Semicustomized Design Framework of Container Accommodation for Migrant Construction Workers

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Abstract: Millions of migrant construction workers (MCWs) worldwide make significant economic contributions to their host countries or regions but often suffer poor housing conditions. It is therefore important to explore new ways to improve housing conditions for MCWs. Based on the concept of sustainable design, the authors propose a semicustomized design framework of container accommodation through improvements to the job process of a classical value engineering process in three aspects. First, a method of design scheme innovation based on Maslow's hierarchy of needs is developed; second, two types of decision makers are integrated in different stages of the design process to satisfy the diversified housing needs of MCWs from social and psychological perspectives; and third, to better measure the housing satisfaction of MCWs, the authors developed an evaluation method of quantifying worker housing satisfaction with different design schemes using the analytic hierarchy process (AHP) method, including an evaluation indicator system with MCW psychological factors. This framework can be used to determine the supply of container accommodation and prices that best fit the needs of MCWs by optimizing the function and cost of design schemes. To demonstrate the feasibility of the framework, a case study is conducted. In addition, the limitations of the framework are discussed. **DOI: 10.1061/(ASCE)CO.1943-7862.0001624.**

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Introduction

According to International Labor Organization statistics, there were 243.7 million international migrants worldwide in 2015 (ILO 2016). In addition, Brazil, China, India, and other developing countries also have a large number of domestic migrants who contribute to the development of their own countries (Arnal and Förster 2010; NBSC 2016; Loganathan and Kalidindi 2016; Fornalé 2017). About 19% of the total number of illegal immigrants, i.e., approximately 11 million people, work in the construction industry in the United States (Golden and Skibniewski 2009, 2010). Many migrants who work in the construction industry are subjected to unjust conditions. An increasing number of experts, relevant organizations, and government departments are focusing on this global social challenge (Hare et al. 2013; Ling et al. 2013; Helbling and Kriesi 2014; Nguyen et al. 2015). In addition to many social welfare concerns, adequate housing, sleep, and privacy are not only basic human rights but also affect efficiency and safety at work and the physical and mental health of migrant construction workers (MCWs) (Powell and Copping 2010).

According to news reports from the British Broadcasting Corporation (BBC) on migrant workers in Singapore (Glennie 2015) and Dubai (Fottrell 2015), studies in China (Shi 2008; Swider 2015), and reports from various countries (Searle et al. 2015; Andrieu et al. 2016) and international organizations (Buckley et al. 2016), the construction industry has a more severe housing-rights problem than other industries (Park et al. 2015). The lack of high-skilled workers caused by poor working and housing conditions has become a worldwide problem in the construction industry (Menches and Abraham 2007; Han et al. 2008; Hare et al. 2013; Chan et al. 2016). Regionally, nationally, and globally, strong efforts are needed to improve the social status of MCWs.

Current policies are inadequate for improving the housing conditions of MCWs. Many countries that have a large number of MCWs either lack laws or regulations on the standard of housing for MCWs or have poor law enforcement. In China, for example, the central government has jointly issued the *Guidance on Improving the Housing Conditions of Migrant Workers* but has not provided functional standards (MOHURD of PRC, NDRC of PRC, MOF of PRC, MOHRSS of PRC, and MOLR of PRC 2007). While local governments have set their own standards, there are obvious inconsistencies among them (Shanghai Municipal Government 2009; Beijing Municipal Government 2015). Furthermore, because of poor enforcement, these regulations have not been effectively implemented, such as male and female MCWs sharing accommodation (Zhu 2016), which also calls for the guarantee of basic housing rights for female workers in China and worldwide.

In addition to enforcing more effective regulations, it is important to focus on the needs of MCWs and rely on new technologies and economic means to solve their problems, promote their social development, and protect their rights and interests. Because MCWs differ individually in terms of age, marital status, and economic

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status, interventions that aim at solving individual housing needs must take these differences into account. It is important to consider both the physical (including physiological) and psychological satisfaction of workers and the economic affordability of housing options. Affordability plays a mediating role between housing expenses and psychological satisfaction (Rahman et al. 2015; Kim and Lee 2018), but the relationship between the two is very difficult to measure because of the psychological differences among MCWs. Hence, it is important to develop a set of scientific methods for designing and selecting accommodation on the basis of different housing preferences and economic conditions of MCWs.

Objectives and Rationale

To improve the poor housing conditions of MCWs, the authors proposed a semicustomized design framework for the design and selection of housing for MCWs based on the integration of Maslow's hierarchy of needs (McLeod 2007) and value engineering (VE) theory. The value engineering methodology (Standard 2007) is basically a structured, organized, disciplined procedure aimed at improving the value of design schemes (Omigbodun 2001; Cheah and Ting 2005; Mahadik 2015). Value engineering applications, especially in the construction industry, have grown significantly (Rwelamila and Savile 1994; Lin and Shen 2007; Chen et al. 2010; Kissi et al. 2017). In the literature of engineering design, value engineering has been used to improve value propositions by seeking the lowest cost (Fulford and Standing 2014), and the goal of value engineering is to find the best among many options (Kissi et al. 2017). Furthermore, a housing satisfaction evaluation system used to measure the function of different design schemes and calculate function coefficients is proposed to evaluate different semicustomized design schemes based on affordability.

Considering container accommodation a highly effective, economical, and environmentally friendly option for providing temporary housing on job sites, the authors chose container buildings as an innovative option to meet the individual needs of different MCWs. Container buildings (including container accommodation) use steel intermodal containers as structural elements [Giriunas et al. 2012; J. Downey, R. Kennedy, and B. Gaffney, "Intermodal container building structures and methods," US Patent No. 20,160,130,795 (2016)]. Container buildings have the advantages of modular construction, low cost, and rapid constructability, as well as sustainable features such as environmental friendliness and energy conservation (Wang et al. 2012; Oloto and Adebayo 2015; Islam et al. 2016). Container buildings also provide a good method to deal with waste and surplus containers (Zhou and Xie 2014). As a typical example of sustainable design practices (McLennan 2004), container buildings have been used in many settings, such as residential real estate, retail stores, hospitals, schools, barracks, and hotels (Crowley and Levinson 2008; Abrasheva et al. 2012; Giriunas et al. 2012; Ham and Luther 2014; Alemdağ and Aydin 2015; Martinez-Garcia 2016). Container accommodation has already been widely used in various types of construction projects, so its feasibility is well established. However, research relating to applications of container accommodation remains inadequate (Wang et al. 2016), in particular providing cost-effective accommodation on a job site. Current housing options emphasize meeting the most basic needs of construction workers and ignore the potential of container accommodation for meeting residents' preferences for better quality of housing spaces such as the protection of privacy, gender equality, and psychological satisfaction.

The paper is organized as follows. The section "*Design Procedure of Sustainable Container Accommodation*" introduces the design procedure of sustainable container accommodation. The section "*Housing Satisfaction Evaluation and the Calculation of Value Coefficients*" explains the principle of housing satisfaction evaluation and the process of calculating the value coefficient. A case study involving construction workers on a real estate project is detailed in the section "*Case Study*." The section "*Discussions*" discusses the limitations of the application of the framework and challenges that should be considered in the application of the framework. Finally, the section "*Conclusions*" offers general conclusions and insights.

Design Procedure of Sustainable Container Accommodation

The authors first discuss the overall value engineering process of semicustomized design. Then key elements of the framework (Fig. 1), *principle of design scheme innovation* on the basis of a function analysis to the evaluation phase and *value calculation and comparative analysis* are explained. Other key elements, *housing satisfaction evaluation and the calculation of value coefficients*, are explained in the section "Housing Satisfaction Evaluation and the Calculation of Value Coefficients."

Overall Value Engineering Process of Semicustomized Design

Before implementing a semicustomized design process using the value engineering methodology (Standard 2007), a job plan based on the general value engineering process must be developed according to the goal of a job. A good job plan will help decision makers to identify new ideas and develop them into alternatives to preliminary and final accommodation schemes. An overall value engineering process of semicustomized design is shown in Fig. 1, which illustrates the job plan process of a semicustomized design (thick solid line). Compared with conventional value engineering, there are three new elements in the framework. First, a method for creating innovative design schemes based on Maslow's hierarchy of needs is incorporated into the framework covering phases from the function analysis phase to the evaluation phase (Fig. 1). The method focuses on the potential of container accommodation for meeting residents' preferences, such as the protection of privacy, gender equality, and psychological satisfaction. Second, two types of decision makers are involved separately at different stages, i.e., governments, contractors, or suppliers of container accommodation in Stages 1 and 2 and MCWs as the final decision maker for the choice of design scheme in Stage 3. Third, a housing satisfaction evaluation system used to measure the function of different design schemes is also proposed to evaluate different semicustomized design schemes in Stages 1 and 2.

A semicustomized design process for choosing temporary housing for MCWs includes three assumptions. First, employers or contractors provide a reasonable number of design schemes on the basis of sustainable technologies and costs. Second, workers will pay more for improved housing conditions that meet their personal housing needs, and employers will cover partial housing costs as part of their operating expenses. Third, workers may freely choose a housing scheme according to their housing preferences, and employers or contractors finish the overall layout and construction in accordance with these choices. Design schemes, after design decisions are made, cannot be changed freely by residents (MCWs), but residents can choose freely among a set of schemes. Therefore, the process is referred to as a semicustomized design. Because MCWs differ in ways that affect their housing needs, the premise of the theoretical framework discussed here is that MCWs choose their

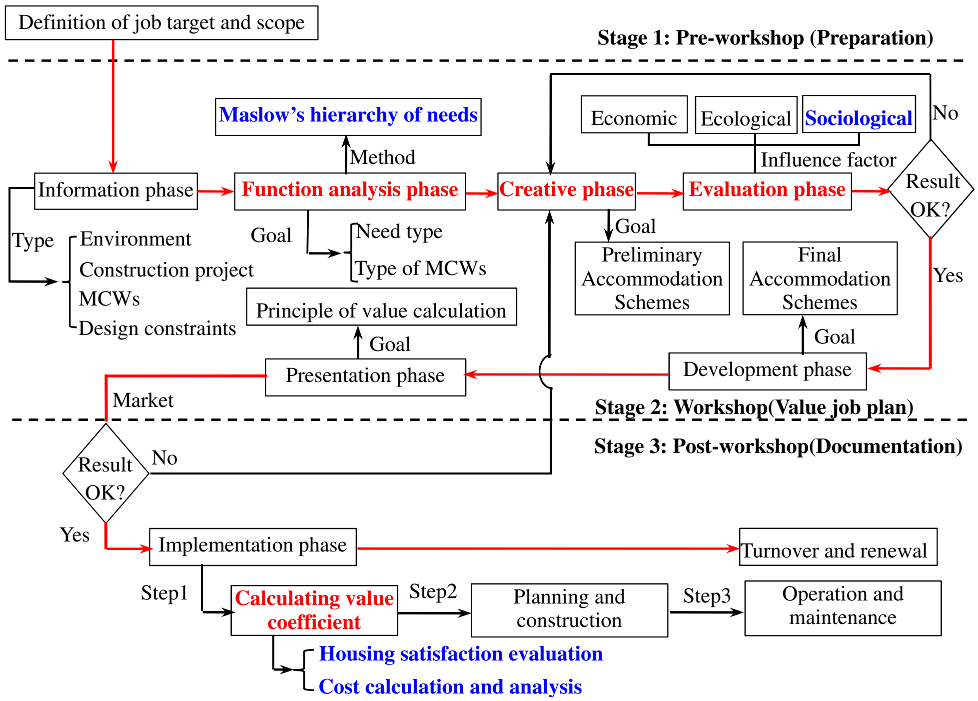

Fig. 1. Overall value engineering process of semicustomized design.

temporary housing options based on their own conditions and needs. The goal of this study is to offer a method that allows workers to choose the best accommodation within a certain range that considers cost or affordability factors for different workers.

Principle of Design Scheme Innovation for Sustainable Container Accommodation

The degree of satisfaction on various housing needs of individuals is dependent on the configuration and layout of internal facilities and amenities for accommodation. The standardized size and structural strength of recycled containers further develop the concept of sustainable design. The size of containers sets the space restriction for designing container accommodation. The function and psychological preferences of residents influence design schemes. Space size and cost also restrict the quantity and size of internal facilities and amenities that meet the function and psychological preferences of residents. To cover all kinds of housing needs of residents and meet space and cost constraints, a phased design principle from the *function analysis phase* to the *evaluation phase* (Fig. 1) to create alternative schemes is further developed based on Maslow's hierarchy of needs (McLeod 2007). Details are discussed in what follows and illustrated in Fig. 2.

The increase in the level of needs in Maslow's hierarchy (Step 1, Fig. 2) represents the accumulation of functional needs, i.e., the realization of an upper-level need is based on the satisfaction of the lower-level needs. A MCW with a higher-level need will require more housing functions. Further, the functional classification of

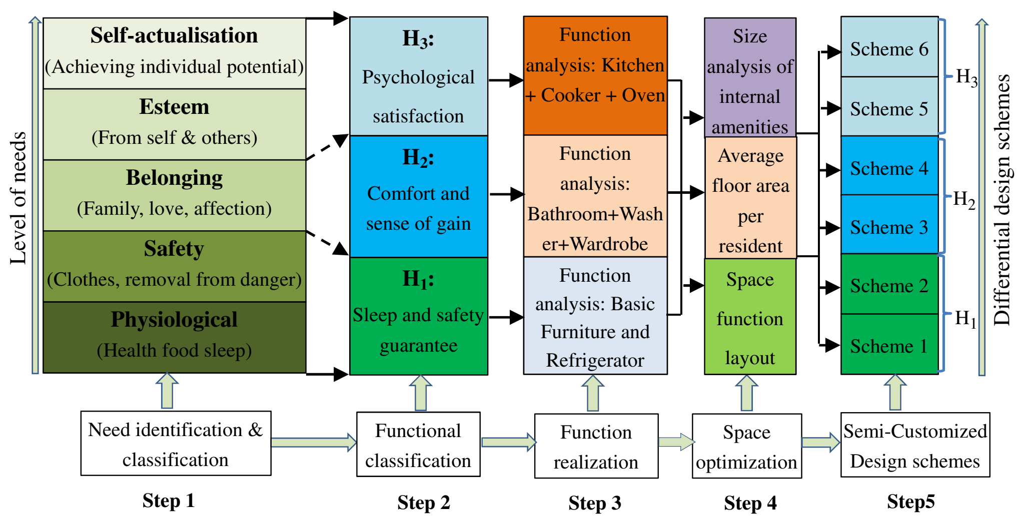

Fig. 2. Process of design scheme innovation based on Maslow's hierarchy of needs.

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design schemes is defined by three continuous intervals, H_1, H_2, and H_3. The three intervals represent the segmentations of schemes in Step 2, functional classification (Fig. 2). Certainly, decision makers can classify different needs according to Maslow's hierarchy of needs (McLeod 2007). Functional classification simplifies the categorization of workers' psychological needs and defines the types of customers (MCWs). Each psychological need level (H_1, H_2, and H_3) corresponds to a specific functional realization. Step 3 shows that function realization depends on the quantity and quality of appliances and furniture. Due to the size constraint of containers, spatial layout must be optimized according to the size of appliances and furniture. The size of appliances and furniture, average floor area per resident, and space function layout indirectly impact the function realization, and the overall space optimization must be strictly enforced in Step 4 (Fig. 2) to improve the efficiency of space utilization. From Steps 2 to 4 (Fig. 2), it represents a continuous process from internal psychological need recognition to external need perception through design innovation, and it is also a process from implicit to explicit (Hall and Nougaim 1968; Alderfer 1969). In Step 5 (Fig. 2), a series of semicustomized design schemes are generalized corresponding to functional categories.

After design schemes are developed, a housing satisfaction evaluation of housing units and calculations of value coefficients will be conducted to identify the number of housing structure units.

Value Calculation and Comparative Analysis of Different Schemes

According to value engineering principles, a scheme with the maximum value coefficient is the optimal scheme for decision makers. By considering housing preferences and costs, the value of housing schemes for different workers is defined using a value engineering concept (Standard 2007) as follows:

$$v_n = f_n / c_n \tag{1}$$

where n = index number of a design scheme; v_n = value coefficient of scheme n; c_n = cost coefficient of scheme n; and f_n = function coefficient of scheme n. The variables c_n and f_n (Li and Zheng 2010; Aminzadeha et al. 2011) can be defined according to the equations

$$c_n = C_n \Big/ \sum_{n=1}^{N} C_n, \quad n = 1, 2, \ldots, N \tag{2}$$

and

$$f_n = F_n \Big/ \sum_{n=1}^{N} F_n, \quad n = 1, 2, \ldots, N \tag{3}$$

where N = total number of schemes; C_n = construction cost of scheme n; and F_n = function score of scheme n.

According to the analytic hierarchy process (AHP) (Satty 1980; Li et al. 2016), the variable F_n can be defined according to the following equation:

$$F_n = \sum_{i=1}^{I} \left(w_{a_i} \times \sum_{j=1}^{J} (w_{a_{ij}} \times s_{a_{ij}}^n) \right), \quad i = 1, 2, \ldots, I; \quad j = 1, 2, \ldots, J; \quad n = 1, 2, \ldots, N \tag{4}$$

where a_i = a subfunction of F_n; w_{a_i} = weighting of a subfunction; a_{ij} = specific criterion of a_i; $w_{a_{ij}}$ = weighting of a specific criterion; $s_{a_{ij}}^n$ = score assigned to a specific criterion in accordance with housing preference of workers; i = index number of a subfunction; I = total number of subfunctions; j = index number of a specific criterion; and J = total number of criteria.

Schemes with the highest value coefficients as calculated by Eq. (1) are provided to each worker for function and cost evaluation. The variable F_n reflects the housing preference of workers and can be decomposed into different subfunctions, each of which is composed of multiple criteria. In Eq. (4), w_{a_i} and $w_{a_{ij}}$ reflect a worker's housing preferences for different subfunctions and criteria, whereas $s_{a_{ij}}^n$ represents the degree of a worker's housing satisfaction that corresponds to a specific criterion.

Furthermore, the original accommodation provided by employers is treated as a baseline and defined as Scheme 0, so that F_0 is the function score of scheme 0, C_0 is the cost of Scheme 0 that employers cover for their workers, and v_0 [Eq. (5)] is the value coefficient of Scheme 0. To reflect the differences among schemes, the equivalent utility value of different target design schemes is compared with the value of the original accommodation Scheme 0 by adjusting the construction cost of each scheme and calculating x_n using Eq. (5) as follows:

$$v_0 = \frac{F_0 / \sum_{n=0}^{N} F_n}{C_0 / \sum_{n=0}^{N} C_n} = \frac{f_0}{C_0 / \sum_{n=0}^{N} C_n} = \frac{f_n}{C_n + x_n / \sum_{n=0}^{N} C_n} \tag{5}$$

where x_n = adjustment cost of equivalent utility value corresponding to change in function score between Scheme 0 and scheme n, which can be further derived according to Eq. (5) as follows:

$$x_n = (f_n \times C_0 - f_0 \times C_n)/f_0 \tag{6}$$

In Eq. (6), a value of $x_n > 0$ indicates that scheme n is better than Scheme 0, and the higher the value of x_n is, the better is scheme n. The variable x_n represents the increase in cost of shifting from Scheme 0 to scheme n and also indicates the potential earnings of a company that provides the container accommodation or the rent that a contractor could collect. A value of $x_n < 0$ means that the value of scheme n is not as high as that of the original Scheme 0, and thus residents should not choose scheme n. Although a new scheme may improve housing conditions and enhance housing satisfaction, an increase in housing costs may lead to a decrease in overall value for residents. In this situation, x_n can be used as a reference for determining corporate or government subsidies as representing the cost of improving the housing quality from the perspective of social welfare.

According to the evaluation results of all MCWs for a set of schemes, the frequency of a specific scheme with the maximum value coefficient is the number of actual needs of the scheme. The sum of frequency of all schemes with the maximum value coefficient corresponds to the total number of MCWs. Therefore, according to the number of MCWs to be accommodated in a container, the total number of containers can be calculated. A more detailed explanation to aggregate MCWs' responses is shown in the "Case Study" section.

Housing Satisfaction Evaluation and the Calculation of Value Coefficients

Sustainable Design Schemes and Value Calculation Principles

Sustainable design is "the philosophy of design of physical objects, construction environments, and services by complying with the principles of social, economic, and ecological sustainability" (McLennan 2004). In comparison with other forms of building construction, container buildings are recognized as a form of sustainable buildings because the construction, maintenance, and disposal of container buildings consume fewer nonrenewable resources, minimize waste, and create healthy and productive environments (Abrasheva et al. 2012; Giriunas et al. 2012; Islam et al. 2016). For the specific type of container buildings described in this paper, economic and ecological sustainability can be quantified using life cycle assessment (Alemdağ and Aydin 2015; Islam et al. 2016). However, the social sustainability of container accommodation may be affected by the evaluators' attitudes and biases. The semicustomized design approach presented in this paper can avoid this problem by allowing residents (i.e., MCWs) to choose freely among available housing schemes on the basis of their individual housing or functional preferences. Here, housing preferences of residents define and determine the value of housing schemes.

Because every scheme has a different life cycle cost and everyone has a unique housing preference and the ability and willingness to pay, Eqs. (1) and (4) are developed to reflect value engineering principles and balance rigid economic cost and sustainability constraints with the flexibility of allowing residents to choose. The value coefficient calculated by Eq. (1) represents the standard for decision-making, i.e., the scheme with the maximum value coefficient will be the best for decision makers (i.e., MCWs).

Housing satisfaction is the most important factor, but it is difficult to calculate because it is qualitative. To reduce subjectivity and randomness in evaluation and correctly reflect the housing preferences of residents, an appropriate method for evaluating housing satisfaction is necessary. A framework that includes design procedure and housing satisfaction evaluation used to assess the design schemes of container accommodation for MCWs is shown in Fig. 3.

The upper portion of Fig. 3 shows the principle of scheme evaluation based on value engineering that comprises two parts to determine the housing value. The first part consists of an indicator system on housing satisfaction evaluation. The other part comprises the structure composition of the added cost of new schemes. The lower portion of Fig. 3 shows the principle of generating housing schemes corresponding to segmentation (H_1, H_2, and H_3) in Fig. 2. In Fig. 3, H_1, H_2, and H_3 represent the continuous segmentation of schemes by functional categories, such as economic, comfort, distinction, and so on; in addition, a series of design schemes from S^1 to S^{12} are differentiated according to the configuration and layout of internal facilities and amenities, which are the results of the phased process of sustainable design described in Figs. 1 and 2. The evaluation of housing satisfaction and the calculation of the added cost will be explained in the following sections of this paper.

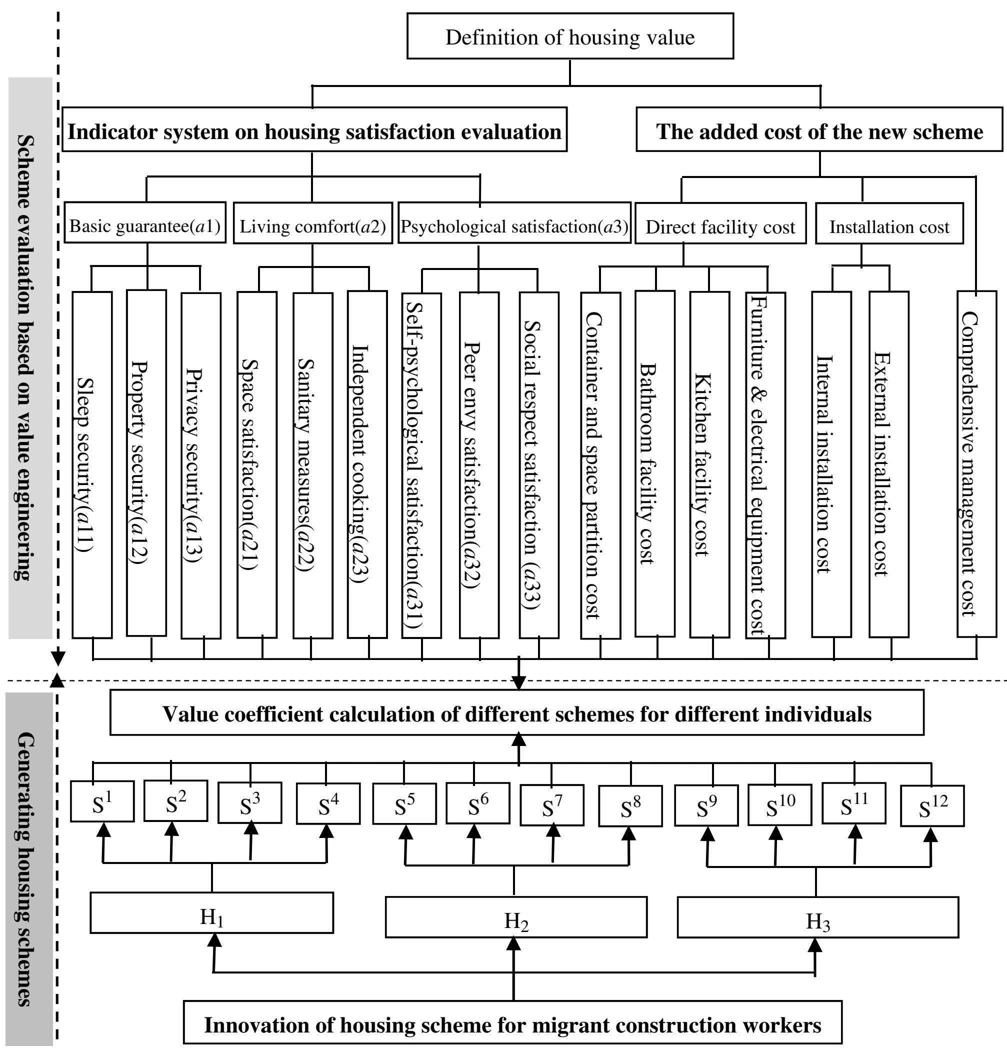

Fig. 3. Framework on evaluating design schemes of container accommodation based on value engineering.

Housing Satisfaction Evaluation Method Based on Analytic Hierarchy Process (AHP)

Indicators for Housing Satisfaction Evaluation

It is important to identify the complex needs of residents, as well as their preferences based on different criteria. The establishment of an evaluation indicator system should therefore not only take into account the needs of various groups of residents but also be as explicit as possible via hierarchical decomposition of different preferences. For this reason, Maslow's hierarchy of needs (McLeod 2007) is used to establish an indicator system that describes housing needs. For the purpose of comparison with the baseline condition, the housing satisfaction (Mohit et al. 2010; Ahn and Lee 2016; Nguyen et al. 2018) that is reflected by function scores with different housing conditions of migrant workers can be divided into three subfunctions, namely, basic guarantee, living comfort, and psychological satisfaction (Fig. 3) according to the analytical hierarchy process (Lai 2011). The basic guarantee ($a1$) is defined as the human right to adequate housing. The basic guarantee can be divided into three specific criteria: sleep security ($a11$) (which requires soundproof design and good ventilation during the hours of sleep), property security ($a12$) (which requires the prevention of theft and fire), and privacy security ($a13$) (for conjugal relations, bodily exposure, and personal habits). Such housing satisfaction is related to the first and second levels of Maslow's hierarchy of needs (Fig. 2). From a practical point of view, many construction projects worldwide have only met the sleep security criterion.

Although the basic guarantee such as sleep and safety is the foundation of living comfort ($a2$), living comfort (Pekkonen and Haverinen-Shaughnessy 2015; Adekunle and Nikolopoulou 2016; Shin 2016) includes more needs than the basic guarantee. Compared to the comfort of illumination (Nasrollahi and Shokri 2016), temperature (Rijal et al. 2015), and humidity [W. J. Ford, and T. C. Dula III, "Portable misting system with combined air/water nozzle assembly," US Patent No. 20,180,093,283 (2018)], living comfort in this paper pays more attention to trade-offs between increases in functional needs and reductions in activity space caused by space constraints of container accommodation. Living comfort in this paper is redefined in terms of the temporary and economic characteristics of container accommodation and can be divided into three specific criteria: space satisfaction ($a21$, namely, physical or physiological satisfaction), sanitary measures ($a22$), and independent cooking ($a23$). The order of $a21$, $a22$, and $a23$ represents a continuous improvement in living comfort according to the principle of Maslow's hierarchy of needs, but the cost also becomes progressively higher.

Furthermore, according to Maslow's hierarchy of needs, residents will seek social and psychological satisfaction ($a3$) only after the aforementioned subfunctions ($a1$ and $a2$) have been satisfied (Chen et al. 2015; Scannell and Gifford 2016). There are three subcategories. Self-psychological satisfaction ($a31$) reflects whether residents are satisfied with their current housing conditions with respect to their own past situation or expectations; peer envy satisfaction ($a32$) refers to whether residents are satisfied with their current housing conditions when compared with those of their peers at a construction site; and social respect satisfaction ($a33$) reflects whether residents are satisfied with their current housing conditions when compared with friends and relatives of similar social status. Psychological satisfaction varies from individual to individual and is closely related to the first two levels of housing satisfaction: basic guarantee and living comfort. Psychological satisfaction corresponds to the fourth and fifth levels of Maslow's hierarchy of needs. The system of structural indicators used for the housing satisfaction evaluation is also shown in Fig. 3.

Determining the Weight of Criteria and Calculating Scores of Housing Satisfaction

Because housing satisfaction is subjective, the authors proposed to use analytic hierarchy process (Satty 1980) to quantify housing satisfaction relating to different design schemes. Since AHP has been extensively discussed (e.g., Zayed et al. 2008; Li et al. 2016), this paper will not repeat its details. Rather, the focus is on determining the weight of criteria and measuring differences between schemes to be evaluated using AHP. Because different MCWs have their own preferences, the weight of each criterion is calculated for each individual worker. Measuring differences between schemes involves scoring different schemes in accordance with evaluation criteria for housing satisfaction. This scoring process reflects the feeling and willingness of a resident toward different schemes based on specific criteria. The function coefficient and function score are calculated using Eqs. (3) and (4).

The following example illustrates the calculation process. The first step comprises the construction of a judgment matrix for different subfunctions (a_i) and criteria (a_{ij}) according to the comparison of pairs of scores on a scale of 1–9 based on the results of a questionnaire collected from one MCW:

$$\begin{array}{cc} & \begin{array}{ccc} \boldsymbol{a1} & \boldsymbol{a2} & \boldsymbol{a3} \end{array} \\ \boldsymbol{M_A} = \begin{array}{c} \boldsymbol{a1} \\ \boldsymbol{a2} \\ \boldsymbol{a3} \end{array} & \left| \begin{array}{ccc} 1 & 1/3 & 2 \\ 3 & 1 & 5 \\ 1/5 & 1/2 & 1 \end{array} \right| \end{array} \tag{7}$$

$$\begin{array}{cc} & \begin{array}{ccc} \boldsymbol{a11} & \boldsymbol{a12} & \boldsymbol{a13} \end{array} \\ \boldsymbol{M_{a1}} = \begin{array}{c} \boldsymbol{a11} \\ \boldsymbol{a12} \\ \boldsymbol{a13} \end{array} & \left| \begin{array}{ccc} 1 & 5 & 1/3 \\ 1/5 & 1 & 1/7 \\ 3 & 7 & 1 \end{array} \right| \end{array} \tag{8}$$

$$\begin{array}{cc} & \begin{array}{ccc} \boldsymbol{a21} & \boldsymbol{a22} & \boldsymbol{a23} \end{array} \\ \boldsymbol{M_{a2}} = \begin{array}{c} \boldsymbol{a21} \\ \boldsymbol{a22} \\ \boldsymbol{a23} \end{array} & \left| \begin{array}{ccc} 1 & 1/5 & 3 \\ 5 & 1 & 1/9 \\ 1/3 & 9 & 1 \end{array} \right| \end{array} \tag{9}$$

$$\begin{array}{cc} & \begin{array}{ccc} \boldsymbol{a31} & \boldsymbol{a32} & \boldsymbol{a33} \end{array} \\ \boldsymbol{M_{a3}} = \begin{array}{c} \boldsymbol{a31} \\ \boldsymbol{a31} \\ \boldsymbol{a33} \end{array} & \left| \begin{array}{ccc} 1 & 1/3 & 2 \\ 3 & 1 & 5 \\ 1/5 & 1/2 & 1 \end{array} \right| \end{array} \tag{10}$$

Here, the matrix M_A represents a worker's comparison matrix for the three subfunctions, namely, basic guarantee ($a1$), living comfort ($a2$), and psychological satisfaction ($a3$). The other judgment matrices (M_{a1}, M_{a2}, and M_{a3}) relate to each criterion that corresponds to the three subfunctions. According to the judgment matrix and AHP, the characteristic vector of the largest eigenvalue of each judgment matrix is regarded as the weight of the subfunctions and criteria. The final score of a scheme is calculated by combining the weight and the score assigned to specific criteria by residents according to Eq. (4). After calculating the largest characteristic eigenvalue, the rationality of the judgment matrix is tested to ensure the validity of the questionnaire results. The relevant characteristic vectors, the maximum eigenvalues, and the results of the consistency test are shown in Table 1.

According to the results presented in Table 1, the weight of each criterion with respect to the value coefficient of each scheme can be calculated for each respondent. The preference weights reflect the order of importance of the different criteria and thus help the respondents (MCWs) to make decisions according to their own needs. Furthermore, the scores for all schemes are calculated using the evaluation scores for different evaluation criteria on a scale of

Table 1. Characteristic vectors and results of consistency test

Judgment matrix	Characteristic vector weighting			Maximum eigenvalue	Consistency test indicators		
					CI	RI	CR
M_A	w_{a1} 0.23	w_{a2} 0.65	w_{a3} 0.12	3.004	0.002	0.58	0.003
M_{a1}	w_{a11} 0.28	w_{a12} 0.07	w_{a13} 0.65	3.06	0.03	0.58	0.06
M_{a2}	w_{a21} 0.18	w_{a22} 0.75	w_{a23} 0.07	3.03	0.015	0.58	0.03
M_{a3}	w_{a31} 0.16	w_{a32} 0.59	w_{a33} 0.26	3.05	0.025	0.58	0.05

Note: The consistency ratio (CR) is a comparison between the consistency index (CI) and the random consistency index (RI).

1–10 for each scheme. Table 2 shows the comprehensive scores and function coefficients of six sample schemes for a specific questionnaire from a selected worker.

Table 2 shows that three criteria that the worker in this example cares about most are sanitation, the protection of privacy, and a large living space. The scores of the six housing schemes show that the worker thinks that Scheme 4 best meets the worker's individual needs. Schemes 3 and 6 have scores similar to that of Scheme 4, but the higher score of Scheme 4 does not necessarily mean that it must be the best choice, because accommodation costs are also an important factor for the calculation of the value coefficient. The results shown in Table 2 are only derived from one worker's questionnaire, and these results only reflect housing satisfaction with the six schemes in terms of one specific worker's opinion. In fact, each worker's preferences may be different. Therefore, all workers complete a questionnaire independently to determine the required quantity of different types of housing units.

Cost Analysis and Calculation of Cost Coefficient

The construction of container accommodation with more functions will add to the construction cost. Therefore, in addition to the housing satisfaction score, the added cost of a new scheme and workers' ability to afford the additional cost are considered to determine the value coefficient.

To calculate the construction costs, the added cost of the new scheme is divided into three parts, as seen in Fig. 3. The first part comprises the direct facility cost, mainly the costs of the container and space partition cost, bathroom facility cost, kitchen facility cost, and furniture and electrical equipment cost. The second part consists of the installation costs, which are divided into internal and external installation costs. Internal installation costs refer to the installation of internal container facilities, including the installation of internal kitchens, bathrooms, and indoor wiring. External installation costs mainly refer to the costs of installing external air conditioning, pipes for cold and hot water systems, stairs, and so forth. The third part of the added costs comprises comprehensive management costs, including the salaries of the management staff and so on. In addition, to make utilities available, it is also necessary to pay for the construction of necessary utilities, the installation of insulation materials, and leakage prevention materials.

According to value engineering theory, the cost coefficients can be calculated according to the planned costs of different schemes and Eq. (2). The calculation process of the cost coefficient is explained in detail in the following section.

Case Study

To demonstrate the feasibility of the method presented in this paper, a container home sales business and a real estate project were selected as a case study. Cost engineers were invited to calculate the construction costs of container accommodation design schemes, and MCWs in the real estate project were involved as decision makers for providing housing satisfaction evaluations. The process was divided into three steps. First, a set of design schemes for container accommodation was proposed according to the aforementioned principles. Second, the construction workers from the real estate project were asked to complete a questionnaire to evaluate and score the design schemes. Finally, the results of Steps 1 and 2 were analyzed.

Alternative Design Schemes and Calculation of Cost Coefficient

Alternative Design Schemes Based on Different Housing Preferences

In this case, a baseline design scheme of standard containers (6.1 m or 20 ft) was used. This is a typical container whose layout design is consistent with that of other large containers following the same modular format, such as the design of a 12.2 m (40 ft) container. Six modular design schemes that fit the construction site were proposed to better satisfy workers' needs based on the design principle of design scheme innovation in Fig. 2. Fig. 4 illustrates the six different schemes.

Table 2. Criterion weightings and calculation of function coefficients from one questionnaire

Criterion	Weighting	Scheme 1	Scheme 2	Scheme 3	Scheme 4	Scheme 5	Scheme 6
Sleep security (a_{11})	0.064	7	7	6	9	9	6
Property security (a_{12})	0.017	7	7	7	8	8	7
Privacy security (a_{13})	0.149	3	7	3	7	7	3
Space satisfaction (a_{21})	0.116	5	3	7	3	3	6
Sanitary measures (a_{22})	0.487	0	0	9	9	6	9
Independent cooking (a_{23})	0.046	0	0	0	0	5	5
Self-psychological satisfaction (a_{31})	0.019	6	7	8	8	10	9
Peer envy satisfaction (a_{32})	0.072	3	5	6	8	9	7
Social respect satisfaction (a_{33})	0.030	5	5	7	7	8	8
Total function score		2.07	2.6	6.94	7.43	6.34	7.18
Function coefficient		0.06	0.08	0.21	0.23	0.19	0.22

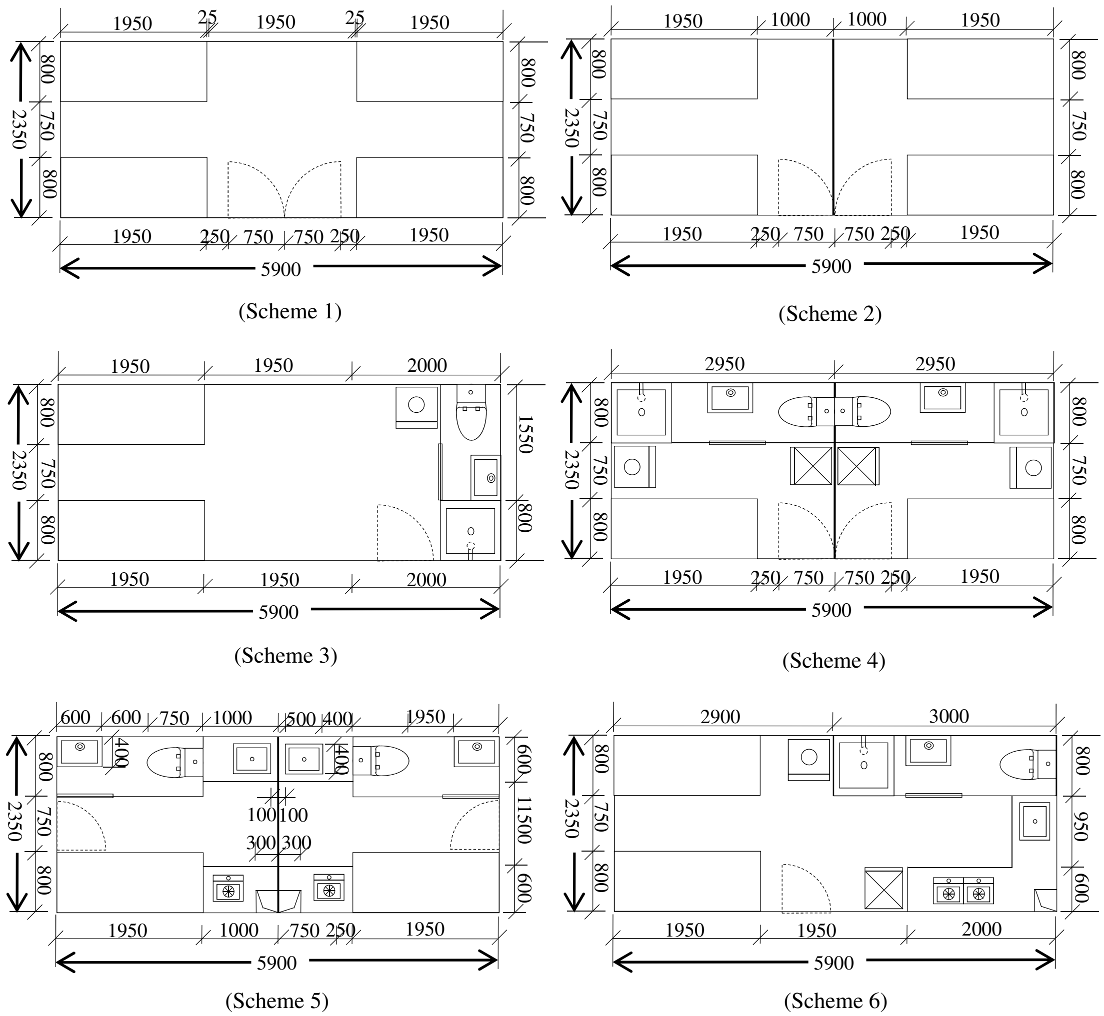

Fig. 4. Evaluated schemes for temporary container housing. Dimensions are given in millimeters.

To compare the function classification of the schemes, i.e., H_1, H_2, and H_3, all six schemes were designed to accommodate four people with reference to local standards in China. Accommodation Scheme 1 in Fig. 4 is simple and most similar to the current accommodation condition of MCWs in China or other countries (Wang et al. 2016). According to field investigations, a standard 6.1 m container can provide accommodation for 4 to 10 people. Scheme 2 in Fig. 4 is another scheme that can improve the privacy of residents but reduces the public space. Scheme 2 reflects a personalized need change corresponding to Scheme 1 in segmentation H_1. It is more suitable for groups of workers, such as friends, father and son, or husband and wife. Schemes 3 and 4 in segmentation H_2 (Fig. 4) have a bathroom. Their advantage is the provision of an indoor shower, but the public space is further diminished. Scheme 3 in Fig. 4 is a scheme where residents need to sleep in a bunk to ensure enough space for them to be able to walk around in the room. In Scheme 4, the protection of privacy is increased, but the space is smaller than in Scheme 3. Schemes 5 and 6 in segmentation H_3 (Fig. 4) extend Schemes 3 and 4 by providing opportunities for cooking. By abandoning the use of a shower, Scheme 5 provides better protection of privacy. Each scheme has advantages and disadvantages and provides a different balance between function, space, and cost. For Schemes 1 and 2, the space is larger and the cost is lower, but the lack of a kitchen and bathroom reduces convenience and living comfort. Schemes 5 and 6 integrate several domestic functions, such as a kitchen and a bathroom, and provide the most functions among all the schemes but sacrifice a large amount of public space and have higher costs. With fewer functions and lower costs, Schemes 3 and 4 represent intermediate choices between Schemes 1 and 2 and Schemes 5 and 6.

Estimation of Construction Costs and Turnover Analysis

The actual costs of each scheme vary depending on the selection of the configured amenities, the amortization of installation costs, the state of the economy, the service life, and the turnover time. Table 3 represent an analysis of the construction cost of different design schemes that shows a basic budget for each scheme in RMB (based on the 2016 price in China; the average exchange rate in 2016 was RMB 100 = USD 15.06). These values are used to calculate the value coefficient for each scheme. The budget for different design schemes is calculated using the costs of the different items shown in Table 3.

Table 3 shows the one-time construction costs for one unit of each accommodation scheme, excluding possible transportation costs or costs for using public buildings and facilities in the workers' accommodation area. Meanwhile, the authors assume that the existing facilities attached to the workers' temporary accommodation are provided free of charge by the employer. While the

Table 3. Analysis of construction costs of different design schemes

Number	Cost items	Unit price	Unit	Scheme 1		Scheme 2		Scheme 3		Scheme 4		Scheme 5		Scheme 6	
				Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
1	Container retrofit	8,000	Piece	1	8,000	1	8,000	1	8,000	1	8,000	1	8,000	1	8,000
2	Composite unit partition	100	m^2	0	0	6	550	0	0	4	364	6	550	0	0
3	Bunk (including mattress)	220	Piece	4	880	4	880	2	440	2	440	2	440	2	440
4	Air conditioner	1,500	pcs	1	1,500	1	1,500	1	1,500	2	3,000	2	3,000	1	1,500
5	Basic electrical equipment	50	Point	7	350	8	400	9	450	12	600	10	500	11	550
6	Wash basin	250	Piece	0	0	0	0	1	250	2	500	2	500	1	250
7	Commode	400	Piece	0	0	0	0	1	400	2	800	2	800	1	400
8	Shower	150	Set	0	0	0	0	1	150	2	300	0	0	1	150
9	Bathroom ventilation fan	80	Piece	0	0	0	0	1	80	2	160	2	160	1	80
10	Antiskid steel floor	80	m^2	0	0	0	0	2	150	5	371	3	256	2	192
11	Aluminum alloy partition	270	m^2	0	0	0	0	6	1,491	16	4,188	13	3,553	9	2,411
12	Sliding door	500	Set	0	0	0	0	1	500	2	1,000	2	1,000	1	500
13	Kitchen table	800	m	0	0	0	0	0	0	0	0	4	3,200	3	2,400
14	Sink and hardware	500	Set	0	0	0	0	0	0	0	0	2	1,000	1	500
15	Electromagnetic furnace	200	pcs	0	0	0	0	0	0	0	0	2	400	2	400
16	Kitchen ventilation	100	Piece	0	0	0	0	0	0	0	0	2	200	1	100
17	Cold water supply	150	Point	0	0	0	0	4	600	8	1,200	6	900	5	750
18	Hot water supply	500	Set	0	0	0	0	1	500	2	1,000	0	0	1	500
19	Drainage system	150	Set	0	0	0	0	5	750	10	1,500	8	1,200	6	900
20	External supporting facilities and miscellaneous materials	5%	Main material cost	10,730	537	11,330	567	15,261	763	23,423	1,171	25,659	1,283	20,023	1,001
21	Installation labor cost	8%	Material cost	11,267	901	11,897	952	16,025	1,282	24,594	1,968	26,942	2,155	21,024	1,682
22	Enterprise comprehensive management	8%	Labor and material cost	12,168	973	12,848	1,028	17,307	1,385	26,562	2,125	29,098	2,328	22,706	1,816
23	Total price			13,141		13,876		18,691		28,687		31,425		24,523	
24	Cost coefficient			0.101		0.106		0.143		0.220		0.241		0.188	

Note: 100 RMB = USD 14.46.

employer will continue to cover the costs of the public facilities, the workers only have to pay for the cost of their housing unit. The implication of this assumption is that the incremental cost of improving the housing conditions of workers is borne by the workers themselves. However, the duration of a construction project may vary, and the turnover time, service life, and maintenance costs of container accommodation may differ. Taking these factors into consideration, including factors related to accommodation turnover, the housing costs are shown in Table 4. These values are based on field investigations.

Table 4 shows that Scheme 5 involves the highest monthly cost of living, assuming that a housing unit turns over twice in a 3-year period. Considering the average wage of Chinese construction workers in 2016, the housing cost requires a monthly payment of RMB 230, or about 6.54% of the monthly wage. If an average unit turns over four times and the use period for each turnover is 1.5 years, the cost of Scheme 5 will be less than RMB 150 per month or 4.2% of the monthly wage. Because the depreciation and rules used to calculate the costs of the various schemes are the same whether turnover and depreciation or one-time construction is considered, the value coefficients of all schemes remain unchanged.

Analysis of Housing Satisfaction Evaluation

Design of Questionnaire

To further evaluate the proposed schemes and determine the actual housing preferences of construction workers, 72 MCWs from a real estate project in Tianjin, China, were selected to complete a questionnaire. Using the analytic hierarchy process, the design of the questionnaire focused on the evaluation indicator system shown in Fig. 3. To make the questions easier to understand, some questions were further simplified during the questionnaire design process. The original questionnaire included three major sections (see Supplemental Data for *Questionnaire on changing the housing conditions of migrant construction workers*). The first section of the questionnaire collected the demographic characteristics of the respondents. The second section gave respondents an opportunity to allocate weights to criteria according to the importance and preference for functional needs. The third section is used to score the housing satisfaction of different criteria for all design schemes to find the optimal scheme for a specific MCW.

To ensure the quality of survey results, a thorough data collection plan was set up by the research group, and the basic process of the plan is shown in Fig. 5. First, an organizational meeting was called that included the owner's manager, the owner's chief engineer, the general contractor's manager, the subcontractors' manager, and interviewers in order to design the data collection plan. Second, workers were classified according to their level of education, i.e., high school, junior school, elementary school, and other qualifications. Third, it was necessary to conduct multiple types of training for different respondents according to workers' work schedule, types of jobs, individual characteristics, and level of education. It was also necessary that conversion from academic language to vernacular language should be considered during the period of training. For example, most MCWs are not familiar with the concept of privacy, so various cases of privacy protection were explained to participants. In the fourth step, the questionnaire was answered in different ways. Young and educated workers that were able to complete the questionnaire independently were grouped according to their schedule of work and rest. Older workers with lower education levels were aided in filling out the questionnaire via one-on-one conversations with helpers.

It is important to verify the results using a consistency test to avoid invalid questionnaires. For this reason, in the design of the questionnaire a two-stage response method was adopted (see the questionnaire in the Supplemental Data). First, to avoid logical inconsistencies, a comparison with the order of importance of three indicators was made by each respondent at the same level of the evaluation indicator system. Next, the respondent rated the results of the comparison of the indicators on a scale of 1–9 to yield a judgment matrix via pairwise comparisons. With detailed and careful preparation, the questionnaires from the 72 workers all passed the consistency test.

Statistical Analysis of Results

Using the methods described earlier, a statistical analysis of the responses from the 72 workers involved in the survey was conducted. The results are presented in Table 5. According to Table 5 corresponding to Fig. 3, the bathroom function was most important, which means that most workers in this project wanted to have an indoor bathroom. Sleep security, privacy security, and space satisfaction were also rated high, whereas the remaining criteria were rated relatively low and had almost the same value. The results show that workers from the project preferred improvements in their housing conditions and in particular those that increase their psychological satisfaction.

Table 6 contains the statistics related to function coefficients from all questionnaires, which reflect the differences in the overall housing preference among the responses of all respondents. Scheme 6 with the most housing functions had the highest mean value, which means that the more functions a scheme has, the higher its score. This result is in line with common sense. There was only a slight difference between "sleep + bathroom" and "sleep + bathroom + kitchen." When the values assigned to the functions of schemes are very similar, the lower-cost schemes are likely to become the most popular based on value engineering.

The statistical results in Table 6 show that most MCWs in this case were willing to pay the cost of improving their housing conditions, but the ability and willingness to pay varied from person to person. When the actual price is not known, most of the workers think that the accommodation with the most functions is the best.

Analysis of Housing Supply and Pricing Strategies

Table 7 shows the statistics of value coefficients calculated from all questionnaires. Scheme 3 had the highest mean value coefficient, which indicated that most workers considered Scheme 3 to be the best for themselves. Scheme 3 had the maximum value with 34 votes (or 47.22% of the total votes), which means that 34 respondents thought that this scheme was most suitable. Scheme 2 was the second most popular with 24 votes (or 33.33%). Scheme 2 adds a simple separation of living space in comparison with Scheme 1, and the popularity of Scheme 2 indicates that the desire for privacy was high. To satisfy the housing and residential preferences of all MCWs, the frequency of the maximum value coefficient is a better indicator for determining the number of housing units than the mean value. Based on four residents per container, Table 7 shows that 3 containers of Scheme 1, 6 containers of Scheme 2, 9 containers of Scheme 3, and 1 container of Scheme 6 will meet the needs of the 72 residents who participated in this case.

Another advantage of applying value engineering to assign accommodation to workers is the reasonable housing pricing determined using the value coefficient for the various schemes and workers according to Eqs. (5) and (6).

Taking one worker's questionnaire as an example to illustrate the results, Table 8 shows the function coefficient, cost coefficient, and value coefficient for the selected worker's questionnaire. According to Table 8, Scheme 2 for the selected worker had not

Table 4. Estimated housing costs taking into consideration turnover of container accommodation

Number	Items	Unit	Calculation rule	Schemes											
				Scheme 1		Scheme 2		Scheme 3		Scheme 4		Scheme 5		Scheme 6	
				Period = 3 years	Period = 6 years	Period = 3 years	Period = 6 years	Period = 3 years	Period = 6 years	Period = 3 years	Period = 6 years	Period = 3 years	Period = 6 years	Period = 3 years	Period = 6 years
(1)	Total construction cost	RMB	Empirical estimation	13,141	13,141	13,876	13,876	18,691	18,691	28,687	28,687	31,425	31,425	24,523	24,523
(2)	Turnover times	Turn	Empirical estimation	2	4	2	4	2	4	2	4	2	4	2	4
(3)	Time consumed per turn	Year	Empirical estimation	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
(4)	Cost per turnover after removal	RMB	(1)×5%×[(2)−1]	657	1,971	694	2,081	935	2,804	1,434	4,303	1,571	4,714	1,226	3,678
(5)	Amortization of transportation	RMB	(1)×10%×[(2)−1]	1,314	3,942	1,388	4,163	1,869	5,607	2,869	8,606	3,143	9,428	2,452	7,357
(6)	Residual value	RMB	(1)×10%	1,314	1,314	1,388	1,388	1,869	1,869	2,869	2,869	3,143	3,143	2,452	2,452
(7)	Total life cycle cost	RMB	(1)+(4)+(5)−(6)	13,798	17,741	14,570	18,733	19,626	25,233	30,121	38,727	32,997	42,424	25,749	33,106
(8)	Annual amortization	RMB	(7)/(2)×(3)	4,599	2,957	4,857	3,122	6,542	4,205	10,040	6,455	10,999	7,071	8,583	5,518
(9)	Cost per person per year	RMB	(8)/4	1,150	739	1,214	781	1,635	1,051	2,510	1,614	2,750	1,768	2,146	1,379
(10)	Cost per person per month	RMB	(9)/12	96	62	101	65	136	88	209	134	229	147	179	115
(11)	Average monthly wage of workers	RMB	Official statistical data	3,500		3,500		3,500		3,500		3,500		3,500	
(12)	Proportion of monthly wage	%	(10)/(11)	2.74	1.77	2.89	1.86	3.89	2.51	5.97	3.83	6.54	4.20	5.11	3.29
(13)	Cost coefficient	—	—	0.101	0.101	0.106	0.106	0.143	0.144	0.220	0.219	0.241	0.241	0.188	0.188

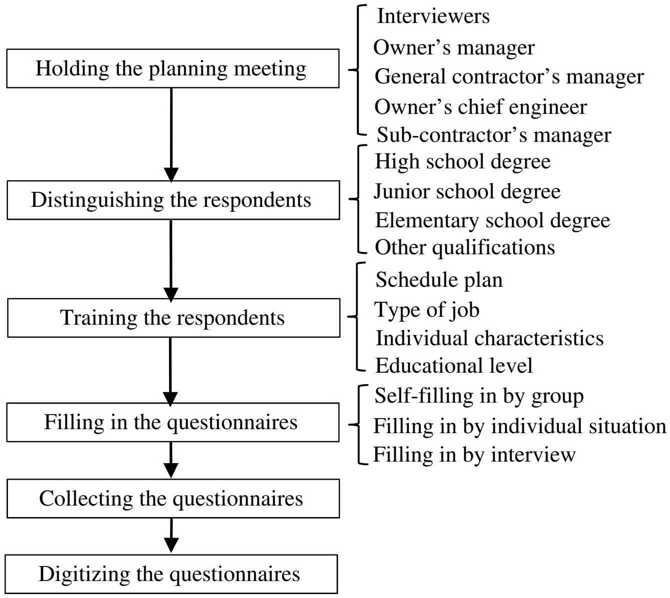

Fig. 5. Investigation plan used to determine migrant workers' preferences for container accommodation.

only the highest function coefficient but also the highest value coefficient, which shows that it best met the worker's housing preferences. Housing pricing can be determined based on the monthly amortization of construction costs. One way to achieve this is to require the worker to pay RMB 101 per month as rent. Another approach involves calculating the rent from the ratio of the function coefficient of a specific scheme to the function coefficient of a baseline scheme. For example, using Scheme 1 as the baseline scheme, it can be estimated that the worker choosing Scheme 2 is willing to pay more, i.e., RMB 113$[(0.176/0.149) \times 96]$. Scheme 2 can be priced at RMB 113 per month, and the profit in percentage of Scheme 2 is thus $(113 - 101)/113$ or 10.6%. On the other hand, if Scheme 6 is selected as the target scheme, about RMB 73$[179 - (0.164/0.149) \times 96]$ should be paid by the business or as a government subsidy for the worker choosing Scheme 6 in comparison with Scheme 1. The major goal of scheme selection based on value engineering theory is to choose the right cost performance, not to choose a scheme with the best functions. Because the differences between the preferences of various residents are great, the application of the aforementioned method is important for meeting the housing needs of different individuals and saving resources. Furthermore, differences in workers' willingness to pay can also be determined from different value coefficients, even if the workers select the same scheme as the best scheme.

Discussions

The container accommodation designed with the framework in this paper can also be applied to the improvement of the housing conditions of migrant workers in other industries because the method is generic. To ensure the success of the semicustomized design concept in other cases, the responsibilities of the two types of decision makers must be clearly defined. The supplier of container accommodations should provide as many design schemes as possible and the consumers should also be as rational as possible. To improve the scalability of the framework and the potential of applications, the following aspects should be focused on.

Table 5. Results of statistical analysis of the 72 questionnaires

Items	Criteria								
	a_{11}	a_{12}	a_{13}	a_{21}	a_{22}	a_{23}	a_{31}	a_{32}	a_{33}
Mean value of weighting	0.167	0.083	0.127	0.112	0.236	0.068	0.064	0.062	0.083
Maximum value									
Frequency	23	4	3	5	36	2	1	0	8
Shared with one criterion	—	—	—	5	6	1	—	—	—
Shared with two criteria	2	2	2	—	—	—	—	—	—
Percentage of all samples	31.94	5.56	4.17	6.94	50.00	2.78	1.39	0.00	11.11

Table 6. Statistics related to function coefficients from all questionnaires

Items	Scheme 1	Scheme 2	Scheme 3	Scheme 4	Scheme 5	Scheme 6
Mean value	0.114	0.125	0.178	0.190	0.192	0.202
Number of maximum values	0	2	2	9	17	45
Number of maximum values shared with one criterion	0	0	1	2	2	1
Number of maximum values as percentage of all samples	0.00	2.78	2.78	12.50	23.61	62.50

Table 7. Statistics for value coefficients calculated from all questionnaires

Items	Scheme 1	Scheme 2	Scheme 3	Scheme 4	Scheme 5	Scheme 6
Mean value	1.129	1.176	1.240	0.862	0.796	1.072
Frequency of maximum value	10	24	34	0	0	4
Number of containers necessary	3	6	9	0	0	1
Number of maximum values as percentage of all samples	13.89	33.33	47.22	0.00	0.00	5.56

Note: Assuming four occupants per container.

Table 8. Function, cost, and value coefficients based on a selected questionnaire

Items	Scheme 1	Scheme 2	Scheme 3	Scheme 4	Scheme 5	Scheme 6
Function coefficient	0.149	0.176	0.169	0.171	0.171	0.164
Cost coefficient	0.101	0.106	0.143	0.220	0.241	0.188
Cost per month (RMB)	96	101	136	209	229	179
Value coefficient	1.475	1.660	1.182	0.777	0.710	0.872

Note: Assuming two turnovers in 3 years.

Impact of Cost Range on Feasibility

The cost difference among schemes will have an important impact on the decisions of MCWs. Many factors affect the construction cost of container accommodation. In addition to various elements mentioned in Table 3, geographical factors, seasonal factors, construction site conditions, traffic conditions, and municipal facilities also affect the construction cost. According to the results of the case study, when the housing cost is considerably less than the wage income of MCWs, the semicustomized design is feasible. Obviously, if the housing cost is too expensive, the implementation of the scheme can be difficult. The ratio of housing cost or expenses to income still needs further investigation with more samples. When the housing cost or expenses exceed the workers' willingness to pay, it is necessary to consider government subsidies or enforce mandatory housing standards for employers to improve housing conditions of MCWs. Certainly, it should be noted that environmentally friendly characteristics of container dormitories with low cost can increase the applicability of the framework.

Impact and Selection of Issuance Form on Price Information for Design Schemes

In the process of conducting the case study, three options exist for releasing price information to all MCWs: ignoring the price or making it absolutely free; paying a certain amount of cost but not being transparent about the price; being transparent about the price. "Absolutely free" or "ignoring the impact of price" will cause the workers to choose the most functional accommodation. "Being transparent about the price" will not make it possible to better understand workers' maximum willingness to pay or payment affordability. Considering it as an exploratory study in this paper, the authors decided to choose the option that asks MCWs to cover a certain amount of the costs in order to better obtain workers' rational choices. The authors also agree that due to the small sample size in the case study, the conclusions can only show the rationality of the framework to a certain extent. In the future, a larger sample survey including other options about releasing price information should be conducted to make a potential contribution to the commercialization and practical application of the proposed framework.

Impact of Extreme Needs of MCWs on Feasibility

The degree of functional differences among schemes should be in line with the ability of workers to pay and their preferences. For example, the most basic schemes satisfy workers with the lowest income and willingness to pay, while schemes with the most functions satisfy workers with higher income and willingness to pay. The continuity of function between basic and enriched schemes should be ensured to provide an optimal solution for all groups. The semicustomized design framework does not address situations where MCWs are financially unable to pay for additional housing functions or MCWs with very high salaries need luxury housing. Affordability and housing preference must be considered in the stage of scheme innovation. Hence, accurately understanding MCWs' functional needs will be very important for the successful application of the framework.

Impact of Workers' Mobility and Occupancy Duration on Feasibility

If the occupancy duration of housing units of each worker is too short, per-capita housing costs will increase with increases in the number of turnovers, and the economic efficiency of container accommodation will be reduced. On the other hand, the choice range of MCWs for housing schemes will be greatly reduced if vacant accommodations chosen by MCWs who have already moved out are continuously reused. Consequently, the housing satisfaction degree for the personalized needs of MCWs will be reduced. Therefore, for those projects with a short construction duration or high mobility of MCWs, the benefits of using the semicustomized design framework will be greatly reduced. To meet the needs of MCWs with high mobility, modular units with more convenient assembly modes and less turnover loss should be further developed and optimized.

Timing Requirements for Design Scheme Selection and Satisfaction Evaluation

It is important to include workers in the selection of design schemes before construction. Companies that provide container accommodation should be capable of timely delivery of container homes to construction sites after selections are made. To effectively incorporate providing container accommodation into construction project timelines, design schemes with different prices and functions should be designed and developed by the supplier of container accommodation according to market conditions before recruiting workers.

The choice of design scheme based on the housing satisfaction evaluation of MCWs should be carried out during the recruitment of workers. Certainly, with the help of social networking platforms, online software can also be helpful in carrying out a housing satisfaction evaluation with high efficiency and high quality.

Validation of Outcomes of Proposed Framework

Repeatability has always been an important challenge in multiple-attribute decision-making, especially in terms of the preferences of decision makers. The authors did not conduct a repeated survey to validate the outcomes provided by the proposed framework (i.e., suggestions to MCWs in terms of housing options) but instead used consistency tests, which have been applied by other studies (Al Khalil 2002; Abdelgawad and Fayek 2010). The decision not to conduct a second or repeated survey is based on three reasons. First, the key to the success of the framework based on AHP, a mature decision-making method, is to control the input to an AHP process, i.e., MCWs' multicriteria decisions. To ensure the consistency of MCWs' decisions at the decision-making time, a detailed work plan and a two-stage questionnaire design method were applied, and all questionnaires in this paper also passed the consistency tests. Thus, in essence, the authors controlled decision-making states instead of outcomes. Controlling decision-making states is a method to ensure the validity of similar multicriteria evaluation problems and has been applied in other studies (Aminbakhsh et al. 2013; Plebankiewicz and Kubek 2016). Second, since it represent multicriteria decision-making, it is highly likely that MCWs will change their preferences the second time due to peer influence and other factors, so conducting a second or repeated interview with MCWs is likely to introduce additional uncertainties into the study. Third, there is a practical consideration. Due to the fact that MCWs may be transferred to other jobsites, getting the same pool of MCWs for a second or repeated survey may present a practical challenge. However, how to ensure that decisions provided by the framework are repeatable and how to find out whether variations in decisions of repeated surveys are mainly caused by the framework design still need further investigation.

Conclusions

In this paper, the authors presented a semicustomized design framework, a method of design scheme innovation based on Maslow's hierarchy of needs. The method improves a value engineering process from function analysis to evaluation in order to better support housing designs of MCWs, integrates two types of decision makers into different stages of a design to satisfy the diversified housing needs of different MCWs from social and psychological perspectives, and uses a concise evaluation indicator system to better measure the housing satisfaction of MCWs.

The case study shows that the framework is a feasible and practical solution for improving housing design and selection of MCWs. The semicustomized design presented in this paper can support the design of the best possible accommodation for construction workers on projects that meet their requirements, as discussed in the previous section. Using the framework, contractors or suppliers of container accommodation can provide a personalized housing plan based on worker preferences for various schemes. Such a framework and associated activities could create personal, business, and social benefits and a win-win-win situation for workers, companies, and society.

Although the method is generic and not subject to the case project, one cannot simply assume that observations from the case study are extensible to all workers in the construction industry. This is because each project is different. Thus, future studies are needed to test the framework on different projects with different worker populations and different financial, geographic, organizational, social, and policy conditions. In addition, the six issues detailed in the "Discussion" section need further investigation to determine their impact on the application of the framework.

Data Availability Statement

Data generated or analyzed during the study are available from the corresponding author by request. Information about the *Journal*'s data-sharing policy can be found here: http://ascelibrary.org/doi/10.1061/(ASCE)CO.1943-7862.0001263.

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Supplemental Data

The questionnaire on changing the housing conditions of migrant construction workers is available online in the ASCE Library (www.ascelibrary.org).

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