ARCHITECTURAL DESIGN INFLUENCE FROM BIOMIMICRY

Dr.M.Elango[1], Dr.K Pratheep Moses [2]

[1]*Associate Professor, School of Architecture and Planning,Anna University, Chennai, India.*

[2]*Associate Professor, School of Architecture and Planning,Anna University, Chennai, India.*

ABSTRACT

The connection between architecture and biology and the starting points for biomimetics in architecture are in the design of projects, where innovation is needed, especially in cases like this as identified by Petra Gruber (2011). The term "Biomimicry" is coined by a Janine Benyus, as a "new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems" (Benyus 1997). Biomimicry approach incorporates the ecological design by looking to Nature as a "Model, Measure, and Mentor" and emphasizes sustainability as an objective of Biomimicry (Benyus 1997).

Keyword: - *Biomimicry, Optimisation of Resources, Architectural design, Vernacular Design*

1. INTRODUCTION

The connection between architecture and biology and the starting points for biomimetics in architecture are in the design of projects, where innovation is needed, especially in cases like this as identified by Petra Gruber (2011). The term "Biomimicry" is coined by a Janine Benyus, as a "new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems" (Benyus 1997). Biomimicry approach incorporates the ecological design by looking to Nature as a "Model, Measure, and Mentor" and emphasizes sustainability as an objective of Biomimicry (Benyus 1997).

2. ANALOGIES BETWEEN NATURE AND TECHNOLOGY

Analogy has been defined as per New Oxford American Dictionary, (2005) "... A comparison between two things, typically on the basis of their structure and for the purpose of explanation or clarification." Analogy means similarity, correlation, and equivalence in terms of function or behaviour.

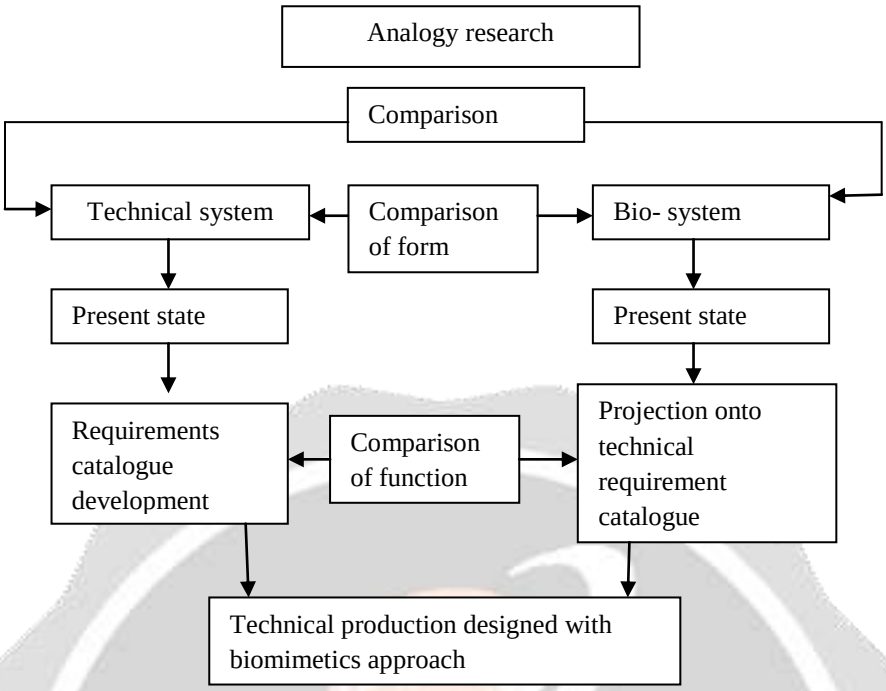

Fig -1: Concept of analogy research according to Nachtigall (2010), translated by Petra Gruber (2011)

2.1 The Study of Honey Bee Hives

"(The honeycomb) is absolutely perfect in economizing labour and wax. - **Charles Darwin**.

It makes the wax that holds the honeycomb together. It takes thousands and thousands of bee hours, tens of thousands of flights across the meadow, to gather nectar from flower after flower, after flower, so it's reasonable to suppose that back at the hive, bees want a tight, secure storage structure that is as simple to build as possible. It chooses the hexagonal shape; so that each wax wall is shared with adjacent cells. (Frisch 1983). From at least 300AD when Pappus of Alexandria posed a question of the efficiency of honey bee hives. Mathematicians have made extensive studies of the isoperimetric properties of the honeycomb cells and believed them to be the most efficient design possible. Laszlo Fejes Toth (1965) discovered that the trihedral pyramidal shape (which is composed of three rhombi) used by the honeybee is not the theoretically optimal three-dimensional geometry.

A cell end composed of two hexagons and two smaller rhombuses would actually be.035% more efficient to the hive economy in terms of efficient use of wax (Gianni 2004).

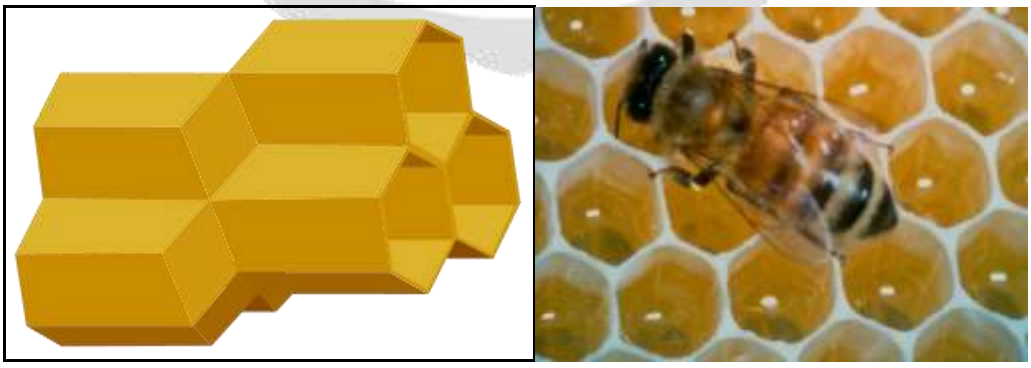

Fig- 2: Opposing layers of honeycomb cells fit together (Laszlo Fejes Toth 1965)

2.2 The honeycomb conjecture

The honeycomb conjecture is the two-dimensional version of the three-dimensional Kelvin problem. The Kelvin problem asks for the surface, minimizing partition of space into cells of equal volume. The solution proposed by Kelvin is a natural generalization of the hexagonal honeycomb in two dimensions.

The honeycomb problem has never been solved, except under special hypotheses. The geometrical properties of the three-dimensional honeycomb cells have also been studied extensively by Thomas Hales in 1999. And proved it On the basis of MacLaurin (1743), in his analysis of the honeycomb "The cells, by being hexagonal, are the most capacious, in proportion to their surface, of any regular figures that leave no interstices between them and at the same time admit of the most perfect bases".

It seems that the honeycomb is minimal with respect to various optimization problems. Even the classical problem can be expressed as a minimization of perimeter for fixed areas or as a maximization of areas for fixed perimeters.

2.3 The essential honeycomb

A hexagonal cell requires the minimum amount of wax for construction while it stores the maximum amount of honey. So the bee uses the most appropriate form possible. A regular shape which fits properly without any waste are geometrical figures with equal sides is equilateral triangles, squares and Hexagons.

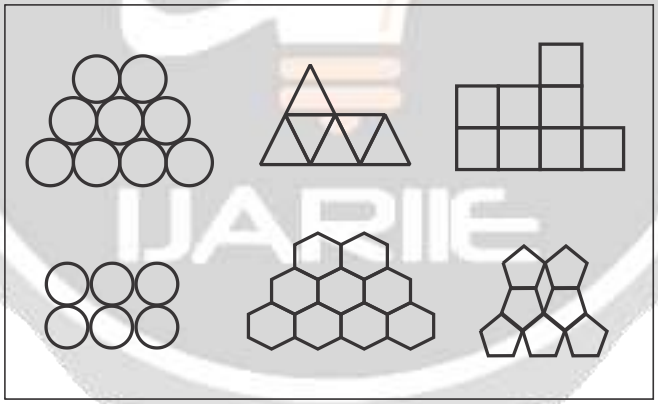

Fig- 3: Putting Together of Regular shapes

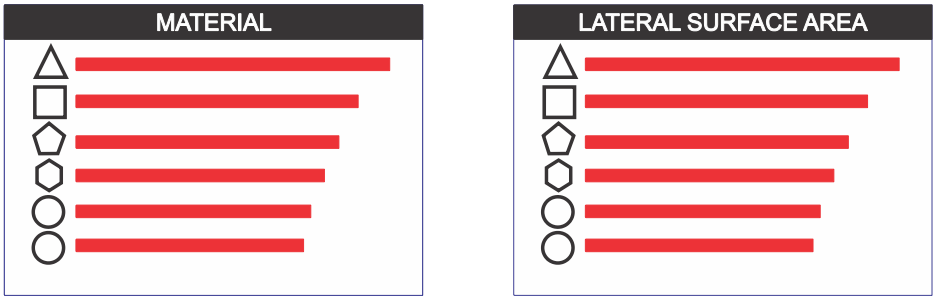

Fig-4: Regular shapes with respect to Lateral Surface area of and equal material consumption

- When we analyses the surface area individually for a given volume of various shapes obviously the circular shape is more efficient than any other shapes.
- Lateral surface area is treated equal to the amount of materials required.

When we analyses the surface area with respect to sharing of walls for a given volume to various shapes obviously the hexagonal shape is more efficient than any other shapes

Table - 3.7: Analyses the surface area and the area calculated individually for a given volume to various shapes on the sharing of walls

Shape	Benefit for consumptions of material	Perimeter	Best design for a given area
Equilateral triangles.	Waste more wax.	10.392 r	$3\sqrt{3}\ r^2$
Squares	Better use of wax.	8r	$4r^2$
Hexagons	Least amount of wax.	6.928 *r*	$2\sqrt{3}\ r^2$

r = considering the radius of the same circle inscribed into the three shapes.

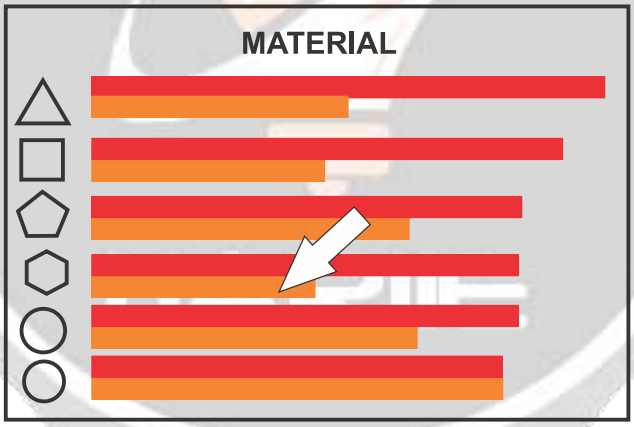

Fig-5: Regular shapes with respect to Lateral Surface area on sharing on a wall basis

2.4 Case study of honey bee hives in Architecture

The application of Biomimicry concept of a beehive to capsule hotels in Tokyo was studied. The research has been developed considering the similar thermal and ventilation requirements between humans and bee colonies as well as similar typology of the bee combs and capsule rooms on the following basis (Despoina Frgkou & Vicki Stevenson 2012).

- The preferable temperature inside the colony is around 34ºc when raising offspring and around 17ºc otherwise. (Hooper 2010).

- Bees achieve a ventilation rate of 50-601 per minute and relative humidity levels of about 45-55% (Shaw 2011).

- Width to length ratio: Average worker bee has a ratio of width to length approximately 1:2 though this is not a standard rule. This has been clarified with British national beehive envelope study states that "The spacing between the combs which honey bees would use in natural hives is two "bee-spaces", roughly 12-16 mm and the distance between the interior partitions of the hive and frames is one "bee-space" roughly 6-8 mm.

- Honey bees re-use the wax from the abandoned hives in order to save time and effort for creating a new one (Waring 2011).

- Bee prefers evaporative cooling in order to reduce high air temperature inside the hive. They collect water drops, which are positioned in the hive, and then the bees fan their wings to pass air of the drop so that the evaporation will achieve a decrease in the air temperature. (Brackney 2009).

The selection of the best (or) the optimum design solution from a set of alternatives is known as design optimization. Traditionally, optimisation is a recognized and mandatory activity in product design mainly due to the fact that most product design problem can be described mathematically but in architectural design only a part quantitative i.e. designs objectives like performance variables and boundaries can be formulized as mathematical prob. The measurement and appraisal of general performance of a building design appears to take place whenever the designer pauses to evaluate what they has done, or when they considers design alternatives in order to reach a decision. As the design assessment can also be a part of the building performance evaluation, (Watson & Crosbiletal 1997). One thing we do not seem to learn from experience, is that we do not often learn from experience alone (Mason 2002).

Pilot survey has been carried out as part of the design studio exercise of the third year architecture students at School of Architecture and Planning, Anna University, Chennai, India. The brief of the design is to develop a design to create the dynamic composition based on the Design variables (Laseau (2000) to special building of housing typology as per Development regulation of CMDA, Chennai city. Their exercise involving the linking their solids and voids as interstitial spaces such as terraces, protruding terraces and introverted spaces, courtyard spaces, and self shading spaces to create the dynamic composition with improving their spatial quality. Each student has to develop four alternatives in stage 1 and they have been asked to identify the best alternative from their intuitive judgement for the main evaluation.

3. OBJECTIVE

The decisions that are made during the act of building in terms of choosing the configuration of spaces and elements and putting them together, is purely within the freedom of an architect's decision. This decision has the consequences of consuming less or more of the materials as resources for a given program.

3.1 Research Methodology

This case study-based approach is an exploratory research that aims to identify how designers' think and arriving at design decisions. Based on his personal experience and understanding about the way architect approach the design process, the researcher felt that by and large, the optimisation of resources attain least priority in his design process and in most cases it is an afterthought. When the Architects largely rely on their knowledge and past experience in arriving at design decisions, they rely on an intuitive approach and feeling. In other words architects are accustomed to making their decisions based on the intuitive method and subjective approach this is the basis for the following research question.

Research question:

- Architects do not consider the material efficiency as a conscious attempt during the pre-design stage.

- The multi criteria decisions taken by an architect during the evolution of architectural design of housing

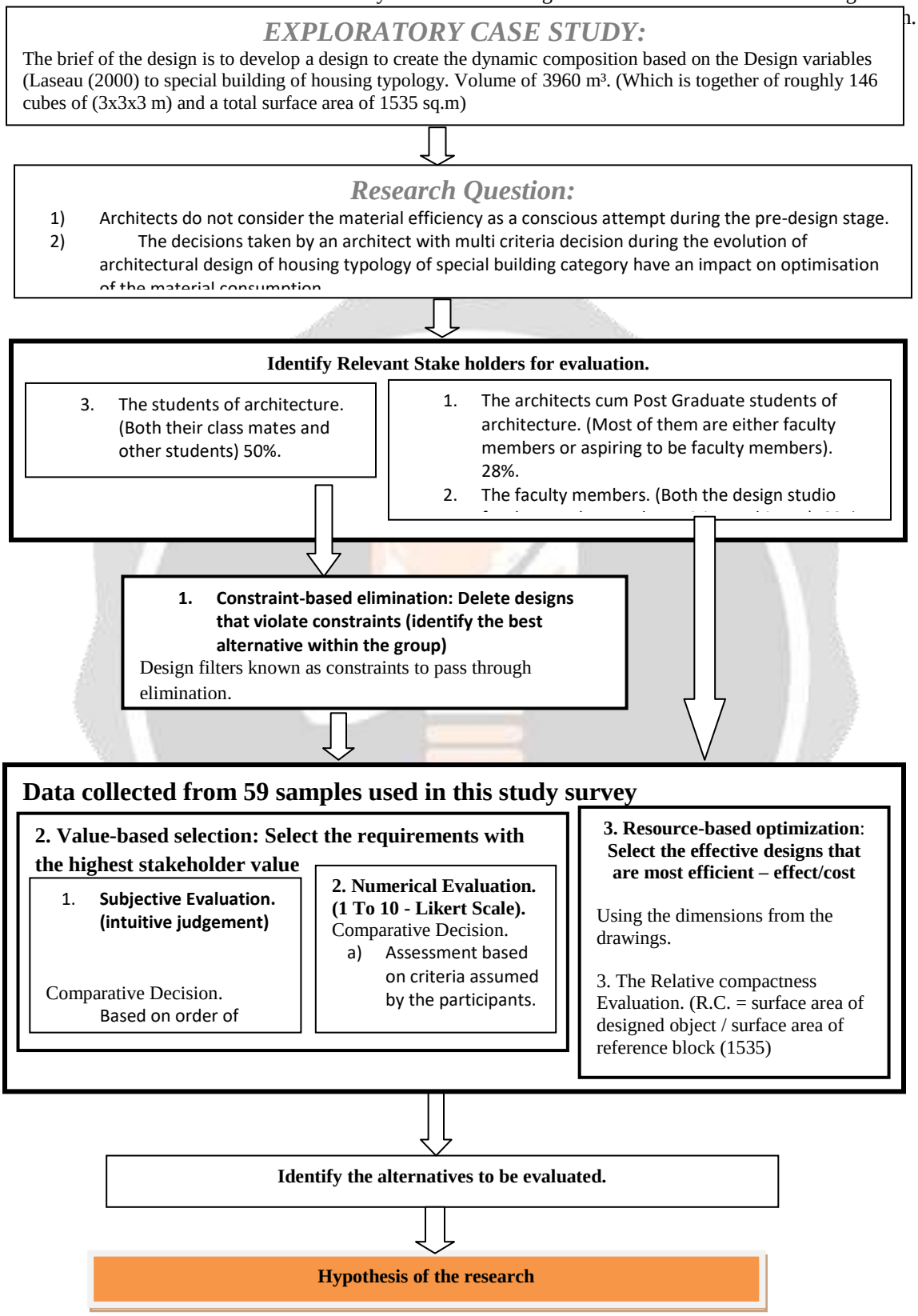

Fig- 6 : Methodology

3.2 Data Collection

Relevant Stake holders used for evaluation in survey method are.

- The students of architecture. (Both their class mates and other students) 50%.
- The architects cum Post Graduate students of architecture. (Most of them are either faculty members or aspiring to be faculty members). 28%.
- The faculty members. (Both the design studio faculty members and practicing architects). 22%
- From the above sample the Post Graduate students of architecture, the design studio faculty members and practicing architects are used for the main questionnaire survey of the research.

3.3 Level of measurement and objectivity of judgment

Based on the methodology of Design Evaluation proposed by Tom Gilb (2005) the researcher picked up the following three maturity stages.

1. Constraint-based elimination: Delete designs that violate constraints;

2. Value-based selection: Select the requirements with the highest stakeholder value;

Resource-based optimization: Select the effective designs that are most efficient – effect/cost;

3.4 Constraint-Based Elimination

Each student have developed minimum of four (4) alternatives based on the interplay of solids and voids created an interesting compositions by simply manipulation of volume equivalent mass and the respective relative compactness for the same as stage one submission. All the four alternatives need to pass the design through the set of design filters known as constraints. The individual student can fix any constraint to eliminate the three options from that 4 alternatives and submit the best possible for the assessment. Their final best design description along with the physical model and 3D visualisation models used for the survey.

3.5 Value-Based Selection

Value theory is the essential foundation of any rational theory of design (March 1976). The real value of a design to a stakeholder depends partly on the technical characteristics of the design, and partly on the planned, perceived and actual use of those characteristics in practice, over time.To evaluate the design the stakeholder can use the following methods.

- Subjective evaluation (Intuitive evaluation method / In evaluation proposals, preferences will be shown for those which most closely reflect the priorities of the evaluator.) and
- Numerical evaluation (10 point Likert scale of preference / Designer establishes priorities among his objectives in a way analogous to weighting and ranking procedures.

3.6 Resource-Based Optimization

Design ideas must also be evaluated with respect to the design costs' relation to our finite resources. Relative compactness based evaluation. Relative Compactness. (R.C. = surface area of designed object / surface area of reference block (1535).

4. Results

The following results are obtained from the design evaluation.

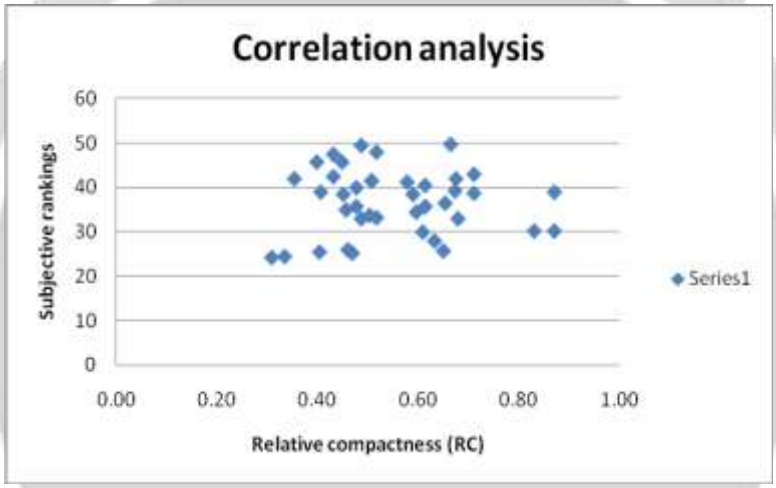

Fig-7: Correlation Analysis – Subjective (Intuitive) Based Assessment vs. Relative Compactness Based Assessment

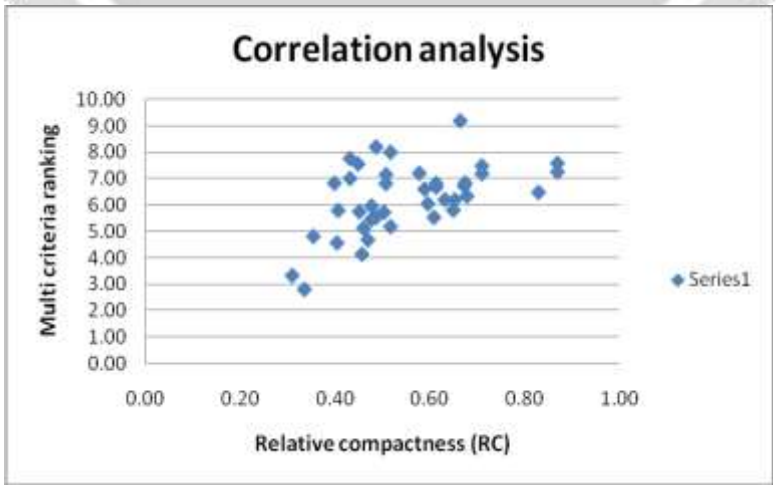

Fig- 8: Correlation Analysis – Multi criteria Based Assessment vs. Relative Compactness Based Assessment

The above results clearly establishing the fact that

- Since the correlation coefficient is very low for Relative compactness evaluation and subjective evaluation with value of r = 0.012008 (Figure 3.26) establish the fact that architects are not giving enough priority to resource efficiency during the pre-design stage. They do not consider the material efficiency as a conscious attempt during the pre-design stage. Hence Hypothesis 1 is proved.

- The intuitive judgment and single objective decision alone cannot be used to judge the alternative to predict the best possible design with the possible minimum information by any designer which can be accessible during the pre-design stage. The decisions taken by an architect with multi criteria decision during the evolution of architectural design of housing typology of special building category have an impact on optimisation of the material consumption. This is clearly an evident from the correlation coefficient is relatively high for Relative compactness evaluation and multi criteria evaluation with value of r = 0.513.

- The results also establish the fact that the Stakeholders' power and influence and decision making criteria, their respective priorities could very well decide the optimisation of resources during the pre – design stage. It requires a multi-criteria tool with a rational approach to relatively prioritise the criteria with respect to the optimisation of resources during the pre-design stage. – this is the basis for the hypothesis of this research as follows:

Hypothesis 1: Architect's quite often giving higher priority to the Design variables relating to the functional aspects, compared to other Design factors such as Performance variables and Context variables. The three determinant variables are not a fully integrated as a conscious attempt during the pre-design stage.

Hypothesis 2: The Architects may be aware of integrating Design factors such as Design variables, Performance variables and Contextual variables. For lack of an appropriate tool they are unable to prioritise the relative significance of Design factors as a conscious attempt during the pre-design stage.

5. CONCLUSION

The above understanding clearly establishing the following:

It is self-evident that design methodology has to establish some criteria for the quality. Without some criteria for improvement or progress, the notion of rationality becomes problematic.

1. As the design process advances, complications inevitably arise – when complications in the design process dominate the scheme, the architect may be compelled to prioritise his design on those complications only.

2. The design decisions and appraisal of general performance of a building design are sometimes dictated by the Limitations of the project such as the budget, a too small site, an inconvenient topography, an unfamiliar palate of materials, contradictory request from client...etc.

3. The perceived gap between the way designs is dealt with by design methodologists and the way designing is experienced by practicing designers. Lack of time and means are prohibitive to most Architects to formulate their own comprehensive theory.

4. A research should be addressed to design methods to date: many so called design methods are not rooted in a sound understanding of the architectural phenomena. Some of the methods, strategies and models developed by the design theoretician's terms often useless or incomprehensible to the down to earth practitioner (Neuckermans 1975).

5. Decisions relating to shape and massing will affect planning efficiency, capital cost and thermal criteria simultaneously (Radford & D'cruz 1987).

6. Designing is a continuous process of selecting and organising appropriate elements, trying to establish which are most relevant and important part in their design process and inevitable ideas changes possibilities are converted into alternatives as proposals and conceived and considered.

7. Most importantly as Julian Vincent et al (2006) points out the major inspiration from biological systems as "In biology materials are expensive and design is complex but cheap". That is the reason why in natural design we come across the complex systems with an absolute minimum for materials.

8. The solution to the problem is to include the physical environment values at the early stages of the design process, leading the way to alternative solutions for architects. Control variables identified with respect to function, climate zone, tendency and the designer inclination, in line with limit values prescribed by the literature and standards.

9. The design sequences that architects have to consider are identified as Constants and Variables. The constants are the one related to the contextual and location factors. The variables are the one which is purely within the freedom of the architect as well as part of the brief (Szokolay et al (2001).

6. Reference

[1] Asha, NL 2010, 'Biomimicry as a metaphor for perfect integration in sustainability, Nature, Biomimicry, perfect integration, Sustainability', Lap Lambert Acadamic Publishing. ISBN: 978-3838399782.

[2] Ashworth, A 1996, 'Estimating the life expectancies of building components in life-cycle costing calculations', Structural Survey, vol.14, no.2, pp.4–8.

[3] Ashworth, A 1999, 'Cost Studies of Buildings', 3rd Edition, Longman

[4] Benyus, JM 2002, Biomimicry: Innovation Inspired by Nature. Perennial, New York.

[5] Bill Petersen, Jr. 2012, Material Honesty in Architecture and Construction.http://www.neenan.com/material-honesty-in-architecture-and-construction/.

[6] Biomimicry Guild 2008, 'What is Biomimicry?', Retrieved 14 September, 2010, from http://www.biomimicryguild. com/guild_ biomimicry. html.

[7] Brackney, S 2009, 'Plan Bee, everything you ever wanted to know about the hardest-working creatures on the planet', Hay house. ISBN: 978-1-8485-0193-5.

[8] Cross, NA 2007, 'Designerly Ways of Knowing. Board of International Research in Design', Basel: Birkhauser.

[9] Michael Pawlyn, Biomimicry: does nature hold the solutions for sustainability ... TED talk.

[10] Petra Gruber 2011, Biomimetics in Architecture – Architecture of Life and Buildings Springer.

[11] Radford, AD & Gero, JS 1988, 'Design by Optimization in Architecture, Building and Construction', Van Nostrand Reinhold Company, pp. 84-90.

[12] Schon, DA 1989, 'Educating the reflective Practitioner', Jossey – Bass, Sanfrancisco.