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Evaluating intelligent residential communities using multi-strategic weighting method in China

Zhi-Ye Huang*

Department of Construction Management, School of Management Science and Engineering, Central University of Finance and Economics, Beijing 100081, China

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ABSTRACT

Many residential communities are claimed to be "intelligent", but their level of intelligence noticeably varies corresponding to the functionality and operational efficiency of the installed intelligent systems. This raises the need for having an effective and practicable method that would allow decision-makers to measure the degree of intelligence of one residential community against another. To achieve this objective, this paper elicits a general list of intelligence indicators of residential communities in China by means of system modeling as a base. Then, focusing in particular on the importance of these intelligence indicators' weights, this paper proposes a dynamic multi-strategic weighting method to facilitate the evaluation of intelligent residential communities. The analytic network process (ANP), entropy method and their combination are proposed as three weighting strategies to meet the need of evaluation at different stages of intelligent residential community's development in China. An experimental case study has been presented to demonstrate how to use the multi-strategic method to confront real-world design tasks. The research aims to provide a practical method to enable the evaluation of intelligent residential communities on more fair ground.

1. Introduction

Now intelligent systems are commonly used in residential communities in China, stimulated by the development of information technology and increasingly sophisticated demand for more comfortable and convenient living environment [1]. As a plethora of components and products have been introduced and made available in the intelligent building markets over the last 20 years, the adjective "intelligent" has been extensively applied to portray the smart properties of residential communities. Real estate developers of residential communities often claim their buildings are more intelligent than others of their kind, but these assertions tend to be vague and unjustified [2]. This raises the need for having an effective and practicable method that would allow regulators to measure the degree of intelligence of one residential community against another; it would also enable developers and design teams to reveal their community's intelligence superiority [3].

Evaluation of intelligent residential communities is highlighted by the high aggregation of the multi-criteria and multi-dimensional perspectives of building intelligence [4]. A balance between these perspectives needs to be struck to cater to the goals and expectations of the consumers [5]. In dealing with such complexities, the multi-criteria decision-making (MCDM) technique has been proposed as a solution to facilitate the evaluation of intelligent residential communities. The central decision problem examined by MCDM methods is how to evaluate and rank the performance of a finite set of alternatives in terms of a number of conflicting decision criteria [6]. MCDM aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process. Thus, most of the MCDM methods require that the criteria be assigned weights of importance. Determining these weights reasonably is always a challenging task [7].

Being a MCDM tool established by Satty, the analytic network process (ANP) has been noted to be helpful in prioritizing intelligent residential communities and justifying their values [2–4,8]. The ANP is one of the most comprehensive frameworks that are available today to a decision maker involving in the analysis of societal, governmental and corporate issues depending on experts' opinion. Its accuracy of prediction is impressive when applied to economic trends, sports and other events for which the outcome later became known [9–11]. In recent years, numerous applications of ANP have been published in the literature [12]. Hybrid ANP models were utilized to handle uncertain judgments in the ANP [13–15]. Yet, although inconsistency tests and pair-wise comparison have been utilized to increase its consistency, ANP still involves

* Correspondence to: Department of Construction Management, School of Management Science and Engineering, Central University of Finance and Economics, No. 39, Xue Yuan South Road, Haidian District, Beijing 100081, China.
Tel.: +86 10 8205 0687; fax: +86 10 8221 9178.
E-mail addresses: hzye110@aliyun.com, huang.zhiye@cufe.edu.cn

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a certain element of subjectiveness [16]. Therefore, the morals and ethics of the researcher implementing ANP play a significant part in the accuracy and fairness of MCDM's conclusions.

As a complement, researchers supporting the use of objective performance measures advocate the use of statistical methods to avoid intentional and unintentional supervisory biases involved in MCDM. Different from MCDM, statistical methods can be applied to assign weights to criteria in terms of correlation coefficients [7]. Statistical analysis always relies on an appropriate sample size to generalize the results for a larger population. A considerably large and valid sample allows a large degree of confidence in the statistical analysis results [17]. However, since the intelligent building industry in China is new and developing, detailed investigations are lacking and a large sample of reliable data for reference is not available [2].

This contradiction between the subjectiveness of ANP and the lack of reliable data for reference constitutes in a way the ultimate decision making paradox. This is the main reason why a multi-strategic weighting approach is needed in dealing with the evaluation of intelligent residential communities.

The methodology of this research was set out as follows. First, a review of existing intelligent building assessment methods was conducted to reveal the limitations and deficiencies of the current research. Then, in sight of Chinese culture, a general list of intelligent indicators was elicited through system modeling. Furthermore, a multi-strategic weighting method combing the ANP (subjective) and entropy method (objective) was proposed and analyzed to evaluate intelligent residential communities in China. Finally, an example was demonstrated to prioritize a set of intelligent residential communities based on the identified and weighted criteria by means of the combined approach.

2. Literature review

2.1. Existing building intelligence assessment methodologies used abroad

Since the development of intelligent buildings in the early 1980s, many researchers have tried to develop techniques for measuring the buildings' level of intelligence for the sake of comparison [18].

A plethora of research efforts have been placed on evaluating intelligent buildings [1]. The rating models of building intelligence have evolved from early intelligent building performance evaluation studies and refined them [19]. Examples of pioneer building intelligence rating methods include the Orbit2.1, post-occupancy evaluation, building-in-use assessment methods, BREEAM, and environmental impact analysis [2]. In addition to these earlier studies, a number of studies have been developed within the last 15 years. For example, building IQ; magnitude of systems integration and its revision; and the intelligent assessment index for buildings [3]. In recent years, sustainability has been increasingly embedded in the concept of intelligent building and accordingly the multi-attribute model for priority setting was used in the sustainability assessment of intelligent buildings [20]. Besides the works of these academics, a number of professional institutes (for example, AIIB, 2001, 2004; IBSK, 2002; CABA, 2004) have published their intelligent performance assessment tools and standards for intelligent buildings [2].

2.2. Existing residential community intelligence assessment methodologies used in China

Since the word "intelligent" was first used to describe residential communities in China at the beginning of the 1990s, substantial amount of research work has been devoted to comparing residential communities anywhere to determine the best, or most intelligent. To simplify the evaluation, many studies were focused on a single aspect of residential community's intelligence, such as the evaluation models developed by Yu et al. [21] and Shen et al. [22]. One of the essential evaluation systems is the "Function-based Rating Method" developed by Lin and adopted by Shanghai Construction Committee in 1999 [23]. The method relied on optimization of functional modules and constructed a four-level structure to realize the overall evaluation. Reviewing the updated literature shows that no original outcomes have been achieved in recent years, since most of researches are simply repetition of the past critical approaches.

Besides, the Ministry of Construction of China has attached great importance to the formulation of codes and standards of intelligent residential communities. Three construction standards have been issued: the Application of Digital Management of Buildings and Residential Areas; The Checking and Acceptance of Digital Technology Application System in Buildings and Residential Areas; and The Application of Digital Technology Application in Operation Services of Buildings and Residential Areas [24]. All the standards are more focused on technologies rather than users' requirements. Up to now, there has been no officially released assessment standard for intelligent residential communities.

2.3. Limitations of building intelligence assessment methodologies

In most cases, the authors and supporters of these methods have identified some weaknesses of the previous methods and then they proposed a new method claiming to be the best method. Yet, the tremendous conceptual complexities involved in these methods make them inapplicable in practice. Meanwhile, their calculation processes are not convincing enough to provide a reasonable assessment result [8]. In addition, depending on experts' opinion to assign weights to criteria in most of the assessment methods makes them prone to intentional or unintentional biases. More importantly, since an intelligent residential community is typical for China, the methods developed abroad cannot fit the culture of China.

3. Proposed multi-strategic weighting method for evaluating intelligent residential communities

3.1. Determination of suitable intelligence indicators

Basically, the intelligent systems installed in residential communities aim to meet occupiers' growing demand by providing efficient property management, energy conservation and ecological environment improvement. Characteristically, in China, the definition of intelligent residential communities was proposed explicitly in related governmental documents [24]: by means of modern information technology, network technology and information integration technology, precision design, optimization and integration, and elaborate construction are combined to elevate residential high-tech level and improve the living environment. Therefore, align with these relevant governmental documents, also in sight of the condition of China, the suitable intelligence indicators used for residential community evaluation are elicited with system modeling.

3.1.1. Propose system structure models for establishing a general list of intelligence indicators

System modeling is an efficient tool for tackling real-world problematic situations. It provides a framework for users to deal with the kind of messy situations that lack a formal problem definition.