Multi-Attributes
Evaluation Methodology for
Emerging Housing Technologies

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
New Delhi
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Attributes for Evaluating Emerging Housing Technologies

1 Objectives

The goal of this research is to develop a multi-criteria evaluation framework for the emerging systems and technologies of residential construction. In order to accomplish the afore-said goal following research objectives have been set:

- Identification and understanding of the issues and attributes of the emerging housing systems and technologies that affect, both positively and negatively, decisions to utilize them in residential construction
- Selection of appropriate decision making tool capable of processing both qualitative and quantitative information on the emerging housing systems and technologies to be evaluated
- Design of the evaluation framework for emerging housing systems and technologies based on the information and knowledge acquired in the previous two steps

2 Introduction

Provision of housing for urban and rural population is a great opportunity and an important challenge for India. Numerous government and private initiatives of varying dimensions are underway to meet this very crucial basic need. The Indian housing value chain is very complex. A plethora of factors and issues need to be addressed in this regard. From the perspective of affordability and sustainability, development and identification of appropriate construction technologies for the housing sector is one of the crucial pieces of this puzzle. A careful evaluation of these technologies is equally important. This research is focussed on the development of a holistic evaluation framework for emerging housing technologies and systems. This evaluation framework will use multi-attribute decision analysis to produce a scientifically sound approach to quantification and evaluation of advantages and disadvantages of emerging systems and technologies.
3 State of the art report

As per Berge’ 2009, a large number of innovative alternate building materials and low cost construction techniques have been developed through intensive research and development efforts during last four decades. In theory these innovative techniques and materials satisfy (and perhaps far exceed) functional requirements as well as specifications of conventional materials / techniques. Selection of the most appropriate one among these emerging technologies is a complex process and depends upon many factors like cost and time certainty, speed of construction, energy efficiency, effectiveness in the use of materials, design flexibility, future maintenance requirements and performance throughout the housing life-cycle, customer satisfaction and acceptance, compliance with building regulation etc. It becomes difficult to make a decision considering so many qualitative and quantitative factors in tandem. Also, a decision maker’s preference needs to be taken into consideration while assessing these materials, for instance, low cost of a material may be most preferred by a person but may not be by another (Schäfer 1999). Some of the major challenges faced in the present housing sector are deficiency of local knowledge about appropriate housing design and current construction practices, non-availability of specialized training to apprise the selection of housing technology, imported housing technologies and materials consume high energy for better conditions, causing cost overrun and imbalance in environment. Repair and maintenance works disturb the quality of the habitat and damage the architectural integrity, building materials and skilled labour are in short supply, leading to inflated prices. Thus there arises a need for the development of a standard framework considering all the attributes which will aid the practitioners in decision making regarding emerging technologies of housing construction.

4 Indian and International scenario

In the recent years, enormous advancement of construction technology, from traditional site-based methods to a “more dynamic combination of methods” (Pan et al. 2012), has brought upon us new possibilities of residential construction. This paradigm is now spread across the globe encompassing a greater use of pre-fabricated systems & innovations. The evidence of such an evolution of global housing-construction philosophy can be seen in the increasing growth of prefabricated house building in Japan (Barlow and Ozaki 2005); off-site fabricated housing in Germany (Venables and Courtney 2004); industrialized building in Malaysia (Kadir et al. 2006); off-site manufacture in Australia (Blismas and
Wakefield 2009) and prefabricated high-rise structures in Hong Kong (Tamet al. 2002; Jaillon and Poon 2009).

Coming to India, housing industry is successful & booming sector of Indian Economy. A large population base, rising income level and rapid urbanization leads to growth in this sector. Scholars have done research in the areas of offsite construction. Planned development must be India’s core centre going forward. Vital implementations such as low cost housing, integrated townships, slum recuperation and renovation, and higher floor space index regime must be adopted. Fast track projects should be the one of the main primary objective. One of the major drawback is shortage of supply of housing units. According to the Ministry of Housing and Urban Poverty Alleviation (MHUPA) in 2012 “there were 18.78 million units housing units short in urban India; nearly 95% of this shortfall was in the economically weaker sections (EWS) and low income group (LIG) housing”. Building codes and schedule of works are the principal public policy instrument that governs choices regarding construction technologies. Nations like India that have recently rationalised building codes may have incorporated into them emerging policy objectives, such as green and sustainable buildings that reduce the embodied energy and carbon footprint, or use of universal design that makes buildings accessible to those with differential economic abilities. Hence, study of different attributes for deciding the appropriate technology is highly essential.

5 Research Gaps

Adoption of emerging housing technologies in the Indian housing sector remains low. To meet the huge demand of affordable and sustainable housing, the sector must use these technologies. While there is no dearth of available technologies, adoption remains low due to a number of factors. The first and foremost barrier is the availability of a scientific, holistic and transparent evaluation framework for emerging housing technologies. Motivated by this issue this proposal seeks to identify appropriate attributes and a composite framework to evaluate the emerging housing technologies.

6 Research Methodology

The development of the holistic evaluation framework proposed in this research will be multi-step process. These steps are as follows:
• **Identification of attributes for the emerging housing systems and technologies under consideration:** Different attributes pertaining to emerging housing systems and technologies are identified in this context and ensured that all the parameters are listed in a systematic way for building evaluation framework.

• **Definition and criteria for the identified attributes:** All the attributes are defined along with their respective evaluation criteria.

• **Review of the attributes by the Technical Advisory Group (TAG):** Attributes along with definitions identified in the above step are presented to the TAG for review and finalization. All the improvements, additions, and revisions suggested by the TAG are incorporated in the list of attributes. ([Please refer annexures for minutes of the meeting held on 8th Oct 2014 and 18th Nov 2014](#))

• **Collection of expert opinions:** Attributes reviewed by the TAG are then presented to experts for their comments. ([Please refer annexures for expert opinions](#))

• **Submission of final report:** Report incorporating all the comments and suggestions shall be submitted to BMTPC for their further proceedings

### 7 Presentation of attributes

Attributes are presented in three level vertical classification systems: Primary level, Secondary level and tertiary level. Attributes are further classified in each level such as Primary level into Mandatory and Preferred & Desired attributes for evaluating systems and emerging technologies. Building systems and housing technologies are primarily evaluated for all mandatory attributes such as strength, stability aspects etc. If the adopted or emerging technology successfully adheres to all the parameters and criteria given in the mandatory attributes, then the technology shall be further evaluated with preferred and desired attributes for implementation and promotion to suit end user requirements. A detailed classification of attributes is given in [Annexure B](#). Definition of identified attributes along with the evaluation criteria is presented in an elaborate manner in the further section.

### 8 Mandatory Attributes (PA')
8.1 Strength and Stability Requirements (SA³)

**Definition:** The structural adequacy of a housing technology, in terms of strength and stability, is an important attribute in the selection of the technology. The system used for construction should be capable of withstanding the design loads calculated as per Indian Standards (IS). Following tertiary attributes are used to make a determination for this mandatory secondary attribute.

8.1.1 Stability against Vertical Loads (TA³)

**Definition:** The ability of a structure to maintain its integrity without failure, both in during-construction phase and post construction phase, when placed under vertical loads calculated as per IS Codes. Loads which are to be considered for checking the load bearing strength of the system can be of two types:

- Dead Load (DL): Calculated as per IS 875 (1) or whatever as applicable
- Imposed Load (IL): Calculated as per IS 875 (2) or whatever as applicable

In order to ensure optimal structural stability, the response of the system is also to be checked for combination of DL and IL (i.e. DL+IL) as described in Clause 8.1 of IS 875 Part 5

8.1.2 Stability against Lateral Forces (TA)

**Definition:** Ability of the structure to sustain its function namely safety and serviceability against earthquake and wind forces. Structure should be designed for earthquake exposure and wind forces both in during construction and post construction phases.

- The Earthquake Load/seismic load (EL) is to be calculated as per IS 1893 -1 (2002)
- Wind Load (WL) is to be calculated as per IS 875 (3)
- As per IS 875 Part -5, the response of the system is to be checked for:
  - DL+IL+WL
  - DL+IL+EL

8.1.3 Performance of Joints (TA)

**Definition:** It refers to the finished quality and serviceability of joints and connections of building elements. For example, beam-column junctions, connectivity between precast...

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1 PA is Primary Attribute in the Evaluation Framework
2 SA is Secondary Attribute in the Evaluation Framework
3 TA is Tertiary Attribute in the Evaluation Framework
members and cast in situ members, connections between sub-structure and super-structure, and host elements such as doors and windows.

- Assess joint stability – probability of rupturing, losing equilibrium etc.
- Assess performance of joints

8.2 Performance and Statutory Compliance (SA)

**Definition:** The proposed system has to be checked for overall performance and compliance against statutory provisions prevalent at the time and location of application. Following tertiary attributes are used to make a determination for this mandatory secondary attribute.

8.2.1 Violation of statutory provisions (TA)

**Definition:** Compliance of the building system and technology with all the statutory regulations at national, state and local level as applicable (if any) such as MOEF, Byelaws etc.

- Declaration should be given by the technology providers stating that the system shall not violate any statutory provisions applicable.

8.2.2 Fire Resistance (TA)

**Definition:** It refers to property of building elements to satisfy for a stated period, resistance to collapse, resistance to penetration of flame and hot gases, resistance to temperature rise when subjected to fire. Performance of the system against fire is to be checked in the following aspects.

- Compliance with IS 3809:2002
- Fire rating as per the current National Building Code (NBC)
9 Preferred and Desired Attributes for Evaluation of Emerging Housing Technologies (PA)

9.1 Functional Requirements (SA)

**Definition:** Secondary desirable attribute for assessing the technology or system against generally accepted functional requirements of housing.

9.1.1 Design Flexibility (TA)

**Definition:** Design flexibility is defined as the ability of the technology to reconfigure the design of the houses as per the requirements with an understanding of possibility of changes as per the functional uses. In simpler terms, it is the ability of a building system to adjust and adapt to changes during the design, construction, and use phases with minimum disruption in process and with minimum cost impact.

The design flexibility should be checked in two following aspects:

- Degree of difficulty in incorporating changes during construction phase
- Provisions for post-construction expandability

9.1.2 Restriction on Number of Floors (TA)

**Definition:** It indicates the height restriction for construction due to structural safety and stability issues or construction process related issues. This attribute determines any restriction on the maximum number of floors (storeys) that can be constructed using the system.

- Limitation on number of floors that can be constructed using the technology under consideration.

9.1.3 Service Life and Durability (TA)

**Definition:** Service life and durability is about end users’ realistic expectations that, subject to less maintenance, a building technology will last for a specified number of years. It also deals with the susceptibility of the technology to different environmental conditions. As it is quite difficult to get data about the average service life of all the systems, especially because many of them are newly introduced, durability can be judged by considering the following parameters:
• Suitability/Limitations for using in all environmental conditions
• Performance under accelerated environment test
• Expected service life of the system with respect to conventional system

9.1.4 Thermal Comfort (TA)

**Definition:** It is measured by the thermal resistance offered by the technology, i.e. the heat flow through a building that depends on the temperature difference, the conductivity and the thickness of the elements. Thermal comfort offered by any system can be assessed by:

- Comparing the thermal transmittance loss of the system with that of traditional construction
- Compliance with IS 3792:1978

9.1.5 Acoustic Performance (TA)

**Definition:** Acoustic performance refers to the reduction or elimination of external noise or decrease the transmission of unwanted noise in the constructed dwelling. Selected technology should restrict the reflection of sound thereby inducing privacy in the rooms of the constructed dwelling. Following are the criteria on which the acoustic performance of a system can be evaluated:

- Sound Transmission loss as per IS 1950 :1962
  - 30 dB or less – Poor
  - 40 dB – Fair
  - 45 dB – Good
  - 50 dB - very good
  - 60 dB - Excellent
- Compliance with MOEF norms: 55 dB at day time and 45 dB at night time
- Compliance with IS 1950: 1962: 65-80 dB for heavy traffic area and 60-70 dB for other areas

9.1.6 End-user-friendliness (TA)

**Definition:** It is defined as the ability of the system to meet the specific requirements of the end users. End-user-friendliness indicates the customer satisfaction and also suitability of the system for building Indian houses across regions and states. It includes criteria cultural and social criteria such as “nailability”, provision for adding fixtures like coolers, air conditioners, etc. Following criteria is to be considered for evaluation:

- Suitability of the constructed building for adopting changes after construction by the occupant.
9.1.7 Weather-Resistance (TA)

**Definition:** Weather-tightness of a building is the resistance of a building to the weather conditions both prevalent and extreme. An emerging technology should by its design and through its construction detailing provide for ‘Deflection’; ‘Drainage’; ‘Drying’; and ‘Durability’ conditions of the building. Weather-tightness attribute allows the building to be evaluated against weather elements of heat, wind, dust, rain, and snow as applicable. Following criteria is to be considered for evaluation:

- Qualitatively, is the proposed technology more effective against weather conditions, when compared with traditional system?

9.1.8 Water Tightness (TA)

**Definition:** It refers to the overall water tightness of the building system both externally and internally, especially along in the sunken portions and along the joints (and connections) between components. This ensures resistance of the building technology against leakage in a variety of prevalent weather and climatic conditions. Following aspects should be checked in waterproofing.

- Requirement of additional waterproofing.
- Effectiveness of waterproofing.
- Chances of fungal growth or contaminants on building elements.

9.2 Constructability (SA)

**Definition:** Constructability, similar to design for manufacture and assembly, is defined as the relative ease of construction given a selected building design. It is the extent to which a building design with a chosen technology provides for ease of construction while meeting the overall requirements of the building. Using the construction expertise, during the design phase, steps are taken to optimize parameters like build-ability, cost effectiveness, resource efficiency, time schedule, quality, safety and overall project goals.

9.2.1 Simplicity in Execution and Versatility (TA)

**Definition:** Steps required during construction and complexity of the process required for the building technology defines simplicity in execution and versatility during construction. With a view to increase productivity and efficiency of the overall system, it
is desirable that the method of execution should be simple, otherwise extensive training and retraining of labour, increased requirement of skilled labour and delays due to system complexity might affect both construction cost and time. Following criteria are to be checked for this attribute:

- No of components for the assembly.
- Ease of construction (such as fixing reinforcements, placing of concrete, fixing building services, assembly and erection procedures, etc.).
- Provision for using any particular element of the system to serve different functional requirements.

### 9.2.2 Design Compatibility (TA)

**Definition:** Compatibility with architectural design or architectural design flexibility allowing expression of form, function and aesthetics in design evolution. Following is the criteria for evaluation:

- Ability to make curved surfaces (e.g. curved walls, domes, arches)
- Concealed piping electrical and plumbing services and provision for incorporating the mechanical, electrical and plumbing services within the proposed building component thickness
- Ability to make sunken floors
- Suitability for wet areas
- Ability to make sunshades and other appurtenances required for a typical house in the regional context

### 9.2.3 Foundation Type (TA)

**Definition:** This attribute captures the type of foundations required for erecting the building with the selected technology. Following criteria are to be evaluated for this aspect:

- Requirement of shallow or deep foundation for erecting the technology.
- Requirement of Heavy or light foundation for erecting the technology.

### 9.2.4 Skilled Labour (TA)
**Definition:** It refers to projection and identification of trained work force required for adopting housing technology for construction. Following criteria are to be considered for this attribute:

- Type of labour required (such as skilled/ semiskilled/ unskilled)
- Level of training required

### 9.2.5 Equipment (TA)

**Definition:** It refers to identification of appropriate equipment related to each stage of construction such as hoist, batching plant, cranes, and any other specialized equipment while adopting a particular technology. Following criteria should be checked for equipment:

- Type of Equipment required, such as heavy/light or standard/specialized.
- Requirement of manufacturing plant and if it is required then, whether is it centralized or on-site?

### 9.2.6 Construction Safety (TA)

**Definition:** Safety deals with the identification and elimination of hazards associated with the technology thereby resulting in zero accidents, and zero lost time injury. The performance of a system against this attribute may be evaluated by:

- Comparing the degree of risk/hazard involved in the system with that of conventional construction method.

### 2.2.7 Temporary Services Requirement (TA)

**Definition:** It refers to the requirement of temporary services for the implementation of the housing technology i.e. mainly the requirement of water, power & other services during construction phase. The performance of a system against this attribute may be evaluated by:

- Requirement of initial power for implementing the technology
- Requirement of water for implementing the technology

### 9.3 Economic Viability (SA)

**Definition:** Economic viability of a chosen technology is its economic competitiveness in the present market conditions and business environment. The technology under consideration must be economically viable for all the stakeholders.
9.3.1 Initial Cost (TA)

**Definition:** It pertains to the overall cost of construction involved in labour, materials, plant and machinery and overheads. For evaluating the systems on this attribute, the following costs are to be compared with that of conventional system:

- Capital Cost.

9.3.2 Speed of Construction (TA)

**Definition:** Speed of construction is linked to the time taken to complete all construction steps and processes for a given technology. Time savings during construction is significant to all stakeholders, therefore, the following criteria needs to be considered for assessing the attribute:

- Evaluating the speed of construction in comparison with traditional construction.

9.3.3 Economies of Scale (TA)

**Definition:** This attribute deals with the Economic feasibility of adoption of housing technology for constructing any number of dwellings so that the component of fixed cost is least variant with the number of dwellings. Following criteria is to be checked for this attribute:

- Minimum number of dwellings to be constructed using the technology.

9.3.4 Lead Time (TA)

**Definition:** Lead time is the latency (delay) between the initiation and execution in adopting the technology for construction of dwellings. Following criteria is to be considered for evaluating the attribute:

- The lead time involved for the technology in comparison with that of conventional system.

9.3.5 Efficiency of Design (TA)

**Definition:** Land being a scarce resource calls for a need to optimize the utilization of spaces. While evaluating emerging construction technologies, space savings and land utilization also becomes an important factor to consider as availability of space is also a constraint for modern construction. The optimal use of space can be measured by taking into account the following consideration:
• The efficiency of design which is given as the ratio of the built-up-area to carpet area.

9.3.6 Supply Chain Reliability (TA)

**Definition:** Construction projects typically involve series of inter-related activities in which successful completion of any particular activity is dependent upon that of its predecessor activities. Thus the failure of even one supplier may lead into the collapse of the entire system. It is always preferable that while selecting suppliers for any housing technology, practitioners should always look for only highly reliable organizations (HROs) in order to ensure delivery of most suitable technologies at the most suitable prices and in the right time. Following consideration is to be assessed for evaluating the attribute:

• The availability of reliable suppliers for a particular construction technology in the very initial stage.

9.3.7 Technology Transfer Possibility (TA)

**Definition:** This attribute pertains to dissemination of technical know-how, skills, resources and production techniques of adopted housing technology from its origin to broader sphere of use. Following criteria is be used for evaluation of this attribute:

The possibility of producing the adopted technology in India using local resources.

9.4 Maintenance (SA)

**Definition:** This attribute deals with the ease with which the regular and periodic maintenance can happen for the adopted technology so as to attain the maximum life period of the constructed building.

9.4.1 Maintenance Cost

**Definition:** It refers to the life cycle cost of the system which includes the recurring cost of maintenance as well as the replacement cost at the end of the service life of the system. The following costs are to be compared with that of conventional system:

• Cost for periodic maintenance of the system
• Replacement cost at the end of the service life of the system.

9.4.2 Frequency of Maintenance (TA)
**Definition**: It refers to the interval between two successive maintenances, such as regular or occasional required for the adopted technology. Following criteria is to be considered for assessment:

- Requirement of regular or occasional maintenance and corresponding time interval

**9.4.3 Type of Maintenance (TA)**

**Definition**: It refers to the severity of maintenance activities needed for the adopted technology. Following criteria is to be considered for evaluation:

- Requirement for major or routine maintenance.

**9.4.4 Ease of Maintenance (TA)**

**Definition**: It refers to the degree of difficulty involved in carrying out maintenance works for the adopted technology. Following considerations are to be used for assessment:

- Availability of workmen needed for maintenance works.
- Availability of tools and technologies needed.
- Availability of materials needed etc.

**9.5 Sustainability (SA)**

**Definition**: Sustainability ensures a better and more sustainable future for the human race and the planet earth at large. It includes those technologies that use less virgin material, less energy, cause less pollution and less waste without compromising on the project’s economic viability and the comfort, safety and other requirements of its occupants.

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*Fig: Balancing Parameters of Sustainable Construction*
It is desirable that while evaluating several housing technologies in order to select the most appropriate one, following aspects of sustainable construction practices should also be taken into consideration:

9.5.1 Eco-friendly Construction (TA)

**Definition:** It has been seen that building construction often affects the surrounding environment and its natural resources in a negative way. The term eco-friendly construction refers to those construction technologies which are conducive to the principles of sustainable development in terms of use of local and renewable materials, energy efficiency, less emission of hazardous materials and pollutants etc.

Following criteria should be considered for evaluating eco-friendliness of construction technology:

- Use of local materials as otherwise the required transportation causes pollution and consumption of fuel which in turn is a scarce resource in present-day context.
- Use of Non-renewable resources in production.
- Use of waste products.
- Recyclability of material.
- Waste generation and utilization of waste generated.
- Emission of pollutants/hazardous materials.

9.5.2 Embodied Energy (TA)
**Definition:** It refers to the total non-renewable energy consumption in acquisition of raw materials, their processing, manufacturing, transportation to adoption of housing technology. It is indicative of the building technology’s overall impact in the environmental context. Selection of technology and procedure of construction should be done in such a way so as to create a proper balance between climatic conditions, material availability, transportation cost etc.

- However in absence of appropriate data, the exact embodied energy for any system may be judged subjectively.

### 9.6 Finish Quality (SA)

**Definition:** Choice of methods and materials greatly affect the workmanship quality and thus the ultimately the finish quality of construction. So while evaluating the technologies of construction, one shall take into account the desired quality of finishes also. Finish quality includes bulging and waving of surfaces, hollowness, surface cracking, thick plastering requirements etc. Broadly the different aspects of finish quality are classified into:

#### 9.6.1 Exterior Finish Quality (TA)

**Definition:** It refers to the finish quality of exterior surfaces (both horizontal and vertical) including exposed concrete surface, masonry, glazing and claddings, different types of sidings, brick exteriors and stuccos etc. obtained using the adoption of housing technology. The term exterior finish quality deals with issues like surface cracking, spalling, bulging and waving of exterior surfaces, hollowing, dampness, and other anomalies etc. Following criteria are to be used to evaluate the attribute:

- Quality of finish obtained in terms of high, medium, low.
- Requirement of finishes.
- Compatibility with surface finishes such as putty, paint etc.

#### 9.6.2 Interior Finish Quality (TA)

**Definition:** It refers to the finish quality of interior surfaces (both horizontal and vertical) obtained using the adoption of housing technology. The term interior finish quality deals with issues like surface cracking, bulging and waving of interior surfaces,
hollowing, dampness, and other anomalies etc. Following considerations are to be used to evaluate the attribute:

- Quality of finish obtained in terms of high, medium, low.
- Requirement of finishes.
- Compatibility with surface finishes such as putty, paint etc

10 Summary & Conclusions

The key outcome of this research work is an efficient and yet “easy-to- implement” set of attributes which will also serve as a Decision Support System (DSS) for the emerging technologies of housing construction. Thus, this set of identified and defined attributes will aid the Indian Real Estate developers to select the most appropriate method of residential building construction from the perspective of affordability and sustainability.

Further to above, the research work would be extended to identify appropriate decision making tool and design an evaluation framework for emerging housing systems and technologies. Evaluation framework developed shall be implemented after conducting performance appraisal certification (PACS) followed by proof of concept. Attributes defined in this report & the evaluation framework doesn’t work as a pro technology provider. Hence, final recommendation for adopting any emerging technology shall be ensured only after performing an onsite evaluation in addition to the report generated from the multi attribute analysis.
11 Appendix A – References

12 Appendix B – List of Attributes

Attributes for Evaluating Emerging Housing Technologies

Primary Attributes
- Mandatory Attributes
  - Strength & Stability Requirements
  - Performance & Statutory Compliances
  - Functional Requirements
  - Constructability
  - Economic Viability
  - Maintenance
  - Sustainability
  - Finish Quality

Secondary Attributes
- Preferred and Desired Attributes
  - Functional Requirements
    - Design Flexibility
    - Simplicity in execution & Versatility
    - Design Compatibility
    - Speed of construction
    - Economies of scale
    - Type of Maintenance
    - Lead Time
    - Efficiency of design
    - Supply Chain Reliability
    - Technology Transfer Possibility

Tertiary Attributes
- Primary Attributes
  - Strength against vertical loads
  - Stability against Lateral Forces
  - Performance of joints
  - Fire Resistance
  - Violation of Statutory Provisions
  - Design Flexibility
  - Restriction on no of floors
  - Service Life/Durability
  - Foundation Type
  - Skilled Labour
  - Thermal Comfort
  - Equipment
  - Acoustic Performance
  - End user friendliness
  - Weather Resistance
  - Water Tightness
  - Internal Finish
  - Embodied Energy
  - Eco-friendliness
  - Tertiary Attributes
Minutes of Meeting

Technical Advisory Group Meeting- 8th Oct, 2014

Multi-attribute Evaluation Methodology for Emerging Technologies

Mandatory Attributes

(i) Secondary Attribute Name: Strength Requirement

(1) Name of “Strength Requirement” to be changed to “Strength & Stability Requirement”.

(2) “Joint Connectivity” to be incorporated under Strength & Stability Requirement”.

(3) “Joint Connectivity” to be changed to “Joint Performance”

(4) Change the name of “Stability against Dynamic Forces” to be changed to “Stability against Lateral Forces”

(5) “Flexural Strength” to be merged with “Load bearing strength”.

(5) Only loads are to be taken from Indian Standards to check structural adequacy. Systems can be designed as per equivalent international standards also

(ii) Secondary Attribute Name: Stability & Code Compliance

(1) Name to be changed to “Compliance with Codes”

(2) Compliance with MOEF & SVA-GRIHA not needed

Preferential Attributes

- The name of “Preferential Attributes” to be changed to “Desirable Attributes”

(i) Secondary Attribute Name: Functional Requirements
(1) A new tertiary attribute to be added for “End-user-friendliness”.

(2) “Design Compatibility” to be checked for architectural designs & building services. Check for structural design compatibility to be reviewed (and if needed, removed).

(3) “Suitability for wet areas” to be captured (might be incorporated in “Design Compatibility”).

(3) “Design Flexibility” check to be bifurcated into two spectrum

- During construction changes
- Post construction changes & expandability

(4) “Water Proofing” to be checked for effectiveness & requirement

(5) “Service life/ Durability” to be checked against suitability of the system for all environment type and results of accelerated environment test

(6) The name of “Thermal Resistance” to be changed to “Thermal Comfort”

(7) The name of “Sound Transmission” to be changes to “Acoustic Performance”.

(8) Restriction on maximum height/ number of floors that can be constructed using a particular system is to be captured.

(ii) Secondary Attribute Name: Constructability

(1) Remove “Construction Quality” as this point is already captured under a separate tertiary attribute, “Finish Quality”.

(2) Level of training required (“Simplicity of Execution”) should be linked with “Skilled Labour”.

(3) “Versatility” should be merged with “Simplicity of Execution”

(iii) Secondary Attribute Name: Economic Viability

(1) The name of “Construction Cost” to be changed to “Cost” as it also captures life cycle cost of the system.

(2) The name of “Land Utilization & Space Savings” to be changed to “Efficiency of Design”.
(3) “Maintenance” to be removed as it will be made a separate secondary attribute.

(4) Technology transfer possibility to be incorporated in order to assess whether the system can be mass produced in India using local/Indian resources (raw materials)

(iv) **New secondary attribute** to be made for: **Maintenance**

(1) Tertiary attribute to be added for **maintenance cost**

(2) Tertiary attribute to be added for **maintenance type** (major/minor)

(3) Tertiary attribute to be added for **frequency of maintenance**

(4) Tertiary attribute to be added for **ease of maintenance** to capture if any special tools or specially trained workforce is needed for doing the repair work

(v) **Secondary Attribute Name: Sustainability**

(1) **Recyclability of material** to be captured under “**eco-friendly construction**”

(2) **Embodied Energy** to be checked qualitatively.

(3) **Waste generation & Waste Utilization** should be captured. Consider changing the name of “**Resource saving material**”.

General Discussion Points:

- Incorporation of end users, industry practitioners & academics in finalization of the model.
- Revisions in line with the first expert meeting (as held on 8th Oct 2014) to be incorporated by 10th Oct 2014.
- Next meeting on 17th Nov 2014 (tentatively).
A target group should be identified for the technologies which are to be evaluated in the proposed framework. However ideally the framework should be generic in nature, which means it should be applicable for all type of housing construction technologies.

The phrase “multi attribute” in the title of research can be considered for changing (as suggested by experts). Order of “Submitted” and “to” should be changed in the report front cover.

This model or evaluation framework is not a pro technology provider. This model, as decided in the expert review committee, is a part of a three stage technology evaluation process. This framework should be implemented after conducting performance appraisal certification (PACS) and it is to be followed by proof of concept (POC).

This model should ensure onsite evaluation in addition to the multi attribute analysis for final recommendation.

The prerequisites of this framework such as required capacity building and establishing a centre of excellence for testing etc. should be included in the agenda of BMTPC.

In addition to that all the prerequisites of this proposed model should also be mentioned very clearly in the preamble of the final report. The preamble should also state the objectives, limitations and validity timeframe for the proposed model.

Regarding the industry/ academia expert feedback (as decided in 8.10.14 meeting at BMTPC), it is further decided that the research report will be kept confidential between RICS and BMTPC. The report will not be shared with any third party, not even with the experts who will be interviewed for their feedback on the proposed model.

The next meeting regarding the changes proposed by all industry practitioners and academic experts should be arranged within 10 calendar days of this meeting (as held on 18.11.14 at BMTPC).

The proposed list of experts to be interviewed:
  - L&T : 3 persons
- IIT Delhi: Prof K. C. Iyer
- Ultratech: S. Chaudhary (If available in Delhi)
- Afcon/SPCL: 1 person
- Sare Homes: 1 person

14 Annexure D – Expert Opinions
**Expert Opinion 1**

Expert Interviewed: Mr. L Ramakrishnan  
Designation: **Cluster Project Manager – Residential Buildings, Delhi Region**  
Organisation: **L&T Construction**  
Date & Time: **20th November 2014 & 10:30 am**

**Expert Comments:**

1. “Local Bye-laws compliance” to be included in mandatory attributes as tertiary attribute.  
2. “Usage of locally available materials” to be included as tertiary attribute in “economic viability” attribute.  
3. “Suiting to local weather conditions & eco-friendly materials” parameter to be checked in the list of attributes.  
4. “Construction friendly” parameter to be incorporated as tertiary attribute in constructability.  
5. List of attributes is very comprehensive.

**Expert Opinion 2**

Expert Interviewed: Mr. M.K. Jha  
Designation: **Contracts Manager – Residential Buildings, Delhi Region**  
Organisation: **L&T Construction**  
Date & Time: **20th November 2014 & 11:30 am**

**Expert Comments:**

1. Suitability to urban and rural housing to be differentiated.  
2. “Initial Power Requirement” to be incorporated as a tertiary attribute in the list of desirable attributes.

**Expert Opinion 3**
Expert Interviewed: Mr. Navneet Kaul
Designation: Segment Head – Affordable & Elite Housing, North Region
Organisation: L&T Construction
Date & Time: 24th November 2014 & 4:00 pm

Expert Comments:

1. List of attributes is very comprehensive.
2. “Scarcity of labour, skill level and mechanization” to be captured and given priority in evaluation.
3. There is a requirement of Standardisation and Organisation of resources.
4. “Requirement of manufacturing plant” to be incorporated.
5. “Susceptibility to External weather conditions” to be incorporated.
6. “No of repetitions” is very important attribute while evaluating any housing technology and should be given priority.
7. Innovations in construction such as prefab cages to be adopted while using emerging housing technologies. Adaptability aspect should be taken into consideration for the technologies.

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Expert Opinion 4

Expert Interviewed: Mr. Vineet Relia
Designation: Managing Director, Gurgaon Region
Organisation: SARE Homes Project Services Pvt. Ltd.
Date & Time: 1st December 2014 & 11:30 am

Expert Comments:

1. Primary attributes should be “Regular attributes”, “Essential Attributes”, & “Desirable Attributes”
3. “Approvals & regulations” to be incorporated in mandatory/regular attributes as a tertiary attribute.

4. “Finish quality” to be incorporated in essential attributes.

5. List of attributes is exhaustive

**Expert Opinion 5**

Expert Interviewed: Mr. Sandeep Navlakhe  
Designation: Vice President – Construction Management  
Organisation: Lodha Group  
Date & Time: 19th November  

**Expert Comments:**

1. List of attributes covers almost all the parameters to evaluate housing technologies. It is better to establish difference between rural and urban housing.

2. Better to include “Acoustic performance” and “Thermal comfort” under code & regulations.

3. “Supply chain reliability” is very important parameter without which the whole technology concept can fail.

4. “Service life” parameter to be explained clearly as it is difficult to predict for a future technology.

**Expert Opinion 6**

Expert Interviewed: Prof. K.C. Iyer  
Designation: Professor  
Organisation: IIT Delhi  
Date & Time: 16th Dec 2014 & 20:40 hrs  

**Expert Comments:**
1. “Durability” and “Serviceability” attributes to be considered in “Mandatory” instead of “Desirable” attributes.

2. “Design compatibility” attribute to be shifted from “Functional requirements” to “Constructability”.

3. “Weather tightness” to be renamed as “Weather resistance”.

4. “Prevention of water tightness and moisture penetration” to be renamed as “Water tightness /Damp proof”.

5. “Cost” to be renamed as “Initial Cost” and “Cost of maintenance, Recurring/replacement cost” to be added under “Maintenance” attribute as end user will have the choice of choosing the technology.
15 Annexure E - Bio-data of Principal Investigators

Dr Anil Sawhney:

Anil Sawhney is the Associate Dean, Director and Professor of School of Construction. He was previously teaching at Indian Institute of Technology (IIT), Delhi as Professor of Civil Engineering. He was also an Adjunct Professor in the School of Built Environment, University of Technology Sydney. Professor Sawhney is a Fellow of the Royal Institution of Chartered Surveyors and a member of the Project Management Institute. From June 2010 to June 2011, he held the position of Chair in Construction Project Management at University of Technology Sydney. With a Bachelor’s degree in Civil Engineering (1988) and a Master’s degree in Building Engineering Management (1990) from India, he completed his doctoral studies in construction engineering and management from the University of Alberta, Canada in 1994. He started his academic and consulting career in the US in 1994.

Professor Sawhney has a rich mix of academic, research, industry and consulting experience gathered working in India, Canada, USA, and Australia. Over the last 20 years, he has built a substantial record of academic leadership and created a strong education, research, consulting, and service program in the area of construction project management and construction management education. Professor Sawhney performed consulting assignments for a large number of organizations including the World Bank under the International Comparison Program from 2002 to 2006. As part of this work, he co-developed a spatial and temporal comparison methodology for the comparison-resistant construction sector. In 2009, he was appointed to the Bureau of Indian Standards panel on construction project management (BIS/CED29/P1). Professor Sawhney also serves on the executive committee of the India Design Innovation Education Forum. Professor Sawhney is well published with over 70 publications in refereed technical journals and conferences. He serves on the International Editorial Board of the Journal of Civil Engineering and Environmental Systems published by Taylor and Francis and the Journal of Information Technology in Construction.

Honorary appointments

School of Built Environment, University of Salford, UK
March 2014 to Present
Honorary Professor
Grenfell-Baines School of Architecture, Construction & Environment, University of Central Lancashire, UK
March 2014 to Present
Associate Member, Centre for Sustainable Development

Institute of Lean Construction Excellence, India
January 2013 to Present
Honorary Advisor

Positions and affiliations with professional organisations

- RICS International BIM Working Group, RICS UK (2013—present)
- Expert Panel, Ashoka and TÜV Rheinland Affordable Housing Council CASA Rating (2012—present)
- Academic Advisory Group of the Project Management Institute India (2012—present)
- Fellow of the Royal Institution of Chartered Surveyors UK (2011—present)
- Executive Committee of the India Design and Innovation Education Forum (2009—present)
- Bureau of Indian Standards CED 29 Construction Management (Including Safety In Construction) Sectional Committee (2010—2014)
- Bureau of Indian Standards—Working Group for Time Management (CED 29/P1/WG 1) and Cost Management (CED 29/P1/WG 2) (2009—present)
- Editorial Board of the Journal of Construction Engineering and Management, American Society of Civil Engineering (August 2005 to 2008)
- International Editorial Board of the Journal of Civil Engineering and Environmental Systems (January 2003 to present)

Recent Research Projects

- Status of BIM Adoption and Outlook in India, RICS SBE and KPMG 2014
- India BIM Survey (PI)
- Evaluation of Emerging Industrialised Housing Technologies and Systems for Affordable and Sustainable Housing Stock in India and the UK (Co-PI)
- Built Environment Modelling for Urban Renewal (PI)

VPS Nihar Nanyam

Er. Nihar Nanyam has recently joined RICS School of Built Environment as an Assistant Professor. Prior to this, he was working with L&T as an Assistant Manager since 2010, handling the responsibility of planning in charge, managing time and cost deliverables for a high rise project in Mumbai and has been consistently rated as a star performer. After pursuing his Bachelors in Civil Engineering from GiTAM
college of Engineering (Andhra University), he further added to his qualification through a master in Construction Technology and Management from IIT, Delhi. He received a gold medal from Indian Concrete Institute in the year 2007 as Best student in the academics.

Projects and Research Work

Nihar has worked on various projects such as Optimization of Construction Schedule for an affordable high – rise housing and has been instrumental in presenting technical papers at NIT, Suratkal, Nirma University & SPCE, Mumbai. Along with this, he has completed MAPS (Mentoring & Augmenting Planning Skills) program, sponsored by IIT Madras and L & T Construction.

Riddha Basu

Riddha Basu has recently joined RICS School of Built Environment as a Research Associate. Prior to that she had been working in L&T Construction as a planning engineer and coordinator (eastern region) for the residential buildings and factories.

Educational Background

Riddha Basu has completed her Bachelors in Civil Engineering from West Bengal University of Technology (WBUT) and received a Gold Medal for the same in 2011. Afterwards she had pursued Masters in Construction Technology and Management from Indian Institute of Technology, Delhi (IIT Delhi).

Projects & Research Work

HORIZONTAL (SLAB) FORMWORK SELECTION MODEL USING ANALYTICAL HIERARCHY PROCESS (AHP).

The project was about quantifying the process of horizontal formwork (here slab formwork) selection, using AHP which is known for its efficient and at the same time simplistic approach to solve multi-criteria decision making problems. Coding for the model was done in MATLAB and Factor Analysis (in SPCS) was used to determine the formwork selection factors to be considered in the model. Performance Analysis of the model was also done in which the model showed 82% accuracy, which was quite satisfactory.

DESIGNING (G+12) STOREY RCC BUILDING
The scope of the project include complete design of the substructure (Pile foundation) and superstructure (slab/beam/column/staircase) of a G+12 building and preparation all necessary architectural and structural drawings using AUTOCAD. Analysis of the structure was done in STAAD Pro.