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Developing a Framework for Innovation in House Construction: An Exploratory Study of Emerging Techniques and Practices †

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Abstract: Using innovation building technology in South Africa as case subjects, this study aims to be an exploratory of the practices and techniques that are used in or as part of the framework in innovation in house construction. The study explored the existing literature on the subject and followed by the proposed framework. The study methodology—The proposed conceptual framework was adopted from the house of quality and multicriteria decision making procedure. Data were collected in two stages and were used to test or validate the framework. The two stages of this study were a questionnaire survey that was targeted at end users, namely contractors of innovation building technologies in the house construction industry. The second stage was interviews targeted at the developers of innovation building technologies who are also referred to as system holders. Regarding the findings of the study—The proposed conceptual framework may be used to measure innovation in house construction and may be used hand in hand with existing South African regulations in the house construction industry. On the other hand, the system holders may use the proposed conceptual framework as a guide in innovation building technology projects. The value of the study is to ensure that innovation building technologies maintain their original advantages and survive the market.

Keywords: innovation building technology; conceptual framework; house construction industry; house of quality; multicriteria decision making

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1. Introduction

Innovation in house construction in South Africa is circumscribed to what is termed innovation building technologies (IBT), which the National Home Builders Regulations Council (NHBRC) defines as the more inclusive of all innovation in artefacts or processes [1]. The IBTs may be found in different field of building construction, but this study is only focused on house construction industry in South Africa. The Housing Consumers Protection Measures Act of 1998 (No 95 of 1998) [2] relates the IBTs as non-standardised construction, which is defined as any form of building that utilises building systems, methods, materials, elements or components which are not fully covered by existing standards and specifications or codes of practice and/ or which are not described or referred to in "deemed-to-satisfy" rules of the National Building Regulations [1]. In some instances, the IBTs may be compared with standard building systems, which include building system, method, materials, elements, or components, that are fully covered by existing South African standards and specifications or codes of practices.

In this study, practice is referred to as the actual application of theories, regulations on construction methods or materials both in design, manufacturing, and construction.

The code of practice, called 'The Application of the National Building Regulations', SANS 10 400, covers the provisions for building site operations and building design and construction that are deemed to satisfy the provisions of the National Building Regulations [3]. On the other hand, the technique is referred to as the skill to execute both the standardised and non-standardised practice in accordance with National Building Regulations. This study is an exploratory of the non-standardised practices as well as the techniques applicable to such practices. It further investigates the existing frameworks and then proposes the new framework towards innovation in house construction. The existing framework in South Africa is performance-based and incorporates the voice and decisions of the engineers. The proposed framework is also performance-based but incorporates both the voice of the engineers as well as the voice of the end user or customer of the IBT systems and products. The significance of the research it to improve on the existing framework regarding IBTs and provide direction for future research. The material covered in this paper forms part of the Doctoral studies, and some will be included in the future publication.

2. Research Methods

A qualitative approach was followed in this research. The study methodology—The proposed conceptual framework was adopted from the two proved theories, which are the house of quality and multicriteria decision making (MCDM) procedure [4–6]. The house of quality was used in the overall design of the proposed framework, whilst the multicriteria decision making, incorporating the analytic hierarchy process (AHP) [6] was used to determine the weights of the customer attributes or voice of the customers [4].

Data were collected in two stages which included a questionnaire survey that was targeted at customers such as the end users or contractors of IBTs in the house construction industry, and then unstructured interviews targeted at system holders or engineers. The survey requested the customer to rate their needs regarding the IBT systems or products, rating them on a Likert scale of 1 to 5, where 1 and 5 represented the least important need and the most important need, respectively [7]. The questionnaire survey results were used as a guide to pair the items of the matrix as close as possible to the customers' needs, The needs of the customers are referred to customer attributes (CAs), whilst the system holders' or engineers' design dimensions are called engineering characteristics (ECs) in this paper The second stage was interviews targeted at the developers of IBTs or system holders, where each participant was asked a question regarding customer satisfaction. The results were recorded and presented in the next section of this paper. Figure 1 shows the summary of the research methods, whereby Part 1 is the qualitative data collection and the review of the literature regarding the existing framework. Then Part 2 involved the design of the proposed framework incorporating the existing framework. Part 3 covers case studies that the framework was tested on and does not form part of this paper.

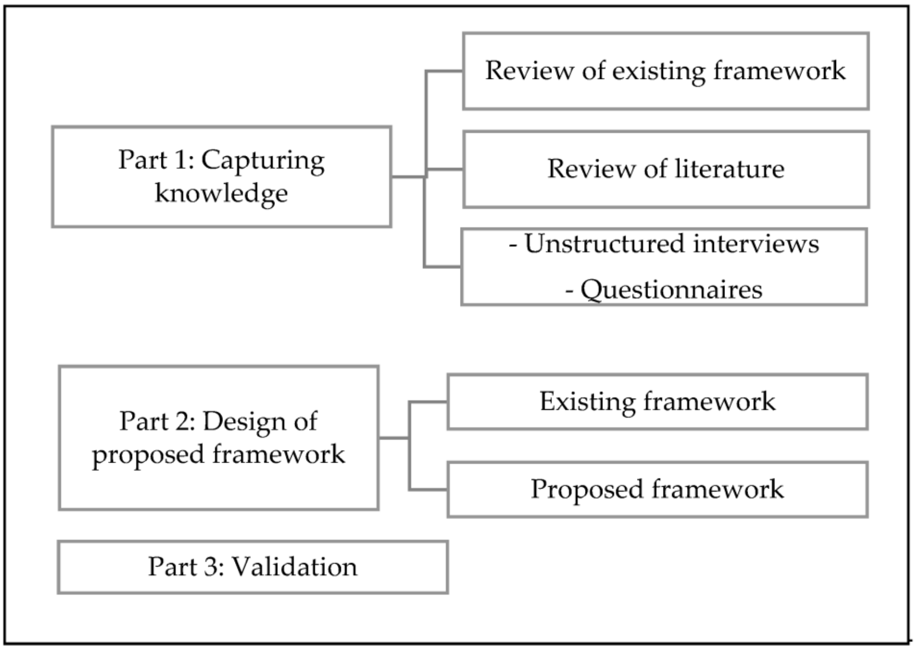

Figure 1. Summary of research methods.

3. Results

This section presents the results of the survey questionnaires, unstructured interviews, the existing framework, as well as the design of the proposed framework.

3.1. Qualitative Results

The results from the questionnaire survey were analyzed using the AHP and presented in Table 1. The priority index may be seen as a measure of importance or priority amongst the given concepts [4].

Table 1. Results of AHP and MCDM of the CAs.

Customer Attributes (CAs)	Priority Index
Structural Integrity	0.541
Durability	0.272
Habitability	0.076
Sustainability	0.075
Ease	0.036
	$\sum = 1$

The IBT developers, system holders and engineers were asked the following question during an unstructured interview: 'What do you see as the most important design dimension in your system or product, that will satisfy your customer the most?' The results were recorded and presented in Table 2:

Table 2. Results from the interviews.

Design Dimensions	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6
Generating Strength	x	x	x			
Generating stability		x	x	x		
Protect against Water		x		x		x
Protect against Fire		x		x	x	
Ensuring sustainability		x				x

3.2. Existing Framework

The existing framework for the National Building Regulations is a four-level framework and stands on two legs. The first leg is the compliance methods with standards or codes, which are the application of the 'deemed to satisfy' design and construction rules. The second leg is the performance-based methods, which are the application of the rational assessment, rational designs, and certification for non-standardized practice, namely IBTs. There is nowhere in the framework shown in Figure 2, where the customer attributes or service is incorporated.

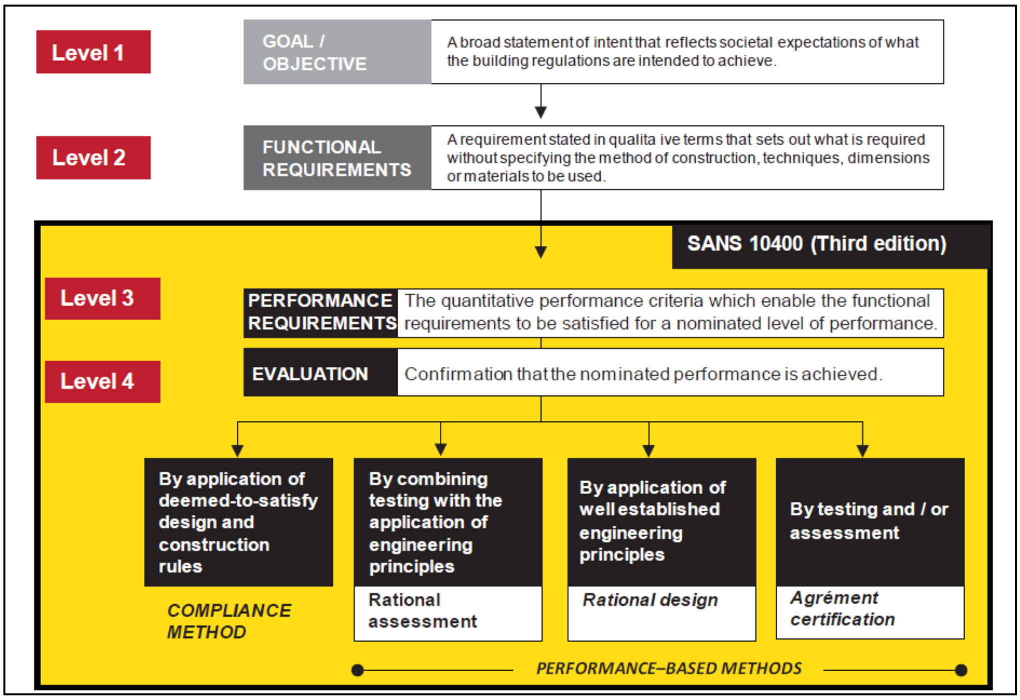

Figure 2. The existing framework for the National Building Regulations [8].

3.3. Proposed Framework

The proposed framework incorporates both the engineering characteristics (ECs) as well as the customer attributes (CAs). The framework is for the non-standardized practices, IBTs, and covers all the first four design dimensions (strength, stability, water protection, and fire protection) that are in the performance-based framework but includes sustainability as the new proposed design dimension. The design dimensions (strength, stability, water protection, fire protection, and sustainability) were measured in deformation (m), degree of compatibility (%), saturation ($\ell/m^2/s$), fire resistance in (s), and carbon footprint (m^2), respectively; Figure 3.

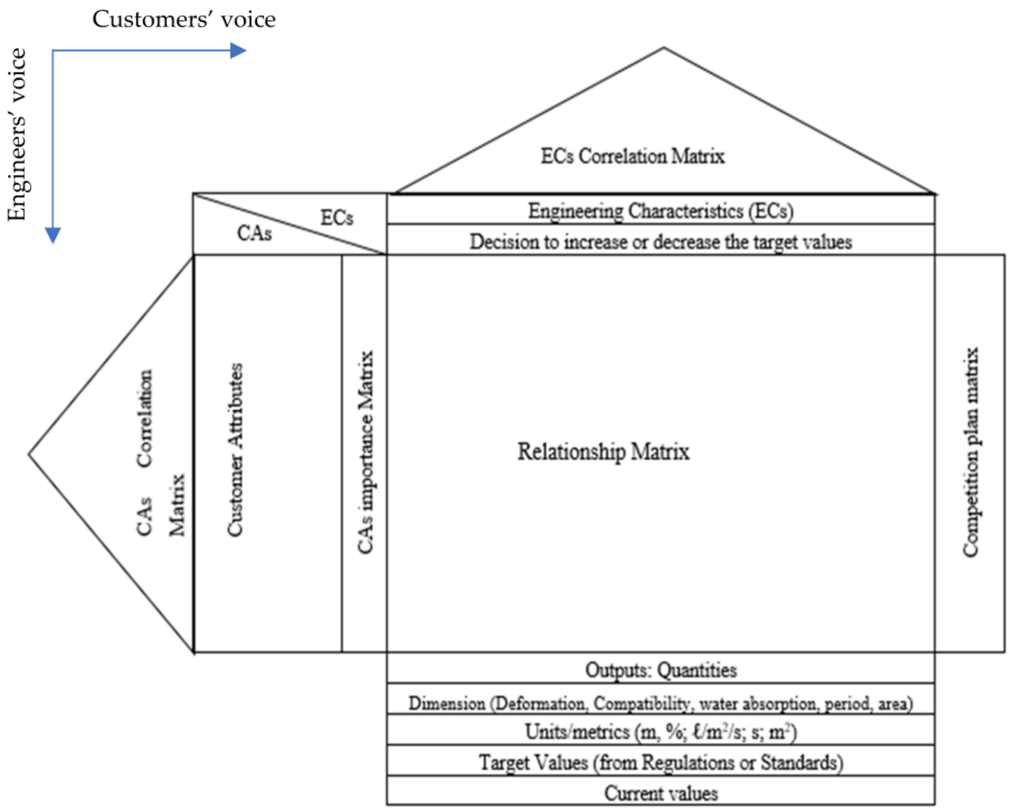

Figure 3. The proposed framework.

When observing Figure 3, it shows that the vertical parts of the proposed framework are all about the engineers' voice and the design dimensions; whilst the horizontal parts are all about the customers' voice. Where the vertical and horizontal meets, the relationship matrix between the engineers' voice and the customers' voice is created. The details of the relationship matrix are further demonstrated in the case studies which are not part of this paper. Figure 3 further shows that incorporating the customers' voices or attributes will lead to the competition plan for the IBT system or product. The other important aspects from Figure 3 are the CAs and ECs correlation matrices, which are meant to establish the co-relationships between the CAs themselves as well as the co-relationships between the ECs themselves. The ACs and ECs relationships will be analyzed using factor analysis in the form of case studies in the future research paper.

4. Discussion

The results of the questionnaire survey were analyzed using the AHP and were presented in Table 1. The results from the questionnaires showed that the most important attribute to customers was the structural integrity of the IBT system or product. The second most important attribute was durability, followed by habitability, sustainability and the least important was the ease of erection or installation of the IBT system or product. Factors that affect the rating of the customer attributes may be associated with safety and security, hence the structural integrity of the system or product was rated the most important. The other factors may be the techniques, which may have contributed to the least importance rating of the ease of erection. It is also possible that the customer may rather opt for the manufactures or system holders to assist in the installation or erection of the system.

The results from the unstructured interviews included 6 participants, and the results were shown in Table 2. The four design dimensions that the system holders and engineers perceive to satisfy their customer the most were (1) generating strength, (2) generating stability, (3) protection against water, and (4) protection against fire. It should be noted that other factors that may influence the decision of the system holders and engineers such as cost of production, profit, and policies were not considered in the interviews. One may think that the sustainability and environmental laws may be important to the system holders but not as to the customers. It is also vital to note that the techniques for incorporating environmental aspects and sustainability in the other design dimensions have become a need for most system holders and engineers.

The results presented in Table 1 can be incorporated in the proposed framework under the CAs importance matrix in Figure 3. On the other hand, the results from Table 2 may be incorporated at the bottom of the framework (Figure 3), to guide the system holders or engineers with their targets. Results from Table 1 will also be utilized to establish the relation matrix between the CAs and ECs. Hence, Tables 1 and 2 are the main inputs to the proposed framework.

5. Conclusions

Although this is ongoing research, the main finding is that the existing National Building Regulations framework for the non-standardized practices can be strengthened by incorporating the customers' voice into the design aspects.

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