DECISION-MAKING FOR EVALUATION AND SELECTION OF SUITABLE INDUSTRIALIZED HOUSING SYSTEM

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ABSTRACT: The evaluation of housing system in order to make the effective decision for application in housing construction has been a challenge for many developing countries. This study examines the novel approach to evaluate and select the industrialized housing system (IHS) that is appropriate for adoption in the rapid housing development project in Addis Ababa, Ethiopia. The method applied in this study comprises critical literature review, experts’ interview and questionnaire survey within the Ethiopian construction industry. Data obtained was analyzed using an analytical hierarchy process research technique and an Expert Choice Comparison software platform. The findings revealed that affordability, quality, and innovation are the most important attributes to be considered for decision-making. In addition, semi-industrialized precast concrete systems are preferable for application cost-effective large-scale housing development. All stakeholders involved in housing development can apply the decision-factors and method used in this study in order to make effective decisions.

Keywords: Industrialized housing system (IHS), Decision-making, Analytical hierarchy process (AHP)

1. INTRODUCTION

Decision-making for evaluation of industrialized housing system (IHS) has increased driven by the technological advancement and rapid construction process [1, 2]. Such advancement in construction technology has shown technological evolution in different countries. However, the evaluation and application of IHS have been studied more in developed countries than on that in developing countries [3]. Subsequently, research gaps have arisen with regard to the IHS evaluation and selection. This paper tries to fill the gap to this body of knowledge and has conducted the evaluation through a novel approach in order to select the suitable IHS for adoption in housing development. As shown in Figure 1, ten IHS were chosen for evaluation based on their wide application for housing development in different countries.

Rapid urbanization and population growth have created enormous pressure on large-scale cost-effective housing development in the city of Addis Ababa, Ethiopia [4]. The existing housing demand is excessive than the housing supply capacity of the housing market [5, 6]. One of the main challenges is the use of appropriate housing system for cost-effective large-scale housing development [7]. The Ethiopian government has also planned to introduce cost-effective industrialized housing systems as a solution for these challenges [8]. Although applications of IHS are important for high rate of housing development [2], there is lack of study and practice on selection and evaluation of IHS.

Fig. 1 The ten IHS selected for evaluation

2. HOUSING SYSTEM DECISION CRITERIA

Previous studies revealed the importance of systematic decision-making for identification of suitable IHS [1, 9, 10]. A recent study has presented three main sets of decision criteria that help to identify the appropriate housing system for adoption, which are the structural, contextual and behavioral factors [1]. Additional sets of factors
such as building project management-related include communication and investment [11], project procurement and project status [12], and the management method employed [11]. Whereas, human-related sets of factors include perception [13], reasoning [14], culture [15], skills and knowledge [16], knowledge management [17], and acceptance [18]. Additional factors that influence decision making include technology development [19], sustainability features [20], stakeholder involvement [21], and financial conditions [22].

All inclusive approach to decision-factors is important to consider for evaluation of IHS [23]. Ilozor, Okoroh, Egbu and Archicentre (2004) have discussed that adoption of suitable housing system has a direct impact on the success of a housing development. Experts’ in the construction industry are well aware of the failure caused by incorrect decisions [24]. Abdullah and Egbu (2010) have presented the comparative advantage gained from each housing system is the basis for its adoption [17]. Therefore, holistic decision-criteria is important to consider in order to make an effective and informed decision according to a given local context.

2.1 Remarks on the review

Previous studies allow to the following remarks:– first, despite the many studies on decision criteria and evaluation of housing system, there is lack of research on regarding developing countries. Second, house builders faced challenges in the systematic process of decision making for housing system selection. Third, it is not common to make comparison among housing systems in overseas in order to identify the suitable one for a given local context. Fourth, a systematic method of decision making is important for making effective and informed decisions.

3. METHODOLOGY

3.1 Research Design

In order to understand the opinion of professionals in the construction industry as well as to provide a detail explanations, this study was conducted based on survey-based study approach [25, 26]. A pilot study was conducted prior to the survey questionnaire with the identified ten experts within the Ethiopian construction industry. The experts are selected based on their significant experience on the industrialized building system being as a manufacturer, supplier, contractor and academician and professional practitioners. Ten sample surveys were conducted and the experts were requested to classify the relevant factors, the challenges and the solutions for the implementation of IHS. In addition, they assessed the significance and the consistency of the questionnaire and made necessary modification prior to modification. The evaluation processes were undertaken using the analytical hierarchy process (AHP) research technique to quantify the subjective evaluation of experts [27] and Expert Choice Comparison (ECC) software as a tool to conduct the AHP assessment. The outline of the research design is shown in Figure 2.

Fig. 2 Outline of the research design

3.2 Evaluation of Decision-factors

Due to the low-level application of IHS, there are limited numbers of experts available in the construction industry of Ethiopia. A general survey was conducted to select thirty experts with an average of fifteen years of experience in order to engage them in the AHP evaluation. The thirty experts were from government officials, academics, manufacturers, contractors, and engineers. A holistic decision-factors were suggested based on literature review as suggested by Pan, Wong, and Hui to make sure that comprehensive criteria were set for the building system assessment [2]. The trustworthy importance of the evaluation was validated through the calculated consistency ratio. Since the consistency ratio for the overall judgment was less than 0.1, the overall evaluation was consistent and valid. Table 1 listed the 6 major and 30 sub decision-factors proposed for evaluation.

3.3 Analysis of Data Collection

Based on the survey data, a different form of data was collected. The data were analyzed following structuring of the decision hierarchy. The overall evaluation process is conducted through the following steps. Initially, as shown in Figure 3, a
A decision hierarchy model was structured in order to conduct the preferential weight evaluation. The priority vector value of the decision-factors was defined based on the pair-wise comparison matrix assessment of the ten experts. Then, the final levels of importance priority vector values of the decision-factors were identified based on a mathematical calculation and normalization of the input values. Furthermore, a pairwise comparison evaluation was conducted to identify the importance weight value of the proposed ten IHSs. Thirty identified professionals and experts are involved in the evaluation. The experts are key players within the Addis Ababa construction industry in the contractors, precast manufacturers, developers; engineers, suppliers, and academician with an average of fifteen years of experience. The evaluation was conducted based on the Saaty’s pairwise judgment scale of 1-9 conducted to every sub decision-factors. Lastly, the normalized outcomes of the alternatives were weighed accordingly; then, the topmost suitable IHS was selected.

4. RESULTS AND DISCUSSIONS

4.1 Priority of Decision-factors

Based on the results of the normalized priority vector shown in Table 2, the top most important main decision-factors are user needs, supply chain, and building industry. These factors need significant consideration in order to make an effective decision for selection of suitable IHS for an application. Previous researchers have also discussed similarly that the three factors have prime importance for IHS decision-making [2, 28]. In addition, these factors are the main focus of attention for the challenges encountered in the development of affordable housing in many developing countries. One of the key encounters is lack of suitable resources with an essential value and reasonable price. This is a communal challenge as the ability of the residents to pay for a better housing is very low and the majority of the population live in the slum. Thus, in order to achieve a high rate of cost-effective housing development, the top three identified decision factors are important to select the appropriate IHS for an application.

The availability of sufficient supply chain and production capacity of building components is a determinant factor for a successful application of IHS for a large scale housing development. In the city like Addis Ababa, Ethiopia, where the manufacturing capacity of affordable building materials and components is not yet well advanced, the situation aggravates the challenge of effective supply chain management [29]. These challenges become the obstacles for wide and sustainable application of IHS [7]. In order to advance the performance as well as to promote the extensive application of IHS, it is necessary to invest in the innovation research of new building components. However, the finding shows that the priority vector value of sustainability has found to be low. This indicates that the concern assumed for sustainability by building experts is less compare
to the focus given to address the challenge of achieving affordable housing with respect to the existing housing demand.

Table 2. Main decision-factors analyzed ranking.

| Main Decision-factor | Priority Vector % | Priority ranking |
|----------------------|-------------------|-----------------|
| Building industry    | 14.36             | 3               |
| Supply chain         | 25.06             | 2               |
| Infrastructure       | 9.60              | 5               |
| Sustainability       | 4.59              | 6               |
| User needs           | 39.28             | 1               |
| Socio-political      | 7.11              | 4               |

4.2 Priority of the Ten IHS

The importance level of priority of the ten IHS shows that the top three housing systems are the most suitable for application in large-scale cost-effective housing development. As it is listed in Table 3, the top three IHS are all precast concrete systems (i.e. concrete slab and stairs (System 7), precast concrete column, beam, cross-walls, floors and stairs (System 6), and precast concrete wall panels (system 8)). As it is shown in Figure 4, the results of this study can be categorized into two distinct groups of either precast concrete systems or steel systems. While the preferential importance of precast concrete systems is high, the steel based housing systems got less preferential importance value.

Table 3. Ranking of the alternative housing systems

| The ten industrialized housing systems | (Normalized Priority Vector %) | Priority ranking |
|---------------------------------------|---------------------------------|-----------------|
| S1: Green terra homes (steel)         | 5.96                            | 10              |
| S2: Yorkon (steel)                    | 6.26                            | 9               |
| S3: Precast concrete wall panels      | 15.38                           | 3               |
| S4: Energy-smart panels (Steel)       | 8.24                            | 5               |
| S5: Fusion building system (steel)    | 7.79                            | 6               |
| S6: Precast concrete column, beam, cross-walls | 16.24 | 2 |
| S7: Precast concrete slab and stairs  | 17.22                           | 1               |
| S8: APS Infill wall system            | 9.40                            | 4               |
| S9: Tunnel form                       | 6.62                            | 8               |
| S10: Innovative green building system (steel) | 6.87 | 7 |
engage both skilled and semi-skilled labors as an opportunity for employment. Additionally, the housing systems help to minimize the use of formwork for construction. In a country like Ethiopia, where wooden formwork is widely used for construction, housing systems that minimize the use of formwork help to reduce the deforestation and protect the environment [33]. Therefore, the three top selected IHS are better options for development of affordable and mass housing.

### Table 4: Characteristics of the suitable housing system

| Structural | Architectural | Industrialized process | Erection | Economic and social |
|------------|--------------|------------------------|----------|--------------------|
| Durability Load bearing components | Flexibility in plan | Concrete components | Easy handling | Lower cost for high quality |
| Fire, sound and water proof | Open system | Middle degree of mechanization | Compatible with conventional system | Adaptability to the needs of various socio-economic groups |
| | Medium to high rise residential | Panelised, and frame and infill techniques | Rapid construction | Need for semi-skilled/ unskilled labor |

### 5. CONCLUSION

The engineering performance of IHS has been the main concern of material research, but the emphasis given to experts’ preference and evaluation is overlooked. In this study, the evaluation and selection of IHS were investigated based on the holistic decision-criteria. The study revealed the top most relevant decision-factors and the appropriate IHS for application in the large-scale housing development in the city of Addis Ababa. Hence, in order to decide the most suitable IHS for application affordability, social benefits and environmental aspects of the local context should be significantly considered. Furthermore, the decision-factors should be considered as part of the holistic factors. The identified housing systems
are an appropriate option based on their economic competitiveness, efficient use of input materials and energy, use of local resources, compatibility with other traditional construction methods, and simplicity of erection. However, the selected systems have some problems with regard to frequent cracks in the joints and costly transportation due to heavy-weight building component parts. The construction industry in the city of Addis Ababa is yet under-developed and needs more advancement in technology application. To address this challenge, a significant emphasis should be given to innovation of materials and scale-up the capacity of local professionals in the construction industry. To conclude, the evaluation and selection methods applied in this study can help decision-makers and developers make better decisions.

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7. REFERENCES

[1] S. Aknam Syed Zakaria, T. Gajendran, T. Rose and G. Brewer, Contextual, structural and behavioural factors influencing the adoption of industrialised building systems: A review, Architectural Engineering and Design Management (2017), 1-24.
[2] Y. Pan, F. K. W. Wong, and E. C. M. Hui, "Application of industrialized housing system in China: A chongqing study," Modeling risk management in sustainable construction, D. D. Wu (Editor), Springer Berlin Heidelberg, Berlin, Heidelberg, 2011, pp. 161-168.
[3] Y. Chen, G. E. Okudan and D. R. Riley, Sustainable performance criteria for construction method selection in concrete buildings, Automation in Construction 19 (2010), no. 2, 235-244.
[4] M. o. U. D. H. a. C. MUDHC, "Statistical execution report 2010-2015," H. a. C. Ministry of Urban Development (Editor), vol. III, Ministry of Urban Development, Housing and Construction, Addis Ababa, 2015, p. 172.
[5] Y. Elias, A. Yonas, T. Teshome, M. Wubshet, A. Aziza and A. Brook, "Housing component, evaluation report," Master Plan Evaluation, EiABC, Addis Ababa, 2011, p. 98.
[6] UN-Habitat., "The state of Addis Ababa," Nairobi, Kenya, 2017, p. 108.
[7] T. Halefom, "National report on housing and sustainable urban development," H. a. C. Ministry of Urban Development (Editor), vol. I, Ministry of Urban Development, Housing and Construction, Addis Ababa, 2014, p. 75.
[8] N. P. C. NPC, "Growth and transformation plan ii gtp ii," National Planning Commission, Addis Ababa, 2016, p. 236.
[9] A. G. F. Gibb, Off-site fabrication: Prefabrication, pre-assembly and modularisation, Whittles Publishing, Caithness, 1999.
[10] S. Nemati, M. Rashidi and B. Samali, Decision making on the optimised choice of pneumatic formwork textile for foam-filled structural composite panels, Int. J. GEOMATE 13 (2017), no. 39, 220-228.
[11] V. K. Vernikos, R. Nelson, C. I. Goodier and P. C. Robery, Implementing an offsite construction strategy: A uk contracting organisation case study, Procs 29th Annual ARCOM Conference, Association of Researchers in Construction Management, 2013, pp. 667-677.
[12] J. Faludi, M. D. Lepech and G. Loisos, Using life cycle assessment methods to guide architectural decision-making for sustainable prefabricated modular buildings, Journal of Green Building 7 (2012), no. 3, 151-170.
[13] C. I. Goodier, S. Austin, R. Soetanto and A. R. J. Dainty, Causal mapping and scenario building with multiple organisations, Futures 42 (2010), no. 3, 219-229.
[14] X. Xue, Cognition and decision making in construction engineering management, 5th International Conference on computer sciences and convergence information technology (ICCIT), IEEE, 2010, pp. 748-750.
[15] R. E. Smith, Prefab architecture: A guide to modular design and construction, Wiley, New Jersey, 2011.
[16] M. N. M. Nawi, A. Lee and K. M. Nor, Barriers to implementation of the industrialized building system (ibs) in Malaysia, The Built & Human Environment Review 4 (2011).
[17] M. R. Abdullah and C. O. Egbu, "The role of knowledge management in improving the adoption and implementation practices of industrialized building system (ibs) in Malaysia," CIB World Conference 2010, vol. I, School of Built Environment, the University of Salford2010.
[18] T. A. Majid, M. N. A. Azman, S. A. S. Zakaria, S. S. Zaini, A. S. Yahya, M. S. S. Ahamad and M. H. Hanafi, Quantitative analysis on the level of ibs acceptance in the Malaysian construction industry, Journal of Engineering Science and Technology 6 (2011), no. 2, 179-190.
[19] M. Arif and C. Egbu, *Making a case for offsite construction in China*, Engineering, Construction and Architectural Management 17 (2010), no. 6, 536-548.

[20] J. S. Goulding, W. Nadim, P. Petridis and M. Alshawi, *Construction industry offsite production: A virtual reality interactive training environment prototype*, Advanced Engineering Informatics 26 (2012), no. 1, 103-116.

[21] S. Pryke and H. Smyth, *The management of complex projects: A relationship approach*, John Wiley & Sons, New Jersey, 2012.

[22] D. Langford and S. Male, *Strategic management in construction*, John Wiley & Sons, Oxford, 2008.

[23] S. Conards and A. Othman, *Industrialized building systems for low-cost housing projects investigating its feasibility in South Africa*, Lambert, South Africa, 2011.

[24] D. Richards, “So, which offsite system is right for you?” 2004, p. 23.

[25] S. L. Jackson, *Research methods, and statistics: A critical thinking approach*, Cengage Learning 2015.

[26] A. Bryman, *Research methods and organization studies*, Unwin Hyman, London, 1989.

[27] T. L. Saaty, *Decision making with the analytic hierarchy process* Int. J. Services Sciences 1 (2008), no. 1.

[28] C. Atkinson, A. Yates, and M. Wyatt, *Sustainability in the built environment: An introduction to its definition and measurement*, Watford: BRE 2009.

[29] H. D. a. A. P. HDAP, ”Ten years plan for housing development and administration,” Ministry of Urban Development, Housing and Construction, Addis Ababa, 2015, p. 56.

[30] I. Majzub, *System building hardware*, Wiley, New York, 1980.

[31] Y. H. Pan, ”Application of industrialized housing system in major cities in china: A case study of chongqing,” *Building and Real Estate*, vol. PhD, Hong Kong Polytechnic University, Hong Kong, 2007, p. 276.

[32] I. Zakari, A. Awal, R. Zakaria, A. H. Abdullah and M. Z. Hossain, *Application of industrialized building system: A case study in kano state, Nigeria*, Int. J. GEOMATE 13 (2017), no. 39, 80-86.

[33] k. Shimelis, ”The impact of alternative construction technology on condominium housing project: The case of Addis Ababa,” *Urban Management*, vol. MSc, Ethiopian Civil Service University, Addis Ababa, 2013.