Modular Architecture.* [Online]
Available at: https://www.igi-global.com/dictionary/modular-architecture/19139
[Accessed 2 Nov 2021].

10. Khan, N., n.d. *Why India Needs More Offsite Modular Homes?.* [Online]
Available at: https://constructiontimes.co.in/why-india-needs-more-offsite-modular-homes/
[Accessed 5 Nov 2021].

11. Marcos Gasc, GKV Architects , n.d. *A Brief History on Modular Architecture.* [Online]
Available at: https://www.gkvarchitects.com/news/a-brief-history-on-modular-architecture
[Accessed 6 Nov 2021].

12. Markevich, M., 2020. *Traditional vs Modular. Choosing the best development option with Kreo.* [Online]
Available at: https://www.kreo.net/blog/traditional-vs-modular.-choosing-the-best-development-option-with-kreo
[Accessed 4 Nov 2021].

13. Modular Advantage Magazine, n.d. *THE (SURPRISINGLY LONG) HISTORY OF MODULAR CONSTRUCTION.* [Online]
Available at: https://www.modular.org/HtmlPage.aspx?name=MA-oi-History-of-Modular
[Accessed 4 Nov 2021].

14. Modular Building Instutite, n.d. *What is Modular Construction?.* [Online]
Available at: https://www.modular.org/HtmlPage.aspx?name=why_modular
[Accessed 1 Nov 2021].

15. Modular Building Systems, n.d. *Modular Design Flexibility and Adaptability.* [Online]
Available at: https://mbs.com.au/blog/modular-design-flexibility-and-adaptability/
[Accessed 07 Nov 2021].

16. Muresan, F., 2019. *What is Modular Construction?.* [Online]
Available at: https://www.ny-engineers.com/blog/what-is-modular-construction
[Accessed 6 Nov 2021].

17. Stacbond, n.d. *Modular architecture. An upward trend.* [Online]
Available at: https://stacbond.com/us/modular-architecture/
[Accessed 3 Nov 2021].

18. Triumph, n.d. *Temporary Modular.* [Online]
Available at: https://www.triumphmodular.com/temporary-modular/
[Accessed 7 Nov 2021].

19. Triumph, n.d. *Why Permanent Modular?.* [Online]
Available at: https://www.triumphmodular.com/permanent-modular/why-permanent-modular/
[Accessed 6 Nov 2021].

20. Velamati, S., 2012. *FEASIBILITY, BENEFITS AND CHALLENGES OF MODULAR CONSTRUCTION IN HIGH RISE DEVELOPMENT IN THE UNITED STATES: A DEVELOPER'S PERSPECTIVE,* Massachusetts: Massachusetts Institute of Technology.

CASE STUDY OF CREATIVE ARCHITECTURE IN MASS PRODUCTIONS THROUGH 3D PRINTING TECHNOLOGY

SUBTHEME: MITOSIS OF MODULES CONTRIBUTION TO TECHNOLOGY

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ABSTRACT

Architects are becoming more adept at using new modular solutions in much creative ways and more interested in the rigid geometries of the past. Even globally contractors and engineers are now busy trying to find the right balance between bespoke design and volume production, and using the latest technology to boost their chances, such as 3D printing. As the world's population is continuously growing, we are facing with the need for faster development and rapid construction on a massive scale. Nowadays the main debate is how mass-produced elements can be made to work with the creative architecture. The overall aim of this paper is to prepare a reference base for the architects for analyzing 3D printing technology on the parameters of creativity, time of construction and low labour cost. This is done by synthesizing some cases studies where the same technology has been used for the rapid construction. The study found that we are facing with the need for faster development and rapid construction on a massive scale, and 3D printing not only contribute in rapid construction but also contribute in producing elements in an almost limitless number of shapes and sizes in mass production.

INTRODUCTION / BACKGROUND

Modular construction is a process in which a building is constructed off-site with under controlled plant conditions, using the same materials and designing to the same codes and standards as conventionally built facilities, but in about half the time. Buildings are produced in "modules" that when put together on site, reflect the identical design intent and specifications of the most sophisticated site-built facility without any compromise.

Mass customization is something if can be applied, you could probably rule the world. And this is more than just an aspiration.

Most important of all, a global shortage of traditional building skills is causing problems for developers and a market that is hungry for new methods of procurement.

The goal of mass production is low-cost manufacturing with speedy construction.

Contractors and engineers are now busy trying to find the right balance between bespoke design and volume production, and using the latest technology to boost their chances, such as 3D printing.

3D printing technology is enabling faster and more accurate production of flexible designs. Building Information Modelling is allowing manufacturers, designers and contractors to play with modular configurations in a way that would have been difficult just a decade ago, and architects are becoming more adept at using new modular solutions in much creative ways and more interested in the rigid geometries of the past.

AIM / PURPOSE

As the world's population is continuously growing, we are facing with the need for faster development and rapid construction on a massive scale.

Nowadays the main debate is how mass-produced elements can be made to work with the creative architecture.

The overall aim of this paper is to prepare a reference base for the architects for analyzing 3D printing technology on the parameters of creativity, time of construction and low labour cost.

At the Manufacturing Technology Centre in Coventry, Skanska, UK is helping to pioneer concrete printing, a process by which elements can be made in an almost limitless number of shapes and sizes by extruding specialized concrete through a robotic arm.

RESEARCH METHODOLOGY

In this paper literature review and synthesis of some cases studies are done, where the 3D printing technology has been used for the rapid construction.

LITERATURE REVIEW:

3D construction Printing (3DCP) refers to various technologies that use 3D printing as a core method to fabricate buildings or construction components.

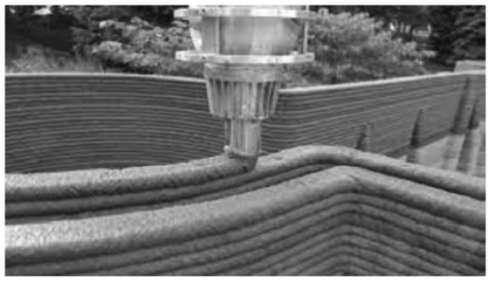

Figure1:

There are a variety of 3D printing methods used at construction scale, with the main ones being extrusion (concrete/cement, wax, foam, polymers), powder bonding (polymer bond, reactive bond, sintering), and additive welding. 3D printing at a construction scale will have a wide variety of applications within the private, commercial, industrial and public sectors. Potential advantages of these automation technologies include faster construction, lower costs, ease of construction, enabling DIY construction, increased complexity and/or accuracy, greater integration of function, and less waste produced.

Demonstrations of construction 3D printing technologies to date have included fabrication of housing, construction components (cladding and structural panels and columns), bridges and civil infrastructure, artificial reefs, follies, and sculptures.

CASE STUDIES:

The technological improvements and market conditions are aligning in such a way that modular construction is now finally ready to deliver the sunlit world of speed, efficiency and flexibility.

The first case study is done of a restoration of a historic water in Palekh (old town in Russia) in August 2018, which was the world's first successful application of additive technology.

It is 26 meters in diameter with a depth of 2.2 meters. During this project, the restoration team, as well as the residents of Palekh, decided to change Sheaf foundation's original shape from rectangular to round. The parapets, which are barriers extended around the fountain base, were 3D printed using structural and geopolymer concretes, gypsum, clay, use mixtures with mineral additives and fiberglass. It set an example of using 3D printer for restoration.

Figure 2:

Second case study is Sudhoferweg 51 House in Germany built in 2021 by an architectural firm Mense- Korte, printed by a Cobod BOD 2 in concrete costing $ 300,000.

The longstanding debate of offsite vs onsite printing has been answered by this project that marries the benefits of both to compensate for some of the limitations of 3D printing concrete, mainly the fact that it can't print in mid-air. By printing certain components off site, they were able to add overhangs and other features that would be impossible to be printed in mid-air on site. Other features of the building were also 3D printed like a bath and a fireplace.

Figure 3:

This image shows the used 3D printer setup where a protective tent needs to be made around the building to maintain consistent temperature and humidity parameters, also mitigating any wind. This counts in the installation cost in the initial stage.

Figure 4:

Consideration of HVAC and plumbing layout in the design was taken care while giving for 3d printing, avoided making the ugly cut in the concrete during the modification after drawing is given for the printing. This printer required around 3 people to operate.

Figure 5:

Proper inspection and quality check was done by measuring the temperature of concrete to check the curing time.

Figure 6:

As it is in Germany, a cavity wall was introduced, Inserting horizontal reinforcements, gravel filling with insulation on top.

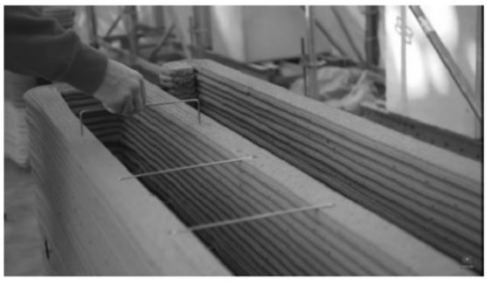

Figure 7:

Precast concrete blocks were used for the roof construction.

The third case study is example of high-rise buildings with modular construction. La Trobe tower in Melbourne, is the highest modular structure in Australia, and Creekside Wharf in Greenwich is one of the tallest in the UK. In Singapore, an executive condo project taking shape on Canberra Drive is believed to be the world's largest modular building project, with eight. The recently completed Crowne Plaza hotel extension at Changi Airport, a PPMC system cut the number of workers required onsite by 40% and the time to construct a floor from two to three weeks to just three or four days.

Figure 8:

The fourth case study is about the Indian context. In the Indian city of Vijayawada, the residents will be allowed to design their own high-rise apartment. The scheme, by Chinese architect Penda, will allow buyers select prefabricated modules from a catalogue, which will then be inserted into the structural frame. The practice describes the approach as using "modern construction techniques to bring back a level of individualism and flexibility for the inhabitants of a high-rise".

IIT Madras House

Figure: 9 & 10:

India definitely needs such solutions that do not require much time, adding the latest "technology enables building a 3D printed house in 5 days and Tvasta Manufacturing Solutions constructed India's first 3D house in IIT Madras by developing their own material mix, which is an extrudable concrete consisting of cement, sand, geopolymers, and fibres.

While 3D printing, the structure was specifically designed hollow to allow provisions for wiring and plumbing without damaging the wall.

The use of such local materials also reduced the need to transport concrete long distances, reducing the environmental impact.

FINDINGS/ ANALYSIS & INFERENCE

"Architecturally, the potential of this technology is very exciting," says Sam Stacey, Skanska's director of innovation. You can have whatever shape or angle you want, including shapes that are impossible to make with conventional moulds.

There is absolutely the potential for this 3D printed technology to be used in conjunction with moulded elements. Also, the business scenario for all forms of automation is improving partly because the cost of the software needed to take a design, and instruct robots to make it, is falling sharply.

The Chinese company WinSun was the first to build a 3D printed house, and in 2013 it was able to print 10 houses in 24 hours. These homes required human assemblage, as their walls were printed at a plant to be transported to the respective sites. The San Francisco startup company Apis Core successfully built a residence of this nature as their final domain in a day in the year 2018, the process was worth around $10,000 USD. Dubai has created a plan for a fourth of the new buildings in the city to be 3D printed by 2025. The city is striving to become the world leader in 3D printing for civil construction.

To achieve the creative architecture, through this technology one can easily have whatever shape or angle, including shapes that are impossible to make with conventional moulds.

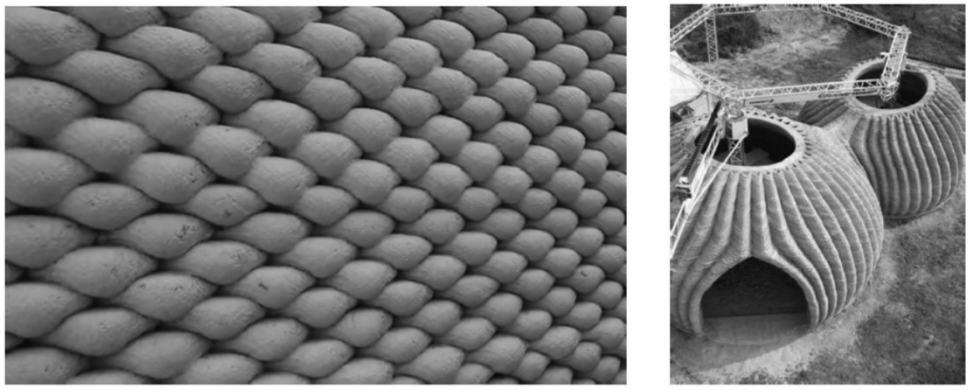

Figure 11: Along with shapes 3D printing provides the possibility of decorative textures and patterns too.

Some people think it is difficult for 3D printing to replace traditional methods, but this paper clears that this technology delivers quite practical solutions. It is possible to have aforementioned construction of conspicuous shapes that barely existed in construction projects so far. Another important factor to consider is in case of disasters: whenever a hurricane or an earthquake destroys infrastructure leaving thousands of people homeless, 3D printers can be used to quickly rebuild bridges, highways, and buildings. Due to its low cost, high efficiency, less construction time, less manpower, eco-friendly nature (can make customized ink by adding eco-friendly additives), extreme weather condition resistivity and low margin of error, 3D printed housing can become a practical option for subsidiary habitational projects.

However, before 3D printing can become a regular feature of modern construction there are technologicalm hurdles to overcome. One of the such is the corrugated appearance of 3D-printed concrete. Another issue is the reinforcement, again to resolve it a number of techniques are being researched including adding chopped fibre reinforcement to the concrete mix or the panels can be designed and printed with voids and later the reinforcement can be introduced by post tensioning.

CONCLUSION

The construction industry will only see better and better designs at increasing levels of efficiency, as more firms are educating themselves on the possibilities of 3D printed construction. One of the most important areas this is happening is within the Mechanical Electrical Plumbing systems. Making considerations for these services in advance means the printer can intentionally leave spacing avoiding cutting holes in drywall later on in the process, and simply be placed where they belong at the proper stage of the print along with reinforcement. This method can eliminate almost all the heavy lifting on the construction project besides the roof.

This technique promotes curves and odd shapes. It offers a quick and economic method for civil construction, thus creating three-dimensional shapes through a computer-controlled process, with a small crew to operate it remotely via tablet. In civil construction, 3D printing is particularly useful to fabricate geometrically complex elements. Due to the reduction of construction time, this technology promises less energy consumption, lower costs and reducing residue production. As any other innovation, there is still a lot to work on and to develop until it represents a viable, sustainable and widely utilized one by the construction industry.

It’s hard to give an exact cost or price of a 3D printed building in 2021, as it depends on the structure’ size and complexity. The simple answer would be that, in this day and age, it’s possible to 3D print a house for as low as $4,000. And that covers the structure of the house (i.e. base, walls, and roof) and in some cases, wiring. Pricing then depends on that construction cost, the area the house is built in, and its purpose.

For high-end projects with 3D printing concrete and additional construction components, one can expect the costs and prices to be higher, but from what I have seen from the case studies than those of comparable, conventionally built houses.

As time goes on, i predict more and more companies will move towards the construction of 3D printed buildings. This, combined with ever-advancing technologies, should bring prices down.

“Conventional housing requires timing, material, logistics, transporting of material, and so on. But if this technology can produce houses in different locales in five days, it would not be a big challenge to build 100 million houses by 2022, “ the finance minister said.

REFERENCES:

1. Jay G. Sanjayan, Ali Nazari and Behzad Nematollahi, 2019, 3D Concrete Printing Technology.
2. Arnaud Perrot, 2019, 3D Printing of Concrete: State of the Art and Challenges of the Digital Construction Revolution.
3. Ronald Rael, 2018, Printing Architecture: Innovative Recipes for 3D Printing.
4. Peter H. Diamandis, 2020, The Future Is Faster Than You Think: How Converging Technologies Are Transforming Business, Industries, and Our Lives (Exponential Technology Series).
5. Peg Robinson, 2018, 3D Materials and Construction Possibilities (Project Learning with 3D Printing).
6. Mark Lawson, Ray Ogden, Chris Goodier, 2014, Design in Modular Construction.
7. Wallance David, 2017, The Future of Modular Architecture.
8. Philipp Meuser, 2020, Prefabricated Housing Construction And Design Manual.
9. https://3dprintingindustry.com/news/3d-printing-construction-architecture-built-environment-134530/
10. https://theconversation.com/3d-concrete-printing-could-free-the-world-from-boring-buildings-106520
11. https://www.archdaily.com/949068/3d-printing-concrete-house-for-the-low-income-families-in-africa-professorxu-weiguos-team-from-thad
12. https://www.sciencedirect.com/science/article/pii/S0008884617311924
13. https://www.archdaily.com/961135/the-future-is-now-3d-printed-houses-start-to-be-inhabited-in-thenetherlands
14. https://housing.com/news/first-3d-printed-house-india/.

PEDAGOGY OF MODULAR DESIGN APPROACH IN ARCHITECTURAL DESIGN FOR BEGINNERS

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ABSTRACT

Architectural design – a unique designing process that takes parts of the system and turns them into a whole holistic solution. In architecture pedagogy, what is more, important is the approach towards solving these design problems at the level of a simple artifact to the level of a megastructure. The challenges are multitude and it is imbibed at different levels incorporating the various architectural and allied technical parameters. IN THIS PAPER IN ARCHITECTURAL DESIGN - How does modular design integrate with the design that results in the eventual architectural solution? This paper focuses on the basics of how to start Architectural design with an understanding of modular design. To make the student understand the modular design process that takes parts of the system. To know the approaches towards solving design problems. to encourage design beginners how important is it to use modularity? Explain a typical process to establish a modular design approach in architectural design. (1) module creation/identification, (2) interface analysis/evaluation, and (3) module selection/configuration, viz., synthesis.

INTRODUCTION

Modular architecture is one of the most dynamic components of design, offering adaptable solutions in generating effective and sustainable spaces.

In architectural design - how does modular design integrate with the design that results in the eventual architectural solution?

Introductory with the basic design approach, the investigation is simple, parameters are not many, but the students are tested for their exposure towards design. In basic design, the problems might be simpler as designing and the architectural design with advancement in semester get complicated with added several considerations. But in n architectural design, the student should get well prepared in totality to cram the design completely.

AIM

To make students understand the essence of the modular design approach in architectural design.

OBJECTIVES

1. To understand the modular design process that takes parts of the system.
2. To know the approaches towards solving design problems.

IMPORTANCE OF MODULARITY IN DESIGN

Modularity applied to design aims at reducing development time through parallel execution of activities (Baldwin, Clark, 2000; Ulrich, 1995), i.e., once Interfaces have been specified, the modules can be developed independently. Interfaces determine how the modules connect, communicate and fit together (Chen, Liu, 2005; Baldwin, Clark, 1997). Thus, students can design and develop modules, independence of modules is the intense innovation in design because students can create and test different solutions in their modules, with multiple design options by the relations of modules.

ARCHITECTURAL INPUTS NEEDED

First, a thorough and informative design brief is an imperative part of architecture design. Brief to ensure address particular challenges and important considerations related to the design project. A complete picture of what the project is all about……. A detailed brief about the project is to be given. The best solution for the project comes from a better understanding of the project. So, understanding the project becomes the prime essential aspect in a design process.

Project name, particular design features, the specific time required to complete, specific considerations and about the site, requirements of the uses of the buildings, etc.

LEVEL OF FLEXIBILITY OR LEVERAGE ALLOWED IN DEFINING THE PROBLEM

Whether Students expect to be given some freedom in the definition of the design problem?

Definitely yes for Students who employ quite different thinking out of the box and stand out from other peers as well as generate a more valuable discussion for learning. Many architects who have won major competitions have done so by breaking and or negotiating the rules to communicate a design solution, which stood out from the competition.

MODULAR DESIGN PROCESS

The student must do a sum of things to progress from the first stages of getting a problem to the final stages of defining a solution.

The modular design process proposes requires lots of effort over the decision system of functional investigation, module selection and module analysis, synthesis, simulation, and evaluation. Investigations involve the exploration of relationships, looking for prototypes in the material available, and the classification of objectives. The analysis is the collection and configuring of the problem. Synthesis is characterized by a challenge to move forward and creates an answer to the problem – the generation of solutions. Simulation involves the critical evaluation of suggested solutions against the objectives identified in the analysis phase.

THE MODULAR DESIGN PROCESS ORGANIZED AROUND THE PRIMARY GENERATIVE IDEAS

What are primary generators?

Primary generators of (Broadbent method) are pragmatic, iconic, canonic, and analogical.

PRAGMATIC DESIGN - is simply the use of available materials, methods of construction, generally without innovation, as if selecting from the catalog.

ICONIC DESIGN - is even more conservative in that it effectively calls for the designer to copy existing solutions and modify them to meet new conditions.

CANONIC DESIGN - relies on the use of rules such as planning grids, proportion systems, and the like. The classical architectural styles and their renaissance success offered opportunities for such an approach.

ANALOGICAL DESIGN - results from the designers using analogies with other fields or contexts to create a new way of structuring the problem. Recommended generic technique for creative thinking is the analogical design method.

Analogical methods are the most promising of these four tactics for form generators.

FUNCTIONAL INVESTIGATIONS THROUGH LITERATURE STUDY, CASE STUDY, SITE STUDY)

LITERATURE STUDY - Students need to think fresh about the problem without preconceptions about the type of solution and understand the nature of the users and their needs whether it is in terms of ergonomics or semiotics.

CASE STUDY - It allows the students to interact with the users and people involved in the processes, where applicable of designing, building, operating, and maintaining the setting. A significant part of learning from the case study happens after the actual fieldwork.

SITE STUDY - site condition is important in the design process, an essential part of the studies. Sustainable designs have become an integral part of the design procedure.

MODULE SELECTION AND MODULE ANALYSIS

PREPARATORY STAGE- The module selection was selected based on the objectives.

MODULE ANALYSIS - It may involve a visit to the setting, interviews with the person involved in any aspect, and gathering of data from a variety of secondary sources.

Students should find out what information will be useful for a design solution.

ORGANIZING AND ANALYSING THE DATA - Highlight the data with significance to the study objectives with analysis. This stage assumes great importance as a decision taken at this stage affects the next stage. The analysis compared to the set of cases, standards, and criteria.

COMMUNICATION STAGE - sharing of knowledge gained through the study in a manner suited to the purpose of the study. Analysis extensively studied by other students and teachers and commented upon by critics.

REPRESENTATION OF DATA - Visual modes e.g., plan, elevation and section or their schematic illustrations and dominance of sketches and photographs. supplemented by textual descriptions and diagrams for communication the rich technical, physical, spatial, and environmental information is obtained. Optional - 3d modelling and simulation, including a walkthrough, or the use of virtual reality in which a person can move through simulated environments and even interact with data being presented.

MODULAR DESIGN CONSTRAINTS

Create constraints within which students must work based on structural constraints, manufacturing constraints, and transportation constraints, and control may range from standards and code of practice to guidelines and recommendations such standards may govern factors of safety utility or appearance.

MODULAR SYNTHESIS – Modular provides unique ability to form the precise synth

CONCEPT – One of the core ideas behind modular synthesis is **interconnectivity.**

The idea comes from the primary generator collected using experimental observation and analysis and modifies the idea with a possible solution in the process by drawing diagrams and flow charts graphically, representing the required relationships.

AVOID FIXED RESULT (INTERNAL CONSTRAINTS) - Students often limit their project by anticipating certain aspects of the design outcome far too early on in the process. If the students focused on a fixed result, then they are denying themself the opportunity to discover what they could not have expected.

FLEXIBILITY – SHOULD be GENERATED BY THE DESIGNER - Internal constraints generally allow a greater degree of freedom and choice since they only govern factors, which are under the designer's control. Design students often fail to identify this simple fact but instead continue to mine their reasons boundlessly and ineffectively against insurmountable problems, which are large of them. The most significant skills designers must obtain are the ability to assess their own chosen constraints.

TRADE OF MODULAR DESIGN - For the modular design, we are considering it is important not just to be technically competent but also to develop aesthetic appreciation, space, form, and line, as well as color and texture, are the actual tools of the trade for the designer.

INFLUENCES AND MENTORS - It is important to have many influences and mentors from outside the school. This allows students to learn from people with vastly different perspectives and considerations. Creating a broader and more interesting forum for discussions and negotiations. Also constantly inform teachers, to keep them engaged in design and process.

SIMULATION

Simulation should be like "why or why I do not" concerning work.

REPRESENTED THROUGH VISUAL VOCABULARY - Ideas visually represented more. Students need to develop a visual sense. Sketches provide clear evidence that the student is thinking about the design in many ways simultaneously.

It involves a sophisticated mental process capable of manipulating many kinds of information, blending them all into a coherent set of ideas, and finally generating some realization of these ideas.

Thus, students develop their own set of guiding principles (radical, formal, or symbolic) and these often set the direction for a design project.

EVALUATION

Students work deliberatively to generate a series of alternative solutions, followed by a progressive refinement, testing, and selection process-minding concept as the background with a set of guiding principles.

MODULAR DESIGN SOLUTION - an integrated response to a complex multi-dimensional problem. Based on some synthetic and highly formative design ideas, students should list all the requirements, understand the requirements of the design, and then state which pairs of requirements interact either positively or negatively. Then effectively breaks the problem down into subproblems, each relatively simple for the designer to understand and solve and produce one or more solutions. Modular Design is a messy kind of business that involves making value judgments between alternatives that may each offer some advantages and disadvantages.

How do students choose between alternate design solutions and find out, which is better than another is and is so by how much?

Put them in order of preferences test those against explicit or implicit criteria and then somehow combine these assessments based on performance and weighting system and for reliable assessments checklist is the best and communicate the design to the teacher with all this progress.

PARALLEL LINES OF THOUGHTS - Modular Design involves both convergent and divergent productive thinking and studies have shown that they can develop and maintain several lines of thought in parallel - Parallel lines of thoughts investigations represent examinations into different aspects of design e.g., Material/interior – developed in parallel.

It is a three-dimensional concept but it goes parallel to the choice of materials that do exist and the detail and they are all combined and it changes.

PROCRASTINATION - DELAYING THE DECISION - The real difficulty with this response to uncertainty is that once a problem has been identified is no longer possible to avoid the consequences of making a decision. Delaying the decision adds to the uncertainty and may thus accelerate the problem. The very process of avoiding or delaying a decision has an effect. Design is a matter of outcome problems as it is of resolving them.

FINAL STAGES OF DEFINING A SOLUTION - The final design solution is the outcome of the series of refinements that it takes throughout the design journey. Many serious deviations from the original design may not result in a good solution.

Generally, it is easier to go in the same direction rather than start a new line of thought.

Embellish the design with detail.

In a design rather like art, one of the skills is knowing when to stop.

REVIEW - The student should be clear in perception along with being accurate and relevant. The reasoning should be fair and significant and the logic should be coherent and valid. Should have command over language where vagueness, ambiguity are avoided by use of exact words and definitions put to use effectively. The evaluation of simple and analogical reasoning, scientific and concept theories should be perfects. In addition, evaluation of source of information, arguments, the relevance of evidence becomes significant for proper reasoning.

CONCLUSION

The architectural design process is a continuous process involving sequential additions, alterations, changes, new incorporations, refinement at various stages. Interestingly, in architectural problems, the solutions may not be one but many. The real challenge in a modular design lies in how best the design solution is approached and how it is solved. The modular designers of today can no longer be trained to follow a set of procedures. Students should not be restricted to traditional problem-solving skills but rather exposed to new innovative skills. Rather they must learn to appreciate and exploit new technology as it develops. The integration of modular design with recent technologies, methods, and innovations will be a challenging one in architectural design. The universal impact of modular design inclinations and the forthcoming architecture will be impacted by this multipurpose design component.

REFERENCES

1. Design Methods in Architecture by Geoffrey Broadbent 1969

2. The Design Student's Journey: Understanding How Designers Think 1st Edition, Kindle Edition by Bryan Lawson 2018

3. Salingaros, Nikos Angelos "Modularity and the Number of Design Choices." *Nexus Network Journal* 3, no. 2 (Spring) (2001).

MONADIC ARCHITECTURE- EXPLORING GEOMETRY AND FORM AS UNITS OF MEASUREMENT

INTERPRETATION OF GOLDEN RATIO OF MAYAN ARCHITECTURE ON FUTURISTIC BUILDINGS

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ABSTRACT:

The paper explores the fundamental system of geometry and proportion of the well-known pre-classical examples of Maya architecture and the objective is to identify the significance of the Maya geometry and Golden ratio in various forms of sacred spaces of their cosmos by using the same geometry to layout and design their architectural physical environment as well as their vernacular houses, altars to complex geometrical formulae used to design great pyramids, temples and the exquisite artworks of Ceremonial centres', analysing its importance and potential to designers in future architectural design.

The methodology of the study included understanding and analysing visually the classic and modern Maya structures, elements contributing to the beauty of Maya geometry and architecture may be extensive use of the geometry and golden mean, content analysis by studying the use of geometry and aesthetics in design and identify the use of the Golden Ratio as a measure in architecture, case studies of soaring pyramid temples and ornate palaces across Mesoamerica represent a zenith of Maya art and architecture and its influence on the successive buildings. Throughout the observation of diverse components and rhetorical distinctions, elements of Maya architecture have become an important key to understanding their religious beliefs and culture as a whole.

The paper attempts to investigate the interpretation of these principles to explore and evaluate harmony design which is closely associated with mathematical relations, Designers can utilize these methods to study and engage the geometrical concepts and apply Golden Ratio in the architecture of futuristic buildings.

KEYWORDS: Golden Ratio, Geometry, Mathematical Proportions, Maya Architecture

1. INTRODUCTION / BACKGROUND

"Without mathematics, there is no art." —Luca Pacioli

Over the centuries, various factors have influenced architecture such as mathematics, culture, and religion. The golden ratio is one of the mathematical rules that has been defined using various names in the past as well as now. To mention a few, PHI, the golden mean, the Golden proportion, and the divine proportion. Almost all of nature's elements are made up of his miraculous ratio (1:1.618). The Golden ratio can be found in nature in the shape of our universe and the human body, the shape of clouds to the shape of flowers and leaves. This ratio can be located in almost all the beautiful elements in nature around us.

The Golden Ratio is one of the mathematical rules that have a significant impact and is used to create visually appealing designs throughout history. In the Renaissance, it became a formalized part of design philosophy. Its frequent appearances in geometry (in pentagons and pentagrams, for example) caught the attention of ancient Greek mathematicians, who began studying it at least 2400 years ago. The ratio is based on the Fibonacci sequence's relationship between consecutive numbers.

According to Marjorie Bicknell-Johnson, Maya priests and Greek Pythagoreans had a lot in common when it came to building the Golden Rectangle. The Maya thought that the gods' first activity when creating the Cosmos was to measure the square with a cord and that they observed the Cosmos' harmony in their geometry. The Pythagoreans believed that numbers were the ultimate truth and that the mathematical movements of planets and stars brought them together.

The Maya used geometric proportions and artistic carving to build everything from basic dwellings to elaborate temples, following Mesoamerican architectural traditions. Various important buildings Maya architecture represents a zenith of Maya art and architecture. the study of numerous components and stylistic distinctions remnants of Maya architecture have become an important key to understanding their religious beliefs and civilization as a whole

2. AIM & OBJECTIVE

1. To understand the principles of geometry and proportioning systems of Maya architecture
2. identify the significance of the golden ratio in various forms of sacred spaces of Maya Architecture
3. To appraise the importance and potential of the golden ratio and explore harmony in Mayan design

3. METHODOLOGY

This research focuses on the understanding and use of Golden Ratio knowledge in the design process to respond to research objectives, by investigating how geometry and aesthetics are employed in the design and identifying the use of the Golden Ratio as a measurement in architecture.

3.1. Understanding a brief history of the Golden Ratio:

3.1.1. The Golden Mean, Phi, the Divine Section, The Golden Cut, The Golden Proportion, The Divine Proportion, and tau are all names for the golden ratio (t).

3.2. Understanding and the study of the Golden Ratio that has been used throughout history to create visually appealing designs.

3.3. Deliberating and analyzing the content of the golden section, use of geometry and aesthetics in design how Maya geometry was, and is, an expression of Maya cosmology and religion

3.4. Study the use of the Golden ratio as a measure in architecture

3.5. The chronology of the study methodology through Content Analysis, case studies, and data collection.

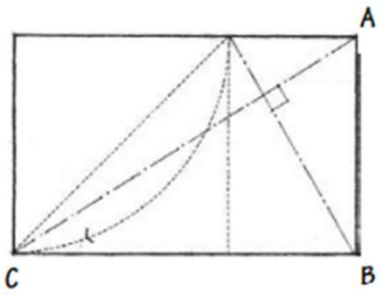
Understanding of the content analysis through following relationship to geometry

3.5.1. Golden Proportion (Phi (Φ) or Golden Ratio is usually denoted by the Greek letter Phi (ϕ), Geometrical approbation of the equation of Phi, based on the classical geometric relations, Theory of Golden Section, Golden Rectangle, Golden Triangle, Golden Angle, Golden Ellipse and Dynamic Rectangle.

3.5.1.a) Golden Ratio and its relationship with Geometry

Concept of Golden Section: The Golden Section can be defined as the ratio between two sections of a line, or the two dimensions of a plane figure, in which the lesser of the two is to the greater as the greater is to the sum of both. It can be expressed algebraically by the equation of two ratios as shown in Figure A'

$$\frac{a}{b} = \frac{b}{a+b}$$



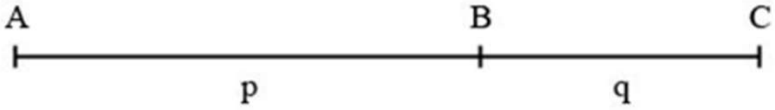
AB = a

BC = b

Ø = Golden Section

$$Ø = \frac{a}{b} = \frac{b}{a+b} = 0.618$$

Figure A: Equation of golden ratio with rectangular division((Ching, F. D. K. 2007).)



$$\varphi = \frac{p}{q} = \frac{p+q}{p} = 1.6180339887 \text{ (approx.)}$$

Figure B: Equation of golden ratio with rectangular division((Ching, F. D. K. 2007).)

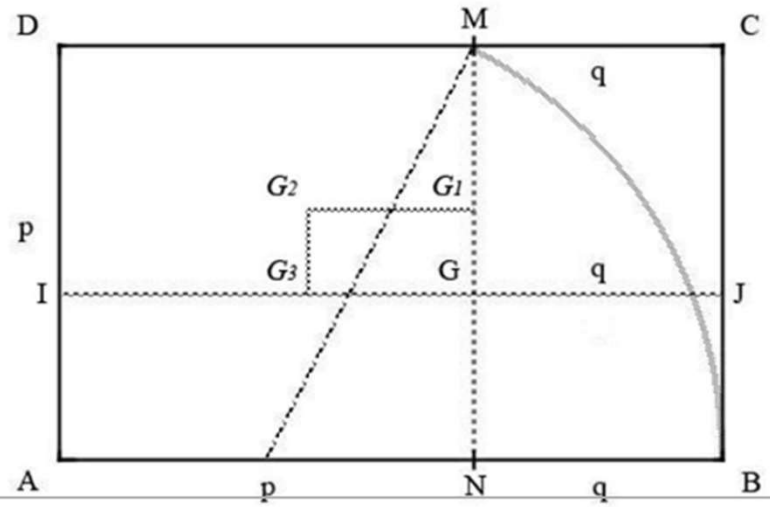


Figure C: Equation of golden ratio with rectangular division((Ching, F. D. K. 2007).)

For line segments, the Gold Section can be defined as the point where the line is divided into two halves with an equal ratio between the bigger and shorter segments, as shown in Figures B and C. The ratio is approximately 1.6180339887, and it is represented in Greek letters,. The pursuit of the Gold Section is frequently regarded as the most pleasant aesthetic point "Akhtaruzzaman, Md. 2011"

Golden Rectangle: The Golden Spiral is created by proportionally reducing the rectangle, as shown in Figure D'. The Golden Rectangle is divided into equal rectangles and equal squares "Akhtaruzzaman, Md. 2011".

Golden Triangle: Connotes an isosceles triangle in which the smaller side is in golden ratio with its adjacent side, , as shown in Figure E' & F'.

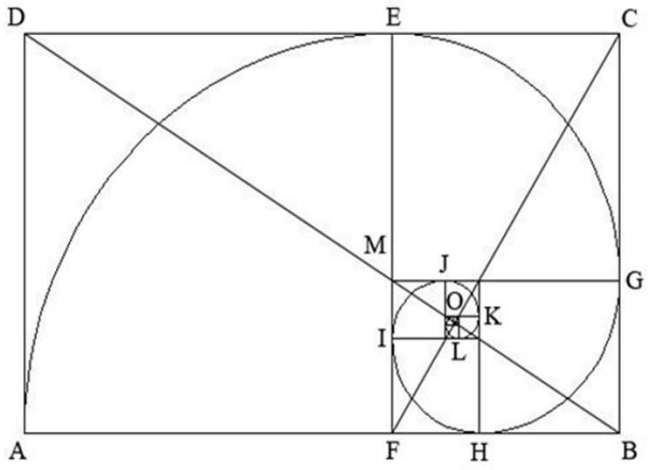


Figure D:The Golden rectangle ABCD and golden spiral AEGHIJKLO "Akhtaruzzaman, Md. 2011"

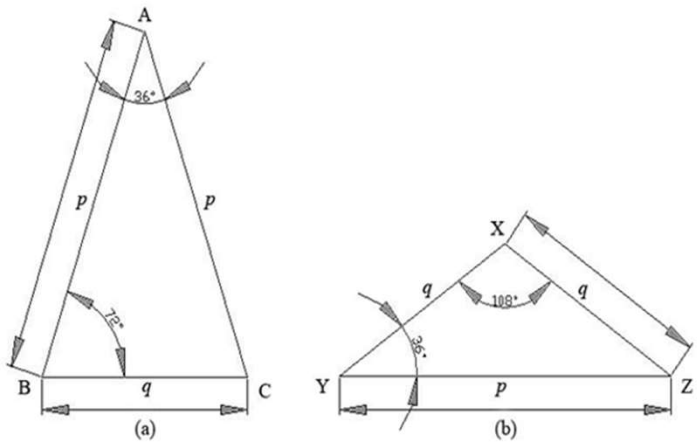


Figure E: Two different types of golden triangle (a) ABC and (b) XYZ "Akhtaruzzaman, Md. 2011"

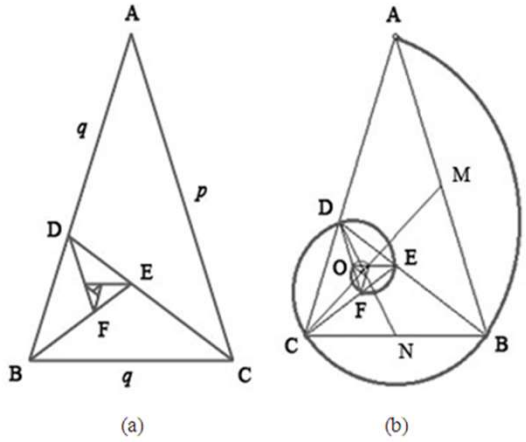
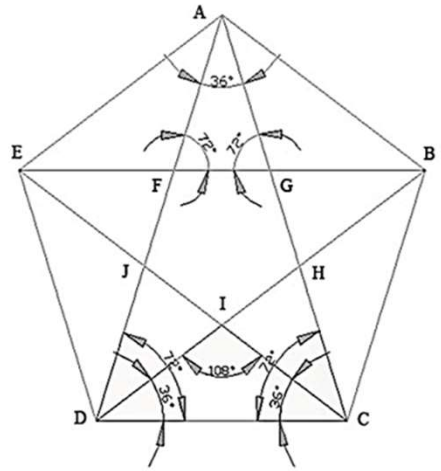
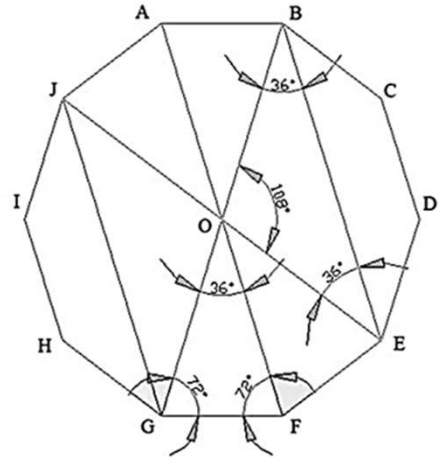


Figure G: Golden Spiral in the Golden Triangle "Akhtaruzzaman, Md. 2011".



(a) Pentagon



(b) Decagon

Figure F: a) Pentagon & b) Decagon-A series of golden triangles construct the Regular Pentagon, Pentagram, Regular Decagon and Decagram "Akhtaruzzaman, Md. 2011

Golden Angle and Golden Ellipse: The Golden Angle is categorized as a circle divided into two proportions of the Golden Ratio, where it is marked 137.5 degrees. Golden Ellipse is an ellipse drawn in the Golden Rectangle "Akhtaruzzaman, Md. 2011".. Figure G' shows the Golden Spiral formed in the Golden Triangle.

Logarithmic Spiral: This can be created by taking an existing golden triangle and bisecting the angles to make another golden triangle and continuing indefinitely.

Dynamic Rectangle: A rectangle can be classified as a static rectangle or a dynamic rectangle depending on the number of ratios. In Golden Section, static rectangles contain rational fraction ratios like 1/2, 2/3, 3/3, etc., whereas dynamic rectangles have irrational fractions like 2, 3, 5, etc "Akhtaruzzaman, Md. 2011". Figure H' shows how Dynamic Rectangle creates a visually pleasing subdivision.

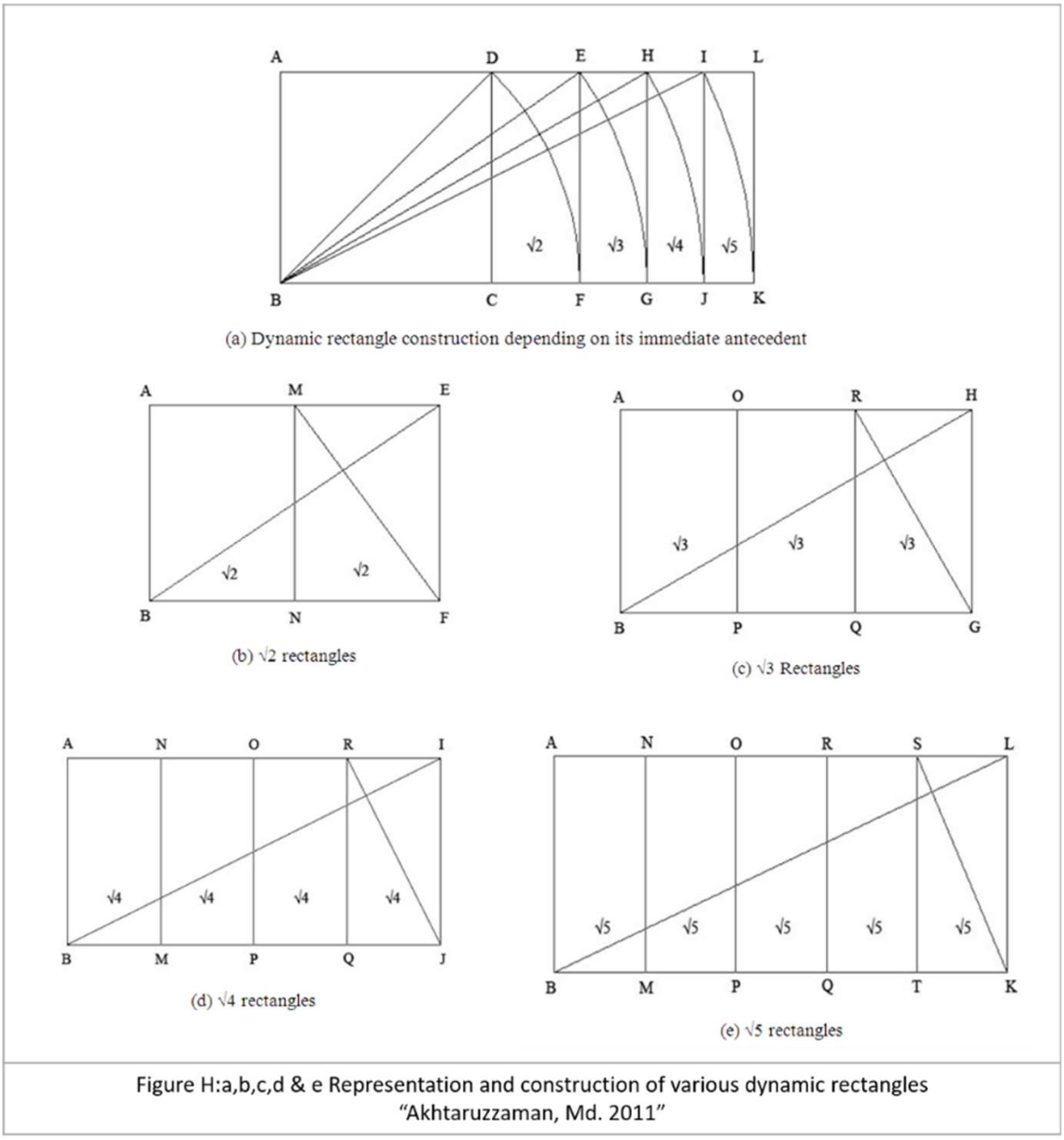


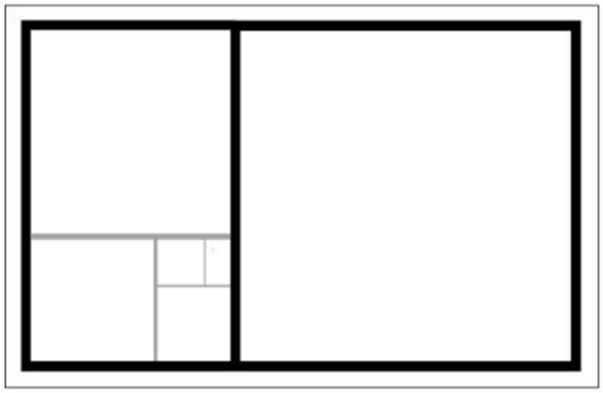
Figure H:a,b,c,d & e Representation and construction of various dynamic rectangles
"Akhtaruzzaman, Md. 2011"

3.5.1.b) Fibonacci sequence and its relationship to Geometry

Emphasizes the usage of Fibonacci numbers in mathematical explanations and the significance of Fibonacci sequences in the design process. recurrence relation of the Fibonacci sequence.

In mathematics, the successive proportions of a series of numbers, which are called Fibonacci numbers, give the Golden Ratio. A number in these series is the sum of the two consecutive numbers before it.

When a Fibonacci number is divided by its immediate preceding number in the sequence, the quotient approximates (for example, 13/8=).The larger the numbers get, the closer it approximates ϕ. Fibonacci numbers are in the following integer sequence: 1,1,2,3,5,8,13,21,34,55,89,144,1;1;2 (1+1);3 (1+2);5 (2+3);8 (3+5);13 (5+8);21 (8+13);34 (13+21), etc. All of the numbers in the sequence after the number '3' get a result of around 1.618 when divided by the previous number.



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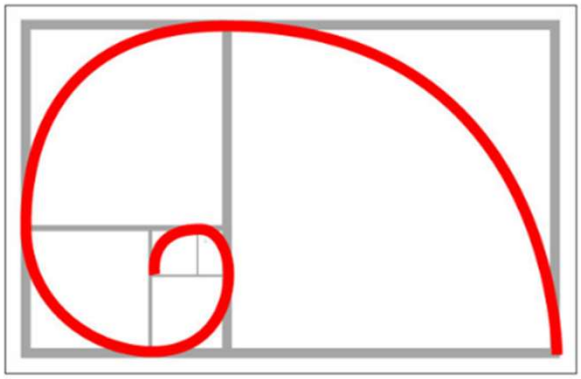

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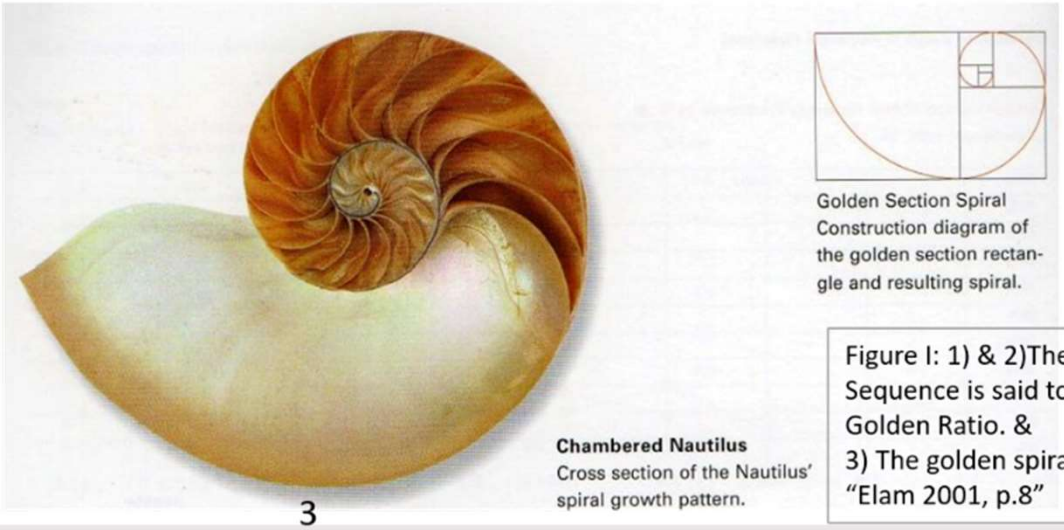


3

Golden Section Spiral
Construction diagram of the golden section rectangle and resulting spiral.

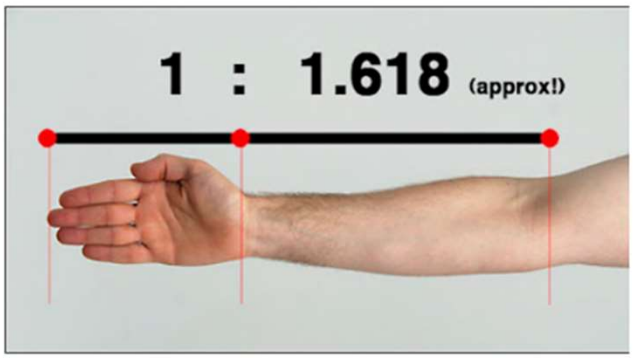
Figure I: 1) & 2)The Fibonacci Sequence is said to be linked to the Golden Ratio. &
3) The golden spiral in nature
"Elam 2001, p.8"

1) When we draw a square within a Golden Ratio rectangle, the rectangular shape that is left over is also of Golden Ratio proportions. This remaining rectangular shape is approximately 1.618 times smaller than the previous Golden Ratio rectangle it sits within.

2) When we draw a spiral based on Golden Ratio rectangles repeated within larger Golden Ratio rectangles,we find that the shape of this spiral is reminiscent of shapes seen in the natural world.

3) Sea shells grows approximately 1.618 times larger during each phase of their growth

The Golden Angle is closely related to the Fibonacci series. The golden angle is the principle of arrangement of leaves and branch arrangement in many plants, especially sunflower seed heads, and in nature as sacred geometry, as evidenced by spirals in nature. as shown in Figure K



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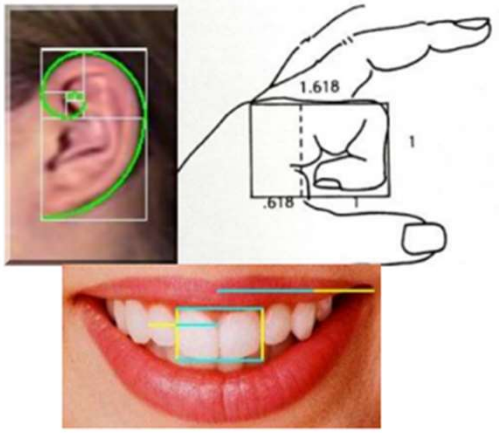


2

Figure J: 1 & 2 human beings & Golden Ratio "https://in.pinterest.com/pin/281543717702236/ https://www.scienceteen.com/golden-ratio/"

Figure J:1 & 2 shows Human beings also are proportioned according to Golden Section. Human hands, arms, ears, teeth, etc. are in phi (golden section) proportions. Spiral of the Ear, teeth and lips are in Phi proportions (in Golden section)

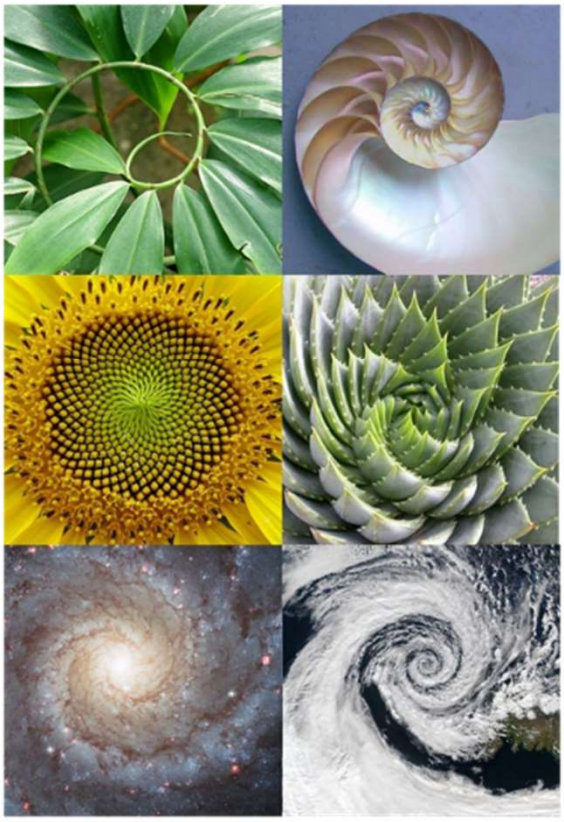


Figure K: sacred geometry : the golden ratio in nature, geomety in nature, fractals in nature, spirals in nature

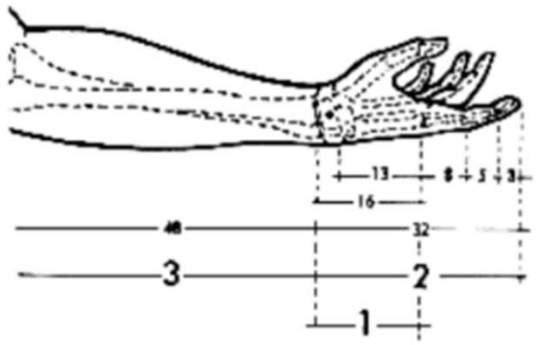


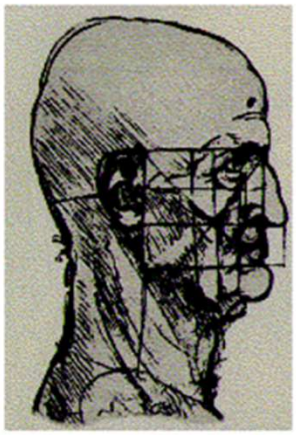
Figure L: The length of the human bone in the finger "Lawlor 1982".

This principle can be seen in animals as well as plants. Figure L' shows the relationship between the Fibonacci Series and the length of human bones in the fingers, hands, and arms "Lawlor 1982".

"According to Steward 1998, Sensory systems are thought to be linked to mathematical structure, Geometric symmetry is a proportional shape principle utilised in art, design, and science to comprehend the nature of the cosmos. Through harmonic proportions, geometric proportions in design can reflect emotions as well as reasoning. Geometry may be used for aesthetic and functional purposes".

3.5.2.Golden Ratio in Art & Architecture: Investigate the use of the Golden Ratio in Great design.

a) Golden Ratio in Art



Leonardo Da Vinci explored the human body involving in the ratios of the lengths of various body parts. He called this ratio the "divine proportion" and featured it in many of his paintings. Leonardo da Vinci's drawing of an old man can be overlaid with a square subdivided into rectangles, some of which approximate Golden Rectangles.

Figure M: An Old man by Leonardo Da Vinci

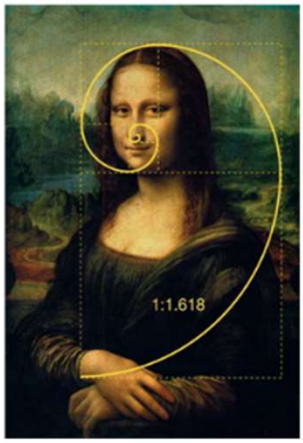
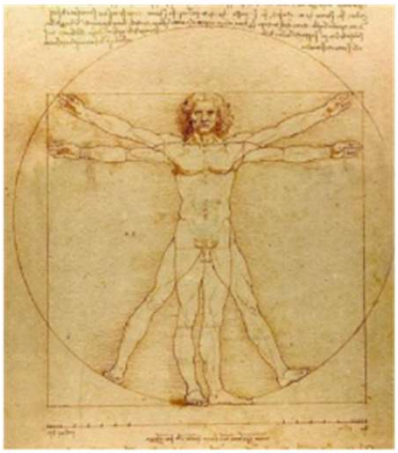
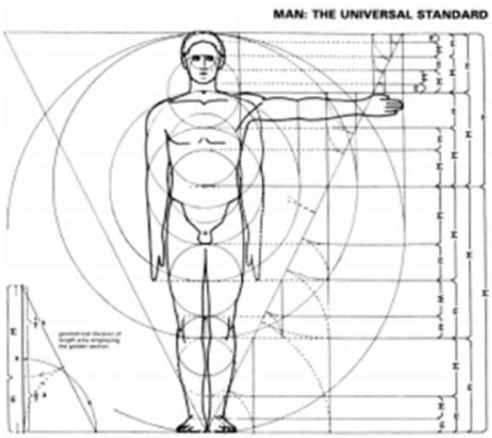


Figure N: Mona-Risa by Leonardo Da Vinci
This picture includes lots of Golden Rectangles. In the above figure 15, we can draw a rectangle whose base extends from the woman's right wrist to her left elbow and extend the rectangle vertically until it reaches the very top of her head.

Figure N: Mona-Risa by Leonardo Da Vinci



Vitruvian Man by Leonardo da Vinci



Geometric division of length by using Golden Section

We can draw many lines of the rectangles into this figure O'. Then, there are three distinct sets of Golden Rectangles: Each one set for the head area, the torso, and the legs.

Figure O: The Vetruvian Man"(The Man in Action)" by Leonardo Da Vinci

Figure P: i) Holy Family by Micahelangelo & ii) Crucifixion by Raphael

The picture is positioned to the principal figures in alignment with a Pentagram or Golden star. In this picture, a golden triangle can be used to locate one of its underlying pentagrams.

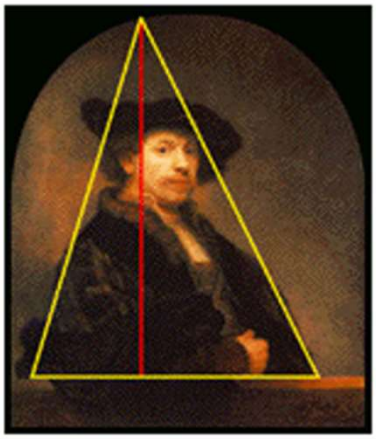
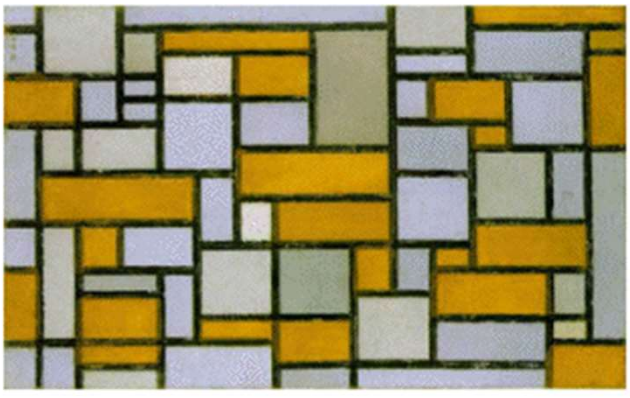
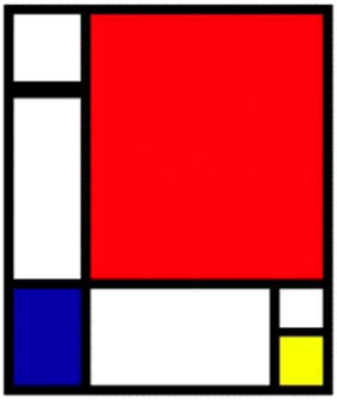


Figure Q: self-portrait by Rembrandt

We can draw three straight lines into this figure. Then, the image of the feature is included into a triangle. Moreover, if a perpendicular line would be dropped from the apex of the triangle to the base, the triangle would cut the base in Golden Section.





1 2

Figure R: 1. Composition with Gray and Light Brown by Piet Mondrian 1918

2) Composition in Red, Yellow, and Blue (1926) Piet Mondrian

b) Golden Ratio in Architecture

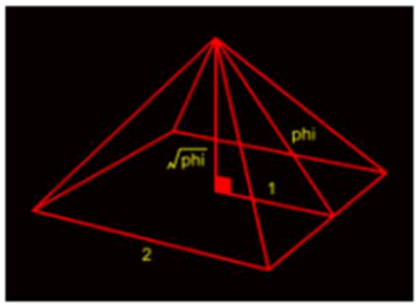
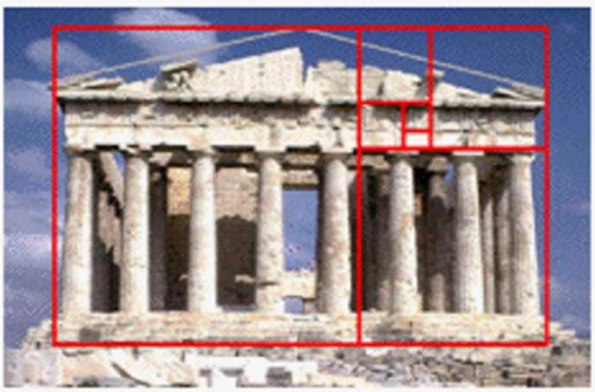


Figure S: The Great Pyramid(www2.rgu.ac.uk)

The Ahmes papyrus of Egypt gives an account of the building of the Great Pyramid of Giaz in 4700 B.C. with proportions according to a "sacred ratio."



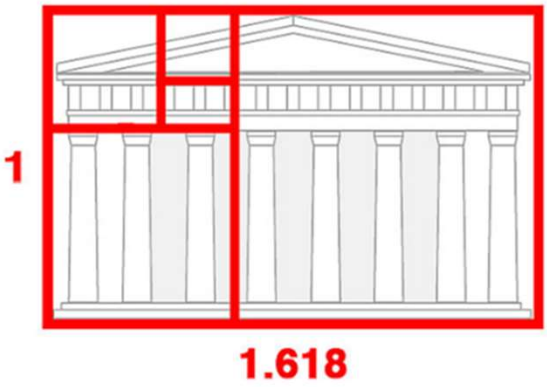


Figure T: The Great Pyramid."www2.rgu.ac.uk."

Parthenon: The structure of the facade of the Parthenon is subdivided using Golden Section proportions. The outer shape of the Parthenon fits within a rectangle based on the 1:1.618 ratio

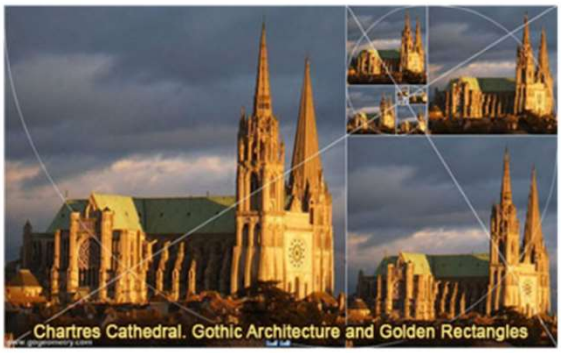
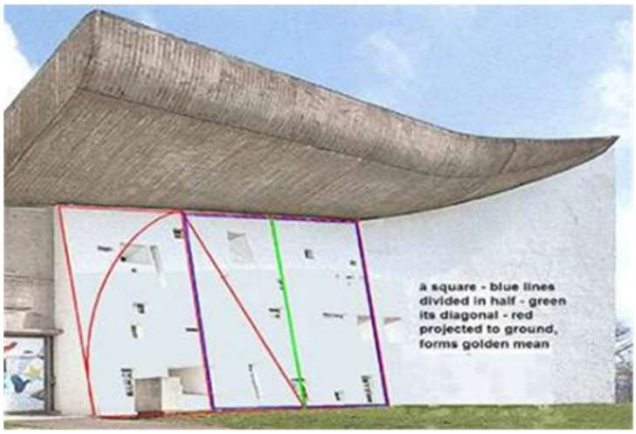


Figure U :Chartres Cathedral. "www2.rgu.ac.uk."

The Cathedral of Our Lady of Chartres in Chartres, France, is a good example of Golden Ratio architecture. The west portion of the original Romanesque cathedral that has survived clearly demonstrates how the Golden Ratio was used in its construction. They attempted to make connection between geometry and art and their building were intricate construction based on the golden section both inside and out.

1



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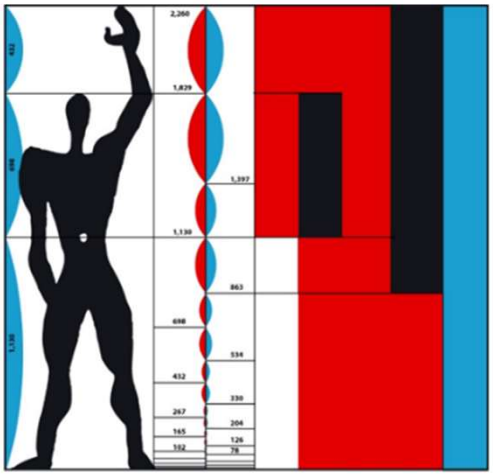


Figure V: 1)Ronchamp church south wall "https://thoughtbarrel91.files.wordpress.com/2014/09/4gm.jpg."
2)The Modulor, Le Corbusier, 1946 "https://live.staticflickr.com/4092/5031911411_5969087df0_b.jpg."

In 1950, the architect Le Corbussier published a book entitled "Le modulator". He invented the word "modulator" by combining "modul" (ratio) and "or" (gold); another expression for the well-known golden ratio.

According to Content analysis, the relationship between geometry in science, art, and design promotes knowledge of natural and man-made nature, Golden ratio and aesthetic beauty, and the fundamental principles that can be used effectively in design. The use of geometric concepts in the design process can help designers in thinking about visual composition and analyzing design in order to enhance creativity.

3.5.3. Architecture and Sacred Geometry

The geometry utilized in the planning and construction of religious structures is known as sacred geometry. Certain geometric shapes and geometric proportions are assigned symbolic and spiritual meanings in sacred geometry.

https://science.howstuffworks.com/engineering/architecture/sagrada-familia.htm

Figure W: Sagrada Familia, Barcelona(https://www.re-thinkingthefuture.com)
Figure W: The use of sacred geometry involves the study of mathematical principles which are followed in the making of "a divine structure", influenced by natural elements, a key part of Gaudi's architecture,
Sagrada Familia links geometry, nature, and organic elements in a seamless way.

Interpretation of geometry relationship between the natural and man-made worlds, man has used Sacred Geometry for many years in the creation of natural lifeforms, certain exact ratios can be found. Traditional civilizations saw architecture as a sacred means of manifesting the heavens. Since Egyptian and Greek times, geometry has been widely used in art, architecture, and design as one of the earliest disciplines and branches of mathematics.

"For the Maya, the sacred was self-sustaining. Their mathematics and geometry expertise was based on meticulous and in-depth observations of nature and its shapes. The goal was to achieve a lasting essence equilibrium with the environment. It was a balance that would not only honor the environment in which it arose but would also be functional in connection to that environment. Maya cultural knowledge transcends the figure in architectural creations. The Maya used geometry to build their spaces in addition to the mathematical precision they acquired in their constructions (due to their advanced astronomical studies). They appreciated and attempted to replicate the beauty of the world around them They grasped the principle of construction through the use of pattern and proportion. According to research conducted by the Architecture Department of the Mexican National Autonomous University (UNAM), the Maya have been building their cities using plans and volumes from pre-Columbian times.

1

Figure Y: 1) Chichén Itzá 03 2011 Templo Kukulkan (El castillo) 1413.jpg

2) The archaeological site of Chichen Itza, Yucatan, Mexico is shown in this map.

2

The Maya's fascination with a Yucatan rattlesnake reflects their search for geometric patterns. The reptile was sacred and venerated by the ancient Maya, to the extent where silhouettes of its skin are etched into infinite architectural buildings. According to tradition, the mystery of all existence is hidden behind its rough skin, which is filled with figures. The rattlesnake's back decoration symbolized a mathematical pattern in motion for the Maya, a dynamic geometric model built by a series of squares known as caynamaté. It's a type of figure, When the rattlesnake moves, the squares on its skin convert into rhombuses, and then back to squares.

3.5.4.Case Study

The maths behind the creation of golden ratio architecture and art helps to explain why each monument has a significant visual appeal. It demonstrates how the subconscious mind can discover and recognize the beautiful harmony that this mathematical equation can offer to all art forms.

One element contributing to the beauty of Maya architecture may be its use of the golden section.

Figure Z:a) golden section over the opening atop the east court at the Maya ruins of Copan in Honduras.

According to Christopher Powell (2010), This study is based on the discovery of a simple set of repeating proportions in Maya art and architecture measurements, After a thorough analysis of Pre-Columbian and modern Maya architectural and cultural forms, he identified these proportions appeared to have been purposely incorporated into the designs of these objects in Pre-Columbian period. The Maya used geometric proportions and intricate carving to build everything from basic dwellings to elaborate temples, following Mesoamerican architectural traditions.

According to Marjorie Bicknell-Johnson, The Maya, like Pythagoras, discovered harmony in the golden mean and devised a simple method for obtaining it by first making a square. As seen in the diagram “Figure Z:b)”, the builders halved the rope to determine the center of a side and stretched it from there to a square corner. The cord was then swung down to create a baseline for a rectangle, the iconic golden rectangle.

3.5.4.a) Special Ratios in Maya Architecture

Powell noticed that many specific ratios emerge repeatedly after researching several classic and modern Maya constructions and even participating in the construction of some Maya structures. These special ratios include square roots of the positive integers up to 55 and the golden ratio (ww.maa.org)

$$\varphi = \frac{1+\sqrt{5}}{2}$$

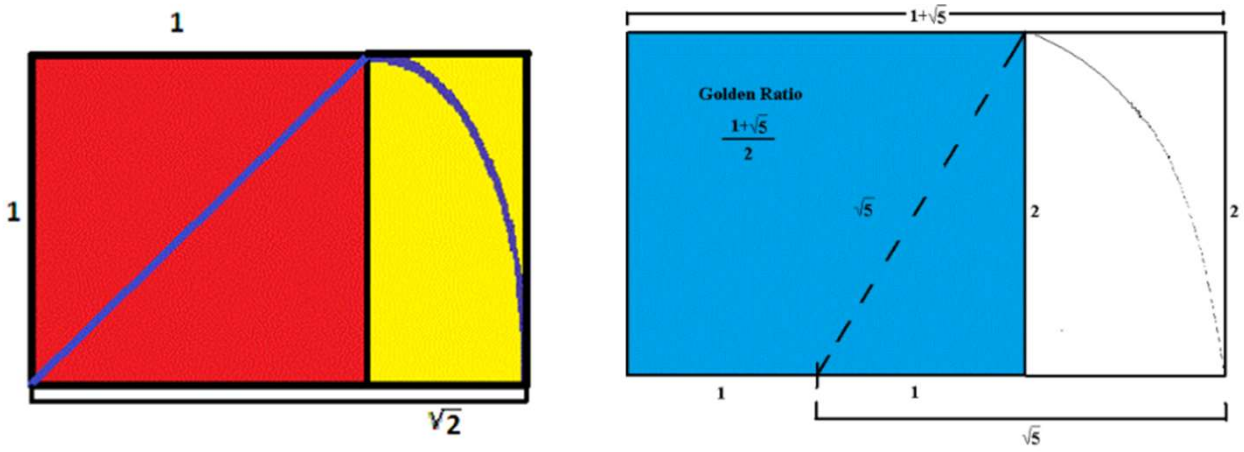


Figure Z:b) golden section over the opening atop the east court at the Maya ruins of Copan in Honduras.

The Pythagoreans held the golden mean in high respect, and it occurs throughout Greek art and architecture. The golden mean, or the ratio of the golden rectangle's length to width, is (1 + 5)/2. If the rectangle's width is 2, the square has side 2 and half-side 1, and the sides of the and the middle triangle's sides are l, 2, and 5. The distance between the arrow and the right corner is 5, and the rectangle's length is (1 + 5).

The Maya defined the god's construction of a square as "its four divisions; its four cornerings; its measurings; its four stakings" in the Popol Vuh, the Mayan book of the dawn of life and the glories of gods and rulers. "Its doubling-over cord measurement; its stretching cord measurement; its womb sky; its womb earth; its four sides; its four corners, as it is claimed," they built a golden rectangle. The Maya noticed the golden rectangle's proportions in nature and believed that buildings built with the golden mean were like flowers. modern Yucatec Maya using this very technique predominantly.

The Maya utilized simple cords to form the foundation for buildings thousands of kilometers away from Greece. They squared the angles by ensuring that the diagonals were equal before using a string to make a figure with four equal sides. The fundamental shape of Maya geometry and the module from which all Creation was generated, each pyramid has a square foundation.

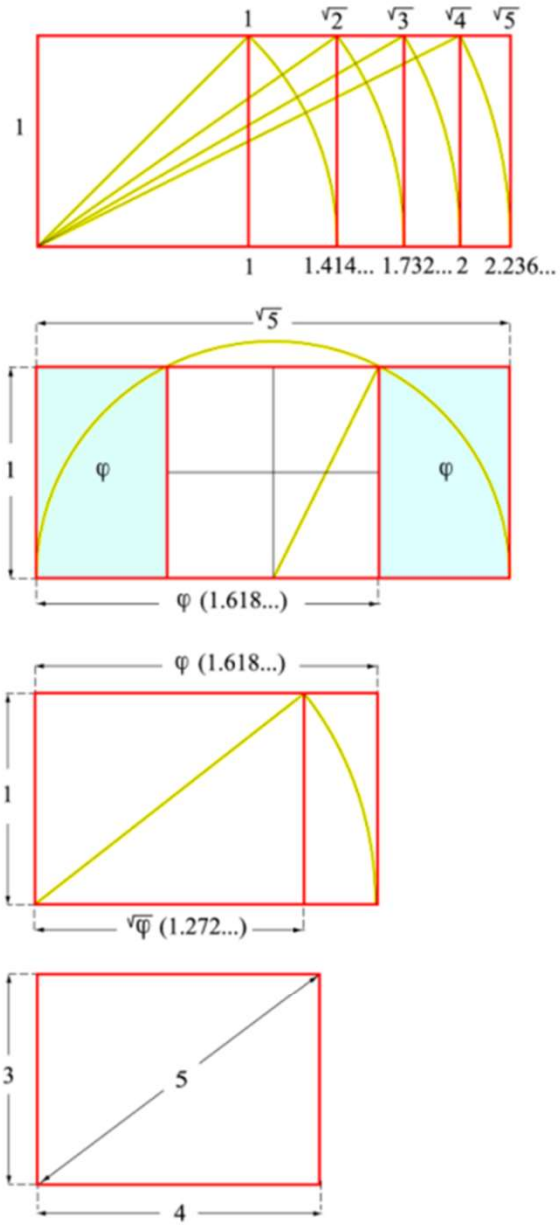
3.5.4.b) DYNAMIC PROPORTIONS AND THEIR PERFECT AND VIRTUALLY PERFECT SUBDIVISIONS

For thousands of years, the square root and phi proportions have been considered a formal set of proportions in this study of Maya art and architecture. From Pythagoras to Da Vinci, great geometers and mathematicians have studied and puzzled over the peculiar and dynamic properties of these proportions, and they continue to fascinate modern geometers and mathematicians. They are called dynamic proportions in modern vernacular in part because of their unique capacity to subdivide and combine into smaller and larger but similar forms. Following drawings show dynamic proportions and virtually perfect subdivisions Figure 1, 2, 3,4,5,6,7,8,9,20, 22,26,33,34 ,35 , “PowellDissertation2010_MayaGeometry.pdf”

These relationships are made clear by examining the most elementary set of regular polygons, the equilateral triangle, the square, and the pentagon, and all other regular polygons that may be derived from these three; for example, the hexagon, octagon, decagon, etcetera. The heptagon and nonagon are not included in this set of dynamic forms.

Figure 1

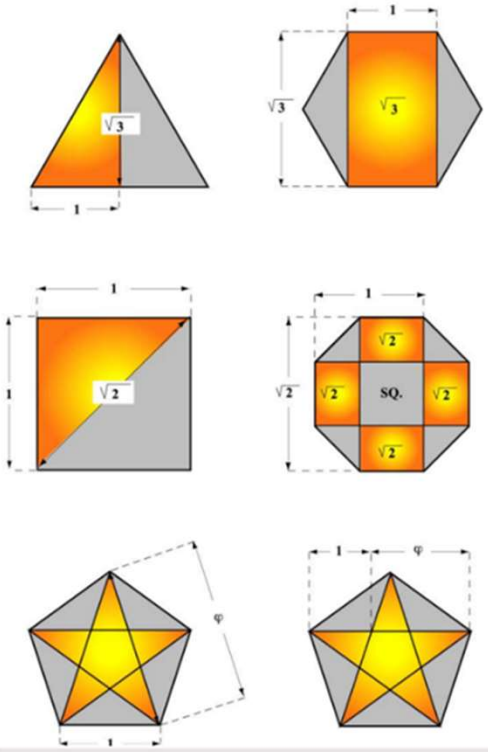
The Square Root, Phi, and Pythagorean 3,4,5 Rectangles



The phi rectangle is made by setting out a square and then splitting a measuring cord at the square's base to find its halfway. The length of the rectangle is then determined by stretching a string from the midpoint at the base of the square to either of the top corners of the square and swinging it downwards until it is parallel to the base of the square. A square root of five rectangles is produced if this technique is conducted from both top corners of the square

Figure 2

The Square Root and Phi Proportions and Regular Polygons



The square root and Phi Proportions Polygons Another dynamic feature of this set of rectangles is that they are rectangular expressions of regular polygon proportions. Examining the most basic set of regular polygons, the equilateral triangle, square, and pentagon, as well as all other regular polygons that can be generated from these three, such as the hexagon, octagon, decagon, and so on, reveals these relationships

Figure 3

The Square Root of Two, the Square Root of Three, Phi and the Shapes of Flowers and Shells

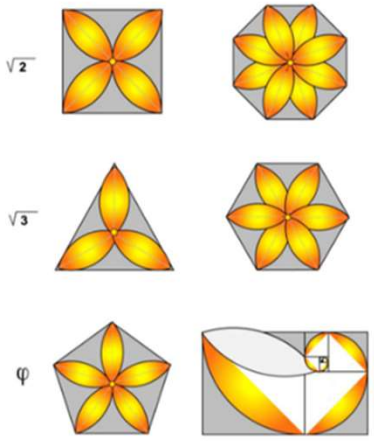
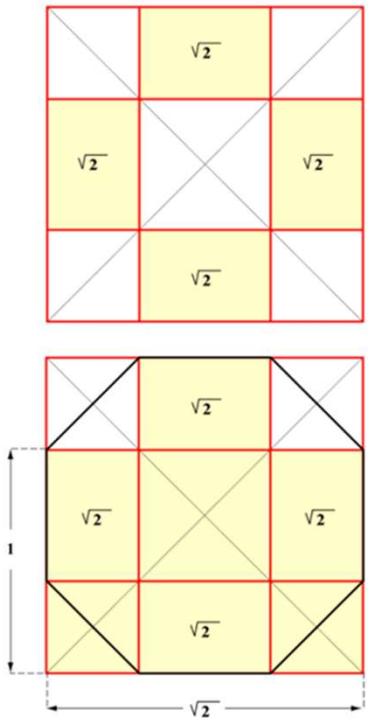


Figure 4

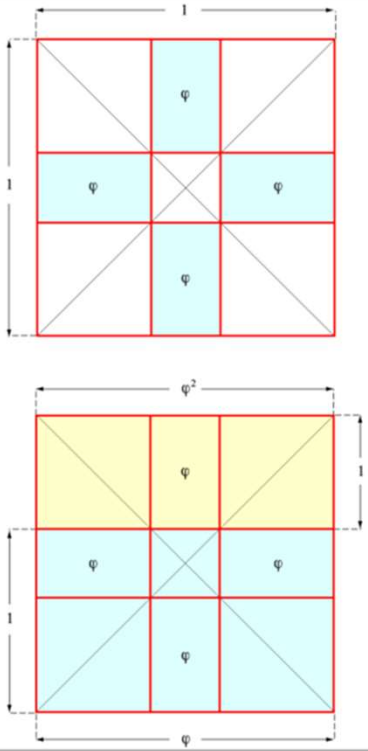
Formula Square-1



Formula Square-1 diagrams the subdivisions of a square by root two rectangles shaded in yellow and the remaining squares in white. The lower diagram illustrates the relationship of the root two subdivisions to a regular octagon (in bold black lines) inscribed in the principle square.

Figure 5

Formula Square-2



Formula Square-2 diagrams the subdivisions of a square by phi rectangles (shaded blue) and the remaining squares are in white. The lower diagram illustrates how these phi subdivisions also divide a square into a phi rectangle with the same length as the square (shaded blue) and a phi squared rectangle (shaded yellow)

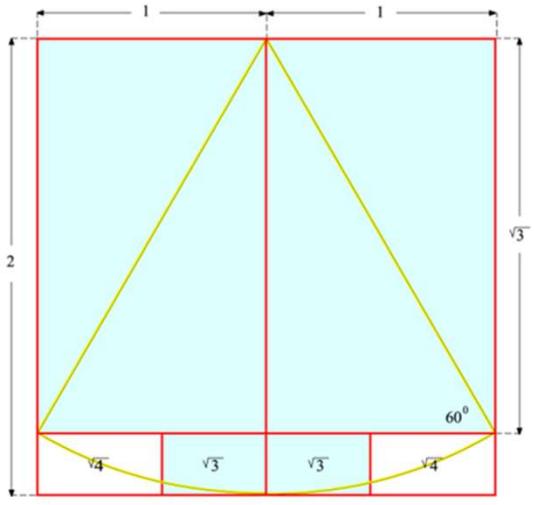


Figure 6

Formula Square-3

Formula Square-3 diagrams the subdivisions of a square by root three rectangles (shaded blue) and root four rectangles (in white). The highlighted diagonals of the larger paired root three rectangles are the radii for the arc that terminates at the center of the base of the square. The remaining space at the base of the square is subdivided by root three and root four.

Figure 7

Formula Square-4

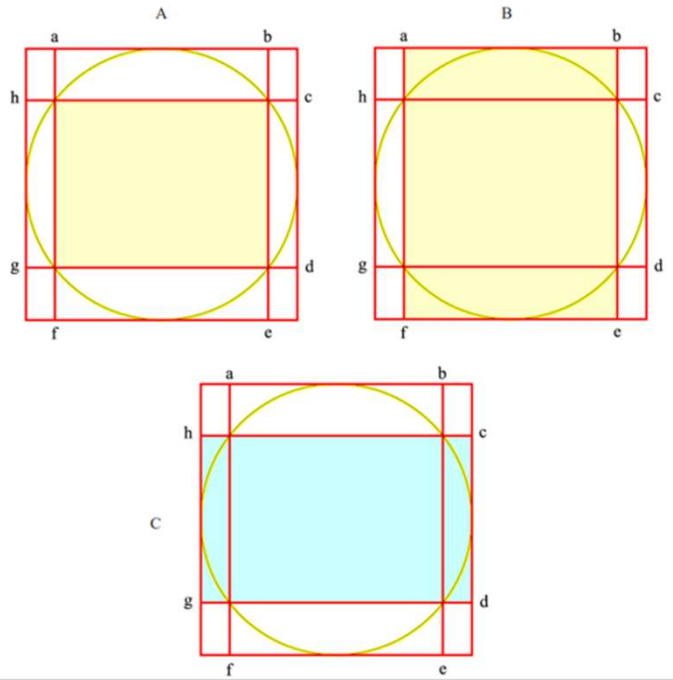
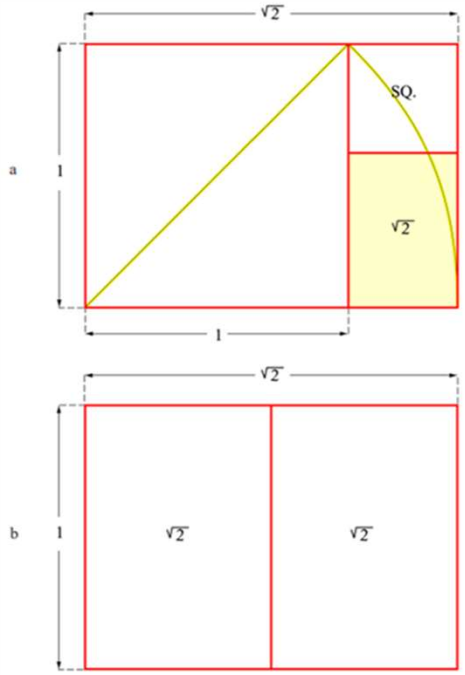


Diagram A shows a root phi rectangle (shaded yellow) inscribed within a circle that is inscribed within a square. Diagram B shows a root phi rectangle (a.,b,e,f) whose width is equal to the length of the root phi rectangle in diagram A and whose height is equal to that of the square. Diagram C shows a phi rectangle (shaded blue) (c,d,g,h) whose length is equal to that of the square and whose height equals that of the root phi rectangle in diagram A

Figure 8

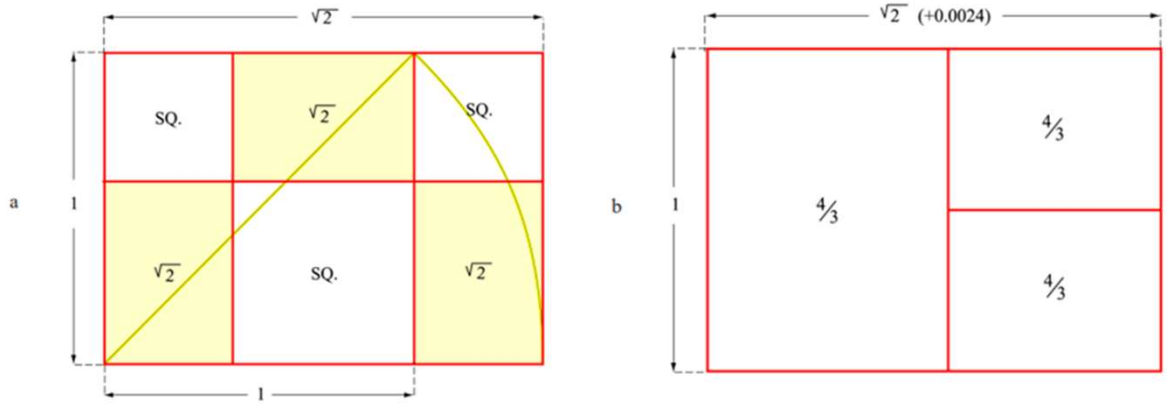
Formulae Square Root of Two-1and 2



Formula Square Root of Two-1 (a) diagrams the subdivision of a root two rectangle by two squares (in white) and a remaining root two rectangle (shaded yellow). The diagonal of the larger square is the radius that determines the length of the base rectangle. Formula Square Root of Two-2 (b) diagrams the subdivision of a horizontal root two rectangle by two vertical root two rectangles. (Note that the root two rectangle is its own gnomon.)

Figure 9

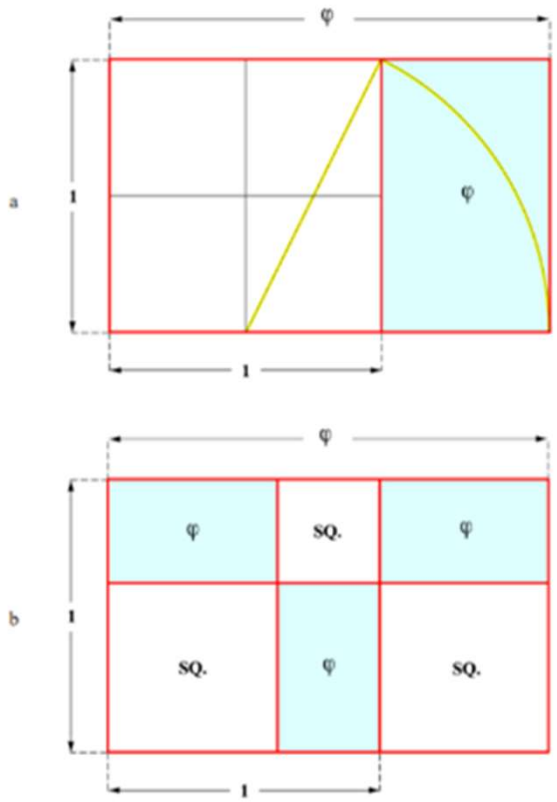
Formulae Square Root of Two-3 and 4



Formula Square Root of Two-3 (a) diagrams the subdivision of a root two rectangle by squares (in white) and root two rectangles (shaded yellow). The highlighted diagonal is 45 degrees and is the radius for the arc that forms the root two rectangle. Formula Square Root of Two-4 (b) is a virtually perfect subdivision of a root two rectangle by a three Pythagorean 3,4,5, rectangle. (The margin of error for this formula is 0.0024.)

Figure 20

Formulae Phi-1 and 2



Formula Phi-1 (a) diagrams the subdivisions of a phi rectangle into a square (in white) and a smaller phi rectangle (shaded blue). The highlighted diagonal from the center base of the square, to its upper corner, is the radius for the arc that forms the phi rectangle. Formula Phi-2 (b) subdivides a phi rectangle into squares (in white) and smaller phi rectangles (shaded blue)

Figure 22

Formula Square Root of Phi-1

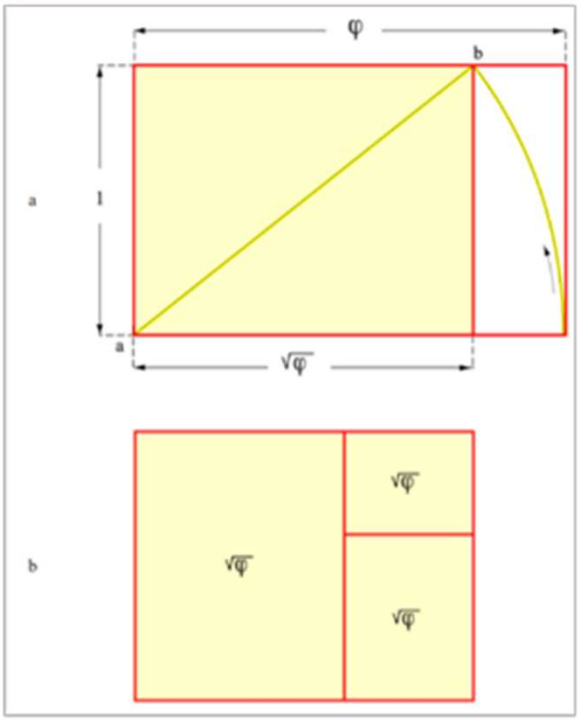
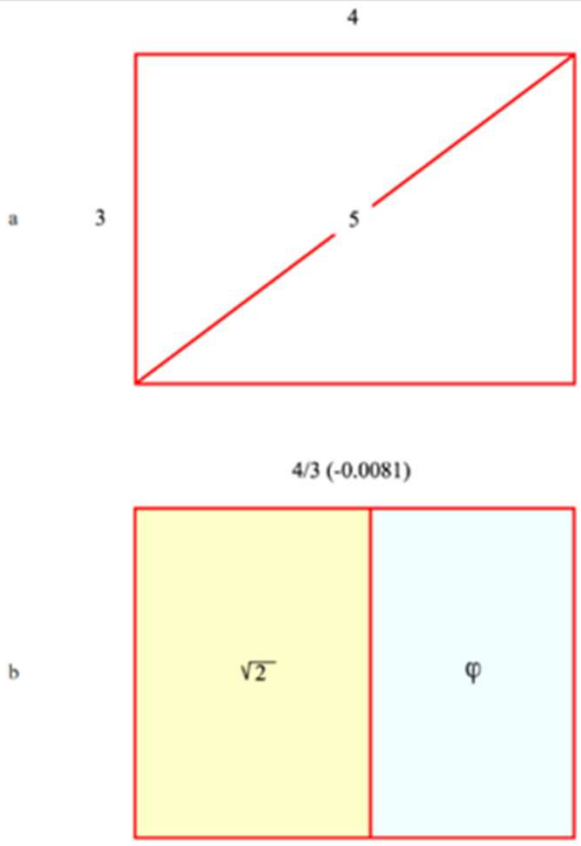


Diagram a illustrates the only simple way I know of to create a root phi rectangle. First, lay out a phi rectangle then stretch a cord or place the points of a compass across the length of the phi rectangle and use this segment as a radius to form an arc to the opposite side of the phi rectangle. The resulting rectangle (shaded yellow) has a length of root phi (1,272...) and a diagonal (a,b) of phi. Formula Square Root of Phi-1 (b) is a root phi rectangle subdivided into three smaller root phi rectangles. The diagonal of the smallest is equal to the height of the next largest, whose diagonal is equal to the width of the largest

Figure 26

Formulae Pythagorean 3,4,5-1 and 2

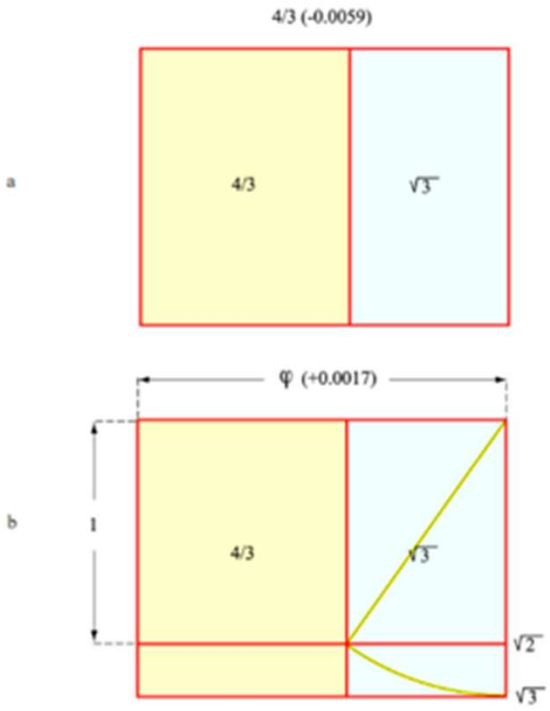


Formula Pythagorean 3,4,5-1 (a) diagrams the relationship of the whole number subdivisions of the sides of this rectangle and its diagonal. Only Pythagorean rectangles have a diagonal that can be divided into even units relative to its sides.

Formula Pythagorean 3,4,5-2 (b) is a virtually perfect formula that subdivides a Pythagorean 3,4,5 rectangle by a root two rectangle (shaded yellow) and a phi rectangle (shaded blue). (The margin of error is 0.0081.)

Figure 27

Formulae Pythagorean 3,4,5-3 and 4

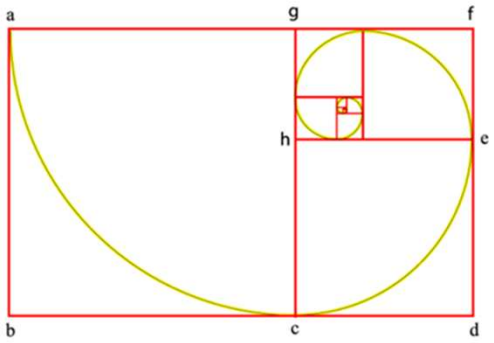


Formula Pythagorean 3,4,5-3 (a) is a virtually perfect formula that subdivides a Pythagorean 3.4.5 rectangle by a vertical Pythagorean 3,4,5 rectangle (shaded yellow) and a root three rectangle (shaded blue). (The margin of error is 0.0059.)

Formula Pythagorean 3,4,5-4 (b) is an elaboration of formula Pythagorean 3,4,5-3. The root three rectangle is subdivided by a root two rectangle (highlighted yellow diagonal) and the base of this root two rectangle is extended across the length of the entire rectangle and produces a virtually perfect phi rectangle with a margin of error of +0.0017...

Figure 33

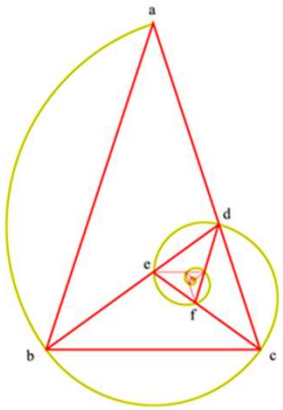
Formula Phi Equiangular Spiral-1



Formula Phi Equiangular Spiral-1 diagrams how a phi rectangle can be subdivided into smaller squares and phi rectangles add infinitum. Add a square (a,b,c,f) to a phi rectangle (a,b,d,f) and the remainder (c,d,f,g) is a similar phi rectangle. Add a square to this smaller rectangle (c,d,e,h) and the remainder (c,d,g,h,) is also a smaller phi rectangle and so on. These squares also provide the radii for the arcs of the equiangular spiral highlighted in yellow. Radii g,a and g,c are used to form the arc a,c; radii h,c and h,e to form arc c,e, etcetera.

Figure 34

Formula Phi Equiangular Spiral-2

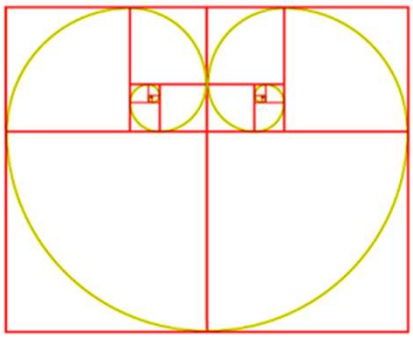


Formula Phi Equiangular Spiral-2. Begin with a triangle whose base (b,c) equals one and the slope (a,b) equals phi. Place a compass or cord at b,c, and make an arc pivoting from b until b,c,crosses the slope a,c (at position d). Draw the line d,b, and c,d,b is a similar triangle to a,b,c at a ratio of one to phi. Place your compass or cord at c,d and pivot from c until c,d crosses line d,b at e and draw line e,c, creating another similar triangle, etcetera. These divisions of a phi triangle also provide the radii to form the equiangular spiral highlighted in yellow. Radii d,a and d,b form arc a,b; radii e,c and e,b form arc b,c; radii f,c and f,d form arc d,c, etceter

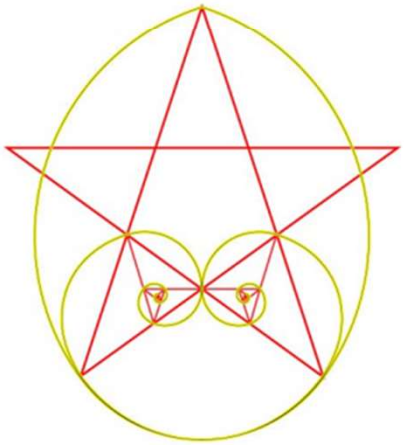
Figure 35

Formulae Phi Equiangular Spiral-3 and 4

a



b



Formula Phi Equiangular Spiral-3 (a) is Formula Phi Equiangular Spiral-1 doubled and mirrored. Formula Phi Equiangular Spiral-4 (b) is essentially the equiangular spiral of Phi Equiangular Spiral-2 created on both sides of the original phi triangle and shows the intrinsic relationship of this formula to the pentagram.

3.5.4.c) GEOMETRY IN MAYA VERNACULAR ARCHITECTURE

The fundamental designs of Vernacular Maya constructions, known as "Casas Mayas" in Yucatán.

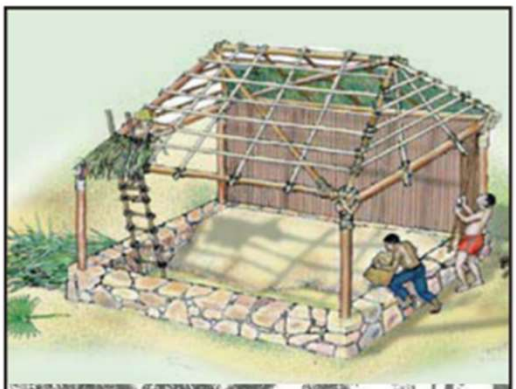
Today, there are two fundamental types of vernacular dwellings in Mesoamerica: apsidal and rectangular. Traditionally, the frames are made entirely of wood beams and poles tied together with vines (bejuco), and the roofs are carpeted with palm fronds or grasses. Walls are usually composed of wattle and daub, although they can also be made of rough stone masonry, adobe bricks, or timber poles or boards. Stucco is sometimes used to finish the walls. The schematic and images (Figures 36-39) below depict a few of the numerous kinds of Maya vernacular houses:

Figure : 36,37,38,39, "PowellDissertation2010_MayaGeometry.pdf"

Figure 36

Diagram A and Photograph 1 of Maya Vernacular Houses

a



b

Diagram a, of a Maya house being built, shows some of the principal components of Maya houses: The low stone wall that is often built around the roof support posts to protect the walls from moisture and rot, the hard packed earth or sascob (deteriorated limestone) floor, the roof frame, and rafters, the bijuco lashings and thatch. Photograph 1 (b) shows apsidal houses, with bare wattle and daub walls, from the Yucatan peninsula.

Figure 37

Photographs 2 and 3, Two Styles of Maya Vernacular Houses, Yucatan Peninsula, Mexico

a

b

Photograph 2 (a) is of a rectangular Maya house with bare wattle and daub walls. Photograph 3 (b) is of an apsidal Maya house with stuccoed and painted wattle and daub walls

Figure 38

Photographs 4 and 5, Two Styles of Maya Vernacular Houses, Chiapas, Mexico

a

b

Photograph 4 (a) is of a rectangular Maya house with a porch and wood plank walls. Photograph 5 (b) is of an apsidal Maya house with wattle and daub walls and a stuccoed doorway.

Figure 39

Photographs 6 and 7, Two Styles of Maya Vernacular Houses, Chiapas, Mexico

a

b

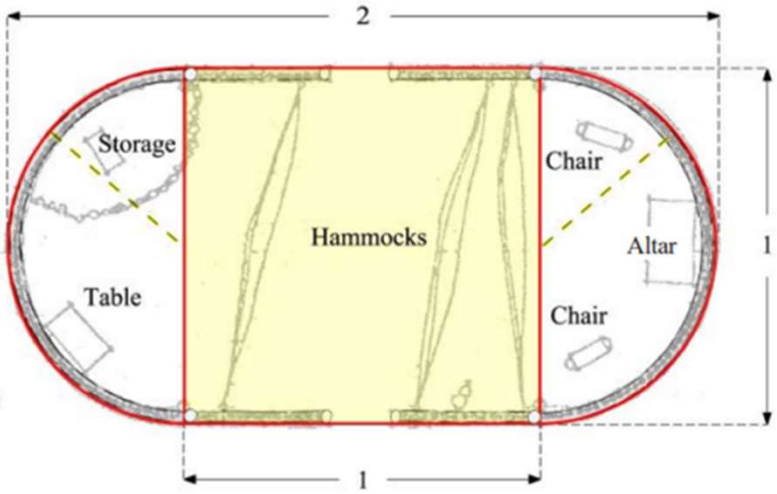
Photograph 6 (a) is of an apsidal Maya house with wattle and heavily daubed walls. Photograph 7 (b) is of an apsidal house with stuccoed masonry walls.

Most of the vernacular houses are designed or laid out with measuring cords by Maya shamans and house builders in the Yucatan peninsula, in the Highlands of Chiapas and Guatemala, and in Honduras

Figure : 40,41,44,45,70,71 “PowellDissertation2010_MayaGeometry.pdf”

Figure 40

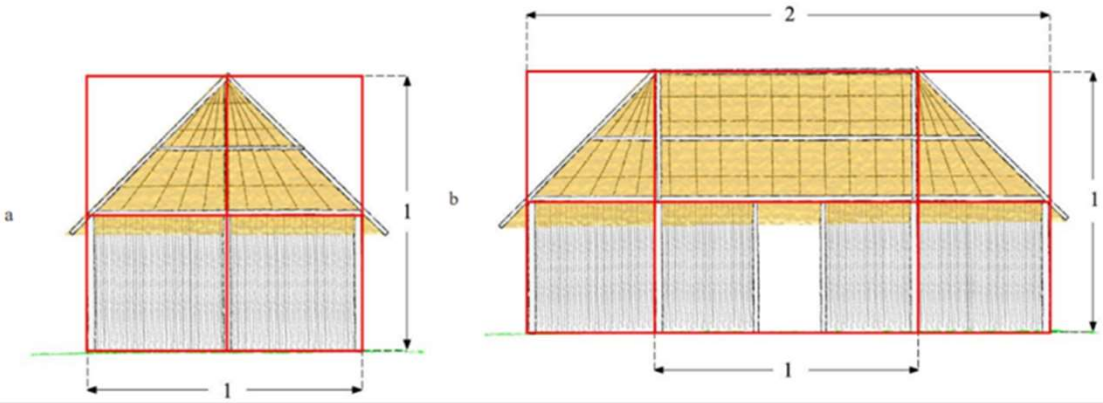
Plan of Maya Vernacular House 1, Don Pedro’s House,
Izamal, Yucatan, Mexico



Maya Vernacular House 1 is probably the most common style of Maya vernacular house in the Yucatan Peninsula. The parallel sides of the apsidal plan and the four principle roof support posts form a square (shaded yellow). The center of the right and left-hand sides of this square, to the corners, are the radii for the half circle arcs that form the apsis. The width to length of the plan is one to two (square root of four)

Figure 41

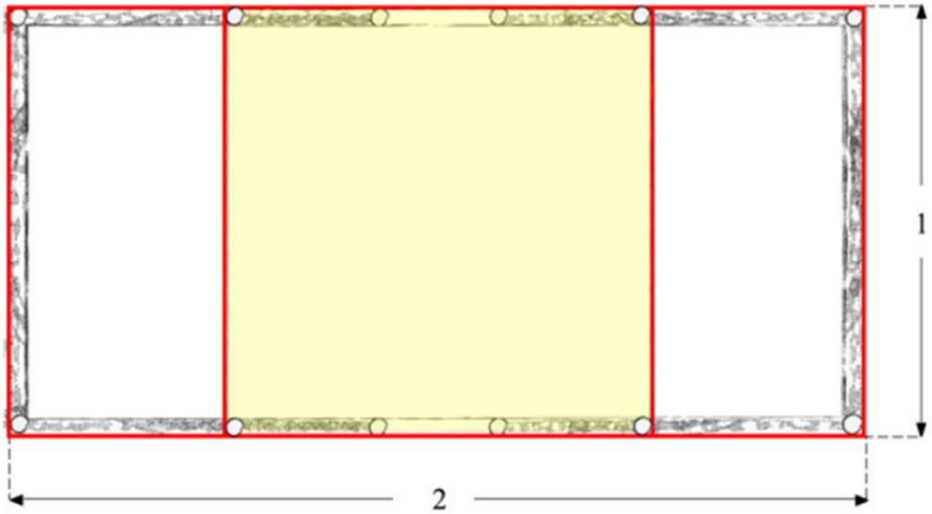
Elevations of Maya Vernacular House 1, Don Pedro’s House,



The side elevation (a) is of equal height and width and is inscribed by a quartered square. The spring line and roof are of equal height. The front elevation (b) has a height of one to a length of two and the pitch of the roof in both elevations is forty-fi ve degrees.

Figure 44

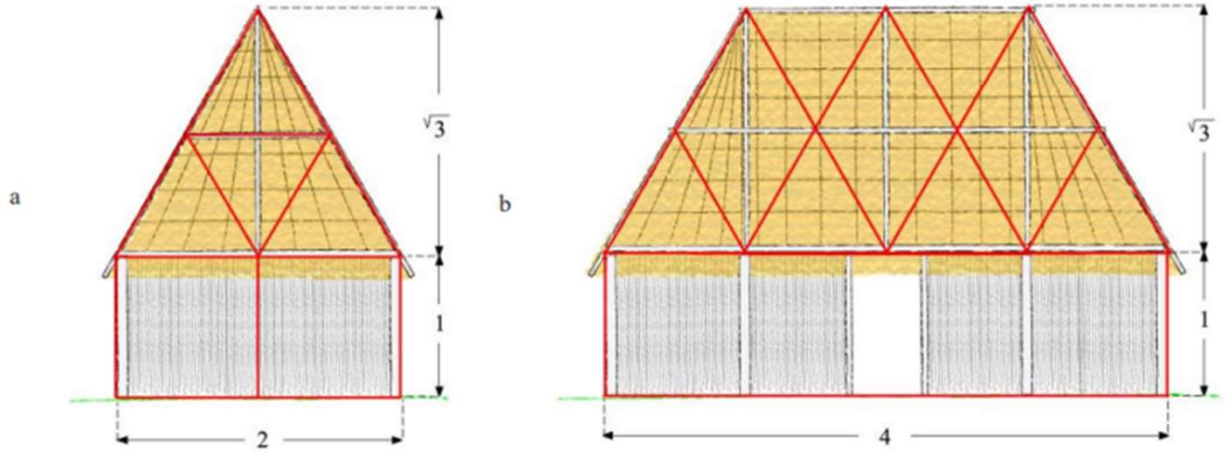
Plan of Maya Vernacular Houses 3, House Built by Don Lucio, Yucatan, Mexico



The width to length of the plan of Maya Vernacular House 3 is one to two (root four). The principal roof support posts form a central square (shaded yellow).

Figure 45

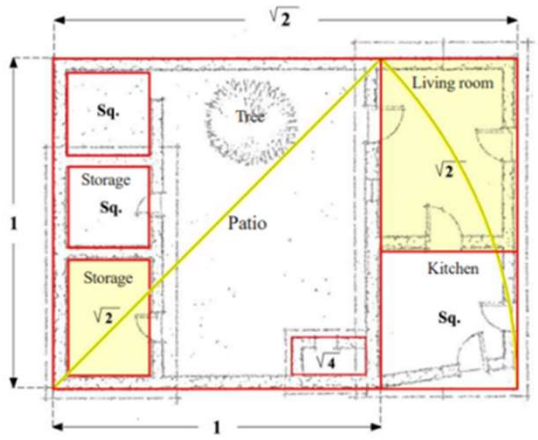
Alternate Elevations of Maya Vernacular Houses 1 and 3, Houses Built by Don Lucio, Yucatan, Mexico



These elevations (a and b) share the same plan designs as Maya Vernacular Houses 1 and 3. The height of the spring line of the side elevation (a) to the width of the house is a ratio of one to two. The roof forms an equilateral triangle. The pitch of the roof in both elevations and all of the diagonal red lines are sixty degrees. The height of the spring line of the front elevation (b) to the length of the house is a ratio of one to four. The height of the spring line to the height of the roof is one to root three.

Figure 70

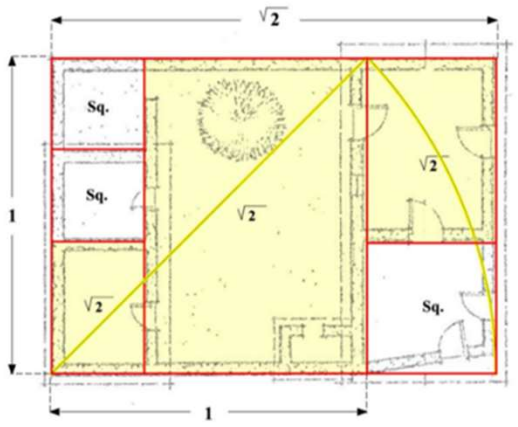
Plan of Maya Vernacular Houses 21,
Santa Maria Chiquimula, Guatemala
Measured Drawing by Bonilla Privaral (1989)



The plan of Maya Vernacular House 21 is of the adobe brick walls that enclose the patio, and the form the walls of the storage sheds, living room, and kitchen. The storage sheds, living room, and kitchen are framed by wood posts (embedded in the adobe brick walls) and beams, the roofs are framed with wood beams and poles and thatched. The entire structure is inscribed by a root two rectangle. The adobe brick walls that enclose the patio and storage sheds are inscribed by a square, the diagonal of which (highlighted yellow) is equal to the length of the plan and is the radius for the arc that terminates at the lower right corner of the diagram. The kitchen is inscribed by a square (in white), and the living room is inscribed by a root two rectangle (shaded yellow). The square patio and the square and root two subdivisions of the kitchen and living room are a clear example of Formula Square Root of Two-1. The interior of the smaller of the two storage sheds is inscribed by a square whose diagonal is equal to the length of the interior of the larger storage shed, which is inscribed by a root two rectangle (shaded yellow). The remaining, semi-enclosed space in the upper left corner of the patio is also inscribed by a square of equal size to the square inscribed in the interior of the smaller storage shed. The front wall of the kitchen (lower right corner) is also the main entrance to the house and is intentionally skewed or angled inward to leave a roofed dry entry to the house, protected from the rains.

Figure 71

Plan of Maya Vernacular Houses 21b,
Santa Maria Chiquimula, Guatemala
Measured Drawing by Bonilla Privaral (1989)



The plan of Maya Vernacular House 21b subdivides the square patio into two root two rectangles (shaded yellow) and two squares (in white) and implies that the architect of this structure may also have been familiar with the root two and square subdivisions of a square diagrammed in Formula Square-1.

3.5.4.d) GEOMETRY IN CLASSIC AND POST-CLASSIC MAYA ARCHITECTURE

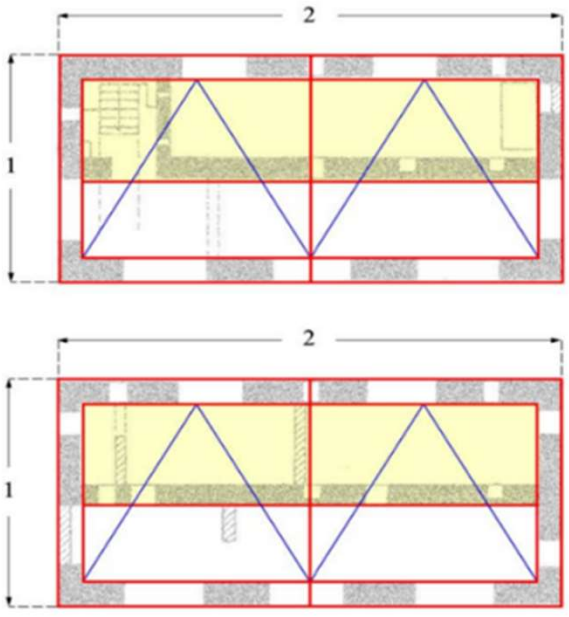
Evaluating and presenting Maya geometry as it appears in the layout and design of Maya objects. The Maya's repeating proportions currently comprise a coherent and interconnected set of rectangular proportions that is, starting with a square, the length of each consecutive rectangle is equal to the diagonal of the preceding one as seen in Figure:76,77,78,79,80,81,82,83,84,85,86,91,93,94,95,96,97,98,

99,133,134,135,148: “PowellDissertation2010_MayaGeometry.pdf”

The examples chosen are based on the availability of published measured drawings, and they represent a wide temporal and spatial range of Pre-Columbian Maya ceremonial architecture, as well as the geometry of classic and post-classic period structures at Palenque, Tikal, and Altar de los Sacrificios, followed by analyses of simple plans from the Post-Classic site. of Chichen Itza, Acanceh, Dzibilchaltun, Xpuhil, Zempoala, and El Tajin. The set of square root, phi, and Pythagorean 3,4,5 rectangles and their sub divisions found in vernacular and ceremonial structures in Pre-Columbian architecture. It is worth noting that the square root, phi, and Pythagorean rectangles are always expressed in relation to the structures' interior and exterior walls (rather than the walls' centres), and that the recommended subdivisions of these rectangles generally focus on the structures' front galleries and entrances.

Figure 76

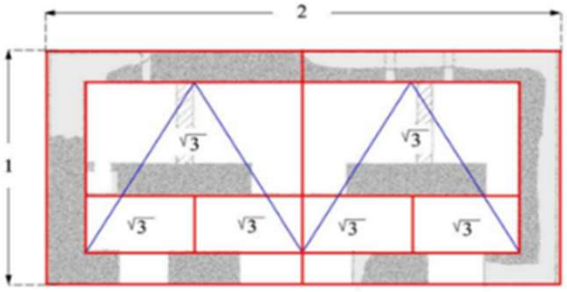
Plan of Houses G and H, Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)



The exterior walls are inscribed by a square root of four rectangles (one to two), and the interior space is subdivided into two, two over root three rectangles, each of which are inscribed by equilateral triangles (blue lines). The interior vault support walls and the rear galleries are inscribed by root four rectangles (shaded yellow).

Figure 77

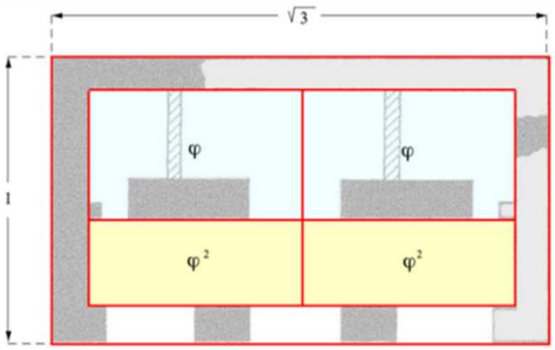
Plan of Temple XVIIIa, Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)



Like Houses G and H, the exterior walls of Temple XIIIa are inscribed by a root four rectangle (one to two), and the interior space is subdivided into two, two over root three rectangles, each of which are inscribed by equilateral triangles (blue lines). The interior vault support walls further subdivide the interior space into four square root of three rectangles (front gallery) and the remaining space into two square root of three rectangles, as per Formula Two Over Square Root of Three-2.

Figure 78

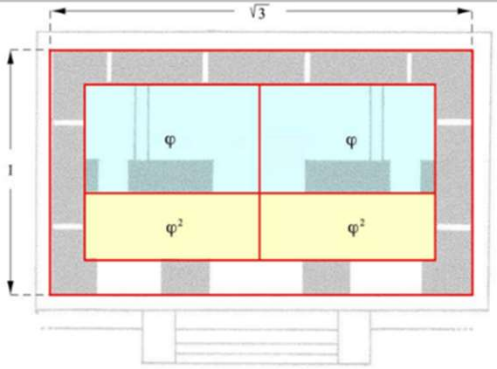
Plan of Temple XVIII, Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)



Temples XVIII and XVIIIa are a pair of temples that share a platform and are arranged parallel to to each other, about one meter apart. Note that the interior and exterior geometry of these temples are essentially reversed. The exterior walls of Temple XVIII are inscribed by a root three rectangle, and the interior space inscribes a root four rectangle. The interior vault support walls further subdivide the double squares of the interior space into two phi-squared rectangles (front gallery, shaded yellow) and the remaining space into two phi rectangles (shaded blue), as per Formula Square-2.

Figure 79

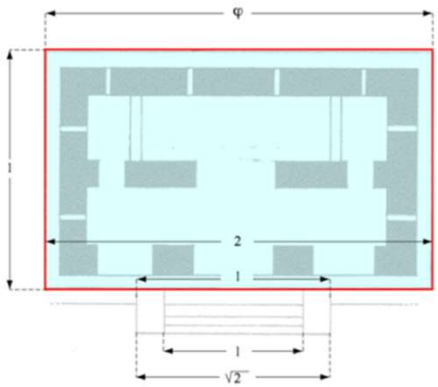
Plan of Temple II, Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)



Temple II shares identical proportions as those described for Temple XVIII on the previous page. The exterior walls are inscribed by a root three rectangle, and the interior space inscribes a root four rectangle. As in Temple XVIII, interior vault support walls further subdivide the double squares of the interior space into two phi-squared rectangles (front gallery, shaded yellow) and the remaining space into two phi rectangles (shaded blue), as per Formula Square-2.

Figure 80

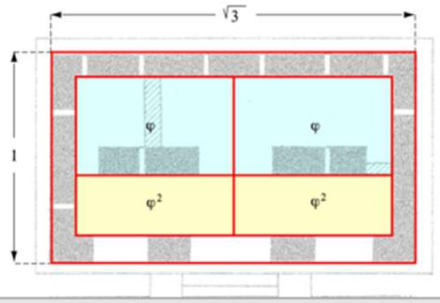
Plan of the Raised Platform and Staircase of Temple II.
Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)



The raised platform of Temple II is inscribed by a phi rectangle (shaded blue). If the width of the staircase is one, than the width of the balustrade is square root of two. If the width of the balustrade is one, the width of the platform is two.

Figure 81

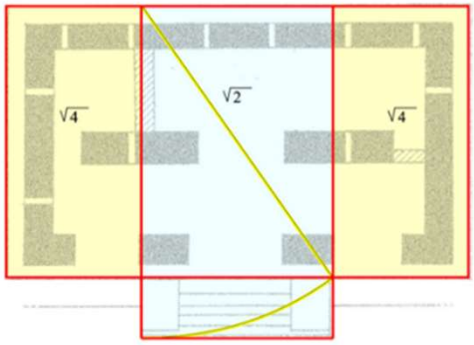
Plan of Temple IV, Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)



Temple IV also shares identical proportions with those described for Temples II and XVIII on the previous pages. The exterior walls are inscribed by a root three rectangle, and the interior space inscribes a root four rectangle. As in Temples II and XVIII, interior vault support walls further subdivide the double squares of the interior space into two phi-squared rectangles (front gallery, shaded yellow) and the remaining space into two phi rectangles (shaded blue), as per Formula Square-2

Figure 82

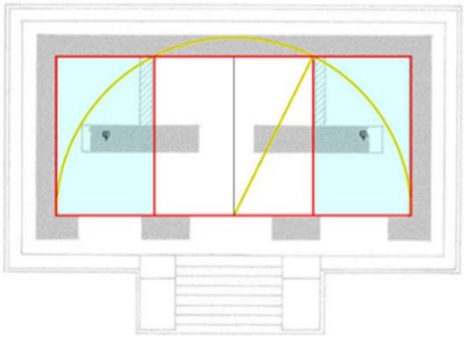
Plan of the Raised Platform and Staircase of Temple IV, Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)



Where the balustrade is attached to the raised platform of Temple IV, straight lines were probably drawn across the width of the platform, creating a root two rectangle, the diagonal of which is demarcated with a yellow highlighted line. This diagonal may have been used as the radius of an arc to determine the width of the balustrade and to produce a root three rectangle (shaded blue). The remaining rectangles to either side of the balustrade form root four rectangles (shaded yellow).

Figure 83

Plan of Temple VIII, Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)



The interior space of Temple VIII is inscribed by a root five rectangle that is subdivided into a square (white) that is defined by the placement of the curtain walls of the rear gallery and two phi rectangles (shaded blue), as per Formula Square Root of Five-3.

Figure 84

Plan of the Raised Platform and Staircase of Temple VIII, Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)

The geometry of the platform of Temple VIII is identical to that of the platform of Temple IV. Where the balustrade is attached to the raised platform of Temple IV, straight lines were probably drawn across the width of the platform, creating a square root of two rectangle, the diagonal of which is demarcated with a yellow highlighted line. This diagonal may have been used as the radius of an arc to determine the width of the balustrade and to produce a square root of three rectangle (shaded blue). The remaining rectangles to either side of the balustrade form square root of four rectangles (shaded yellow).

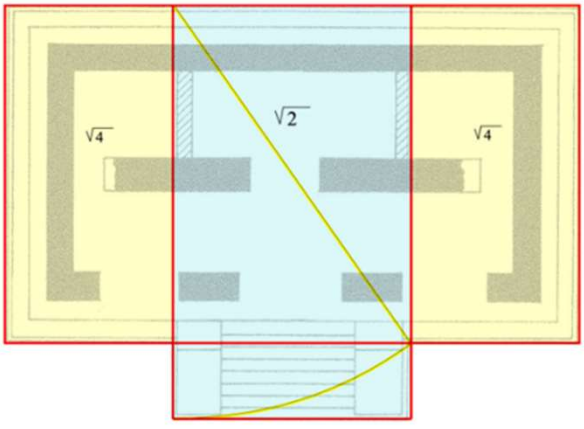
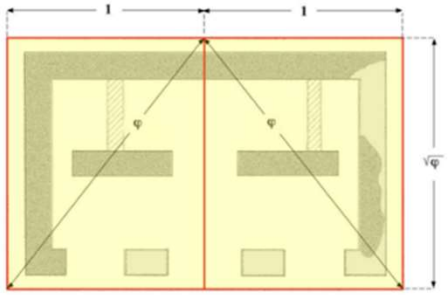


Figure 85

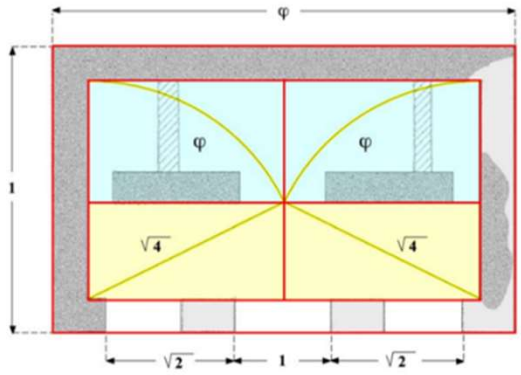
Plan of the Raised Platform of Temple XII,
Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)



The raised platform of Temple XII is inscribed by a rectangle with a length of two to a width of root phi.

Figure 86

Plan of Temple XII,
Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)



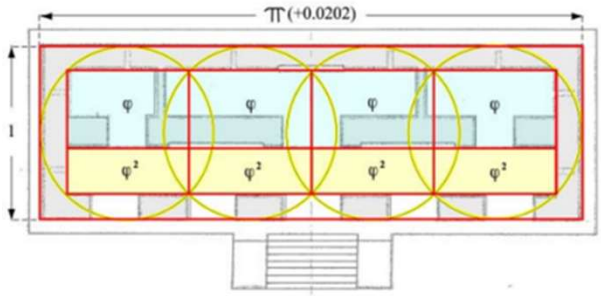
The exterior walls of Temple XII are inscribed by a phi rectangle. The front gallery is inscribed by two root four rectangles, the diagonals of which are the radii for the arcs that defi ne the two phi rectangles that inscribe the rear gallery and principle roof support piers. If the width of the central entrance is one, then from the central entrance to the outer edges of the lateral entrances is root two

Figure 91

Plan of the Temple of the Inscriptions,
Palenque, Chiapas, Mexico
Measured Drawing by G. F. Andrews (1974)

The interior walls of the Temple of the Inscriptions are inscribed by a rectangle with a ratio of one to four that is divided into four squares. The front gallery subdivides these squares into phi squared rectangles (shaded yellow) and phi rectangles (shaded blue), as per Formula Square-2. Four circles inscribe the four squares and defi ne the width of the walls. Whether intentional or not, this formula produces a width to length ratio of one to pi minus 0.0202. Where the balustrade is attached to the raised platform (Figure b), straight lines are drawn across the width of the platform, creating a root phi rectangle, the diagonal of which is demarcated with a yellow highlighted line. This diagonal is the radius of an arc that determines the width of the balustrade and creates a phi rectangle (shaded blue). The remaining rectangles to either side of the balustrade are squares (shaded yellow).

a



b

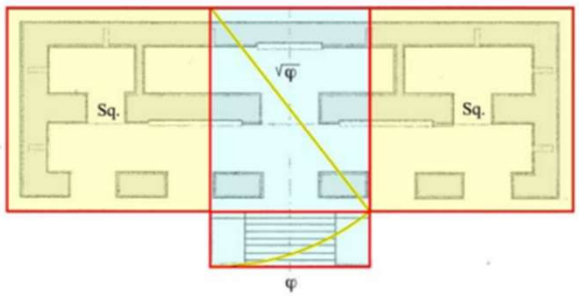
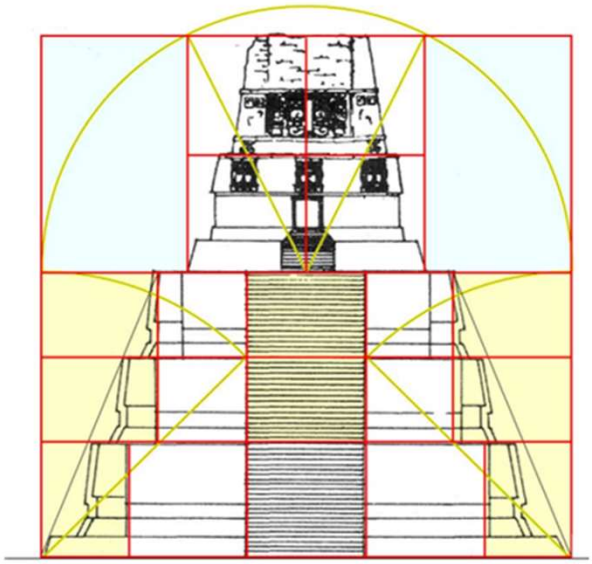


Figure 93

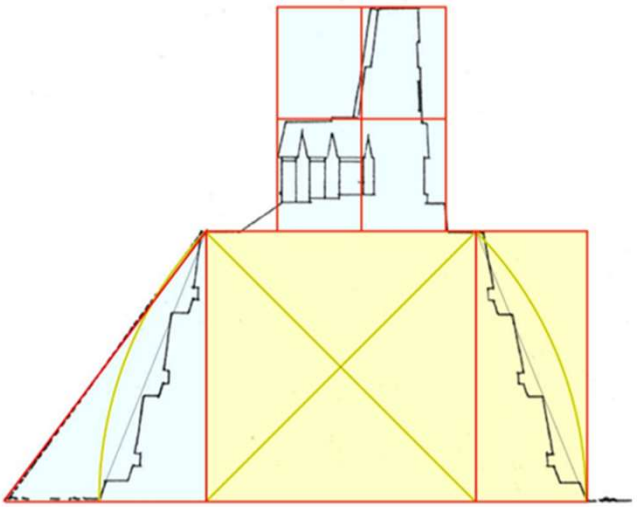
Elevation of Temple I, Tikal, Guatemala
Measured Drawing by J.A. Gomez R. (Marquina 1951)



Inscribed on either side of the staircase are square root of two rectangles that are subdivided into squares (the vertical risers of the three terraces in white). The remaining spaces and inset corners are inscribed by square root of two rectangles (shaded yellow). The staircase, too, is subdivided into a square root of two rectangle and a square. The yellow highlighted diagonals are forty-five degrees and are the radii for the arcs that define the height of the upper terrace. The temple proper is inscribed by a square (in white). The horizontal center of the square divides the roof from the roof comb. The diagonals from the center base of this square to its upper corners are the radii for the arc (shaded blue) that defines the phi rectangles to either side of the temple. The phi rectangles, along with the central square, form a square root of fi ve rectangle subdivided via Formula Square Root of Five-3.

Figure 94

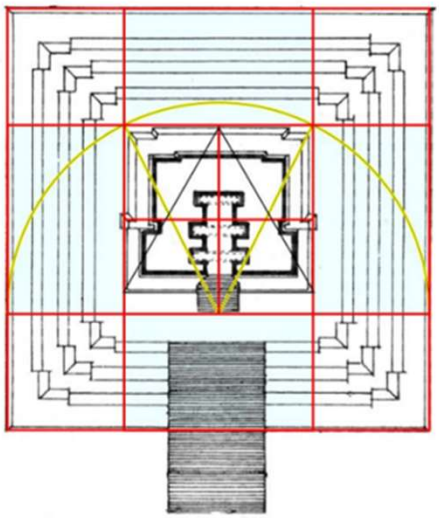
Section of Temple I, Tikal, Guatemala
Measured Drawing by J.A. Gomez R. (Marquina 1951)



The width of the upper platform of the three-tiered base of Temple I is equal to its height, forming a square whose diagonals are shown in yellow highlighted lines. These are the radii for the arcs that form square root of two rectangles to either side of the square (shaded yellow on the right side). The section of the temple is inscribed by a Pythagorean 3,4,5 rectangle (shaded blue) that is quartered. The triangle formed from where the top of the staircase meets the upper platform to the base of the pyramid is a Pythagorean 3,4,5 triangle (also shaded blue). If the base of this triangle is three, its height is four and the slope of the stairs is five

Figure 95

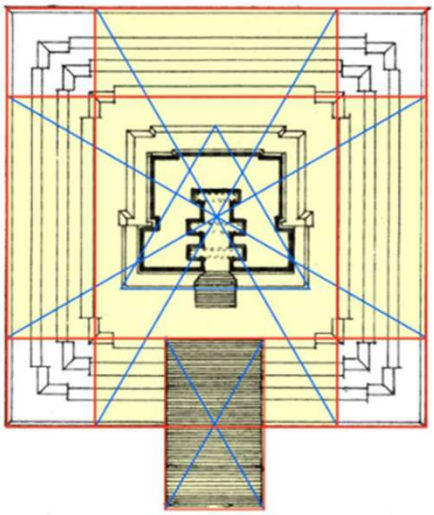
Plan of Temple I (a), Tikal, Guatemala
Measured Drawing by J.A. Gomez R (Marquina 1951)



The plan of the pyramidal base of Temple I and the plan of the temple proper, including its stair□case, are inscribed by squares. The square that inscribes the temple is quartered and the diagonals drawn from the lower center of this square to its upper corners are radii foe the arc that defi nes the phi rectangles (shaded blue) to either side of it. This process would be repeated at a ninety-degree angle to produce the phi rectangles to the front and rear of the temple

Figure 96

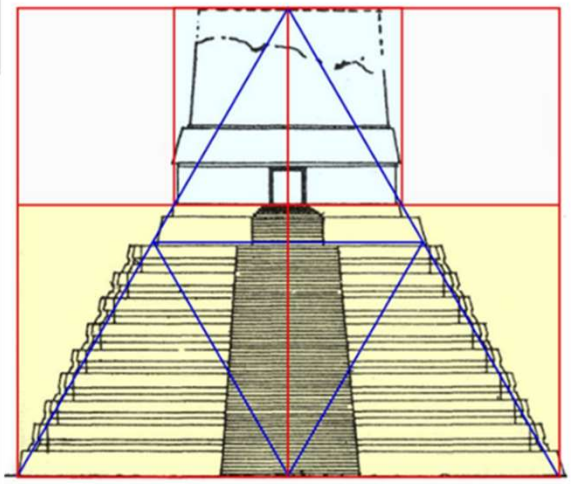
Plan of Temple I (b), Tikal, Guatemala
Measured Drawing by J.A. Gomez R. (Marquina 1951)



The plan of the temple proper, not including the staircase, inscribes an equilateral triangle (blue lines). Straight lines drawn from the edges of the square upper platform to the edges of the base of the pyramid form square root of three rectangles (shaded yellow, with their diagonals, drawn in blue lines, forming equilateral triangles). The plan of the principle staircase is also inscribed by a square root of three rectangle whose diagonals (also in blue lines) form equilateral triangles.

Figure 97

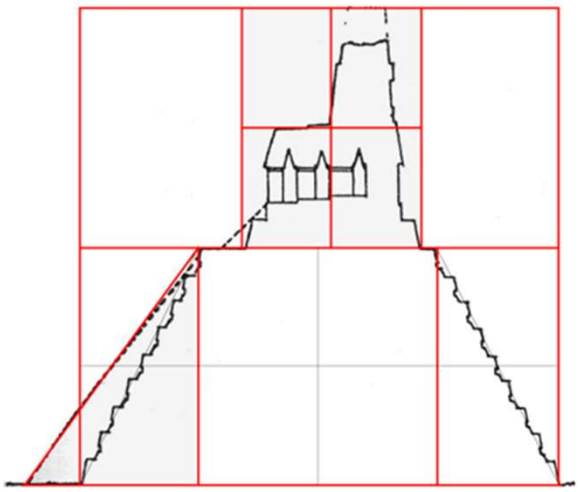
Front Elevation of the Temple II, Tikal, Guatemala
Measured Drawing by J.A. Gomez R. (Marquina 1951)



The front elevation of Temple II is inscribed by a virtually perfect two over square root of three rectangle that is subdivided via Formula Two Over Square Root of Three-e. The width of the pyra□mid, to the base of the temple, is inscribed by a square root of four rectangle (shaded yellow). The temple is inscribed by a two over square root of three rectangle (shaded blue), and the remaining space to either side of the temple is inscribed by square root of phi rectangles (shaded gray). An equilateral triangle is inscribed in the virtually perfect two over square root of three rectangle that defi nes the slope of the pyramid, and this equilateral triangle is divided in half at the top of the pyramid

Figure 98

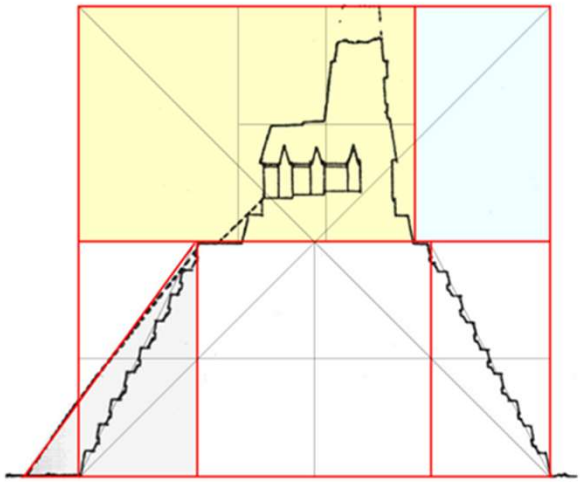
Section of Temple II (a), Tikal, Guatemala
Measured Drawing by J.A. Gomez R. (Marquina 1951)



The side section of the pyramidal base of Temple II is inscribed by a square root of four rectangle subdivided by a central square that is equal to the width of the top of the pyramid and two smaller square root of four rectangles to either side of this central square, the diagonals of which (fi ne black lines) defi ne the angle of the slope of the pyramid. Identically to Temple I, the section of the temple proper is inscribed by a quartered Pythagorean 3,4,5, rectangle, and the staircase is inscribed by a Pythagorean 3,4,5, triangle (shaded grey).

Figure 99

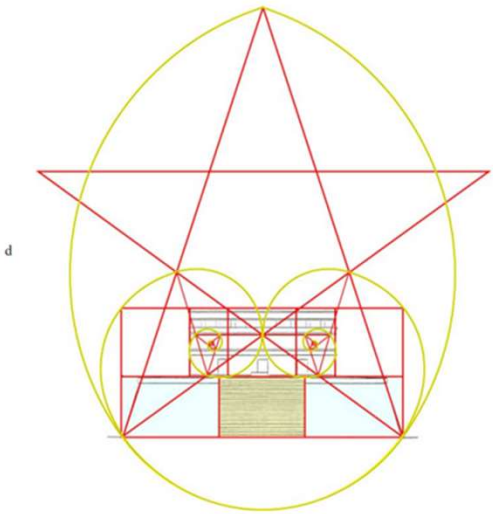
Section of Temple II (b), Tikal, Guatemala
Measured Drawing by J.A. Gomez R (Marquina 1951)



The section of Temple II may also be inscribed by a virtually perfect square that is divided hori□zontaly in half at the top of the pyramid. As noted in the previous diagram, the pyramid may be inscribed by a square root of four rectangle that is subdivided by a central square that is equal to the width of the top of the pyramid and two smaller square root of four rectangles to either side of this central square. The upper half of this diagram is inscribed by a virtually perfect square root of four rectangle that is subdivided at the rear of the temple by a square root of two rectangle (shaded blue) and a square root of three rectangle (shaded yellow), as per the Formula Square Root of Four-4.

Figure 133

South Elevation of Structure 3C7 (d), Chichen Itza, Yucatan, Mexico
Measured Drawing by Karl Ruppert (1952)



the diagram that overlays Structure 3C7 speculative. Because the angle of the platform and the angle of the base of a pentagram are seventy-two degrees, I decided to place the base of the pentagram, with its equiangular spirals, at the base of the platform. Note how the spirals fi t neatly within the temple and frame the doorways. Also note how the rectangle that inscribes the structure fi ts neatly within the spirals

Figure 135

East Elevations of Structure 3C7 (b and c), Chichen Itza, Yucatan, Mexico

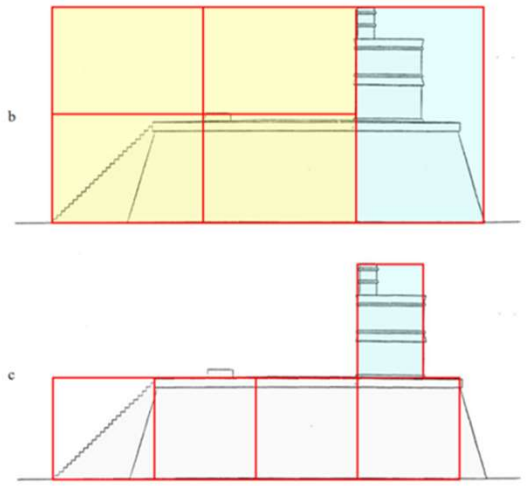
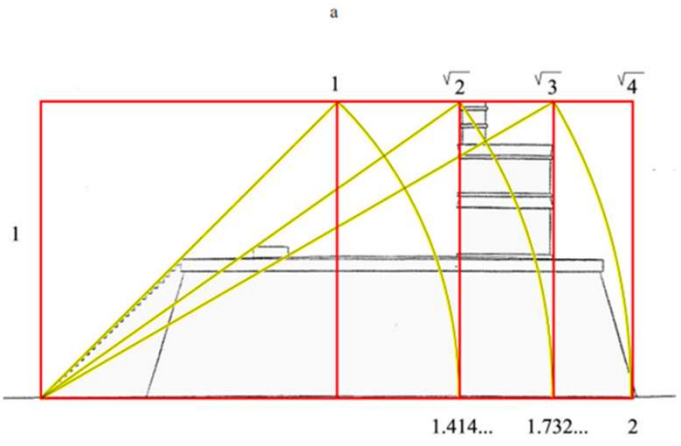


Diagram b inscribes the east elevation of Structure 3C7 by a virtually perfect square root of four rectangle, subdivided by a square root of two rectangle (quartered and shaded yellow) and a square root of three rectangle (shaded blue), as per Formula Square Root of Four-3. Diagram c shows the relationship between four squares, the upper platform, the temple, and the staircase (red lines). The east elevation of the temple proper is inscribed by a phi rectangle (shaded blue)

Figure 134

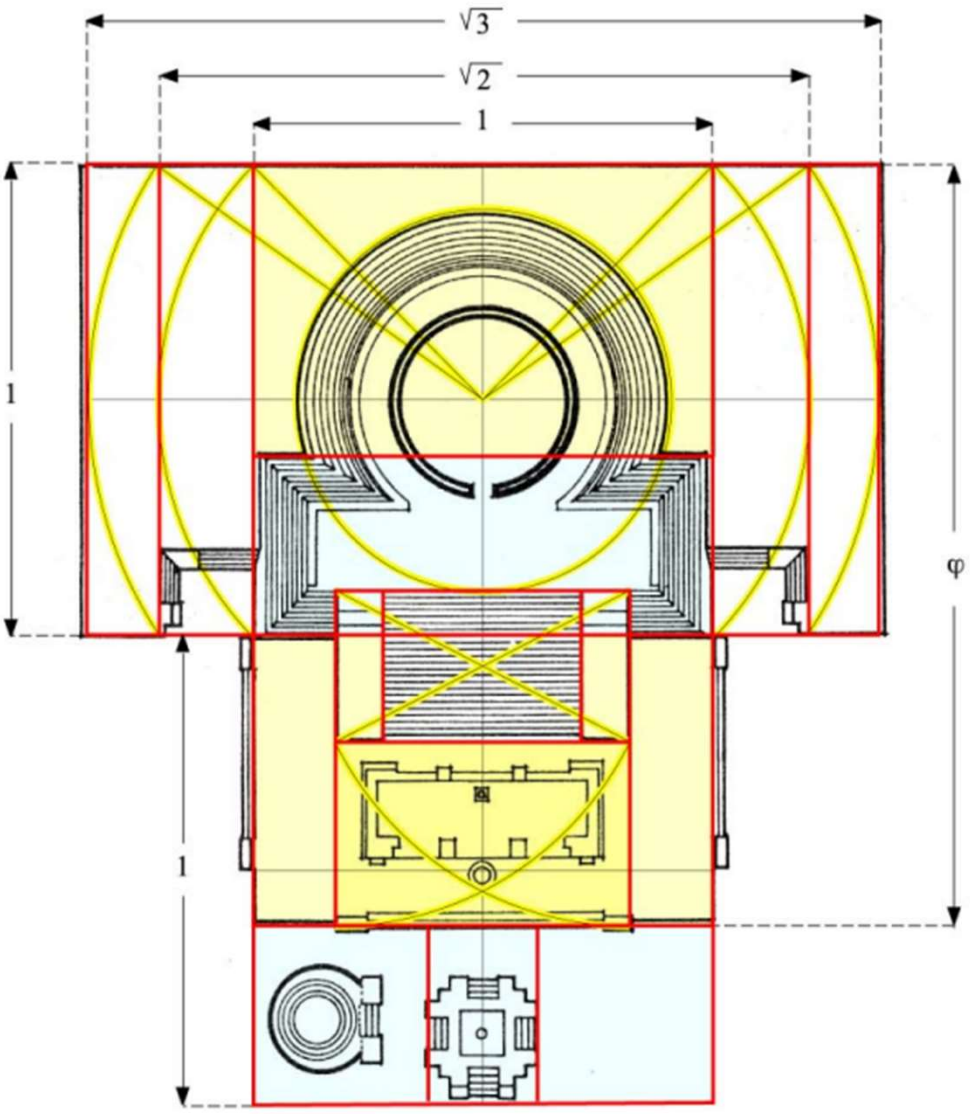
East Elevation of Structure 3C7 (a), Chichen Itza,
Yucatan Peninsula, Mexico
Measured Drawing by Karl Ruppert (1952)



The east elevation of Structure 3C7 (a) is inscribed by a square root of four rectangle that is subdi□vided by a square, square root of two, and square root of three rectangles. Note how the forty-fi ve□degree diagonal of the square is the angle of the staircase and how the diagonals of the square root of two and three rectangles frame the rectangular altar on the top of the platform

Figure 148

Plan of the Temple of the Gods of the Wind
Zempoala, Veracruz, Mexico



Beyond the Maya region, at the Late Post-Classic site of Zempoala in Veracruz, the Temple of the Gods of the Wind as shown in the Figure: 148, “PowellDissertation2010_MayaGeometry.pdf”

combines some of the proportions seen at an intriguing level of complexity. A circular elevated platform with a single staircase and a square raised platform with four staircases are located on the plaza in front of the main structure. The primary construction is a steep platform that is rectangular in the front and semi-circular in the rear is inscribed by a phi-squared rectangle (shaded blue),, and it supports a circular temple at the top. This steep platform's back sits on a low, U-shaped, rectangular platform the remainder of which is a phi rectangle (shaded light yellow).. A stairway and balustrade at the platform's front provide access to a higher platform rectangular temple with a columnar altar at the center of the front entrance creating a square root of two rectangle.

3.5.4.e) GEOMETRY IN CLASSIC AND POST CLASSIC PERIOD MAYA ART

As per "PowellDissertation2010_MayaGeometry.pdf", the following observations disclose rules and norms that characterize the composition of Mayan art and the codices. From the study, there was no apparent correlation between particular geometric proportions and specific subject matter, Maya artists and geometers were guided by certain general principles.

1. There is no obvious underlying geometry. On the contrary, it appears to be consciously hidden.
2. Bilateral symmetry is not essential but certainly important.
3. Intentional asymmetries are frequently observed; for example, one corner of Lintel 11 Yaxchilan Figure170, is noticeably off-square.
4. Body postures frequently follow the underlying geometrical composition's principal angles and curves.
5. Objects such as people, arms, legs, spears, and snake bars often touch or are parallel to the underlying mathematical composition's primary lines and curves. These lines rarely travel through the centers of these things.
6. The brow, hands, and feet are very essential and are virtually always touched or crossed by vital junctures or principal lines of the geometrical pattern. The geometrical program's principle lines almost invariably separate the headdress from the head of human creatures.
7. Navels, noses, and the temple region of the head are frequently focal points of the geometry, though not as often noted in the compositions as are hands, feet, and brows.
8. The hieroglyphic writing is secondary to the rest of the composition. Glyph blocks are frequently incorporated and accounted for in mathematical compositions, but brief inscriptions may have filled empty space. Names and titles are frequently crossed by geometrical principle lines, and some appear to have been added after the artistic composition was suited to the geometrical composition.

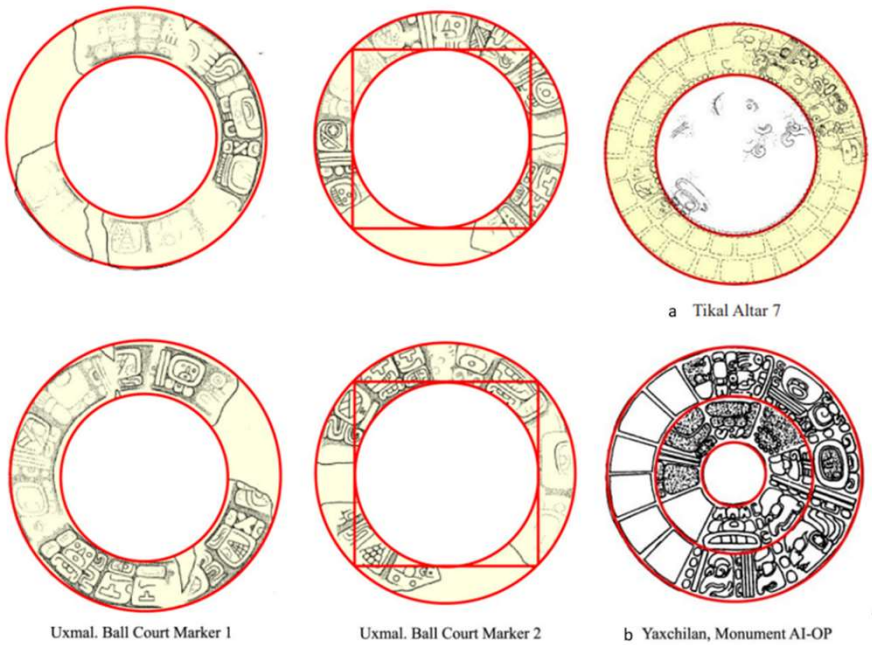
The following diagrams show the significance of Geometrical proportion as shown in Figure: 163,164 ,165,167,170,171,173,177,181,200,218,228,232,235,253,259,262; "PowellDissertation2010_MayaGeometry.pdf"

Figure 163

Ball Court Markers 1 and 2, Uxmal
Yucatan, Mexico
Measured Drawing by Ian Grahm

Figure 164

Altar 7, Tikal and Monument AI-OP, Yaxchilan
Measured Drawing by W. R. Coe (a) and S. G. Morley (b)



a Tikal Altar 7

Uxmal. Ball Court Marker 1

Uxmal. Ball Court Marker 2

b Yaxchilan, Monument AI-OP

The above are ball court markers from either side of the principle ball court a Uxmal. If the diamℤeter of the inner circle of Ball Court Marker 1 is one, then the diameter of the outer circle is phi. If the diameter of the inner circle of Ball Court Marker 2 is one, then the diameter of the outer circle is square root of two.

If the diameter of the inner circle of Tikal Altar 7 is one, then the diameter of the outer circle is phi. If the diameter of the inner circle of Yaxchilan Monument AI-OP is one, then the diameter of the outer circle is four. If the diameter of the middle circle of Yaxchilan Monument AI-OP is one, then the diameter of the outer circle is ph

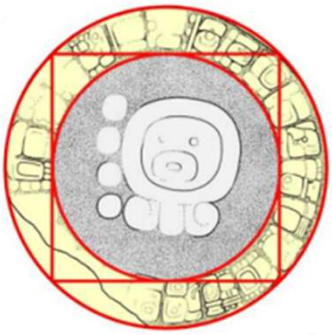
Figure 165

Monuments 69,11,and 34 and Altar 001, Tonina
Chiapas, Mexico
Measured Drawings by Ian Grahm

Tonina. Monument 69

Tonina Altar 001

Tonina. Monument 11



Tonina. Monument 34

The inner circles are the diameter of the width of the squares inscribed in the outer circles. If the diameter of the inner circles is one, then the diameter of the outer circles is square root of two, as per Formula Circle-a.

Figure 167

Altar 10, Tikal,
Peten, Guatemala
Measured Drawing by W. R. Coe

If the diameter of the inner circle is one, then the diameter of the outer circle is square root of phi. The diameter of the square that inscribes the inner circle is virtually equal to the diameter of the outer circle, as per Formula Circle-2 The square that inscribes the outer circle is subdivided into a phi rectangle (shaded blue) and a phi squared rectangle (shaded yellow), as per Formula Square-3

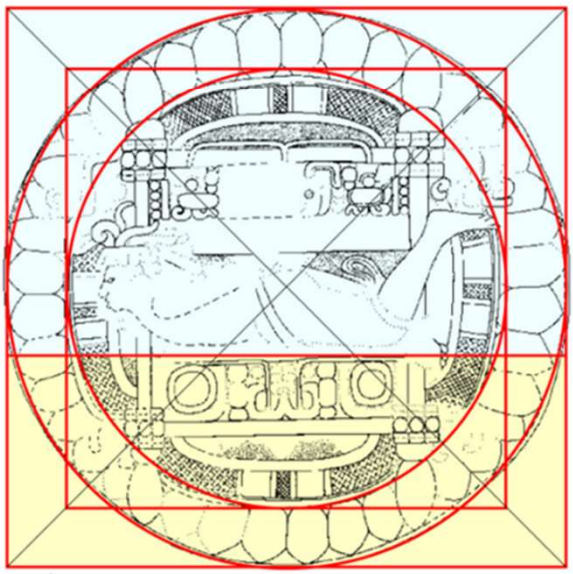


Figure 170

Square Hieroglyphic Text Blocks 1
Measured Drawings by Ian Grahm, Rubbing By Merle Greene Robertson

Altar Q, Copan

Lintel 11, Yaxchilan

Monument 141, Tonina

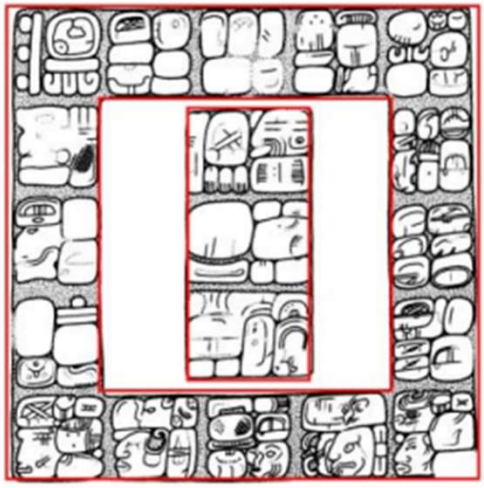
Lintel 1, Yula

Hieroglyphic text blocks inscribed by squares.

Figure 171

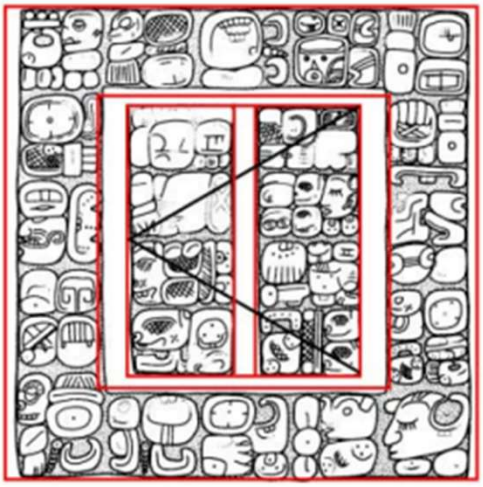
Square Hieroglyphic Text Blocks 2
Measured Drawings by Ruth Krochock

Lintel 2



Lintel 3

Lintel 4

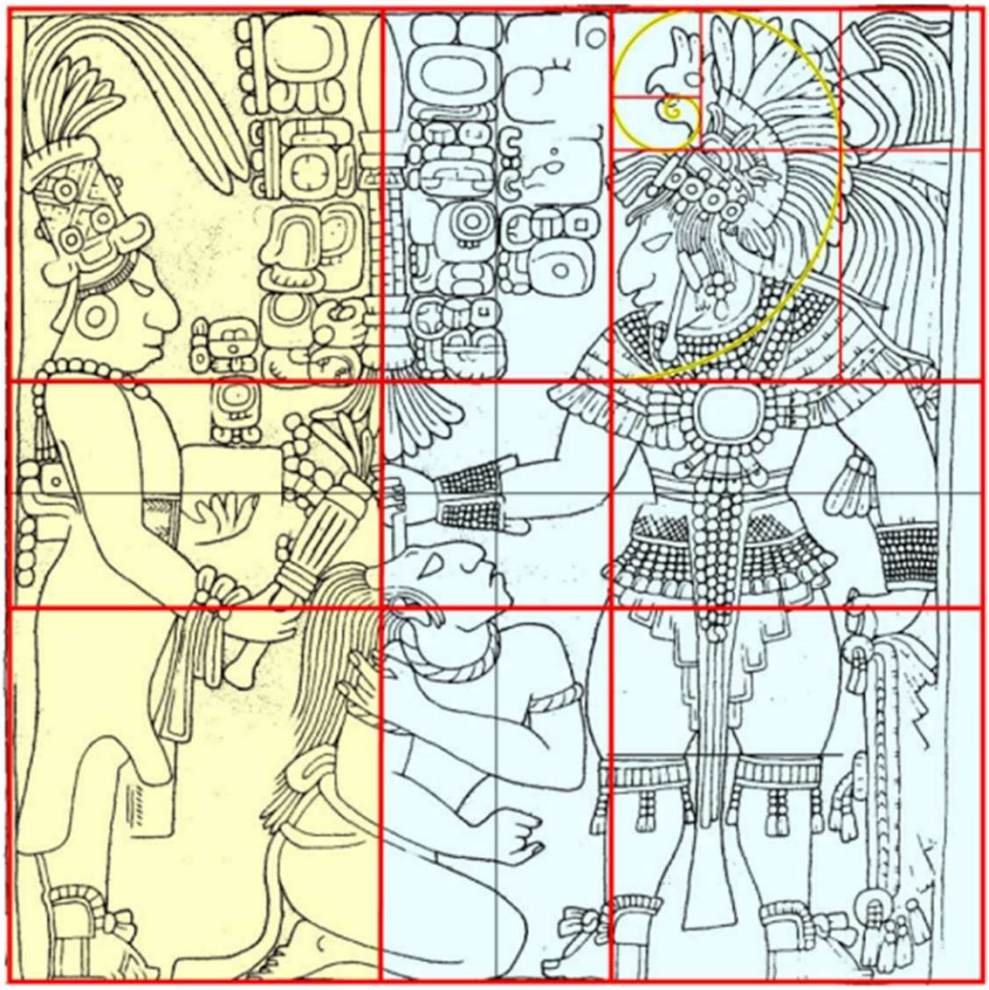


Lintel 5

For each of these lintels from the Las Monjas Temple at Chichen Itza, the ratio between the inner and outer squares is one to phi. The bar of hieroglyphics within the inner square of Lintel 2 is inscribed by a root five rectangle. The two bars of hieroglyphics within the inner square of Lintel 3 are inscribed by a square. The two bars of hieroglyphics within the inner square of Lintel 4 are inscribed by a two over root three rectangle (that inscribes an equilateral triangle) and the bars themselves are inscribed by two, two over root phi rectangles. The bar of hieroglyphics within the inner square of Lintel 5 is inscribed by a root four rectangle.

Figure 173

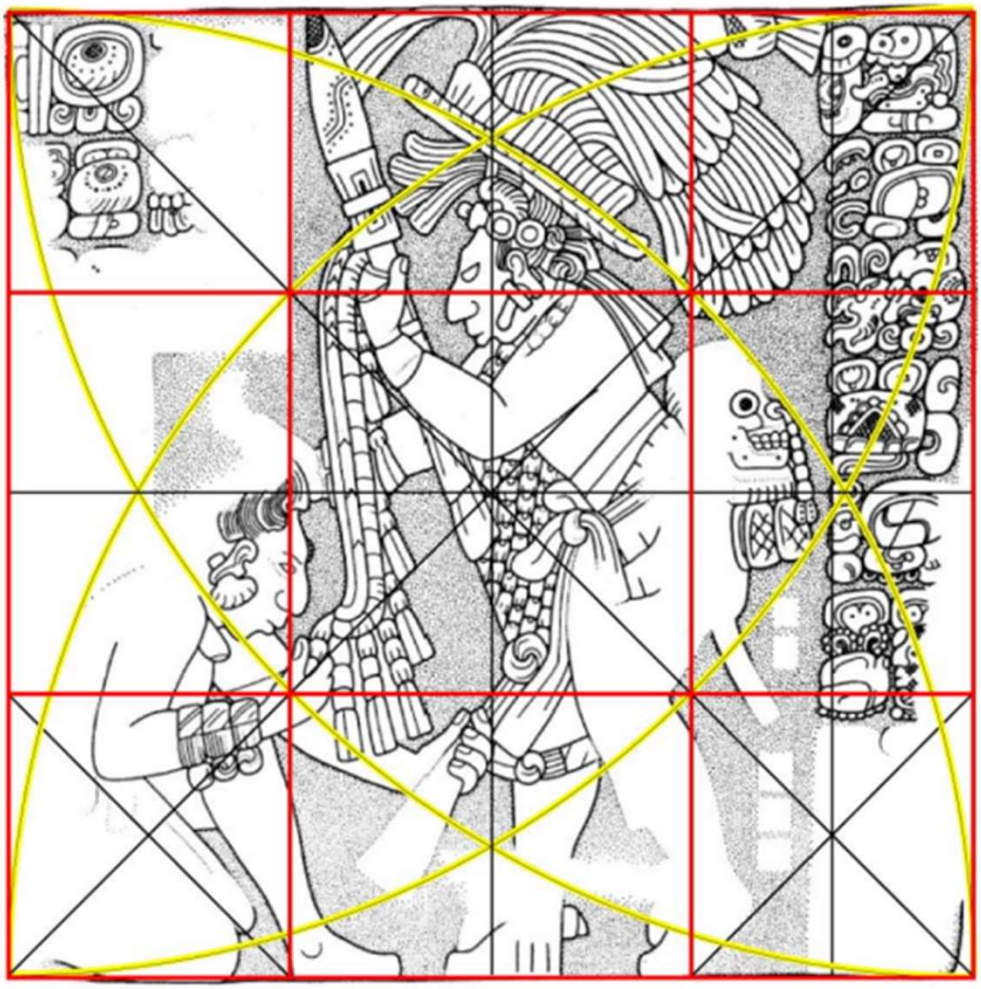
Yaxchilan area, Chiapas, Mexico
Measured Drawing by Ian Grahm



The La Pasadita Lintel is inscribed by a square that is quartered (fi ne black lines) and subdivided by a phi rectangle (shaded blue) and a phi squared rectangle (shaded yellow), and into smaller squares and phi rectangles (bold red lines), as per Formula Square-2. The square in the upper right corner is further subdivided into squares and phi rectangles, and an equiangular spiral is added that conforms to the curve of the quetzal bird headdress of the standing male fi gure and terminates in its mouth. Note how the hands of the human fi gures, the position of the spear, and the blocks of hieroglyphic texts conform to this proposed geometrical diagram

Figure 177

Lintel, 45, Yaxchilan,
Chiapas, Mexico
Measured Drawing by Ian Grahm

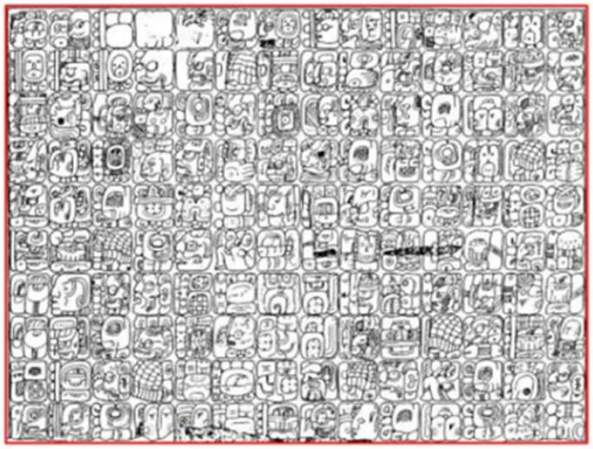


Lintel 45 is inscribed by a square that is dynamically subdivided into smaller squares and square root of two rectangles via Formula Square-1. Note that both of the human fi gures are leaning forward as if to fi t within the arcs (highlighted yel□low lines) whose radii are the sides of the square. Note also the placement and the angles of the feet of the fi gures, the angle of the thighs of the seated fi gure, the placement of the hands of both fi gures and the position of the left arm of the standing fi gure relative to the suggested geometrical diagram.

Figure 181

Pythagorean 3,4,5 Hieroglyphic Text Blocks 1
Measured Drawings by Merle Greene Robertson (a) and Ian Graham (b)

The Center Tablet of the Temple of the Inscriptions, Palenque

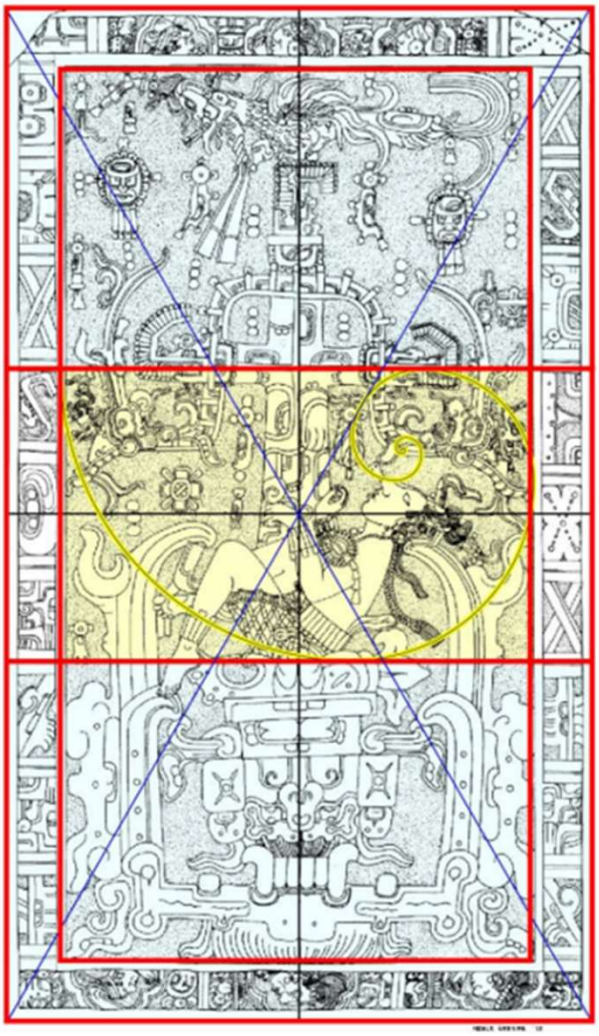


Panel 1, Calakmul

Hieroglyphic text blocks inscribed by Pythagorean 3,4,5 rectangles

Figure 200

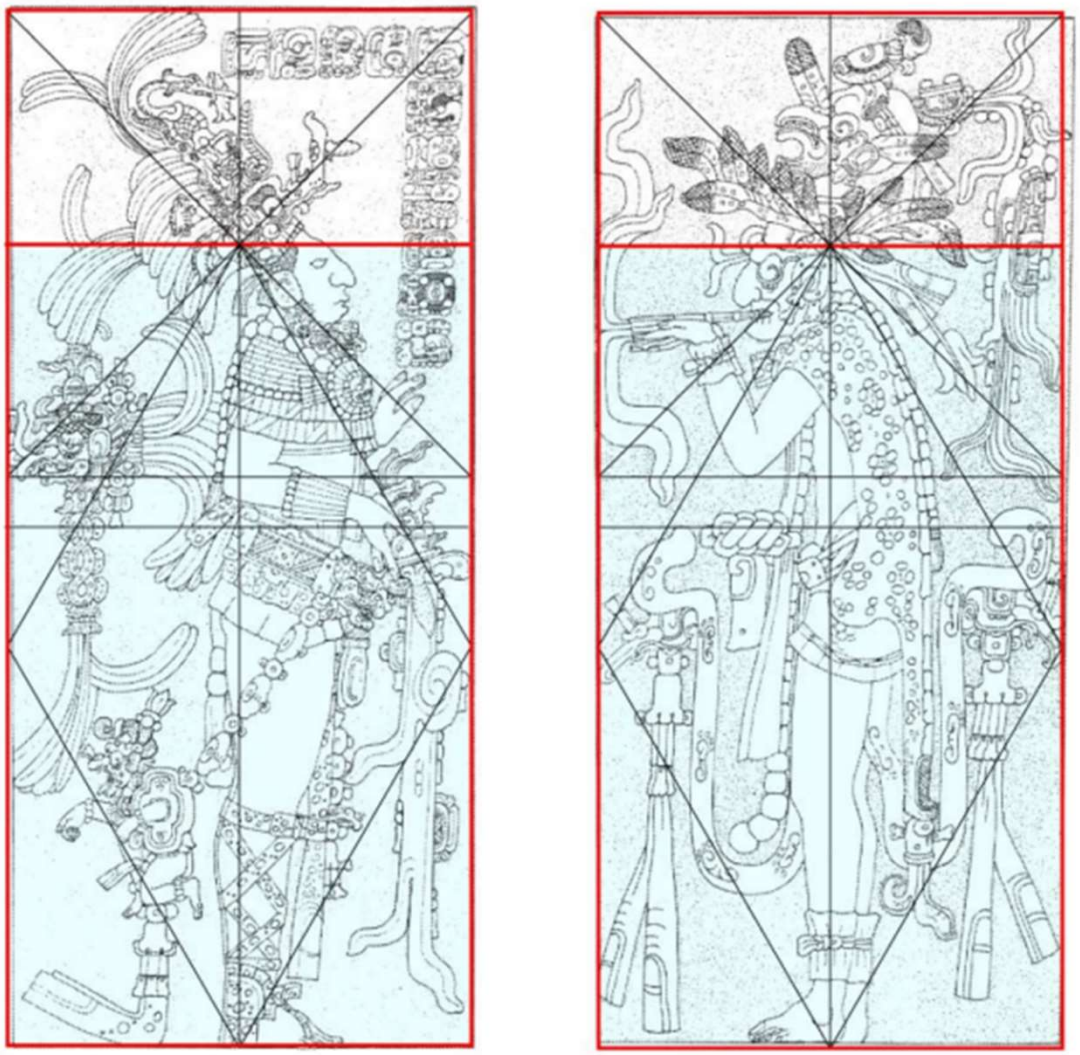
Sarcophagus Lid (a), Temple of the Inscriptions, Palenque, Chiapas, Mexico
Measured Drawing by Merle Greene Robertson



The Sarcophagus Lid from the Temple of the Inscriptions at Palenque is inscribed by a root three rectangle that is subdivided by a root four rectangle (white) and two phi rectangles (shaded blue), as per the virtually perfect Formula Square Root of Three-3. Where the root four rectangle cuts across the inside of the sky band it defi nes a phi rectangle (shaded yellow)

Figure 218

East and West Jambs, Temple of the Cross, Palenque, Chiapas,Mexico
Measured Drawings by Merle Greene Robertson

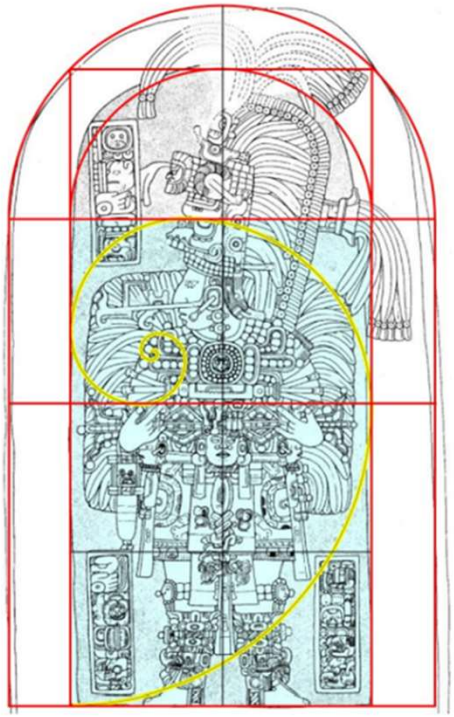


a b

Both the East (b) and West (a) Jambs are inscribed by virtually perfect root fi ve rectangles that are subdivided at the brows of the standing fi gures by root three rectangles (shaded blue) and root four rectangles (in white), as per Formula Square Root of Five-4.

Figure 228

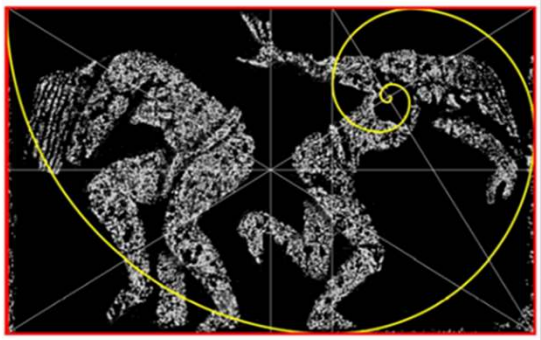
Stela 16 (c), Tikal, Peten, Guatemala
Measured Drawing by W. R. Coe



The same quartered square used to produce the root two rectangles in the diagram above may be used to create the phi rectangle shown here (shaded blue). Note that the phi rectangle terminates at the brow of the monster headdress worn by the standing fi gure.

Figure 235

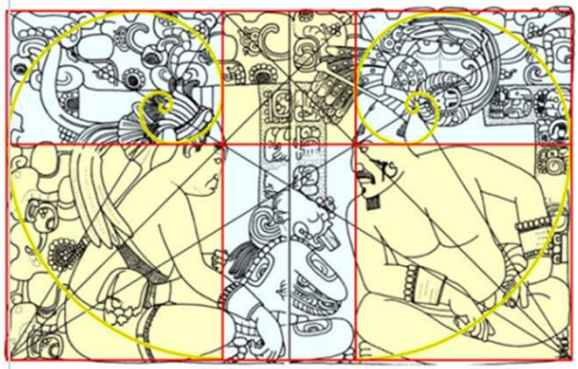
Two Dancers, Yaxchilan area, Chiapas, Mexico
Rubbing by Merle Greene Robertson



This rubbing of a relief panel is inscribed by a phi rectangle with an inscribed equiangular spiral.

Figure 232

Relief Panel (Unknown Provenience)
Museo Amparo, Puebla, Mexico
Measured Drawing by Christian Prager



This relief panel is inscribed by a phi rectangle that is subdivided by squares (shaded yellow) and smaller phi rectangles (shaded blue), as per Formula Phi-2. Equiangular spirals are added to the lateral phi rectangles.

Figure 253

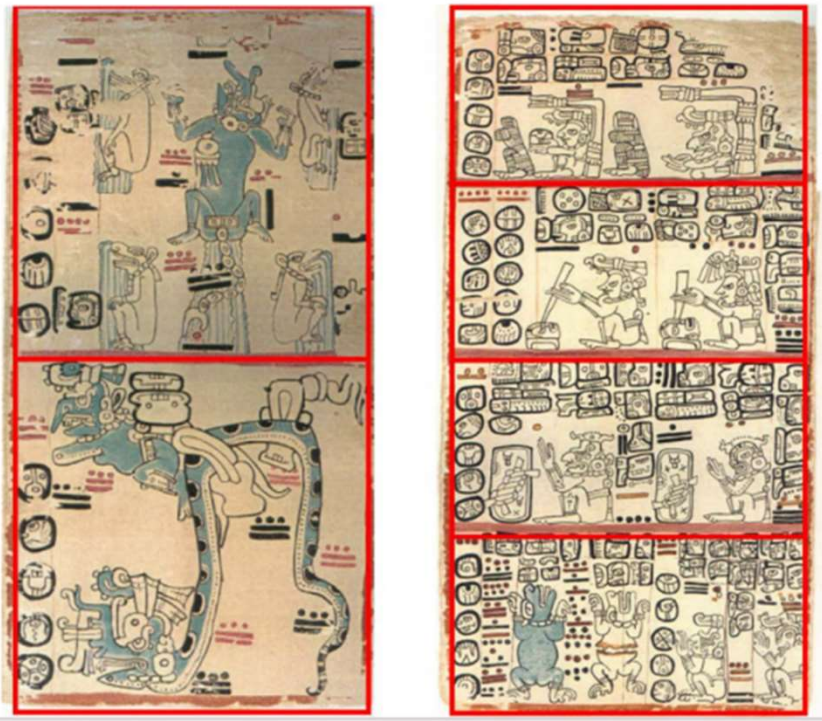
Incensario 1, Palenque, Chiapas, Mexico

The fl anges of Incensario-1 are inscribed by a root four rectangle that is divided in half at the brow of the deity. The central design elements between the fl anges are inscribed by two root four rectangles that are one half the width of the root four rectangle that inscribes the fl anges (highlighted yellow)

Figure 259

Madrid Codex, Pages 31 and 101

Page 31 | Page 101

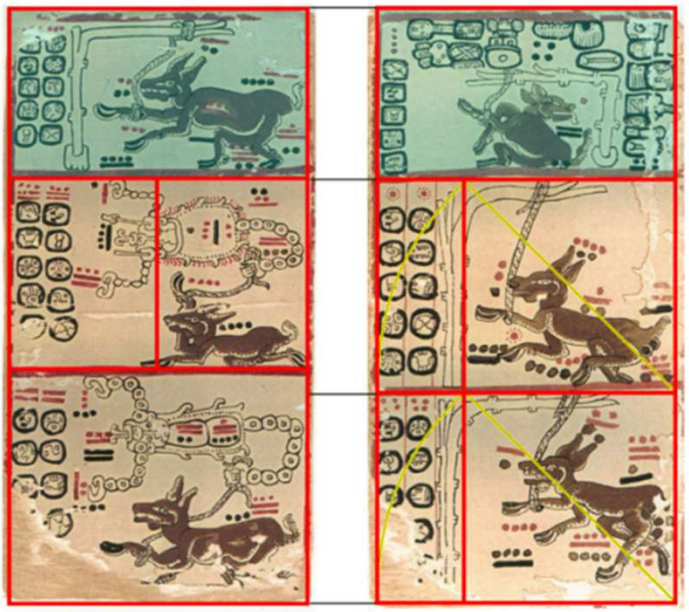


Page 31 is a square root of four rectangle divided in half into two squares. Page 101 is a square root of four rectangle subdivided into four equal-sized square root of four rectangles, as per For□mula Square Root of Four-b.

Figure 262

Madrid Codex, Plates XII and XI

Plate XII | Plate XI



Both Plates XII and XI are inscribed by square root of four rectangles that are subdivided into square root of three rectangles (shaded blue) and root two rectangles, as per Formula Square Root of Four-4. The remaining root two rectangle of Plate XII (unshaded) is further subdivided into three Pythagorean 3,4,5 rectangles, as per Formula Square Root of Two-3. The corresponding square root of two rectangle on Plate XI is divided in half into twwo smaller root two rectangles. The diagonals of the squares within these root two rectangles are the radii of the arcs that determine their lengths (yellow highlighted lines).

3.5.4.f) THE SQUARE ROOT AND PHI PROPORTIONS IN THE MAYA UNIVERSE

The Maya were and continue to be keen observers of nature, weather, the seasonal cycles of flowering plants, and the migration patterns of birds and animals, in addition to the motions of the sun, moon, planets, and constellations. Their daily existence is built on an intimate knowledge of changes in their environment. The timing of burning, planting, weeding, and harvesting corn and other crops, when to cut wood and harvest thatch, when and where to build a home, when and what to hunt and where, when and why to perform ceremonies: all of these activities are precisely orchestrated in relation to their profound knowledge of their physical universe.

Figure 289

Flowers

Three some, four some, and five some flowers (flowers with multiples of three, four, and five petals)

Based on the study from "PowellDissertation2010_MayaGeometry.pdf" how the square root and phi proportions are rectangular expressions of the proportions inherent in the equilateral triangle, square, and pentagon in the first two diagrams of this dissertation (Figures 1 and 2). The majority of flowers have three, four, or five petals, or multiples of three, four, and five petals. In fact, botanists divide flowers into four basic groups: Three Somes, Four Somes, and Five Somes (flowers with petals arranged in multiples of threes, fours, and fives), and the much less common Irregulars, which are usually bi-petaled (mostly found in the flowers of legumes) or cone-shaped (mostly found in the petals of a few species of lilies). As a result, the proportions seen in most flowers are the same proportions used to design Maya art and architecture. These proportions are nowhere more plainly and abundantly reflected in nature than in the shapes of flowers as seen in Figure 289,291,292,293,296.

Figure 291

Flower Iconography and Churches 1

Flowers and geometrically stylized fl owers on the facade of the church at San Juan Chimula, Chiapas, Mexico.

Figure 292

Flower Iconography and Churches 2

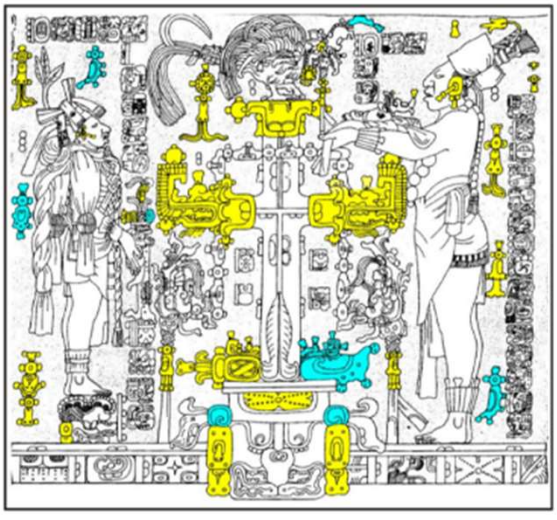
Geometrically stylized flowers on the facade of a church in Yucatan, Mexico

Flowers and geometrically stylized flowers on the facade of the church at San Juan Chimula, Chiapas, Mexico.

Modern "Christian" crosses in the Maya highlands invariably display carved or painted flowers at their extremities. I have often seen these modern crosses adorned with fresh flowers. Churches, too, prominently display geometrically stylized flower iconography

Figure 293

The Cross Tablet, Temple of the Cross, Palenque, Chiapas, Mexico



Flowers and shells often hang or float in the background of sacred scenes, particularly in the art at Palenque

Figure 296

Jade Ear Flares

Ear flares, worn ubiquitously by Maya nobles and royalty, are flowers made oof jade. The flower ear flares of the gods are almost always surmounted by cut shells; cut shells are also worn as diadems and necklaces by gods and kings. The Maya Gods K and N, as well as human figures, are sometimes depicted as emerging form sea shells. Ancestors are portrayed emerging from flowers and flowering trees

Powell has theorized that flowers are the reason why the Maya chose to adopt square root and golden mean ratios. These specific ratios occur naturally in flowers, which were and continue to be very precious to the Maya. The Maya do not cultivate flowers, yet wildflowers are important to them and are frequently used in religious events as sacrifices. Flowers and shells are also prominently featured in many classic Maya artworks.

4. FINDINGS/ ANALYSIS & INFERENCE

4.1.The Maya developed and used a sophisticated planar geometry system. Planar geometry is any shape that can be drawn using a straight edge and a compass (or more simply, any shape that can be drawn using a cord).

4.2.Maya mathematics appeared to be made up of equations, theorems, and ratios that relied solely on whole numbers. A Maya geometer would have found the dynamic subdivisions of the square root and phi to be even more dramatic. The Pythagorean 3,4,5 rectangle can also be virtually perfectly subdivided by the root and phi rectangles and thus was probably considered an integral part of this coherent and interrelated system of measurement and proportion.

4.3.The aforementioned dynamic subdivisions were demonstrated to be mathematically perfect subdivisions. Along with these "perfect" subdivisions, that appear repeatedly in Maya art and architecture designs. "Virtually perfect" because the relatively minor inaccuracies of these subdivisions would be nearly difficult to discover without the application of mathematical calculations based on irrational numbers.

4.4.The examples studies through this research analyzing rectangular structures and measured drawing of architecture from “PowellDissertation2010_MayaGeometry.pdf” & mathematical structure and astronomical content found in Maya hieroglyphic books and inscriptions shows the basic planar forms allowed statistical analysis of their relative proportions, series of repetitive proportions emerged that were related to one another in an intriguingly simple manner. These proportions are none other than the root rectangles (from the square roots of one to five) that so fascinated Pythagoras and other ancient geometers and that were intrinsic to the early development of planar geometry.

4.5. Two other rectangular proportions were found to be repeating, with ratios of 1 to 1.272 and 1 to 1.618. Although the diagonal of the first was discovered to be equal to the length of the latter, these rectangles did not appear to be related to the previously identified set of root rectangles at first. However, in a planar geometry, the proportion of 1 to 1.618..., known as the Golden Ratio or phi (1.272... being the square root of phi), is organically tied to the root fi ve rectangle. The Pythagorean 3,4,5 rectangle (with a width of three units, a length of four units, and a diagonal of five units) was also discovered to be repetitive, despite its seeming unrelatedness to the square root and phi rectangles.

4.6. Subsequent anthropological research of Maya vernacular architecture and geometry revealed at least some Maya were still using the square root and phi proportions to layout and design their houses.

4.7. The Maya's repeating proportions currently comprise a coherent and interconnected set of rectangular proportions; that is, starting with a square, the length of each consecutive rectangle is equal to the diagonal of the preceding one. The phi and Pythagorean 3,4,5 rectangles, as well as their ties to this fundamental set of rectangular proportions, are also discussed.

4.8. The Pre-Columbian objects studied include primary examples of ceremonial architecture, bas-relief stone, and stucco art panels and stelae, and pages from Pre-Columbian codices.

4.9. The Classic Maya used geometry extensively in the construction of their homes and buildings. They were able to make right angles and rectangles with sides in unique ratios that they discovered in nature, particularly in flowers, by utilizing simple knotted measuring cords. The golden mean and square roots of tiny integers were among the unusual ratios.

4.10. Geometry was extensively used in the architecture of the classic Maya. Geometry was also utilized in their art, according to the evidence. Attempts to find a measurement system employed by the Maya, on the other hand, have largely failed. It appears that bodily parts were utilized as units of measurement, such as an uinic, which is a person's height or "wingspan" from fingertip to fingertip. There are also multiple references to the usage of a measuring string in religious ceremonies and while laying out constructions. In the depiction of the creation of the universe, a measuring thread is even referenced at the opening of the Maya holy scripture Popol Vuh. Powell, who conducted modal ethnographic interviews

5. DISCUSSION:

Scale and proportion are important in design, and the golden ratio is thought to produce an aesthetically beautiful and balanced result. In architecture, the golden ratio is essentially exquisite aesthetic detail that provides an astonishing impression of artistry. For centuries, architects, artists, and designers have recognized and followed the golden ratio of proportion, which can be seen in many notable landmarks and masterpieces all around the world. Whether you agree with or disagree beauty is derived from the golden ratio which brings balance, proportion, and careful consideration to the forefront of any building will ensure a beautiful appearance.

To create proportions in buildings that are pleasing to the human eye and feel balanced, Architects have used geometric principles to plan the shapes and spatial forms of structures since antiquity. It's also known as the 'Golden Constant' because it manifests everywhere. By a combination of golden rectangle golden triangle, and logarithmic spiral, architects can design multitudes of shapes ranging from pentagrams to icosahedrons with 30 points and beyond.

The golden ratios have a wide range of uses. It may be found in nature, blended into fantastic pieces of art, and even used in marketing campaigns to influence our purchasing decisions. It's no wonder that architects use it to give buildings a sense of balance and height, to create enigmatic shapes, and to design beautiful layouts.

In Architecture, the Golden ratio-Golden section is still used as a basic geometric principle-timeless archetype, as it creates a universal sense of harmony when they see or stand in a building designed with this principle. And perhaps we see "The Golden Ratio is evident across the natural world's "architectures,"

6. SUMMARY/CONCLUSION

Maya gained a thorough understanding of the "Maker and Modeler's" use of geometry in the creation of the universe. This evidence also suggests that the Maya consciously imitated the shapes of their cosmos' sacred space by using the same geometry to layout and design their own creations, the architecture of their physical environment, from the simple geometry used to layout their vernacular houses, altars, and milpas to the complex geometrical formulae used to design the great pyramids and temples, as well as the exquisite works of art in the long-abandoned ruins of their magnificence." PowellDissertation2010_MayaGeometry.pdf,"

Based on the study, In the process of architectural design, the golden ratio is particularly critical for designers to produce harmonious designs. Mathematical correlations, the use of geometry, and aesthetics are all important factors that contribute to the harmony of design and the Golden Ratio can be used to produce overall harmony in the building. The Golden Ratio, with all of its unique mathematical features, will not only be the underlying principle of beauty and harmony in nature but also in architecture. these principles will continue to lead young designers to explore and investigate the Golden ratio as a measure in the design process and comprehensive studies.

Several architects in the twentieth century experimented with incorporating Mayan architectural aspects into private and public structures in the distinctive style of architecture known as "neo Maya style" in the United States, Mexico, and Central America.

"Designers can utilize these methods to study and engage with geometrical concepts through hands-on activities and appreciate the mathematical contribution of classic Maya civilization".

REFERENCES/BIBLIOGRAPHY

1. Golden ratio - Wikipedia
2. https://en.wikipedia.org/wiki/Maya_architecture
3. https://www.scienceteen.com/golden-ratio/
4. http://www2.rgu.ac.uk/subj/ats/TeachingWeb/teaching/t22/Wk6-Composition/Composition01.htm
5. https://radianz.co/what-is-golden-ratio-in-architecture/
6. https://www.buriedmirror.com/latest/culture/architecture/maya-architecture-and-the-golden-mean/
7. "THE MAYA AND THE GOLDEN RATIO" :https://mbicknelljohnson-wordpress-com.cdn.ampproject.org/v/s/mbicknelljohnson.wordpress.com/2015/07/29/the-maya-and-the-golden-ration/amp/?amp_gsa=1&amp_js_v=a6&usqp=mq331AQKKAFQArABIIACAw%3D%3D#amp_tf=From%20%251%24s&aoh=16349948300764&referrer=https%3A%2F%2Fwww.google.com&ampshare=https%3A%2F%2Fmbicknelljohnson.wordpress.com%2F2015%2F07%2F29%2Fthe-maya-and-the-golden-ration%2F
8. https://www.re-thinkingthefuture.com/rtf-fresh-perspectives/a1202-importance-of-geometry-in-architecture/
9. https://mayansandtikal.com/mayan-architecture/
10. https://en.wikipedia.org/wiki/Yaxchilan
11. https://www.historyonthenet.com/mayans-overview-civilization
12. https://www.maa.org/book/export/html/158976
13. https://www.historyonthenet.com/mayans-overview-civilization
14. https://www.maa.org/press/periodicals/convergence/maya-geometry-in-the-classroom-special-ratios-in-maya-architecture
15. https://lavacaindependiente.com/en/canamayte-maya-architecture-and-sacred-geometry/
16. Christopher Powell., 2010.,*The Shapes of Sacred Space: A Proposed System of Geometry Used to Lay Out and Design Maya Art and Architecture and Some Implications Concerning Maya Cosmology*
17. PowellDissertation2010_MayaGeometry.pdf,
18. Classic Maya site of Palenque. measured drawings from the four volume series,
19. The Art and Architecture of Palenque by Merle Greene Robertson,'
20. Powell, Christopher. Sacred Geometry Lecture, 2011 MAA Study Tour.
21. Tedlock, Dennis (translator). Popol Vuh: The Mayan Book of the Dawn of Life, Revised Edition, Simon & Schuster, 1996.
22. Maya Exploration Center: http://www.mayaexploration.com/index.php
23. https://kids.kiddle.co/Golden_ratio
24. https://repositories.lib.utexas.edu/handle/2152/ETD-UT-2010-08-1700
25. https://www.canva.com/learn/what-is-the-golden-ratio/

RESEARCH PAPER (IDRC WORKSHOP)

PEDAGOGY IN ARCHITECTURAL DESIGN (FOR BEGINNERS)

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INTRODUCTION

Architecture in simpler words is the art and science of designing buildings and structures.

Starting with the basic design approach, the inquest is simple, parameters are not many, but the students are tested for their exposure towards design. In basic design, the problems might be simpler as designing and the design with advancement in semester get complicated with added several considerations. In architectural design, the student should get well prepared in totality to cram the design complete. Students design ideas and notions are very nascent at this level and is not very complicated.

RESEARCH QUESTION

IN ARCHITECTURAL DESIGN - How they integrate various parameters, trickling down to simpler solution, integrate with the design inquest results in the eventual architectural solution?

AIM

To make student understand the essential of design that is building is not only monument which positions only for aesthetic reason but it is to occupy human beings and has to be functional and meaningful connection with environment, appropriate technologies, and social structure.

OBJECTIVES

1. To understand Architectural design an unique designing process that takes parts of the system and turns them into a whole holistic solution
2. To know the approaches towards solving these design problems at the level of a simple artifact to the level of a megastructure
3. To understand the multitude challenges and the design imbibe at different levels incorporating the various architectural and allied technical parameters

METHODOLOGY

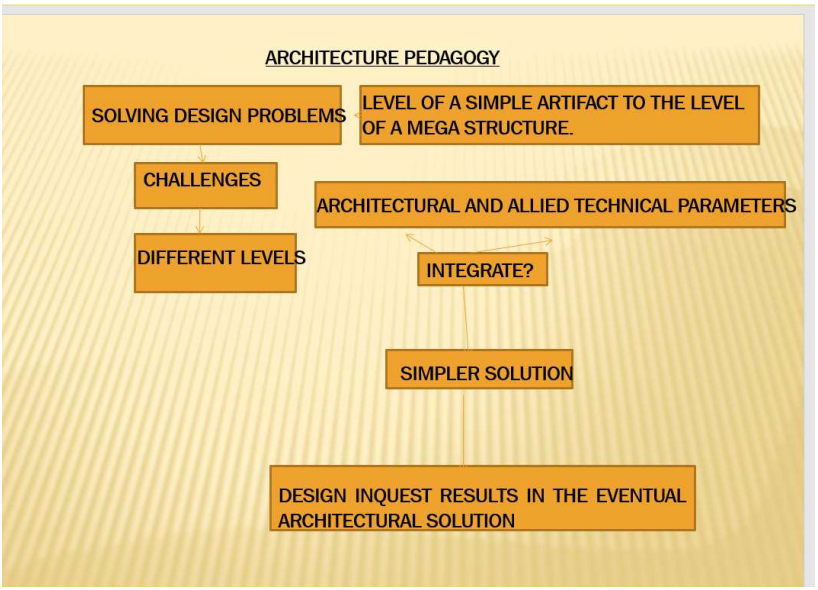

Figure 1- ARCHITECTURE PEDAGOGY

ARCHITECTURAL DESIGN INQUEST

First, a thorough and informative design brief is an imperative part in architecture design. Brief to ensure address particular challenges and important considerations relation to the design project. There will be number of rules, outlined in the brief. It is an essential point of reference for effective decision-making and problem solving process.

ARCHITECTURAL INPUTS NEEDED

A complete picture of what the project is all about……. A detailed brief about the project is to be given. The best solution of the project comes out of the better understanding of the project. So understanding the project becomes the prime essential aspect in a design process.

Project name, particular design features, specific time requirement to complete, specific considerations and about site, requirements of the uses of the buildings etc.

LEVEL OF FLEXIBILITY OR LEVERAGE ALLOWED IN DEFINING THE PROBLEM

Whether Students expects to be given some freedom in the definition of the design problem

Definitely yes for Students who employ quite different thinking out of the box and stand out from other peers as well as generate a more valuable discussion for learning. Many architects who have won major competitions have done so by breaking and or negotiating the rules to communicate a design solution, which stood out from the competition.

DESIGN PROCESS

The student must do a number of things in order to progress from the first stages of getting a problem to the final stages of defining a solution.

The Markus/Maver maps of the design process suggest that we need to go through the decision sequence of analysis, synthesis, appraisal, and decision'. Analysis involves the exploration of relationships, looking for patterns in the information available and the classification of objectives. Analysis is the ordering and structuring of the problem. Synthesis on the other hand characterized by an attempt to more forward and creates e response to the problem – the generation of solutions. Appraisal involves the critical evaluation of suggested solutions against the objectives identified in analysis phase.

THE DESIGN PROCESS ORGANIZED AROUND THE PRIMARY GENERATIVE IDEAS

What are primary generators?

Primary generators of (Broadbent method) are pragmatic, iconic, canonic, and analogical.

Pragmatic design - is simply the use of available materials, method of construction, generally without innovation, as if selecting from catalogue.

Iconic design - is even more conservative in that it effectively calls for the designer to copy existing solutions and modify them to meet new conditions.

Canonic design - relies on the use of rules such as planning grids, proportion systems and the like. The classical architectural styles and their renaissance success offered opportunities for such an approach.

Analogical design - results from the designers using analogies with other fields or contexts to create a new way of structuring the problem. Recommended generic technique for creative thinking is analogical design method.

Analogical methods are the most promising of these four tactics for form generators.

ANALYSIS (LITERATURE STUDY, CASE STUDY, SITE STUDY)

LITERATURE STUDY

Understand fundamentally and primarily about building up a level of confidence of trust. That is the very must stage and not much focus about buildings per say, that is it is not about solutions or ideas about buildings. Students need to think fresh about the problem without preconceptions about the type of solution and understand the nature of the users and their needs whether it is in terms of the ergonomics or the semiotics.

CASE STUDY

The case study applied in myriad ways, as a learning tool, a data collection method, a methodology and a research design. It affords the students the opportunity to interact with the users and people involved in the processes, where applicable of designing, building, operating, and maintaining of the setting. A significant part of learning from the case study happens after the actual fieldwork.

STAGES IN CONDUCT OF CASE STUDY

Preparatory stage: The case study actually begins with the formulation of the aim of the study. The cases selected based on the objectives. The selection finalized only after permission to access the cases. The specific data collection methods decided and organized at this stage.

DATA COLLECTION STAGE

It may involves visit to the setting, interviews with person involved in any aspect of the case and gathering of data from a variety of secondary source.

Student should find out what information will be useful for a design solution.

ORGANIZING AND ANALYZING THE DATA

Highlight the data with significant to the study objectives with analysis. This stage assumes great importance as decision taken at this stage affects the next stage, which is the communication of the data to others. The analysis compared to the set of cases, standards, and criteria.

COMMUNICATION STAGE

Sharing of knowledge gained through the study in a manner suited to the purpose of the study. Analysis are extensively studied by other students and teacher and commented upon by critics.

REPRESENTATION OF DATA

Bubble diagrams, concept diagrams, proximity charts are staples of data representation and analysis. Visual modes e.g. plan, elevation and section or their schematic illustrations and dominance of sketches and photographs in case study representation, supplemented by textual descriptions and diagrams for communication the rich technical, physical, spatial and environmental information that obtained. Optional - 3d modeling and simulation, including walk through, or the use of virtual reality in which a person can move through simulated environments and even interact with data being presented.

SITE STUDY

Microclimates, landscape design, climatic factors, site condition have been important in design process, which have become essential part of the studies. Energy efficient designs have become an integral part of the design procedure. It should also take into consideration the ecological factors for comfort of the user.

EXTERNAL CONSTRAINTS (SITE, LOCATION, SPECIFIC CONTEXT)

Create constraints within which students must work based on DCR and control may range from standards and code of practice to guidelines and recommendations such standards may govern factors of safety utility or appearance.

SYNTHESIS

Concept - Moving quickly towards some ideas about the solution from studies.

Ideas in the production of a conceptual plan .Idea comes from the primary generator collected using experimental observation and analysis and modifies idea with possible solution in the process by drawing bubble diagrams and flow charts graphically, represent the required relationships, The flow of people in around a building.

AVOID FIXED RESULT (INTERNAL CONSTRAINTS)

Students often limit their project by anticipating certain aspects or the design outcome far too early on in the process. If the students focused on a fixed result then they are denying themself the opportunity to discover what they could not have expected.

FLEXIBILITY – SHOULD GENERATED BY THE DESIGNER

Internal constraints generally allow a greater degree of freedom and choice since they only govern factors, which are under the designer's control. Design students often fail to recognize this simple fact but instead continue to pit their wits endlessly and fruitlessly against insuperable problems, which are largely of them. The most important skills designers must acquire are the ability to evaluate their own self-imposed constraints.

TOOLS

For many of kinds of design we are considering it is important not just to be technically competent but also to have a well-developed aesthetic appreciation, space, form and line as well as color and texture are the very tools of the trade for designer.

INFLUENCES AND MENTORS

It is important to have many influences and mentors from outside the school. This allow to learn from people with vastly different perspectives and considerations and to then apply thinking back in to architecture creating a broader and more interesting forum for discussions and negotiations. Having broad motivations and influences will allow to constantly inform teacher and to keep them engaged in design and process by showing them a perspective, which is unique, and outside their own.

ANALYSIS

Analysis should be like “why or why I do not” with respect to work.

REPRESENTED THROUGH VISUAL VOCABULARY

Ideas represented more in a visual way. Students need to develop visual sense and usually need to be able to draw well. Sketches provide clear evidence that the student is thinking about the design in many way simultaneously.

It involves a sophisticated mental process capable of manipulating many kinds of information, blending them all in to a coherent set of ideas and finally generating some realization of these ideas. Usually these realizations are later the form of a drawing in plan, but also in section and elevation to whatever needs should arise.

Thus students develop their own set of guiding principles (radical, formal, or symbolic) and these often set the direction for design project - Concept or parti

SELF-CRITICISM

Learn self-criticism at every level of deign. A teacher should also keep in mind that the teaching criticism should help students to define and depend on their own standards of aesthetic judgment and value and the interaction with the fellow students is transparent and productive instead of just being competitive.

CREATIVE THINKERS

In general, and students in particular seem to have the ability to change the direction of their thinking thus generating more ideas. Learning from their own mistakes is usually more powerful than relying on gaining experience from others.

DRAWINGS

Design drawings are part of the mental process of thinking about a design. In this view of design, the designer performs the act of drawing not to communicate with others but to pursue a line of thought. As the image of the drawing develops, it enables the designer to new possibilities or problems. Thus the drawing appears to talk back to the designer ending a problem to discovered and a solution created.

APPRAISAL

LINE DRAWINGS

Students work deliberatively to generate a series of alternative solutions, followed by a progressive refinement, testing, and selection process-minding concept as the background with set of guiding principles.

Design solution is characteristically an integrated response to a complex multi dimensional problem. Based on some synthetic and highly formative design idea, students should list all the requirements, understand the requirements of the design and then state which pairs of requirements interact either positively or negatively effectively breaking the problem down in sub problems each relatively simple for the designer to understand and solve and produce one or more solutions. Design is a messy kind of business that involves making value judgments between alternatives that may each offer some advantages and disadvantages.

How student choose between alternate design solutions and find out, which is better than another is and is so by how much?

Put them in order of preferences test those against explicit or implicit criteria and then somehow combining these assessments based on performance and weighting system and for reliable assessments checklist is the best and communicate design to teacher with all this progress. Students identified not so much by the kinds of problem they tackle as by the kinds of solution they produce.

INCUBATION PERIOD

This is the period essential for students completely off in proceeding design and to help them the teacher take these students to their heads and the advice they generally give them are to stop for while (incubation period) and then return to the problem where the students find themselves free to go off in new direction than they were before.

Design clearly involves both convergent and divergent productive thinking and studies of good designer at work have shown that they are able to develop and maintain several lines of thought in parallel - Parallel lines of thoughts investigations represent examinations into different aspects of design e.g. Material/interior – developed in parallel.

It is a spatial concept but it goes parallel to the selection of materials that do exist and the detail and they are all joined together and it changes (LAWSON, 2005)

Design solutions extensively studied by other designer and teacher and commented upon by critics.

PROCRASTINATION - DELAYING THE DECISION

The real difficulty with this response to uncertainty is that once a problem has been identifies is no longer possible to avoid the consequences of making a decision. Delaying the decision, it adds to the uncertainty and may thus accelerate the problem. The very process of avoiding or delaying a decision has an effect. Design is as much a matter of finding problems as it is of solving them. It is important to recognize the problem identified likely to be a function of the designer approach but also of the time available.

FINAL STAGES OF DEFINING A SOLUTION

The final design solution is the outcome of the series of refinement that it takes throughout the design journey. Much of serious deviations from the original design may not result in a good solution.

Generally it easier to go in the same direction rather than start a new line of thought

Embellish the design with detail

In a design rather like art, one of the skill is knowing when to stop.

As a result, students often fail to get down to the level of detail required of them by their tutors.

(BRAWNE, 2003) suggests that there are two ways in which designers can retreat back up the hierarchy of problem by escalation and regression

REVIEW

The student should be clear in perception along with being accurate and relevant. The reasoning should be fair and significant and the logic should be coherent and valid. Should have command over language where vagueness, ambiguity avoided by use of exact words and definitions put to use effectively. The evaluation of simple and analogical reasoning, scientific and concept theories should be perfects. In addition, evaluation of source of information, arguments, relevance of evidences becomes significant for proper reasoning.

SUBJECTIVE PERCEPTION

Design solutions remain a matter of subjective perception what may seem important to one teacher or external examiner or designer may seem so to others.

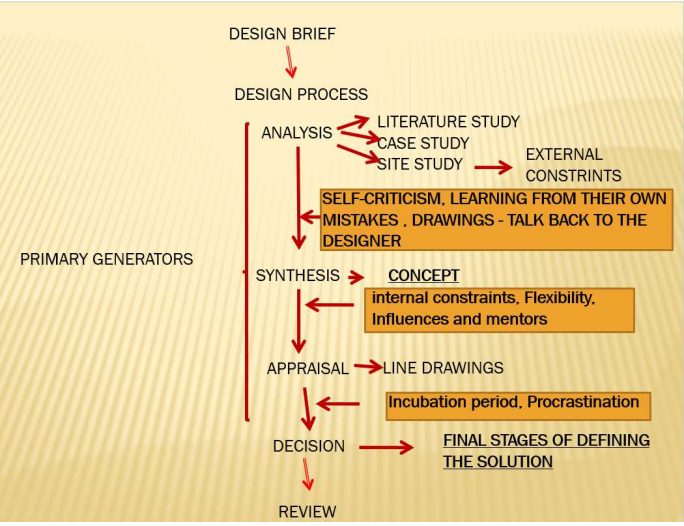

Figure 2 - DESIGN PROCESS

CONCLUSION

Architectural design process (FIGURE 2) is a continuous process involving sequential additions, alterations, changes, new incorporations, refinement at various stages. Interestingly, in architectural problem, the solutions may not be one but many. The real challenge in a solution lies in how best the design solution is approached and how it is solved. The designers of today can no longer be trained to follow a set of procedures. Students should not to be restricted to the traditional problem solving skills but rather exposed to new innovative skills. Rather they must learn to appreciate and exploit new technology as it develops. The integration of design with recent technologies, methods, and innovations will definitely be a challenging one in the design. That also leads to so many unexplored areas or less travelled areas in architectural design.

BECAUSE IN SHORT ARCHITECTURE IS MORE OF A CREATIVE TOOL THAN ANYTHING ELSE IN THE WORLD.

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BIBLIOGRAPHY

1. BRAWNE, M. (2003). *ARCHITECTURAL THOUGHT:THE DESIGN PROCESS AND THE EXPECTED EYE.*
2. LAWSON, B. (2005). *HOW DESIGNERS THINK THE DESIGN PROCESS DEMYSTIFIED.*

LEARNING ARCHITECTURE WITHOUT ARCHITECTURE

EXPERIENCED BASED LEARNING BY UNFOLDING THE RUDIMENTS OF ARCHITECTURE FROM NATURE

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"The sense of self, strengthened by art and architecture, allows us to engage fully in the mental dimension of dream, imagination and desire. Instead of creating mere objects of visual seduction, architecture relates, mediates and projects meanings. The ultimate meaning of any building is beyond architecture; it directs our consciousness back to the world and towards our own sense of self and being." (Pallasmaa 1996)

ABSTRACT

Creative thinking is an important aspect of architectural education both to the learner and to the educator and Foundation Design studio plays a vital role in nurturing fresh young minds that pursue architecture with dreams. Since this course is the starting point of the architectural education the learner needs to be exposed to many creative and thought-provoking exercises rather than topics of course contents introduced to them through exercises that follow steps to complete learning goals. This paper illustratively demonstrates observations made in Foundation Design studio in one such exercise where forms in Nature were used as a potential resource to understand design elements, principles, and structure. The exercise changed their perspective of viewing these natural forms and displayed a better understanding of architecture.

AIM

The paper aims at investigating the concept- *"Experience- based learning"* from *nature as a latent resource to learn Architecture.*

OBJECTIVES

- To demonstrate that familiar objects in nature can be used to understand architecture.
- To observe and study the natural design features like lines, shapes, pattern, forms, colors and textures of different potential examples.
- To explore and identify the design principles of the examples chosen from nature.
- To analyze in detail the strength, rhythm/ pattern of growth of the example from nature.
- To interpret the various possibilities of its application in Architecture.
- To demonstrate that learning through creating experiences display interesting ways to understand and gain knowledge.

BACKGROUND OF RESEARCH

Nature is definitely a mystery around us that never remains the same and never enough to be known to all. Each day and every moment we look at various wonderful examples of many inspiring and interesting natural forms. The various natural forms we see in our everyday life are not just wonders of its own beauty but potential resources to observe, analyze and study from. Historically, man has learnt a lot of lessons from nature. A keen observation of various examples of nature will unfold the different elements and principles of design that can be related and applied in architecture for that matter in any field of knowledge.

RESEARCH METHODOLOGY

The design studio is where an educator educates a learner to design creatively through inspiring interactions and examples with students. Foundation Design Studio otherwise named as Basic Design studio course of Architecture forms the most vital learning period for any student in Architectural education. The course by itself focuses on introducing the various elements and principles of design through many interesting exercises. As a Basic Design Educator, one should not only introduce these elements and principles of design but create thought provocative opportunities for students to observe and explore the learning objectives of the course. One such experimentation of learning objectives to students in the Foundation Design Studio was to introduce an exercise about natural forms which would unfold and share different potential examples in Nature that exhibit various design elements and principles forming the basis of Architecture at the foundation course.

• ANALYSIS AND SYNTHESIS

The methods implemented to research on the topic "Experience-based learning" are as follows

I. Design exercise
II. Observation
III. Student works
IV. Attitude scale
V. Students feedback

I. DESIGN EXERCISE

The objective of the Exercise

- The main intention of this exercise was to unlock the natural design elements along with the design principles found in an object collected from nature.
- The key feature of the natural object collected is studied and abstracted in the form of a physical model representing the key feature.
- To create an interesting experience to understand architecture from natural objects around during the monotonous online course of study.

II. OBSERVATION

Due to global pandemic conditions, this particular batch had commenced learning architecture especially a subject like a Basic design course unusually on an online mode. This exercise gained a lot of response which was seen in their pace of work, understanding, and outputs of the design exercise.

The exercise was introduced to the students after a few simple exercises that introduced them to the various elements and principles of design. Since the students had to come up with their own choice of natural object to observe, explore, identify and understand the various elements and principles of design, it changed their perspective of looking at the natural objects around them. The exercise has a second component where the key structural feature of the chosen natural object needs to be analyzed and represented as an abstracted three-dimension model. This component of the exercise was enjoyed the most as it was about creatively abstracting the key structural feature with knowledge of material and model-making skills. Below is a pie chart obtained by conducting surveys through Google forms from students of the batch in response to the exercise conducted. The Pie chart in Figure 1, shows that their level of interest was high when working on the exercise.

Figure 1 – Student feedback of the exercise- Google forms

III. STUDENT WORKS

Following are a few examples of student works with inferences on the exercise analyzed and synthesized to bring out the understanding of learning objectives from "Experienced based Learning" in this case with Nature as a latent resource.

STUDENT WORK -1
THE NATURAL OBJECT SELECTED IS "HONEYCOMB"

The chosen natural object by the student for study, analysis, and abstraction is "Honeycomb." The understanding of design principles like axis, rhythm, unity, repetition, balance, symmetry, harmony, etc., and the design elements of the natural object like shape, form, color, texture, etc. is illustratively demonstrated by the student in Figure 2.

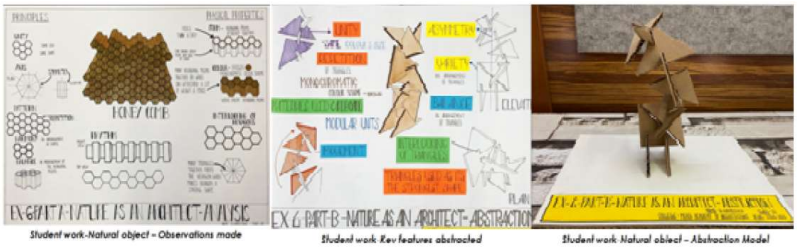

Figure 2 – Student work-1- Honeycomb- Observations, Abstraction and abstraction model

Figure 2, below shows the key feature "interlocking of repeated shapes" abstracted as a three-dimensional model with the representation of the design principles identified in the Honey Comb.

INFERENCE

The natural object "Honeycomb" exhibits the characteristics of "Modular architecture" or "Modularity in architecture" , which is a contemporary 1 concept in Architectural Design. The student was able to immediately relate to the concept of "Modular architecture" at ease by the study of Honeycomb.

STUDENT WORK-2

THE NATURAL OBJECT CHOSEN IS "CLOVE"

The chosen natural object by student is "Clove". Figure 4, exhibits the illustrative demonstrations of design principles like Axis, symmetry, Repetition, balance, proportion, etc., and elements of design like color, pattern, form, shape, etc. observed by the student. Figure 3, exhibits the demonstration of the key feature "Balance" observed in the natural object "Clove."

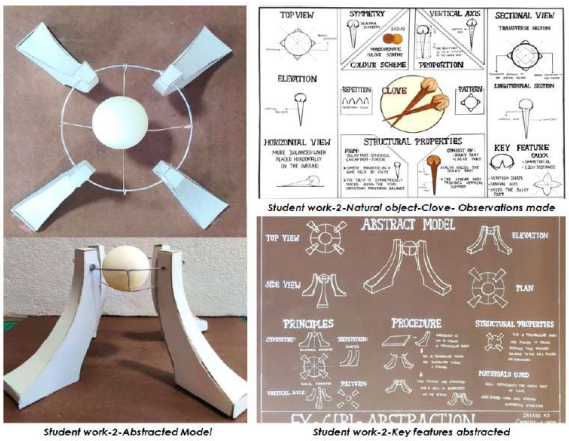

Figure 3 – Student work-2- Clove- Observations, Abstraction and abstraction model

Inference

The natural object "clove" exhibits the key feature "Balance." A good example, the student could relate in architecture is the Rainier Tower, designed by Minoru Yamasaki.2

IV. ATTITUDE SCALE

A brief questionnaire survey was conducted to contemplate students understanding and response to the exercise given in the form of Google forms. About 87% of the students found the exercise to be interesting and 67% of them sustained their interest level during exercise. All the students found the exercise to be interesting to learn the design elements and principles

		How interesting was the exercise according to you?	What was your level of interest when working out the exercise?	How did you find the exercise in terms of understanding principles and elements of design?	
Student responses	Fair	0	0	Easy	0
	Satisfactory	0	0	Difficult	0
	Good	87.50%	32.50%	Interesting	100
	Excellent	12.50%	67.50%	None	0

Figure 4 – From Statistics obtained from Google form filled by students

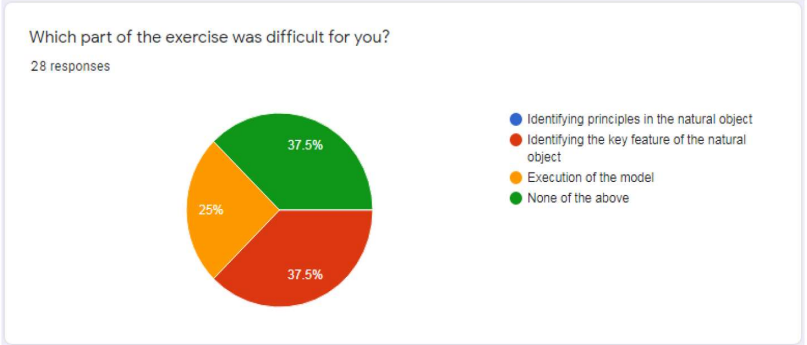

Figure 5 – From Statistics obtained from Google form filled by students

The above Figure 5, shows a Pie chart that explains though there were few difficulties in an exercise like the execution of the model or identifying a key feature for abstraction, the students never found the identification of principles difficult rather found it to be interesting.

V. STUDENTS FEEBACK

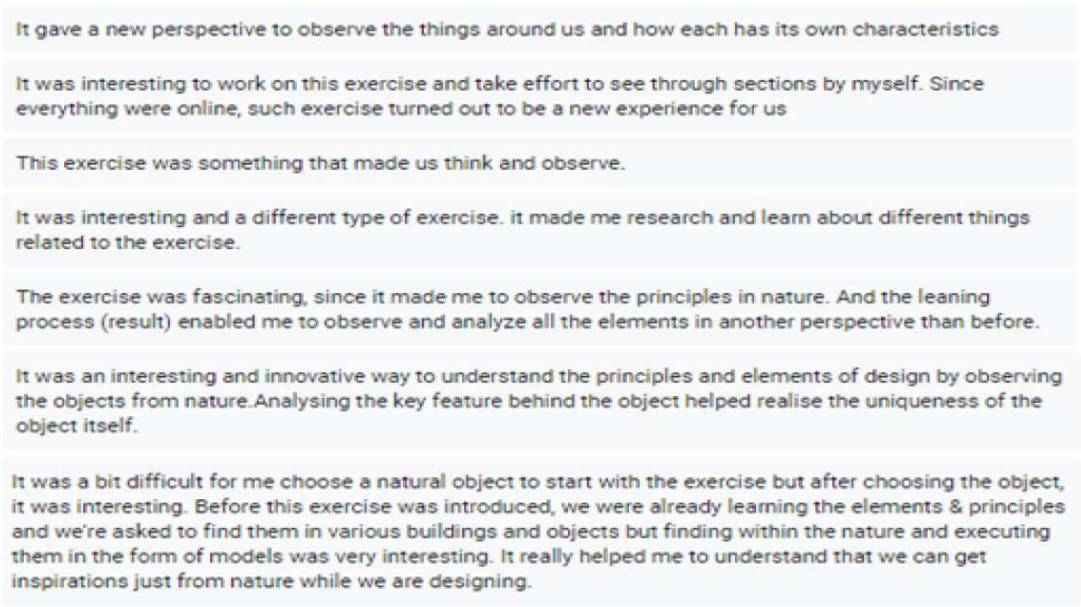

Figure 6- Feedback from students

The above *Figure 6*, is a screenshot of a few responses wherein students express their interest they had doing the exercise and how it changed their perspective in looking at the things around them. A few students also stated that their observation skills have improved and how nature is an inspiration to Architectural design.

CONCLUSIONS

An inference from the above demonstrations of student works, attitude scales, and feedbacks, one can understand that the design elements, design principles, structural strength, a keen sense of perception, drawing and observation skill which is interconnected have developed through the exercise with Nature as a potential resource to learn from. Also, this kind of experience-based learning is more effective.

The above *Figure 6*, is a screenshot of a few responses wherein students express their interest they had doing the exercise and how it changed their perspective in looking at the things around them. A few students also stated that their observation skills have improved and how nature is an inspiration to Architectural design.

SIGNIFICANCE OF HISTORY AND GEOGRAPHY IN THE TOWN PLANNING OF PUDUCHERRY – A LITERATURE REVIEW

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ABSTRACT

Puducherry is an old colony of the French Empire located in the southern tip of India. The unusual history of Puducherry has enormous influence on its geography and architectural heritage. Owing to this history, the central town of Puducherry (Old name Pondicherry) is an interesting arrangement of two distinct styles of architecture French (Neoclassism) and Tamil Style. This article explores the history and geography of Puducherry, its influence on the town planning and the design aspects of the building styles during colonial period. The study reveals the historic relationship between East and West; and about the architecture and town planning principles of Puducherry settlement.

KEYWORDS

Puducherry, history, town planning, French architecture, Franco-Tamil architecture

INTRODUCTION

City of Puducherry

"Pondicherry" is the French interpretation of the original name "Puducheri" meaning 'new settlement'. Puducherry is a seaside town on the east coast of South-India, located south of Chennai in the province of Tamil Nadu. The city of Puducherry forms a Union Territory with other old French colonies Mahe, Karikal and Yanam. In Puducherry, a number of features can be observed that are representative of colonialism, French colonialism and post-colonialism.

Colonial Historic-Geographic built heritage

Between roughly 1500 and 1950, European powers held political control, created colonies all over the world and ruled over them (Flint, 2007). French colonies are typical colonies created for the same reason as other European powers, but some features differentiate the French colonies from other colonies. A colonial city is formed by segregation: the French and the local population live in the different parts of town and there is little to no interaction between them. The French part of the city had unique style of buildings to accommodate the interest of the French population.

Historic-geographic influence of Puducherry

The fortified town, planned on a grid pattern in oval shape, encompasses two different parts, Tamil and French, divided on both sides of the canal (Figure 1). The Tamil town in turn has an intimate fabric of Hindu, Christian and Muslim quarters. The Hindu quarter grew around the nucleus of temples in the north west. Another nucleus around Immaculate Conception Cathedral gave rise to Christian quarter. Muslim quarter developed around the Qutpa Mosque.

The French Town / white town has structures in the European classical style while the buildings in the Tamil Town / black town have a strong vernacular influence of surrounding Tamil Nadu. A unique blend of two contrasting European and Tamil architectural patterns, resulted in a Franco-Tamil architecture style, reflecting the cross-cultural impact.

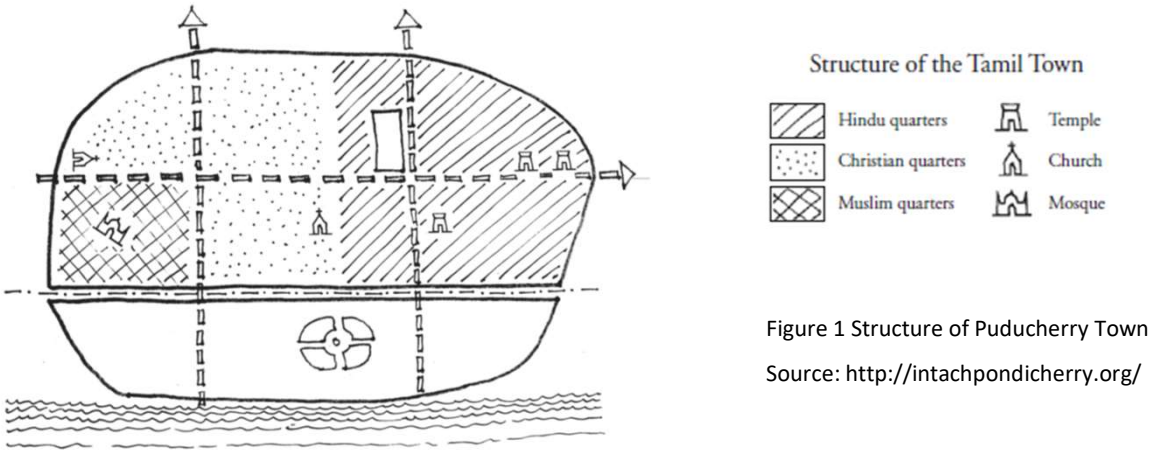

Figure 1 Structure of Puducherry Town

Source: http://intachpondicherry.org/

Following is a brief of the History of Puducherry and its influence on Geography

PREHISTORIC PERIOD

Many sources, including (INTACH, 2004), indicate that in prehistoric times, Puducherry was known as Vedapuri, a seat of vedic learning and home of Sage Agastya, while (Perumal, 2014) mentions that there was no conclusive evidence for the same. Archaeologists found evidence of Roman trading in First century AD, near Puducherry. It was concluded that Puducherry was a major port mentioned by Romans as Poduke which was probably named after either a Tamil word Potikai (a meeting place) or the local Poduvar Clan.

PRE-COLONIAL PERIOD

During the later period, Puducherry was a small village of farmers and fisherman which formed a part of various kingdoms - Pallava, Chola, Pandya, Vijayanagara, Maratha and Muslim rulers. Portuguese and Dutch were the first to establish trading bases at Puducherry. In 1673, French purchased the land which forms the current central town, from the local Senji king. They set it up as a trading port with a small fort and corrupted the name to Pondicherry. Tamil areas were segregated and to the south of the fort.

COLONIAL PERIOD

In 1690, Dutch took over Pondicherry from the French. Influenced by Neoclassism, they planned for a grid-based town with broad orthogonal roads. They only completed only the North Eastern part of the town by the time French purchased it back from Dutch four years later.

French expanded on the grid-based concept to the entire town, except the Muslim quarters. They moved the natives to the western side known as the Tamil Town (Ville Noire/Black Town) which in turn had Hindu, Christian and Muslim quarters and Natives remained on the Eastern side known as the French Town (Ville Blanche/ White Town).

These two towns had distinct architectural styles and both were segregated by a storm water canal with only two bridges over it, indicating a high level of segregation between the towns. Over a time period, the city took an oval shape with fortified walls, which are now replaced with a highway (Boulevard).

In 1761, entire Pondicherry was occupied by British and completely razed to ground. It was returned to French in 1765 and the town was reconstructed on same foundation. French Town did not regain its previous opulence though, due to economic constraints.

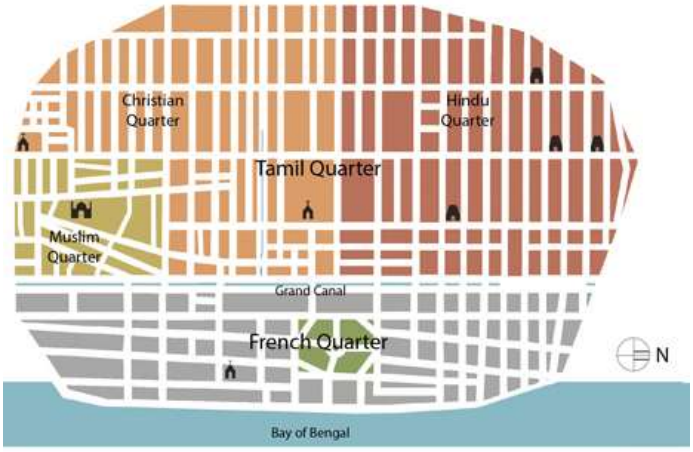

Figure 2 Grid-based layout of Pondicherry heritage town

Source: http://intachpondicherry.org/

POST-COLONIAL PERIOD

In 1954, French gave independence to Pondicherry. It was formed as a Union Territory of India, instead of merging it with Tamil Nadu state, to persevere of its culture and heritage. It was renamed as Puducherry in 2005. However, in the recent years most of the buildings in Puducherry were replaced or disfigured by non-traditional architecture.

AIM

To analyse the historic and geographic connections of Puducherry, its influence on the town planning and the design aspects of the building styles during colonial period.

OBJECTIVE

- To analyse history and geography of Puducherry during colonial period
- To document the historic and geographic influence on the town planning and architectural style

RESEARCH QUESTION

Does history and geography hold any significance in the town planning and architecture styles of Puducherry during colonial period?

METHODOLOGY

Interpretive Historical Research method was applied to the analysis of available sources as articles, old maps, photos and videos from online archives to understand the native Tamil and French Neoclassical Architecture of Puducherry.

- Historical influence - The influence of history was analyzed on the origin of the peculiar Puducherry style of Architecture also known as Franco-Tamil Architecture.
- Tamil influence on French town - Structural, functional and visual elements of French Town were studied and analysed to understand the original French Architecture, influence by the local architecture, construction practices and climatic conditions.
- French influence on Tamil town - Tamil Town was studied in detail to understand the native elements of typical South-Indian architecture of Tamil Nadu and those adopted from French Architecture.

INFERENCES

French town – Architectural Features

The French Town had both residential and government buildings and was built on the beach side around Government Square, now known as Bharathi Park. During colonial period, there was mainly upper class and a little of middle class. To please these French citizens, the French Town was based on the then fashionable style of Neoclassism and the buildings were fashioned on the architectural form known as “Hotel particulier”.

The streets are usually characterized by continuous wall to wall construction, full or partial street frontage, high garden walls, elaborate gateways, and solid walls divided into smaller panels by the use of verticals (pilasters) and horizontals (cornices). Buildings were generally two storied on much larger plots than their counterparts in Tamil Town. These had architectural elements like high-rise ceilings, high arched doors, continuous parapets (decorated with loopholes or terracotta balusters), wooden balconies and windows with louvres or wooden shutters and bands.

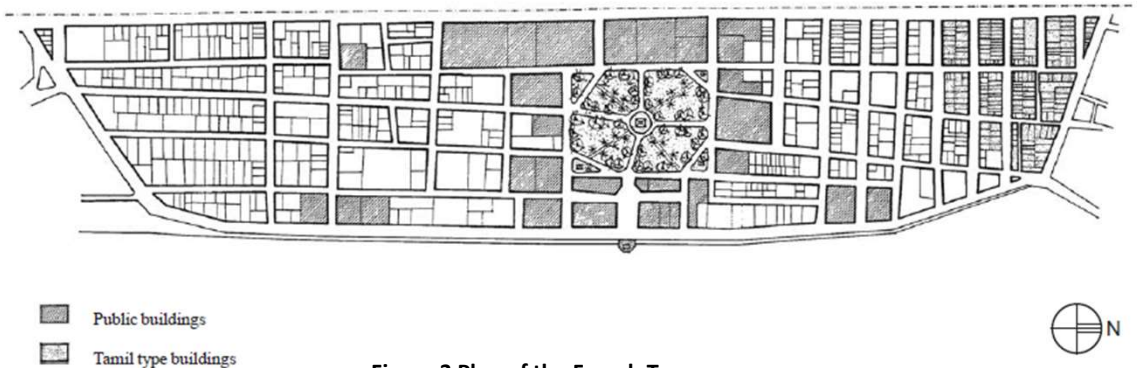

Figure 3 Plan of the French Town
(Source: http://intachpondicherry.org/)

Public buildings were grand two storied structures on even larger plots, based on French architecture adapted to local conditions usually with arcades in the ground floor and colonnades in the first floor.

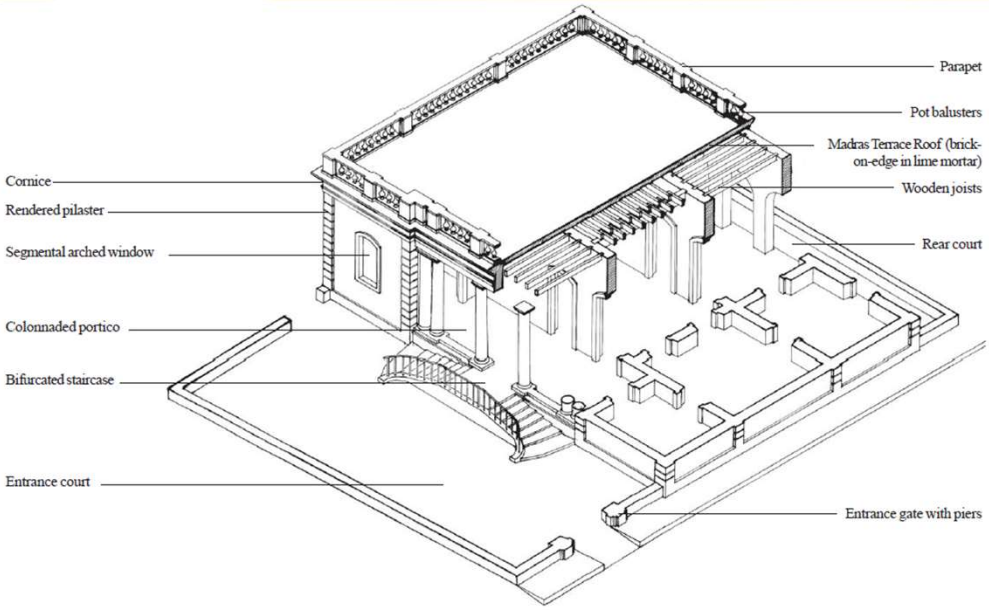

Figure 4 Sectional Isometry of 16, Rue Dumas
(Source: http://intachpondicherry.org/)

INDIAN INFLUENCE ON FRENCH TOWN

The French did not adopt any visual elements of Tamil Architecture, but adopted a number of structural elements like Madras terrace roofing, red oxide flooring, occasional teak wood flooring and water proofing using local lime terracing technique. Locally available materials were utilized like seashell lime, burnt bricks, terracotta tiles, terracotta balusters, teak and local wood. The buildings were adopted to the tropical climate by flat roofs instead of pitched roofs, larger openings, aligned windows and doors and operable louvres or cane work.

TAMIL TOWN – ARCHITECTURAL FEATURES

The Tamil town in turn has an intimate fabric of Hindu, Christian and Muslim quarters. The Hindu quarter grew around the nucleus of temples in the north west. Another nucleus around Immaculate Conception Cathedral gave rise to Christian quarter. Muslim quarter developed around the Qutpa Mosque.

Figure 5 Plan of the Tamil Town
(Source: http://intachpondicherry.org/)

Tamil Town shared a common architectural pattern on the entire settlement in spite of religious differences with subtle variations incorporate in the built form. They shared typical Tamil architectural elements like Thalvaram (street verandah), Thinnai (semi-public verandah space with masonry benches for the visitors), carved doors, combination of flat and pitched roofs, Mutram (central courtyard), private spaces followed by a rear court yard.

Thalvaram and Thinnai protected the walls from direct sun and rain, while Mutram provided air circulation through updraft, and in case of tiling they trap the heat. The mix of covered, semi-covered and open spaces provided choices according to climate. Direct openings and large openings were avoided in contrast to the French Town.

Tamil streets have intimate scale and interactive nature owing to Talavaram and Thinnai and so are known as talking streets. The streets are homogenous by the use of connecting elements like lean-to-roofs, cornices, pilasters or engaged columns and ornamental parapets.

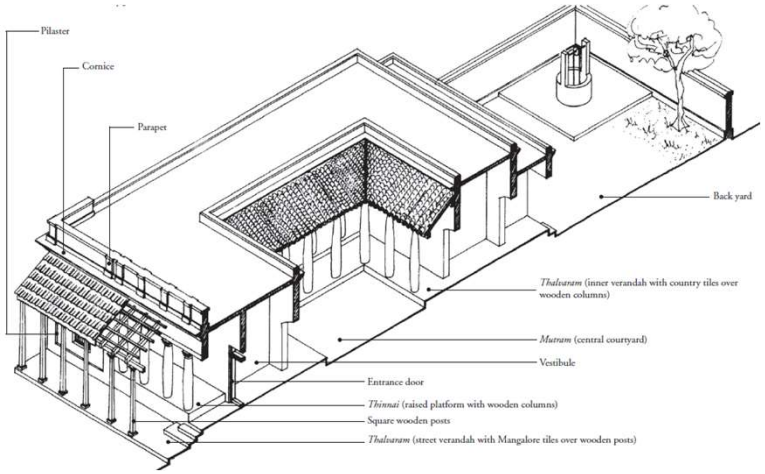

Figure 6 Features of Typical Tamil House
(Source: http://intachpondicherry.org/)

FRENCH INFLUENCE ON TAMIL TOWN

Tamil Town adopted French style without losing its nativity, which gave rise to the term Franco-Tamil Style. In particular, the wealthier Tamil households built two storied-buildings with the ground floor of Tamil Type and First floor with French features like arched windows, plaster decorations, fluted pilasters, columns with capitals, and end ornament elements.

Figure 7 House at caziar Street (Rue de cazy), Puducherry
(Source: http://intachpondicherry.org/)

Figure 8 Franco-Tamil building on Rue Calve Subbraya Chetty, Puducherry
(Source: http://intachpondicherry.org/)

CONCLUSIONS

SIGNIFICANCE OF HISTORY IN TOWN PLANNING OF PUDUCHERRY

Puducherry was a village in Tamilnadu in which Dutch traders entered in 1600s leading to major changes in economy, society and culture. In 1673, French purchased an oval shaped land of about 20 sq kms from a local king and built a fortified city divided into French and Tamil Town and named it Pondicherry. The period after that saw movement of the power to British and back many times until 1815 when the city was taken over by French for the final time. They have ruled the City until Pondicherry gained independence in 1954. The influence of British on the architecture is almost nil while there was a tremendous influence of French Architecture on the architecture of the city and its buildings. Even after its independence, the historic part of the city retained its original aura and grandeur as a partly French and partly Tamil settlement.

SIGNIFICANCE OF GEOGRAPHY IN TOWN PLANNING OF PUDUCHERRY

The oval shaped fortified city, that is Pondicherry was planned in a grid pattern. A canal cutting through the land played a role in segregating the French and Tamil into French town and Tamil Town. The French was based on architectural form known as “Hotel particulier” characterized by two storied buildings, high-rise ceilings, high arched doors, pilasters, cornices, wooden balconies and windows with louvres or wooden shutters and bands. The French Architecture borrowed Tamil Structural elements like Madras terrace roofing, used locally available materials and adopted to the tropical climate by using elements like flat roofs and larger openings.

The Tamil town had typical Tamil architecture using elements like Thalvaram, Thinnai, carved doors, combination of flat and pitched roofs, Mutram. Tamil Town adopted French style by building two storied-buildings with the ground floor of Tamil Type and First floor with French features.

REFERENCES

1. Flint, C. &. (2007). *Political Geography: world-economy, nation-state and locality.* Harlow: Pearson Education Limited.
2. INTACH. (2004). *Architectural Heritage of Pondicherry.* Pondicherry: Sri Aurobindo Ashram Press.
3. Perumal, R. (2014). Prehistoric Times of Pondicherry. *HuSS: International Journal of Research in Humanities and Social Sciences*, 22-28.
4. doi:https://doi.org/10.15613/hijrh%2F2014%2Fv1i1%2F53844

CHETIINAD ARCHITECTURE- ITS VARIOUS TENSE

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"Architecture should speak of its time and place, but yearn for timelessness" stated by Frank Gehry graces Chettinad Architecture well. One cannot experience Tamil Culture fully without crossing paths with Chettinad Architecture. Its architecture is closely linked to the lifecycle rituals of the Chettiar community.

CHETTINAD OVERVIEW

Chettiars moved to a dry arid area (in and around Karaikudi) from previously flooded Cauvery Poompattinam for a safer settlement around the 13th century. This eventually became the Chettinad region, Chettiars till date have grouped themselves around nine temples. flayatrangudi, Martrur, Vairavan, Iraniyur, Pillayarpatti, Nemankovil, fluppaikudi, Sooraikudi, and Velangudi were the initial nine villages which later spread to 75 villages spread around Ramanad, Pudukottai and Thirumangalam districts. Chettiars were traders and merchants of salts, gems, jewelry and textiles which took them to various places such as Srilanka, Singapore, Malaysia, Cambodia, Vietnam and Burma. Chettiars used to import Burma teak to add to their sumptuously rich interiors. Apart from their architecture, food and their customs are also widely known.

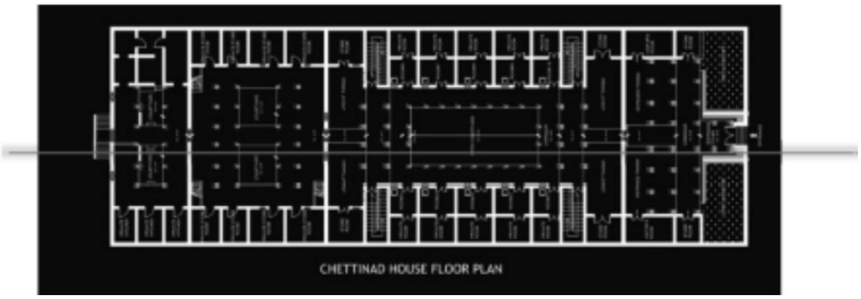
Ayyiram Jannal Veedu

Chettinad Architecture -in its PAST

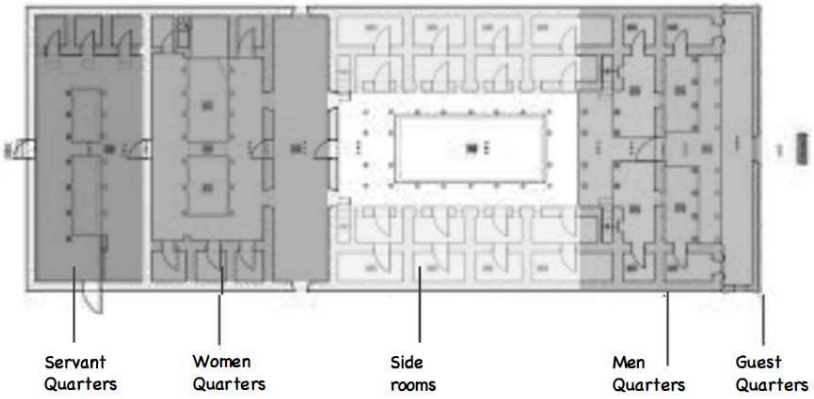
Planning- Chettiars incorporated various influences they had brought home from their constant travels. The result is a very particular architectural style and atmosphere.

The concept of the Chettinadu house originated from their lifestyle rituals starting from having raised plinth of 2M to avoid damage due to flooding, learnt from their previous experience in Cauvery Poompatinam.

Chettiars wanted to absorb temple planning to bring in the positive energy which resulted in having series of openings in the central axis. This also this works as a point of connectivity for this huge horizontal spread house.



Catering to their occupational lifestyle, the planning falls into four sub divisions - guests, men, women and servants.



Since the very nature of their business attracted frequent visits from guests and foreign businessmen, this led to the formation of outdoor thinai and visitors room. Chettiars involved in banking and trading brought home a lot of valuables which were safely kept in side rooms (Ullarai, Velliarai) . Generations of families used to stay within one unit, leading to planning of various small sized rooms around the central courtyard. These rooms are intentionally designed small, so as to keep the area of the rooms to the minimum, and the isolation to almost nil, focusing on bringing the entire family together at all times. The joint family customs were followed for many years and it is one of their strongest traditions which influenced the planning of breaking the residential quarters into men and women quaters, placing the men's interaction space near the entrance and women's interaction space in the interior, almost near the backyard for privacy and safety reasons.

The kitchen and the bhojana hall were designed huge in scale, so too the courtyards to cater to all functions including marriage. Provisions for outdoor kitchen were also given to accommodate such events. The servant quarters were placed near the backyard next to the kitchen and the bhojana hall (dining hall) and they have a separate entry, so none of those activities interfered with the men's or guest chamber when they dealt with business and other trade affairs. Chettiars designed their houses in such a way that right from birth to death the house catered to all needs.

The houses were usually one storey with huge grand terraces. The orientation of the houses was towards East/West, main entrance was towards East and on the West side of the house there would be a garden which acted as the main source of fresh air. The courtyard worked as a thermostat which controlled the temperature of the house.

Terraces and courtyard

Aathangudi tiles

Cooling Techniques: To escape from floods they moved to dry arid areas, which had its side effects the hot sun, and to counteract this they built thick red soil bricks walls, used light colored chunnam(lime plaster) and coated with egg white to reduce the temperature of the interior. Double roof system and chajjas were included to keep the interiors cool.

Materials- Stepped rubble work with stone, mud and mortar foundation, baked red soil bricks, country tiles and wooden logs were some of the materials used. The famous aathangudi tile is one of their unique building materials which was an outcome of various exposures the Chettiars had due to trading. The pigment on those tiles were imported from Italy. Mud tiles and cement flooring are also used..

Architectural Elements: Roofs of different adjoining rectangular units sloping towards the central courtyard forms a unique roofscape. Wooden columns, arches and intricately carved doors mark the identity of Chettinad Architecture. Balusters, cornices and parapets increase the grandeur of these mansions.


Architectural Elements

Almost five decades back the joint family custom was followed strictly, and they had single family business for all the men in the family, predominantly involving travelling, resulting in all women of the family staying together in these big mansions. The planning suited all needs of the user at that time.

CHETTINAD ARCHITECTURE -IN ITS PRESENT

In recent times, the men of the family started moving out to various cities/ countries for education and occupation purposes, resulting in nuclear setups, thereby leaving their houses in their village. The elders of the family stayed back to take care of these houses, the Chettinad Architecture adapted itself based on these changing needs. The side rooms alone were kept closed, while the remaining parts of the house were in full functional use, and as and when the family visited, the side rooms were used.

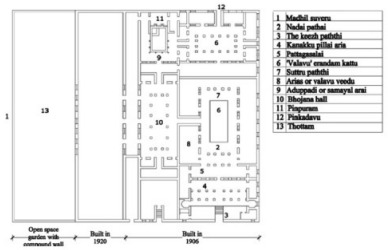
Recent cultural change/ economical pressure instigated breaking down of families and dividing movable, immovable properties. This in turn has led to breaking down of these huge houses into small units of independent users, but the odds of this happening is very less as the magnificence of the architecture and the detail of work put into it is inducing the users to find alternate uses. Some of the known examples are the Chidambara Vilas, Saratha Vilas etc. Saratha Vilas located in Kothamangalam is a 34500 sq. ft. property, including buildings, courtyards and gardens. It has been painstakingly restored, and converted into an eight-bedroom boutique hotel by two French architects Bernard Dragon and Michel Adment who are passionate about the preservation of Chettinad and its history .


Saratha Vilas images

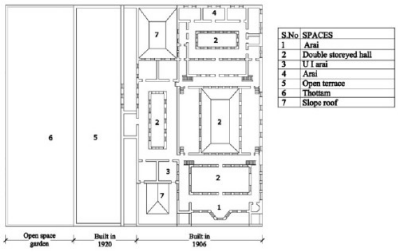
Chidambara Vilas on the other hand is a 110 years old mansion located in Kadiapatti and restored into a luxury heritage resort by the Sangam Group.

The few functional uses of the old mansion have been restored in the new heritage hotel, like the thinai and kanakupillai room (accountant's room) which are still used as guest recieving area and hotel accounts room respectively. The bhojana hall is used as a restaurant and the kitchens are restored with the addition of modern equipment. The central courtyard which initially housed major events is now used as a traditional activity/ performance space. Apart from this some of the spaces are reused in a different manner to cater to the present need, like the compound wall height is increased and it is used as a display wall for Chettinad artifacts, the arais (side rooms) initially used for sleeping and storing valuables is now used as store room and the garden is converted into a swimming pool with other amenities. Some additions have been made to the existing mansion to fulfil the needs of the heritage hotel. Guest rooms and house keeping are some of the additions made to the existing house. Materials and the outer skeleton have been retained to the maximum and only minimal changes are done staying true to the ethics of conservation.

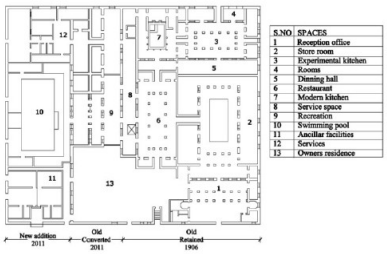

Before/ After Restoration



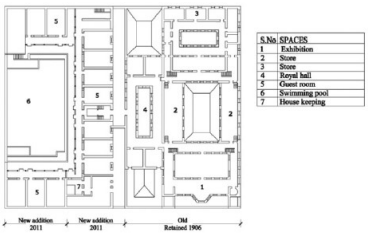
Ground Floor Plan – Original mansion.



First Floor Plan – Original mansion.

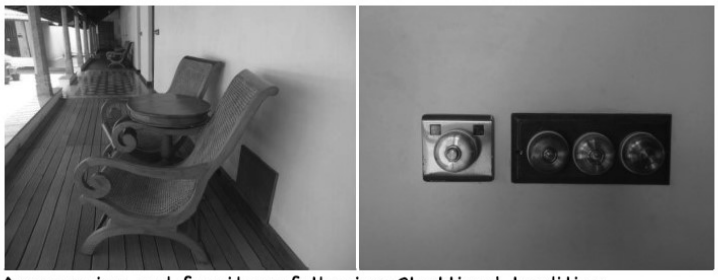


Ground Floor Plan – Heritage Hotel



First Floor Plan – Heritage Hotel

Guest Bedroom interior



Accessories and furniture following Chettinad tradition

CHETTINAD ARCHITECTURE -IN ITS FUTURE

The current users are finding it hard to maintain these big mansions due to lack of funds and workmanship. But, since the architecture speaks highly about the culture and preserves many memories of their ancestors, they are finding alternate uses to preserve their unique architecture style. The old buildings with heritage value are converted into resorts and hotels, and since many of the houses were designed to cater to big events, some of the houses are getting converted to huge wedding halls. So as Gehry stated: Chettinad Architecture gave a marked identity to the time and place it was built in and now with restoration and reuse and simple adaptability it is yearning for timelessness too.

REFERENCES:

1. Yatin Pandya, "CONCEPTS OF SPACE IN TRADITIONAL INDIAN ARCHITECTURE."
2. Bernard Dragon, Michel Adment,UNESCO, ",INDIAN HERITAGE PASSPORT PROGRAMME ON THE CHETTINAD TRAIL IN TAMIL NADU"
3. Ranee Vedamuthu, Jayanthi Dhakshinamoorthi, and Kumudhavalli Sasidhar "ADAPTIVE REUSE AND RESTORATION OF A CHETTINADU MANSION, PUDUKOTTAI, TAMILNADU, INDIA. 2014.

ROLE OF MINARETS IN CONTEMPORARY- MOSQUE DESIGNS

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ABSTRACT

In this study one mosque for different placement of minarets are analysed in terms of their location, usage, features and interpretation in the design.

Through the selected samples, the above mentioned parameters are studied and compared with the pre- modern period samples. The changed functions and introduction of new ideas to their design is also discussed.

The study aims

- *To explore on the purpose of the minarets in the contemporary mosque architecture.*
- *To study the emergence of minaret in mosque architecture.*
- *To identify and evaluate the impact of minarets in historic vs. contemporary mosques.*
- *To conclude on the need of the minarets in modern mosque architecture.*

This Paper also explores the history of the minarets to study and trace the type of minarets and their function in preaching. Whether there is a need to modernise according to the trend or maintain the traditional design. What are the major factors in designing the modern minarets in mosques?

Without understanding the tradition the modern designs cannot be underlined. So this study deals with how the minarets were looked upon in the past and how the traditional element has been used in the contemporary mosques. On this basis, the study focuses on the attempt of interpreting minaret design, through the analysis of the mosques. The analysis is based on the use of the minarets in the mosque design.

1. INTRODUCTION

Mosque is where the Muslims gather to engage in communal worship, spiritual retreat, education matrimony, and other significant socio- cultural activities. It is a culture bound place of worship, representing local and regional architectural traditions.

It is very important for the faithful, but the mosques are not built according to divine patterns: the two main religious text for Muslims, the Quran and the hadith, provide no clear rules as what a mosque should look like; however, the Quran does stress the value of the edifice as a place for remembrance of god and the hadith prescribes a list of profane actions that are not allowed in a mosque to keep the sacred in the minds of its knowing and acting participants. There are a host of historical similarities and differences, and the interplay of regional and material relationships. Aesthetic differences are most evident in the pre- modern mosques. There are no regulations with respect to Islamic architecture.

Wherever Islam spread, the Muslims adapted the local architectural style for the construction of the mosques. In countries as varied as China and Mali, mosques were built in the local architectural styles for centuries. In Tamil country for close to a millennium the Muslims built their mosques in the Dravidian – Islamic architectural style.

Distinguishing elements of a mosque are

- the minaret,
- miharab,
- mimbar and
- the dome.

These elements seek innovation, aesthetic, contextual, or place specific ideals without loss of validity, truth, or value over a period of time.

Methods of data collection: documentation and observation. Collected data were analysed by deductive, inductive and comparative analyses.

2. MINARET

A minaret is a tall, slender tower like structure usually associated with mosques or other religious buildings, which is located within or adjacent to the building. Minaret show variation in shape, size and ornamentation in different regions.

Different regions tend to feature variations on **minaret** shape and ornamentation. The structure will include four sections (base, shaft, cap, head), but they can be rectangular (sometimes found in North Africa), cylindrical (found in Iraq and other parts of the Eastern Islamic world), or pencil-shaped with several balconies (as in Turkey).

Minarets are modernised according to trend without neglecting the need and budget and some of them sustain the traditional design with local community choice.

The two main factors to design the minarets are the need and the budget.

2.1. FUNCTION OF A MINARET

They contain balconies which are reached through stairs built inside the minaret, principally on which the 'muezzin' stands to call the worshipers to pray.

Originally it was designed to call for prayer in the past but now it's not needed functionally due to the advanced technology. But it became a vital architectural component of a mosque design and is still considered as a must for its symbolic meaning.

An elevated free standing, visually significant figure which is taller than any connected support structure. Minaret provide a visual focal point to the community and also acts a s a landmark. In those days call for prayer used to be called from the gallery encircling the shaft of the minaret by the muezzin, but today it is called from the prayer hall which is connected to the speaker system on the minaret.

2.2. HISTORY OF MINARET AS A TRADITIONAL ELEMENT OF MOSQUE

The Prophet's Mosque constitutes the prototype of mosque architecture, starting from the early years of Islam, during the rule of Omar. The concept of the mosque of prophet dominates the early Islamic religious architecture as it dictates the plan of almost every Jami mosque built.

As Jeremy john quotes, Omar was "portrayed as an almost obsessive mosque-builder"; he is believed to have decreed that all congregational mosques should be laid out according to a common standard and this standard had later become the standard for the religious architecture of Islam. (Johns, 1999:69, 109, 110-112)

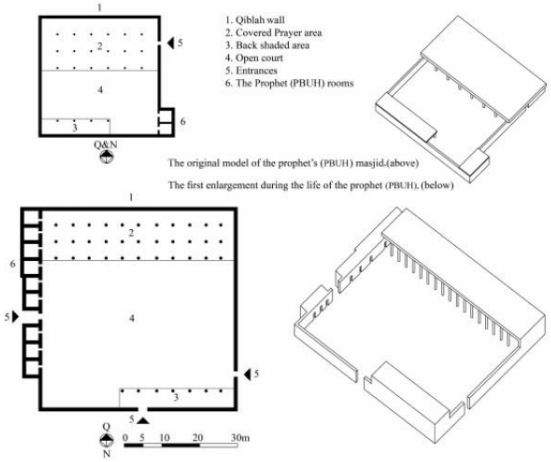

Figure 1: (Above) The Prophet's masjid before qiblah transmission without the minaret (Source: Oldham and Elkhateeb, 2008); (Below) The masjid after qiblah transmission (Source: Grabar, 1987)

Norberg Shulz describes minaret as a "mere reminder of heaven" as it is in a vertical axis positioned comparatively free in relation to the nearby buildings. It is believed to express a prior link between earth and sky. (Norberg Shulz, 1986: 12) Likewise, in Arabic liturgy, it is also defined as the "gate from heaven and earth" and identified with the Arabic letter *alif* (which is a straight vertical line). (Johnson, 1979: 173)

It is believed that the functional core of the minaret is to call for the prayer. The first faithful came to pray without any call but when Jews used a horn and the Christians used a clapper, they wanted something unique for their own use. After some deliberation it was decided human voice will be used to call for prayer.

The old days mosque dint have any minarets at first, the call for prayer was done from the city walls or from the roofs of buildings. (Bloom, 2001: 55) It is stated in hadiths, that the Muslim community of Medina was called to prayer from the roof of the house of the Prophet.

Creswell states that, the minaret first came in to practice under Umayyad dynasty in Syria, where there was a first contact with the Syrian church towers, which was later adopted and spread throughout the lands they conquered.

According to Creswell, the minaret that we are aware of today appeared in the Abbasid period (i.e. after 750 CE). For Creswell, six mosques belonging to that period all have a single minaret connected to the wall opposite the mihrab. In these mosques, the intention for building the minaret was to reveal the power of Abbasid authority in religion. People opposing to the Abbasid power like Fatimids were not using minaret as it was their symbol of power. Thus Fatimid mosques did not have towers (Creswell, 1926: 134-40, 252-8, 290-8).

However Johnson indicates the first known minaret appeared around 80 years after prophet's death and another theory says it first appeared from the Roman temenos watch tower (Hillenbrand, 1994).

In later period minarets showed variation according to the period and the region they were being built in to. Minarets were in square, polygonal, conical and cylindrical. One of the earliest known **minarets** was the 8th century as part of the Great Mosque at Damascus **Error! Reference source not found.**. The oldest surviving **minaret** dates back to the Great Mosque of Kairouan, built in Tunisia in 836.

Figure 2: on the left, Minaret of the Bride, Great Mosque of Damascus (source: https://madainproject.com/content/media/collect/umayyad_mosque_001288.jpg)

Figure 3: on the right, Minaret of the Great Mosque of Kairouan, built in Tunisia in 836 (source:https://en.wikipedia.org/wiki/Great_Mosque_of_Kairouan#/media/File:Panorama_of_the_courtyard_of_the_Great_Mosque_of_Kairouan.jpg)

Ottoman mosque architecture uses tall pointed minarets and large domes. In most of the mosques there were single minarets attached to a corner or in the centre of the mosque IN bigger mosques there were two, four, or even six minarets built. It is believed that only a reigning sultan can erect more than one minaret in a mosque. Before the nineteen century the minarets were very rare in Arabia, outside mecca and medina. The level of flamboyance of a minaret generally determines its origin and period. (Creswell, 1926: 134-40, 252-8, 290-8)

ANALYSIS OF THE CASES SELECTED

3.1. THE GREAT MOSQUE OF XI'AN (SHAANSI, CHINA, 742 CE)

Figure 4: Chinese-style minaret of the Great Mosque of Xi'an(source:https://sinificationarchitecture.wordpress.com/islamic-architecture-in-china-xian-as-a-case-study/)

Although there are not any traditional minarets or domes, it is said that “The Introspection Tower”, a two-story pagoda located in the third pavilion, was used to call for prayers (adhan).

3.2. Mosque of Hassan II in Casablanca, Morocco

It is the second largest functioning mosque in Africa and is the 7th largest in the world. Its minaret is the world's second tallest minaret at 210 metres (689ft). It has a laser beam fitted at the top, which is electronically operated in the evening. It is oriented towards Mecca, across the sea and has a range of 30 kilometres (19 mi). The minaret is said to enhance the visual alignment of the boulevard. It is square in shape thrusting skyward.

Figure 5: Minaret of Mosque of Hassan II in Casablanca (source: https://www.atlasobscura.com/places/hassan-ii-mosque)

The upper part of the minaret of the **mosque of Hassan II in Casablanca,** the tallest structure associated with a religious building anywhere in the world. It houses a computer centre from which technical services throughout the mosque complex are controlled; on important occasions a powerful laser beam can be projected from the summit.

3.3. Shafiq Amash Mosque, Beirut, Lebanon

The siting of the minaret at one corner ensures that both it and the mosque as a whole are prominently visible despite the presence of nearby high – rise buildings.

Figure 6: Shafiq Amash Mosque, Beirut, Lebanon (source: https://islamicarchitecturebydxx.blogspot.com/2017/01/shafiq-amash-mosque-lebanon.html)

3.4. Bin Madiya Mosque, Dubai, UAE

The brick- clad exterior of the mosque contrast with the square minaret with its white balcony and oblique edge. The square minaret of the Great Mosque, Dakar, a building dating from the 1970s closely modelled on the historic ninth-century Qarawiyyin Mosque in Fez.

Figure 7: Bin Madiya Mosque, Dubai, United Arab Emirates (source: http://www.artoak.com/bin-madiya-mosque)

3.5. SHEIKH ZAYED GRAND MOSQUE

It is located in Abu Dhabi, the capital city of the United Arab Emirates

Figure 8: Sheikh Zayed Grand Mosque in Abu Dhabi (source: https://www.abudhabitalking.com/sheikh-zayed-grand-mosque-2/)

Sheikh Zayed Grand Mosque Center (SZGMC) offices are located in the west minarets. The library, located in the northeast minaret, serves the community with classic books and publications addressing a range of Islamic subjects: sciences, civilization, calligraphy, the arts, and coins, including some rare publications.

3.6. YEŞILVADI HOUSINGS MOSQUE (İSTANBUL, 2004)

Figure 9: Yeşilvadi Housings Mosque, Istanbul (source:https://mosqpedia.org/img/cache/thumbnail/ikGJRJyhW66hVzxB2XeAyyyd7n1B6eG6oETsXS7J)

As a very innovative function, the minaret is also serving as a sundial. By its shadow falling onto the markings inscribed to the ground of the main piazza, it is planned to show the time. In this mosque, the usage and interpretation of minarets has reached to a high level and finally a consistent mosque design was acquired.

3.7. THE STATE MOSQUE OF SELANGOR

This probably is the most monumental mosque in Malaysia. The enamelled dome and the four slender ottoman- style minarets which frame the mosque are visible from a great distance.

Mohamed Makiya's design features the tallest minaret (intended to serve as an observation tower) and a prayer hall surmounted by the grandest safavid- style dome.

The Sultan Salahuddin Abdul Aziz Shah Mosque is the state mosque of Selangor, Malaysia. It is located in Shah Alam. It is the country's largest mosque and also the second largest mosque in Southeast Asia by capacity.

Figure 10: The state mosque of Selangor, Malaysia (source: https://www.twenty20.com/photos/6d1d987b-3746-4daa-958b-342bf5c12145)

CONCLUSION

Minarets were erected in 1,2,4,8 numbers according to the scale of the mosque and the region. Traditional minarets were erected with just one purpose that is to call for prayer, but in the contemporary mosques there are different purpose with the traditional value.

In some minarets there are no access to the top of the minaret. And few minarets are just used for the placement of the speakers for call of prayer. Figure 5: Minaret of Mosque of Hassan II in Casablanca (source: https://www.atlasobscura.com/places/hassan-ii-mosque)houses the computer centre in the minaret. Figure 8 houses the office and library in the minaret.

Some mosques are even built without the minarets, but using a symbolic element instead such as in Figure 4: Chinese-style minaret of the Great Mosque of Xi'an(source:https://sinificationarchitecture.wordpress.com/islamic-architecture-in-china-xian-as-a-case-study/). Eventually minarets acts as a landmark to the place along with all the other purposes.

REFERENCES

1. B. Fletcher, *A History of Architecture on the Comparative Method*, 17th Edition, London: The Athlone Press, 1963.
2. J. M. Bloom, "*Creswell and the Origins of the Minaret*", *Muqarnas*, Vol. 8, 2001.
3. J. M. Bloom, *Minaret: Symbol of Islam,* Oxford: Oxford Studies in Islamic Art 7, 1989.
4. Norberg-Shulz C (1986). "The Architecture of Unity". Architecture Education in the Islamic World - Proceedings of Seminar Ten in the Series of Architectural Transformations in the Islamic World. Sponsored by Aga Khan Award for Architecture. Singapore: Concept Media.
5. P. Johnson, *Civilization of the Holy Land*, Lon-don: Weidenfeld and Nicolson, 1979.
6. R. Thapar, *A History of India, Part-1*, U.K.: Hazell Watson & Viney Ltd., 1976.
7. P. Brown, *Indian Architecture (Islamic Period)*, Bombay: D.B. Taraporewala Son & Co. Pvt. Ltd., 1981.
8. S. Grover, *The Architecture of India: Islamic*. New Delhi: Vikas Publishing Private, 1981.
9. Erzen J, Aydan B (1996). "*Kinali Island Mosque, Istanbul*", "The Parliament Mosque, Ankara", and "TEK Mosque, Golbasi, Ankara". Architecture.
10. Johns J (1999). "*The „House of Prophet*" and the *Concept of the Mosque*". Bayt Al-Maqdis: Jerusalem and the Early Islam. Jeremy John's ed. Oxford: Oxford University Press.

DIGITAL TRANSFORMATION OF CONSTRUCTION INDUSTRY

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ABSTRACT:

In the current pandemic circumstance, the digital platform is becoming increasingly dominant in day-to-day activities, and it is essential to contemplate how to implement it in the built environment. Due to the coronavirus pandemic, businesses are slowing down, and in some cases, economic decline is crushing companies. Despite the tremendous challenges faced today and in these difficult times, the construction industry is remaining resilient. The worldwide situation has been an acceleration in motivating the construction industry to use digital platforms to help the company to speed ahead in the competitive world. Pandemic conditions have posed a devastating threat to our cities, forcing architecture and urban design to evolve. What springs to me as a concept is what will be cutting-edge and ground-breaking in the construction sector. In the architecture industry, new ways will be to use technology such as Virtual Reality and Augmented Reality as no physical touch is required, which is necessary for today's situation. The need of the hour is to recognize the necessities and communicate them remotely to the customers, maintaining the physical distance. The prime challenge for the architects is convincing their clients that the proposed virtual view will be identical to the actual layout. This research aims to understand and explore the interactive digital platforms and software for the construction industry. Also, how would it be helpful to the construction industry's stakeholders?

KEYWORDS: Virtual Reality, Pandemic, Digital Technologies, Augmented Reality

Figure 1 (Piqsel)

INTRODUCTION:

Many firms, especially the construction industry, have adjusted their lives and economies due to the pandemic, as the recession will last for years. Many businesses across the world are questioning how long they will endure the pandemic situation. People have become more aware of how-to live-in cities and communities due to the covid-19 pandemic situation. It has demonstrated the capability of technology and the technique for applying it to the built environment. These effects will have a significant impact on the environment, and humans will need to adapt. Unexpectedly there is a setback to the world facing the pandemic condition of coronavirus forcing us to re-examine our surroundings. And it looks that no matter how hard we try, it is becoming resistant to our reactions. We have been in our homes for the past year due to unforeseen circumstances. Now that we are dealing with reality, we have realized that our homes are not simply places to sleep but also places to work. Given the current scenario, it will be impossible to adapt to the new normal if we continue with the centuries-old technologies. As a result of the coronavirus outbreak, businesses around the world were encouraged to embrace digital platforms. Coronavirus has prompted people all around the world to reconsider their daily routines. Coronavirus has prompted people all around the world to reconsider their daily routines. Coronavirus has forced the world to rethink the daily lives of each individual. As there is a ban on travelling or simply meeting people in the actual world, now is the moment to live up to the saying "Necessity is the mother of Invention" (Dictionary.com). Businesses have come to a halt as social estrangement has become the new normal workers can continue to work from home using a digital platform. Firms that can digitally use technology will have a competitive advantage in the marketplace. Every company in the globe is opting for remote work. possibilities and virtual mode for chat or discussion. Each architectural element is significant not only in terms of places and in terms of architectural structures because it is a reflection of our culture. However, the virtual realm is now more essential than the physical world since it provides an experience similar to genuine circumstances. The architect has been ignoring the virtual world for a generation. For a generation, the architect has ignored to use the virtual world. The stunning design provides experiences that are impossible to duplicate in virtual environments, yet the digital possibilities are vast and more accessible from afar. The architectural and design sectors should think about how to design a space.

It takes into account the rapidly evolving digital scene. The coronavirus pandemic is merely a reminder to the industry to commence adopting the new technological enhancements. Digital technology in architecture will ensure that all the consultants and the contractors are imparting similar interpretations. Although pandemic conditions have posed a catastrophic threat to our cities, architects and urban designers have been obliged to innovate. Discovering a modern and innovative approach to architecture and real estate is one idea that comes to mind. This study attempts to determine how interactive platforms can be used in pandemic conditions and benefit the construction industry.

REAL ESTATE:

As the global influence of COVID-19 grows, real estate businesses, developers, and agents are looking for new ways to keep landlords and tenants connected in the digital world. Despite the employment of virtual tools before the pandemic, technological advancements increased the brokerage firm's response to the current global disaster. Real estate has always been a thriving industry that quickly adapts to changes and different styles. Because of the coronavirus's growth and influence, businesses were adversely affected, and they are scrambling to find new means to reach customers. That's why many companies in real estate have commenced working on virtual reality as a tool for their business. Using Virtual Reality (VR) technology and interactive
interface, real estate companies can give a live demo to clients in real-time without exposing them outside the world. Not only does virtual reality become a tool for communicating with clients, but it also offers a means of teaching employees without putting them in danger from the coronavirus. Typically, clients visit multiple sites before deciding on what they want. This necessitates frequent travel to different sites, which are both time-consuming and costly. Clients can virtually tour houses from the comfort of their own homes, which helps to prevent the coronavirus from spreading. The virtual reality headgear enhances the experience by allowing guests to take a three-dimensional tour of the location. With the help of a virtual tour experience, clients can easily choose between apartments or
offices that are worth buying or not. Architectural visualization has become a reality thanks to virtual reality technology, allowing architects to virtually tour customers around the inside and exterior of a project, describing the design down to the tiniest elements. Immersive technologies like Augmented Realities (AR) and Virtual Realities (VR) can considerably be
developed by guiding buyers to give better-quality proficiencies, agents, and sellers alike. Not only for potential tenants or purchasers but also for sellers and realtors during times of probable downturn when buyer-to-seller and buyer-to-agent ratios decrease considerably, AR and VR can save significant time and money.
Guided tours and interactive visits are the two types of 3D virtual tours available.
Guided tours are pre-recorded marketing videos that are either virtual or 360-degree views. Guided tours are ideal for existing properties because they are simple to set up and only require a panoramic camera to record the sights. To offer a lively experience to clients must use VR headsets.
Interactive visit: allows the user to move into the property by clicking the spots in the field of view. Creating interactive tours is more communicating that the guided tours also more efficient in showing properties.
Potential buyers will soon be able to virtually wander freely in their prospective home or office thanks to immersive technology, just by donning a VR headset or viewing an AR on their smartphones or tablets. And it's possible that this is the secret to achieving instant success in today's very volatile real estate market. For real estate developers, the current times are the most challenging time for multiple aspects. New and innovative technologies can be created with the help of the internet and remotely operated technological equipment. Using digitization will be a game-changer for the developer because clients can communicate digitally during the pandemic.
Benefits of Virtual Reality technology in real estate: VR eliminates the prices of staging a property and transforms several marketing initiatives. Virtual reality saves time and money since it removes the need for property showcases and travel. Users can virtually view properties from anywhere within the world when powered with VR; VR provides better personalization and increases revenue. VR enables realtors to gain valuable insights into customer behaviour and preferences, used to improve future interactions.

Figure 2 (pxfuel)

Figure 3 (LUNAS)

Figure 4 (Business World)

ARCHITECTURAL FIRMS:

Technological advancements are shifting architecture, the world's oldest profession, from 2D to 3D ideas in the virtual world. The use of augmented reality has just begun and is doing wonders in transforming civil construction. The augmented reality benefits the whole team consisting of architects, engineers, project managers, and site managers. Virtual elements interact with existing features in augmented reality, making it feasible to create virtual architectural designs that are exact replicas of the real thing. This reduces errors, improves efficiency, accuracy, and saves money and time on the job site. Using a BIM system during the development phase reduces incompatibilities and unpleasant surprises while saving money and time.

Often the drawing is challenging to understand on-site augmented reality assists in providing a more accurate view of what to build with all layers and materials. The blueprints and virtual models can help with project comprehension, project execution, and even directing personnel through intricate construction geometry. Augment is software that permits the user to understand 3D models in the actual phase and to the scale converting the plan into the 3D hologram. Designers, for example, might use the platforms on their smartphones or tablets to increase their customer base. Using an Augmented Reality device is needed and several companies manufacture AR hardware. AR gadgets, glasses, and construction helmets with glasses are all accessible, and they're all used to speed up work on the job site.

There are four types of AR devices available heads-up displays, Holographic displays, Smart glasses, and handheld. Some giant leaders sell these AR devices Microsoft Hololens 2, Magic Leap One, Epson Moverio, Google Glass Enterprise Edition, Vuzix Blade, and many more. AR may be used to understand design incompatibilities by virtually walking around the model. This mode allows architects and contractors to collaborate on changes that happen on-site relating to construction and stability also can assist in the prefabrication of a building component. AR can be used for visualization, allowing city planners and engineers to examine a structure after an incident to determine the reason, such as a fire or an earthquake. This helps to gauge the effect on the construction and rectification that could be done in upcoming projects to avoid such disasters. Many augmented reality technologies can transform the plans into 3D models instantly few applications are as follows:

MORPHOLIO AR SKETCHWALK: is an AR tool that allows the designer to view the sketches to give the client and themselves a real perception of space. Positioning I pad on the sketch in the plan so that the client may walk through it by increasing walls, giving him an interactive and clear idea.

DAQRI SMART HELMET: is an intelligent helmet that allows visualizing projects in 3D models as an immersive and large-scale 3 D environment. Teams can accord work with each other by comparing the site progress with the actual design.

Measure Apps for IOS and Android: With the measuring software installed on their phones, users can use their phones as digital rulers, calculating distances in real-time. This program can be used to make measurement drawing plans for an actual room.

Augment: is an application that allows 3D models in real-time to scale, creating 3D holograms. This platform is available on the smartphone used by product designers, sales, and marking teams for boosting sales by reducing the proto-type costs.

GAMMA AR: this uses augmented reality to overlay the BIM 3D model via smartphones or tablets; it allows comparing the actual work with information in the model. It permits understanding the planning, avoiding errors, and reducing construction costs.

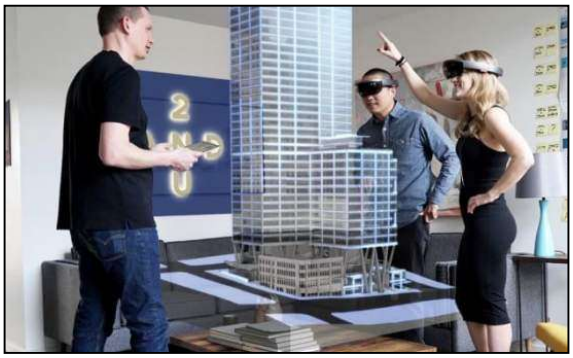

Figure 5 (Affinity VR)

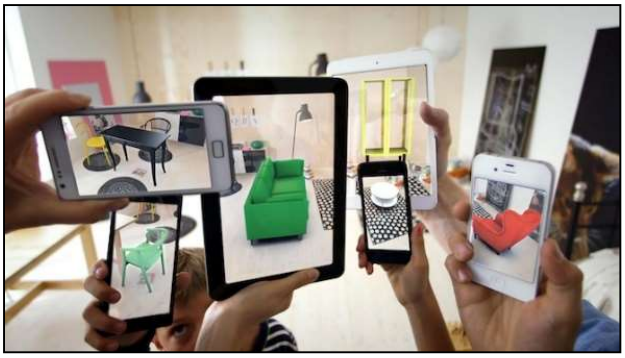

Figure 6 (Visual Retailing)

RETAIL INDUSTRY:

Every client wants to see the physical product which they can touch and feel and then purchase. But in the current scenario, the physical world has halted where no one can travel to check anything. So, the industry has to be innovative to create an online experience for the customers with the assistance of AR. Virtual objects can be placed in real-world scenes in AR, allowing customers to see the item and subsequently purchase it online. Ikea former player in the furniture is using AR to attract clients where one can try multiple pieces of Swedish decor in a room. Introducing its Place application, Ikea allowed customers to try their various collections for the home without actually visiting the store. The actual reason is permitting users to navigate through several of Ikea's assistance at a similar period in augmented reality. Also available in the room collections option, which is a similar item but with Ikea-curated collections for consumers. Ikea's customer experience has improved due to this app, compared to other organizations where customers value experience.

Another company using AR is Amazon on phones where one can place any product they need for home. There are thousands of products in categories for easy selection of the client. Once the customer picks a product the app will revert to camera mode, and by simply rotating or moving the camera spot is selected. Retailers and customers are taking AR into serious consideration as it has become a trend. The benefits of AR for the retailer are engaging the customers, visualizing the purchased content, improving customer satisfaction and shopping experience, reducing physical contact.

The Magic app is an iOS app that allows quickly building a floor layout, another intriguing piece of software. The rest of the app created the floor layout by quickly tracing the corners of the floor with the smartphone camera. It is a lot easier to make amazing 3D views using this software.

CONCLUSION:

Today invention in digital technology is redefining the construction and infrastructure sector size, and the pace will soon change as we move towards technology and digital solutions. As the rate of change continues to accelerate, the ability to be cutting-edge, inventive, and reinvent commerce and deliver solutions will become a selling point. The digitization of architecture not only conserves time and money, but it also builds an outstanding deal possible. Building complex structures employing a 3D printer, scanning existing buildings for maintenance, and documentation services by using drones, computer game goggles with 3D visualization. The Internet of Things (IoT) is a particular application that will soon become a way of life in digital architectural design. Adopting the IoT in the construction industry is essential as it benefits from BIM software IoT provides a steady flow of relevant data that can be shared with all stakeholders and present the insight virtually. IoT helps in managing the site efficiently by tracking the supply assets. IoT allows the entire team to utilize their time by lowering project costs and assuring the timely delivery of new equipment and other resources. IoT helps in providing real-time data by tracking the working environment where there is no exposure to dangerous situations. Everything is currently developing in a series of massive leaps, particularly in the sphere of technology. In architecture, there are constant changes in the way we work, think, and create. Digitalization in the sector is advancing along with the adoption of new technology like virtual construction in 3D before the physical commencement of the project, aimed to anticipate any problems that may arise during construction. Some of the industry's leading software companies are helping existing requirements of architects and designers by offering them access to their services. Many firms, including Autodesk, Adobe, and Graphisoft, have made their tools available for free. Google Meet, Zoom, and Google Drive are just a few of the many technologies used to engage with clients. Massive advancements have rendered architect work, particularly design procedures, automated in response to recent digitalization approaches.

BIBLIOGRAPHY

1. AffinityVR. *VR and AR in Architectural Design Presentations*. 21 Nov 2019. https://www.affinityvr.com/vr-and-ar-in-architectural-design-presentations/. 28 Oct 2021.
2. Bahadursingh, Nathan. *What the Coronavirus Reveals About Architecture*. n.d. https://architizer.com/blog/inspiration/stories/what-the-coronavirus-reveals-about-architecture/. 16 Oct 2021.
3. Besecker, Beck. *47 AR Examples – The Definitive Guide to Augmented Reality in Retail*. 03 March 2019. https://www.marxentlabs.com/ar-in-retail-top-augmented-reality-retail-apps-guide/. 15 Oct 2021.
4. Business World. *10 Uses and Benefits of Virtual Reality in Tourism*. 12 July 2019. https://www.businessworldit.com/ar-vr-technologies/10-uses-and-benefits-of-virtual-reality-in-tourism/. 26 Oct 2021.
5. Dictionary.com. *Necessity is the mother of invention*. n.d. https://www.dictionary.com/browse/necessity-is-the-mother-of-invention. 18 Oct 2021.
6. Digiteum Team. *How IoT Can Improve*. 30 March 2020. https://www.digiteum.com/iot-construction-industry. 19 Oct 2021.
7. Kostelac, Jordan. *From voice-activated lifts to augmented reality, coronavirus spurs use of proptech by real estate sector*. 26 May 2020. https://www.scmp.com/business/article/3085980/voice-activated-lifts-augmented-reality-coronavirus-spurs-use-proptech. 13 Oct 2021.
8. Liszewski, Andrew. *Ikea Expands Its Augmented Reality App, Lets You Fill an Entire Room With Virtual Swedish Furniture*. 23 Sept 2019. https://gizmodo.com/ikeas-expands-augmented-reality-app-lets-you-fill-an-e-1838362429. 18 Oct 2021.
9. LUBELL, SAM. *Commentary: Past pandemics changed the design of cities. Six ways COVID-19 could do the same*. 22 April 2020. https://www.latimes.com/entertainment-arts/story/2020-04-22/coronavirus-pandemics-architecture-urban-design. 20 10 2021.
10. LUNAS. *Virtual Reality (VR) Tour Boosting Apartments Sales on Real Estate and Construction Market*. n.d. https://www.lunas.pro/interactive-virtual-reality-tour.html. 27 Oct 2021.
11. Marr, Bernard. *How The COVID-19 Pandemic Is Fast-Tracking Digital Transformation In Companies*. 17 March 2020. https://www.forbes.com/sites/bernardmarr/2020/03/17/how-the-covid-19-pandemic-is-fast-tracking-digital-transformation-in-companies/?sh=3a0b9de6a8ee. 15 Oct 2021.
12. mobileLIVE. *Is AR and VR a game-changer for the real-estate industry?* 28 March 2019. https://medium.datadriveninvestor.com/is-ar-and-vr-a-game-changer-for-the-real-estate-industry-285361f9182b. 15 Oct 2021.
13. PaleBlue Corporate. *Best AR Devices for 2020*. 3 February 2020. https://pale.blue/2020/02/03/best-ar-devices-for-2020/. 18 Oct 2021.
14. Piqsel. *Website Under Construction*. n.d. https://www.piqsels.com/en/public-domain-photo-zwruq. 25 Oct 2021.
15. pxfuel. *man, woman, wearing, vr goggles, poster, fantasy, cartoon, family, virtual reality, two people*. n.d. https://www.pxfuel.com/en/free-photo-oqpjk. 20 Oct 2021.
16. ServReality. *HOW VIRTUAL REALITY MAY BE USEFUL DURING THE COVID-19 EPIDEMIC*. n.d. https://servreality.com/blog/how-virtual-reality-may-be-useful-during-the-covid-19-epidemic/. 13 Oct 2021.
17. Souza, Eduardo. *9 Augmented Reality Technologies for Architecture and Construction*. 14 April 2019. https://www.archdaily.com/914501/9-augmented-reality-technologies-for-architecture-and-construction. 15 Oct 2021.
18. TMD STUDIO LTD. *Virtual Reality Uses in Architecture and Design*. 21 Jan 2017. https://medium.com/studiotmd/virtual-reality-uses-in-architecture-and-design-c5d54b7c1e89. 16 Oct 2021.
19. Visual Retailing. *New Reality of Retail: VR, AR, and AI use cases*. 13 Feb 2018. https://visualretailing.com/blog/2018/2/new-reality-retail. 28 Oct 2021.
20. YODERS, JEFF. *What Is Augmented Reality, and How Can It Help Architects and Contractors?* 20 April 2021. https://redshift.autodesk.com/what-is-augmented-reality/. 17 Oct 2021.

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PEATA has come to the age of youth on completion of 37 years of its inception. All great institutions have humble beginning. During years 1962 to 1965 architects whenever they met in Municipal offices at V. T., Bandra or at Ghatkopar, they used to talk about their grievances. There is nothing new about it. It is today's phenomenon too. But the murmur then was different. Circulars were confidential. Architects were suddenly confronted with faith accompli "Sorry, now Commissioner has instructed not to approve any plans in the wards". Some influential could get through but rest were left high and dry. They were flabbergasted. In those circumstances several young architects contemplated the positive actions and approach. Side by side the efforts of continuing education by means of work shops, seminars, symposiums, study tour being integral part of activities of any professional body were carried out wherever possible jointly with other like-minded bodies.

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