A gid utility-based model for interior renovations selection

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ABSTRACT
Due to the natural environment and the consumption of the earth’s resources, the ecological damage and resource depletion have become a serious problem facing the world in recent years. To understand the design process of the interior decoration and its associated environmental issues, a plan was developed on how to introduce the green interior design concept with a view of creating a safe, healthy, green low-carbon and high-quality living space, where The FDM, AHP and cloud theory were used to deal with complex interior renovations decision issues mainly due to information uncertainty, time lapse and complexity of the problems, with, therefore, the feature cloud model employed to analyse multi-stage risk decision problems. The research results enabled customers to make decisions quickly without relying on the personal experience and ability of designers and experts. The GID decision model verified the feasibility and rationality of the method proposed in this study, which, having high analysis ability was capable of accurately predicting decisions.

1. Introduction
Due to the natural environment and the consumption of the earth’s resources, the ecological damage and resource depletion have become a serious problem facing the world in recent years.

In the last decade, new sustainable building technologies have been developed and applied to envelop renovations, installation of renewable energy systems building stock (Ali and Al-Nsairat 2009; Andrić et al. 2017). Interior renovation can damage the environment and is among the industries most responsible for environmental pollution and waste production (Acre and Wyckmans 2014). With regard to the issue of severely increased global greenhouse gas emissions, the influence of the attitudes of individuals and corporate social responsibility on greenhouse gas emissions is worthy of exploration (Peloza and Shang 2011). A study pointed out that one person spent about 80–90% of their time in the indoor environment every day (Codinhotto et al. 2009), suggesting the necessity of pursuing a comfortable indoor space. Building materials is a growing interest in developed countries. At each stage of interior renovation, practitioners should select environment-friendly materials, use recyclable products, guide consumers to understand the value of interior decoration, and develop a design industry trend that allows safety, health, energy conservation, and art to coexist. Housing suppliers therefore continuously seek methods to redesign programs and products to meet customer needs. Generally, a house buyer remodels even a newly built dwelling unit in prime condition (Hofman, Halman, and Ion 2006; Ozaki 2003). Inadequate quality standards of direct-aid interior-design programs have raised concerns regarding not only quality but also the understanding of the indoor housing quality attributes that consumers value. Thus, for the clear and comprehensive vision of natural resources management within the building sector, the environmental cost of all phases of building life-cycle should be considered (construction, operation, renovation, recycling/landfilling (Andrić et al. 2017; Hwang and Low 2012).

To understand the design process of interior decoration and the associated environmental problems, the present study applied the fuzzy Delphi method (FDM), analytical hierarchy process (AHP), and cloud theory to develop a space planning decision model for green, low-carbon interior design: the green interior design (GID) model. Risk consciousness was included to verify the feasibility of the model’s feasibility. The study presents an introduction and literature review, followed by the data analysis methods, case study, results, and discussion. Moreover, research findings, conclusions, and future research objectives are briefly summarised. The FDM, AHP, and cloud theory were used to resolve the decision problems of complex interior renovations caused by information uncertainty, time lapses, and problem complexity. Therefore, a feature cloud model was employed to analyse multistage risk decision problems. After a literature review, several environmental factors that influence people’s living decisions, mainly the indoor spaces of buildings and residential environment plan options, were identified (Ali and Al-Nsairat 2009; Liu et al. 2012; Zuo and Zhao 2014).
This study investigated the design process of interior decoration and the associated environmental issues. A plan was developed for introducing the concept of green interior design for creating a safe, healthy, green low-carbon, and high-quality living space. Livelihood discussions were analysed with the GID model for residential interior environments to verify the feasibility of the model. Furthermore, the proposed hybrid model can be applied to various multicriteria decision-making problems.

2. Literature review

2.1. Cloud model theory

The cloud model (Li, Liu, and Gan 2009) is a new cognition model of uncertainty proposed based on probability theory and fuzzy set theory (Chiclana et al. 2007; Zadeh 1965). It can be defined as follows: DEFINITION 1: Given a qualitative concept T defined on a universe of discourse U, X ⊆ U, let x ∈ X be a random instantiation of the concept T and Gr(X) ∈ [0, 1] be the membership degree of x belonging to T, which corresponds to a random number with steady tendency. Then, the distribution of the membership over the domain is called a membership cloud, or simply, a cloud (Li, Liu, and Gan 2009; Liu et al. 2019). DEFINITION 2: The characters of a cloud y are depicted by three numerical parameters, namely expectation, entropy En and hyper entropy. Here, Ex is the centre value of the qualitative concept domain, En measures the ambiguity of the qualitative concept and He represents the dispersion degree of cloud droplets and the random variation of the membership (Li, Liu, and Gan 2009; Liu et al. 2019; Wang et al. 2015). The cloud can be written as $\tilde{y} = (Ex, En, He)$. Ex expresses the expectation of the interval judgment, $[Ex - 3En, Ex + 3He]$ best represents the qualitative judgment (99.74%, 3En rule), and a normal cloud is depicted in Figure 1. Note that the cloud $\tilde{y} = ([Ex, Ex], En, He)$ is named as an interval cloud when the expected value is an interval range $[Ex, Ex]$.

2.2. Linguistic in AHP by cloud models

In Saaty’s AHP, the decision-maker is asked to provide his/her ratios $a_{ij}$ for each pairwise comparison between alternatives A1, A2, A3, . . . , An for each criterion (objective) in a hierarchy and also between the criteria (Saaty 1990). The measurement on a ratio scale of the pairwise comparison is central in AHP. To make comparisons, a scale of numbers should be used to indicate how many times more important or dominant one element is over another element with respect to the criterion or property being compared (Huang et al. 2016; Saaty 2008). Then, decision-maker obtains a reciprocal numerical pairwise comparison matrix by selecting a particular numerical scale to quantify the linguistic pairwise comparison data. In practice, experts are often highly accustomed to providing their preferences or assessments using linguistic terms instead of numerical values (Li et al. 1998; Saaty 2008; Wang et al. 2014). Natural languages usually involve ambiguity and uncertainty, so we model linguistic terms in AHP using normal cloud models which consider both the fuzziness and randomness. The linguistic terms in AHP and their corresponding numerical scale model by normal cloud models are listed in Table 1. Their figures are also shown in Figure 2.

3. Data analysis methods

3.1. Questionnaire design

The methodology of constructing an evaluation framework in order to select an interior renovation supplier

![Figure 1. Normal cloud and its numerical characters.](image-url)
in the industry referred to by the same name for this study has three phases. In the first phase, suppliers with excellent ability to deliver were emphasised. In the second phase, the consistency of criteria was identified. In the third stage, the AHP was combined with cloud theory to obtain the value of building interior renovation certification levels. Finally, this model was used to certify the building interior renovation certification level of an illustrious interior renovation company to select the most suitable project.

**3.2. Index factor description**

**3.2.1. The interior renovations service of evaluation criteria**

Sixteen experts were invited in the FDM process to express their opinions on identifying the consistency of evaluation criteria for the selection of suppliers. Considering the practical experience in the field of carbon management in the real estate and interior design industries, the study identified three managers in their firms, who were responsible for the implementation of green procurement and energy management; four suppliers from the interior renovation industry; and nine university professors, whose research were related to green building research and energy management in the interior renovation industry.

### Table 1. Linguistic in AHP and their corresponding normal cloud models.

| Linguistic terms                          | Normal cloud models |
|-------------------------------------------|---------------------|
| equally important (eq)                    | (1, 0.3, 0.02)      |
| weakly more important (wm)                | (2, 0.3, 0.02)      |
| moderately more important (mm)           | (3, 0.3, 0.02)      |
| moderately plus more important (mpm)     | (4, 0.3, 0.02)      |
| strongly more important (sm)             | (5, 0.3, 0.02)      |
| strongly plus more important (spm)       | (6, 0.3, 0.02)      |
| demonstratively more important (dm)       | (7, 0.3, 0.02)      |
| very, very strongly more important (vvsm) | (8, 0.3, 0.02)      |
| extremely more important (em)             | (9, 0.3, 0.02)      |

**3.2.2. Literature reviews for evidence**

Through a literature review and expert group’s recommendations, this study developed a questionnaire for assessing interior design space planning. After compiling useful factors for space planning from relevant literature, the study applied the FDM to collect experts’ and scholars’ viewpoints; the collected viewpoints were later used for determining evaluation factors. Compared with non-experts, experts can usually provide more insightful and incisive viewpoints. In particular, the experiences and specialized skills of experts are considerably more valuable than those of non-experts (Chiang 2019).

Moreover, experts and scholars who are university professors and high-ranking managers and who are associated with building design, property management, and hotel management industries were interviewed and invited to revise the selected factors and propose potentially overlooked factors. The selected and newly added factors were then compiled and incorporated into a 16-item questionnaire (Table 2).

**3.3. FDM method**

Copies of the questionnaire were distributed to the participating experts through e-mail, postal mail, or personal delivery. The questionnaire completion progress was monitored through phone calls. The questionnaire survey was conducted between July 2018, and October 2019. The FDM technology is used to screen suitable factors for interior renovations. The expert group average was calculated for conservative and optimistic values of each measure i, which were eliminated, other than the two standard deviations (Ishikawa et al. 1993; Lee and Seo 2016). The minimum $C_i$, geometric mean $C^G_i$, maximum $O^L_i$ of the conservative values, as well as the minimum $O^U_i$, geometric mean $O^G_i$, maximum $O^U_i$ of the optimistic values, were calculated.

**Figure 2.** Linguistic terms in AHP modeled by normal cloud models.
Table 2. Factors for assessment criteria items.

| Related Factor | Related References |
|----------------|--------------------|
| Construction projects | (Hwang and Low 2012) |
| External sunshade design | Proposed by experts |
| Corporate social responsibility | (Benavides-Velasco, Quintana-Garcia, and Marchante-Lara 2014; Hoehn, Upchurch, and Okumus 2007; Pelosa and Shang 2011) |
| Protection of consumer rights | Proposed by experts |
| Indoor temperature control | Proposed by experts |
| Interior design | (Akadiri et al., 2012; Chiang 2019) |
| Building materials | (Andric et al. 2017; Chiang 2019; Shen et al. 2017) |
| Construction crisis management | (Loosemore 1999; Sahin, Ulubeyli, and Kazaza 2015) |
| Installation of renewable energy systems | Proposed by experts |
| After sales service | Proposed by experts |
| Resort Hotel’s Image | Proposed by experts |
| Innovative Technology | (Claver-Cortés et al. 2007) |
| Waste and pollution prevention | Proposed by experts |
| Functional requirements system planning | (Lutzendorf 2018) |
| Environmental awareness | Proposed by experts |
| Easiest & Maintain | (Chiang 2019) |

Subsequent to the completion of the data collection process, the FDM analysis results were useful in refining the questionnaire items and deleting factors with insufficient discriminatory power. In general, experts’ consensus regarding a factor is evaluated using the measures G'. A higher G' value for a specific factor indicates greater consensus among experts with regard to the factor; therefore, this factor is more suitable for inclusion in an evaluation factor set. Furthermore, the values of M' and Z' were calculated to determine the consistency of expert opinions. The differences observed were convergent, and the consensus value of G' was calculated to screen the indicators (Lee, Wang, and Lin 2010; Lee and Seo 2016). FDM was applied for factor screening to remove factors with a low discrimination index and simplify the questionnaires further. The analysis results are shown in Table 3; there was an expert consensus threshold value (G') of 7.0. Six factors, namely, Construction projects, External sunshade design, Indoor temperature control, Resort Hotel’s Image, Innovative Technology and Easiest & Maintain, had a value less than 7.0 and were thus removed; 10 factors remained.

3.4. Approach of GID decision-making process

In the first stage, the FDM technique was used to select 10 factors, and in the second stage, cloud model theory analysis was applied to analyse data from the expert questionnaire survey that were divided into two major facets, i.e., interior design and corporate social responsibility, and they were classified as the main aspects basis the expert group’s recommendations. Using eight evaluation factors from the second floor and by establishing classification of the overall evaluation criteria, our objective is ensuring experts can understand the purpose of this study when filling a construct GID. Therefore, user operation needs are limited but have a positive effect on building materials, installation of renewable energy systems, and functional requirements system planning. The integration of corporate social responsibility into interior design corporate business practices and operations are limited but have a positive effect on waste and pollution prevention. Assessing environmental awareness by a firm begins with pursuing a universal definition for CSR and the corporation’s role in modern society. Using the decisions of the expert group to adjust assessment facets and criteria, we identified that the visitor group mainly

Table 3. Results of calculation of factors with FDM.

| Criteria | Pessimistic value | Optimistic value | Geometric mean | Consensus value |
|----------|------------------|------------------|----------------|------------------|
| Construction projects | C₁₁ = 3.00 | C₂₁ = 8.00 | C₃₁ = 5.00 | C₄₁ = 7.38 | M₁ - Z₁ = -0.63 | G₁ = 6.33 < 7.0 |
| External sunshade design | C₁₂ = 2.00 | C₂₂ = 7.00 | C₃₂ = 5.00 | C₄₂ = 7.56 | M₂ - Z₂ = -0.06 | G₂ = 6.27 < 7.0 |
| Corporate social responsibility | C₁₃ = 5.00 | C₂₃ = 8.00 | C₃₃ = 6.00 | C₄₃ = 8.13 | M₃ - Z₃ = 1.13 | G₃ = 7.36 < 7.0 |
| Protection of consumer rights | C₁₄ = 2.00 | C₂₄ = 8.00 | C₃₄ = 6.13 | C₄₄ = 8.69 | M₄ - Z₄ = 0.56 | G₄ = 7.18 < 7.0 |
| Indoor temperature control | C₁₅ = 2.00 | C₂₅ = 8.00 | C₃₅ = 5.44 | C₄₅ = 8.06 | M₅ - Z₅ = -0.38 | G₅ = 6.63 < 7.0 |
| Interior design | C₁₆ = 2.00 | C₂₆ = 8.00 | C₃₆ = 6.38 | C₄₆ = 8.94 | M₆ - Z₆ = 1.56 | G₆ = 7.54 < 7.0 |
| Building materials | C₁₇ = 3.00 | C₂₇ = 8.00 | C₃₇ = 7.05 | C₄₇ = 9.00 | M₇ - Z₇ = 2.25 | G₇ = 7.67 < 7.0 |
| Construction crisis management | C₁₈ = 4.00 | C₂₈ = 8.00 | C₃₈ = 6.00 | C₄₈ = 8.44 | M₈ - Z₈ = 0.44 | G₈ = 7.10 < 7.0 |
| Installation of renewable energy systems | C₁₉ = 2.00 | C₂₉ = 8.00 | C₃₉ = 6.19 | C₄₉ = 8.94 | M₉ - Z₉ = 1.75 | G₉ = 7.52 < 7.0 |
| After sales service | C₁₁₀ = 4.00 | C₂₁₀ = 8.00 | C₃₁₀ = 6.25 | C₄₁₀ = 8.25 | M₁₀ - Z₁₀ = 0.00 | G₁₀ = 7.13 < 7.0 |
| Resort Hotel’s Image | C₁₁₁ = 2.00 | C₂₁₁ = 7.00 | C₃₁₁ = 4.69 | C₄₁₁ = 7.06 | M₁₁ - Z₁₁ = -0.63 | G₁₁ = 5.71 < 7.0 |
| Innovative Technology | C₁₁₂ = 2.00 | C₂₁₂ = 8.00 | C₃₁₂ = 5.94 | C₄₁₂ = 8.75 | M₁₂ - Z₁₂ = -1.19 | G₁₂ = 6.79 < 7.0 |
| Waste and pollution prevention | C₁₁₃ = 5.00 | C₂₁₃ = 8.00 | C₃₁₃ = 6.13 | C₄₁₃ = 8.13 | M₁₃ - Z₁₃ = 1.00 | G₁₃ = 7.38 < 7.0 |
| Functional requirements system planning | C₁₁₄ = 2.00 | C₂₁₄ = 8.00 | C₃₁₄ = 6.38 | C₄₁₄ = 9.06 | M₁₄ - Z₁₄ = 0.69 | G₁₄ = 7.01 < 7.0 |
| Environmental awareness | C₁₁₅ = 3.00 | C₂₁₅ = 8.00 | C₃₁₅ = 6.19 | C₄₁₅ = 8.38 | M₁₅ - Z₁₅ = 0.19 | G₁₅ = 7.13 < 7.0 |
| Easiest & Maintain | C₁₁₆ = 2.00 | C₂₁₆ = 7.00 | C₃₁₆ = 5.50 | C₄₁₆ = 7.44 | M₁₆ - Z₁₆ = -0.06 | G₁₆ = 6.24 < 7.0 |
comprised elementary users and occupant family group audiences.

The cloud model, propounded by Li, Liu, and Gan (2009), is a cognitive model that reflects uncertainties of things in the universe and concepts in knowledge, which, when compared with traditional linear models, has outperformed these models as it has the ability to detect both linear and nonlinear relationships with high predictive accuracy (Leong et al. 2015; Liu et al. 2019). The use of the normal cloud model has provided successful results for the construction of models of linguistic words (Huang et al. 2016; Liu et al. 2019; Yang, Yan, and Zeng 2013; Yang et al. 2014).

### 3.4.1. Introduction of the GID cloud model theory framework

In this study, cloud model theory was divided into two stages. The first stage involved conducting a consistency check on the evaluation results of each expert; this check was conducted to ensure the validity of the questionnaire responses and evaluation results of each expert. Initially, a pretest was conducted with nine professors to ascertain the face and content validity of the survey questionnaire. The second stage entailed integrating expert opinions to determine the weight of each evaluation factor and consequently improve the reliability of the items. The survey results are more objective, appropriate, and consistent with actual needs. Subsequently, a pilot test was conducted with suppliers to evaluate the questionnaire with respect to the wording, clarity, relevance, and time spent. This was essential in ensuring that the evaluation results were objective and applicable and met actual needs.

### 3.4.2. Introduction of the GID criteria theory framework

The GID analysis is based on three steps. First, a hybrid AHP and cloud theory were used to deal with complex interior renovations, and multi-stage risk decision problems were analyzed using the feature cloud model. We obtain the individual cloud comparison matrix from interval assessments and the opinion of experts I, whose CI ≥ 0.1 is rejected to avoid the influence of bad opinions. The geometric mean technique is used to compute the cloud weights of matrix $\mathbf{\hat{A}}_{\text{m}}$. Second, the GID utility-based model results from our questionnaire are applied to reduce mistakes to meet certain standards. Third, the individual cloud weights were calculated to determine the weights of the risk factors, and the associated weight vector of the ICOWIA operator was identified as an interval cloud. Thus, the utility values predicted using AHP and cloud theory show that the optimal and worst case will produce a cloud expected utility value. Finally, the final group AHP, utility values and cloud weight vector are obtained by calculating the weight vector of the risk factors and analyzing the utility evaluation and ranking of these factors.

AHP analysis was used to calculate the assessed weight (or priority) of each decision element (See Table 1). A hybrid AHP and cloud theory were used to deal with complex interior renovations the feature cloud model employed to analyse multi-stage risk decision problems. At this stage, experts and researchers were still the objects of investigation. Therefore, the various relevant elements, definitions, and criteria are explained to help readers better understand the goals of this study. As each person had a different attitude towards risk, our calculations utilized a moderate amount of risk to perform the analysis. Let $C_1 = (3, 0.3, 0.02)$ (mm), $C_2 = (4, 0.3, 0.02)$ (mpm) and $C_3 = (5, 0.3, 0.02)$ (sm) be three normal cloud models in the same universe of discourse.

$$\begin{align*}
\mathbf{\hat{A}}_s &= \text{Synthetic}(\mathbf{\hat{A}}_s) = (E_{\mathbf{x}_1}, E_{\mathbf{n}_1}, E_{\mathbf{h}_1}) \\
\mathbf{\hat{A}}_{\text{m}} &= \text{WeightedAverage}(\mathbf{\hat{A}}_s) = (E_{\mathbf{x}_{\text{m}}}, E_{\mathbf{n}_{\text{m}}}, E_{\mathbf{h}_{\text{m}}}), i = 1, 2, 3, \ldots, m
\end{align*}$$

(1)

The opinion of expert i, whose $C_{\mathbf{I}_i} \geq 0.1$, is abandoned to avoid the influence of bad opinions, and the opinions of the rest m experts decision-maker are considered (Huang et al. 2016; Yang et al. 2014). The feedback information of the group opinion of m experts contains the synthetic cloud opinion $\mathbf{\hat{A}}_s$ and the weighted average cloud opinion note $\mathbf{\hat{A}}_{\text{m}}$.

The synthetic cloud model calculated by cloud weights, given any positive reciprocal cloud matrix $\mathbf{\hat{A}}$. The entropy and hyper-entropy of the synthetic cloud model are both greater than that of each individual cloud model. That there should be more uncertainties when the AHP’s pairwise comparisons, every two elements need to compare with each other only once, are provided in practice. (See Equation (2)) is $C_s = (4, 0.5613, 0.0327)$. Where $\mathbf{\hat{A}}_{ij} = 1/\mathbf{\hat{A}}_{ji}$ and $\mathbf{\hat{a}}_{ij} = (1, 0, 0)$. The geometric mean technique is utilized to compute for the cloud weights of matrix $\mathbf{\hat{A}}$:

$$\mathbf{\hat{A}} = \left[ \begin{array}{c}
\hat{A}_{11}(E_{\mathbf{x}_{11}}, E_{\mathbf{n}_{11}}, E_{\mathbf{h}_{11}}) \hat{A}_{12}(E_{\mathbf{x}_{12}}, E_{\mathbf{n}_{12}}, E_{\mathbf{h}_{12}}) \ldots \hat{A}_{1n}(E_{\mathbf{x}_{1n}}, E_{\mathbf{n}_{1n}}, E_{\mathbf{h}_{1n}}) \\
\hat{A}_{21}(E_{\mathbf{x}_{21}}, E_{\mathbf{n}_{21}}, E_{\mathbf{h}_{21}}) \hat{A}_{22}(E_{\mathbf{x}_{22}}, E_{\mathbf{n}_{22}}, E_{\mathbf{h}_{22}}) \ldots \hat{A}_{2n}(E_{\mathbf{x}_{2n}}, E_{\mathbf{n}_{2n}}, E_{\mathbf{h}_{2n}}) \\
\hat{A}_{n1}(E_{\mathbf{x}_{n1}}, E_{\mathbf{n}_{n1}}, E_{\mathbf{h}_{n1}}) \hat{A}_{n2}(E_{\mathbf{x}_{n2}}, E_{\mathbf{n}_{n2}}, E_{\mathbf{h}_{n2}}) \ldots \hat{A}_{nn}(E_{\mathbf{x}_{nn}}, E_{\mathbf{n}_{nn}}, E_{\mathbf{h}_{nn}})
\end{array} \right]$$

(2)
Definition cloud matrix AS (Equation (3)); the priority vector of the positive reciprocal synthetic cloud matrix in can be calculated as

$$\tilde{w_i} = \left( \frac{\sum_{j=1}^{n} \tilde{a}_{ij}^{-1}}{n} \right)^{-1/n}$$

(3)

Then, we obtain the final cloud weight (score) for alternative $A_i$ as

$$\tilde{S}_i = \sum_{k=1}^{n} w_{ik} \tilde{e}_k .$$

(4)

The final score $\tilde{S}_i$ is a cloud number $\tilde{S}_i = (Ex_i, En_i, He_i)$. We can rank the alternatives quickly by comparing the parameters of cloud numbers:

- If $Ex_i \geq Ex_j, En_i < En_j$, and $He_i < He_j$, then $A_i$ absolutely dominates $A_j$;
- Otherwise: If $Ex_i < En_j$, and $En_j < En_i$ or $He_i < He_j$, we say $A_j$ averages dominates $A_i$,

$$w = (0.2592, 0.1798, 0.0146), (0.3003, 0.2083, 0.0169), (0.4405, 0.3506, 0.0248).$$

In Equation (5), $w1 = (0.2592, 0.1798, 0.0146), w2 = (0.3003, 0.2083, 0.0169), w3 = (0.4405, 0.3506, 0.0248)$, then $Ex1 = 0.2592, Ex2 = 0.3003, Ex3 = 0.4405$. As $Ex3 > Ex2 > Ex1$ using the ranking rules of cloud models, the ranking of the priority vector $\tilde{S}_3 > \tilde{S}_2 > \tilde{S}_1$.

### 3.4.3. The Proposed GID utility-based Model

The analysis results (Tables 4 and 5) (Weighting value of overall $[W_i = 1]$) reveal the GID criteria and the selected decision-making factors. The GID calculation process must adhere to a consistency test consisting of two indices, namely, the consistency index “CI” and the consistency ratio (CR). For the $CI_1$, 0 denotes that the survey data are consistent, $CI_1 = 1$ denotes that the data are erroneous, and $CI_1 \leq 1$ denotes that the data are within an acceptable margin of error. For the $CR$, ≤0.1 according to the questionnaire data, the data is consistent and credible. This implies that our survey results and conclusions meet a certain criteria (i.e., CR ≤ 0.1) (Chiang 2019; Saaty 1990, 2008). The data value of these dimensions were used to calculate the relative weighting values (Liu et al. 2019; Wang et al. 2015).

Where $En_1 = (Ex_1 + Ex_2)/2$ and $En_2 = (Ex_1 + Ex_2)/2$. If $En_1 = He_1 = En_2 = He_2 = 0$, then the interval cloud reduces to an interval number and $d(\tilde{y}_1, \tilde{y}_2) = \frac{1}{2} (|En_1 - Ex_2| + |Ex_1 - Ex_2|)$.

Let $\tilde{y}_1 = (Ex_1, Ex_2, En_i, He_i)$ (i = 1, 2, ..., n) be a set of interval clouds in the domain $U$, then the interval cloud ordered weighted averaging (ICOWA) operator is defined as

$$ICOWA(\tilde{y}_1, \tilde{y}_2, \ldots, \tilde{y}_n) = \sum_{i=1}^{n} w_i \tilde{y}_i,$$

where $n = (n_1, n_2, \ldots, n_n)^T$ is the associated weight vector of the ICOWA, satisfying $n_1 \in [0, 1]$ and $\sum_{i=1}^{n} n_i = 1$, $\forall i = 1, 2, \ldots, n$. The aggregated value by means of the ICOWA operator is also an interval cloud and can be calculated as follows:

$$ICOWA(\tilde{y}_1, \tilde{y}_2, \ldots, \tilde{y}_n) = \left( \frac{\sum_{i=1}^{n} w_i En_{i(i)}}{\sum_{i=1}^{n} w_i En_{i(i)}}, \frac{\sum_{i=1}^{n} w_i Ex_{i(i)}}{\sum_{i=1}^{n} w_i Ex_{i(i)}} \right)^{-1},$$

(7)

It is noted from Table 6 that Protection of consumer rights perspective has the highest weight with 0.1587 and the weight of Building materials process perspective has the 0.1539. Among these criteria, energy management and functional requirements systems plan human resources construction costs of real estate developers. Moreover, waste pollution and prevention of pollution are regional environmental problems. Thus, planning, designing, and environmental awareness and novel construction methods must be emphasized in developing housing projects. Further, the interior design (2-1-1 ~ 2-1-4) and corporate social responsibility (2-2-1 ~ 2-2-4) degree of preference (P) is set as 16. Thereafter, the utility values are predicted by using the AHP and cloud theory (Table 7). The calculated results show that the worst case will produce a cloud expected utility value (CEUV) of 0.53 and the best case will produce a CEUV of 0.9007.

### Table 4. Weighting value of interior design.

| Criteria | (2-1-1) | (2-1-2) | (2-1-3) | (2-1-4) |
|----------|---------|---------|---------|---------|
| (2-1-1)  | (1, 0.3, 0.02) | (1.875, 0.327, 0.019) | (1.188, 0.185, 0.011) | (1.063, 0.159, 0.009) |
| (2-1-2)  | (0.533, 0.048, 0.003) | (1, 0.3, 0.02) | (1.063, 0.159, 0.009) | (1.063, 0.159, 0.009) |
| (2-1-3)  | (0.842, 0.113, 0.007) | (0.941, 0.133, 0.008) | (1, 0.3, 0.02) | (1.313, 0.211, 0.012) |
| (2-1-4)  | (0.941, 0.133, 0.008) | (0.941, 0.133, 0.008) | (0.762, 0.096, 0.006) | (1, 0.3, 0.02) |
| Eigenvector | (3.317, 0.627, 0.037) | (4.757, 0.927, 0.054) | (4.012, 0.772, 0.045) | (4.438, 0.860, 0.050) |

Consistency Index(CI) = 0.019, Consistency Ratio(CR) = 0.021
Table 5. Weighting value of corporate social responsibility.

| Criteria | (2-2-1) | (2-2-2) | (2-2-3) | (2-2-4) |
|----------|---------|---------|---------|---------|
| (2-2-1)  | (1, 0.3, 0.02) | (2.125, 0.379, 0.022) | (1.188, 0.185, 0.011) | (1.063, 0.159, 0.009) |
| (2-2-2)  | (0.471, 0.036, 0.002) | (1, 0.3, 0.02) | (1.125, 0.172, 0.01) | (1.125, 0.172, 0.01) |
| (2-2-3)  | (0.842, 0.113, 0.007) | (0.889, 0.123, 0.007) | (1, 0.3, 0.02) | (1.156, 0.178, 0.01) |
| (2-2-4)  | (0.941, 0.133, 0.008) | (0.889, 0.123, 0.007) | (0.865, 0.118, 0.007) | (1, 0.3, 0.02) |
| Eigenvector | (3.254, 0.614, 0.036) | (4.903, 0.957, 0.056) | (4.177, 0.806, 0.047) | (4.344, 0.841, 0.049) |

Consistency Index(CI) = 0.026, Consistency Ratio(CR) = 0.029

Table 6. Weighting values of criteria and cloud eigenvalue.

| Criteria | Level Wi | Overall Wi | Overall Sequence | Ex1 | Ex2 | Ex3 | KOWA |
|----------|----------|------------|-----------------|-----|-----|-----|------|
| (2-1-1)  | 0.3078   | 0.1539     | 2               | 0.040 | 0.046 | 0.068 | 0.355 |
| (2-1-2)  | 0.2188   | 0.1094     | 8               | 0.028 | 0.033 | 0.048 | 0.001 |
| (2-1-3)  | 0.2492   | 0.1246     | 3               | 0.032 | 0.037 | 0.055 | 0.118 |
| (2-1-4)  | 0.2242   | 0.1121     | 6               | 0.029 | 0.034 | 0.049 | 0.026 |
| (2-2-1)  | 0.3174   | 0.1587     | 1               | 0.041 | 0.048 | 0.070 | 0.396 |
| (2-2-2)  | 0.2192   | 0.1096     | 7               | 0.028 | 0.033 | 0.048 | 0.001 |
| (2-2-3)  | 0.2364   | 0.1182     | 4               | 0.031 | 0.035 | 0.052 | 0.072 |
| (2-2-4)  | 0.2270   | 0.1135     | 5               | 0.029 | 0.034 | 0.050 | 0.031 |
| Total    | 2        | 1          | -               | 0.259 | 0.300 | 0.441 | 1     |

4. Case study

Surveying related articles and site visits, we have chosen a space with optimal indoor environments. To verify the feasibility of this model, we used the Taipei City “Green Interior Decoration Project” as an example application. Of the 40 “Green Interior Decoration Project” site visits conducted in Taipei City, we selected six projects as subjects for the empirical case study. Four selected cases were decorated with environmentally friendly materials and sound insulation materials, and basis statistical evidence, they should promote environmental protection and energy education. By applying the design technique environment and energy-saving skills, people can experience and understand how to save energy. To facilitate judging interior environment, a brief description of the houses has been presented below.

- **House Case H1**: The estimated renovation costs are about US$8,080/m². Installment plans and bank financing are allowed. The house is over 16 years old and located at the city center, in a noisy environment, but the building quality is moderate.
- **House Case H2**: The estimated renovation costs are about US$7,930/m². Installment plans and bank financing are allowed. The house is over 10 years old and located at the Taipei City Daan District with satisfactory traffic and taxies; however, space is a rather small, and the environmental condition and building quality are moderate.
- **House Case H3**: The estimated renovation costs are about US$6,500/m²; however, payment is on a non-installment basis. The house is over 20 years old and located in the Taipei City Shilin District with less traffic and low taxes, suitable space, and quiet and scenic environmental conditions; however, the building quality is unsatisfactory.
- **House Case H4**: The estimated renovation costs are about US$7,330/m². Installment plans and bank financing are allowed. The house is over 14 years old and located at the Taipei City Neihu District with satisfactory traffic and taxies; however, space is rather small, and the environmental condition and building quality are moderate.

When comparing the four case studies, Case Study H1 is a better model (See Tables 8 and 9 and Figure 3). Thus, the model will be able to adjust the quantized utility function values according to our respondents’ attitude toward risk. When adjusting these values, it is necessary to also update Table 7. A change in the decision elements will affect the relationship between different CEUVs. Thus, decisions can be made to maximize utility.

5. Results and discussion

Research findings

The decision GID Utility-Based Model we used to choose residential interior renovations is based on scientific calculations and empirical case studies. With the proposed approach, the initial residential design of a project can be effectively intervened, so that users or consumers can truly participate in the design, and the residential construction service can be provided in a unique, but non-universal way. Considering the global trend of promoting green energy nowadays, when
Table 7. Cloud expected utility value for criteria.

| Criteria | Overall Wi | Exi | CEUV |
|----------|------------|-----|------|
| (2-1-1)  | 0.1539     | 3.99% | 6.78% |
| (2-1-2)  | 0.1094     | 2.84% | 4.82% |
| (2-1-3)  | 0.1246     | 3.23% | 5.49% |
| (2-1-4)  | 0.1121     | 2.91% | 4.94% |
| (2-2-1)  | 0.1587     | 4.11% | 6.99% |
| (2-2-2)  | 0.1096     | 2.84% | 4.83% |
| (2-2-3)  | 0.1182     | 3.06% | 5.21% |
| (2-2-4)  | 0.1135     | 2.94% | 5.00% |
| Total    | 1          | 25.92% | 44.05% |

Table 8. AHP assessment results for criteria and CEUVs.

| Criteria | Overall Wi- Min | Overall Wi- Max | H1 | H2 | H3 | H4 | H1 | H2 | H3 | H4 |
|----------|-----------------|-----------------|----|----|----|----|----|----|----|----|
| (2-1-1)  | 9.82%           | 16.69%          | 9.27 | 9.27 | 7.21 | 9.27 | 0.88/1.5 | 0.88/1.5 | 0.69/1.17 | 0.88/1.5 |
| (2-1-2)  | 4.96%           | 8.44%           | 6.12 | 7.14 | 6.12 | 6.12 | 0.3/0.51 | 0.3/0.51 | 0.3/0.51 | 0.3/0.51 |
| (2-1-3)  | 6.44%           | 10.94%          | 5.05 | 5.05 | 4.04 | 5.05 | 0.32/0.55 | 0.32/0.55 | 0.26/0.44 | 0.32/0.55 |
| (2-1-4)  | 5.21%           | 8.86%           | 8.16 | 9.18 | 6.12 | 8.16 | 0.42/0.71 | 0.42/0.71 | 0.37/0.57 | 0.42/0.71 |
| (2-2-1)  | 10.45%          | 17.75%          | 8.08 | 9.09 | 5.05 | 9.09 | 0.94/1.6 | 0.94/1.6 | 0.52/0.89 | 0.94/1.6 |
| (2-2-2)  | 4.98%           | 8.47%           | 5.88 | 6.86 | 5.88 | 6.86 | 0.35/0.59 | 0.35/0.59 | 0.35/0.59 | 0.35/0.59 |
| (2-2-3)  | 5.79%           | 9.85%           | 5.88 | 7.84 | 5.88 | 6.86 | 0.41/0.69 | 0.41/0.69 | 0.35/0.59 | 0.41/0.69 |
| (2-2-4)  | 5.34%           | 9.08%           | 5.88 | 6.86 | 4.90 | 6.86 | 0.37/0.64 | 0.37/0.64 | 0.27/0.45 | 0.37/0.64 |
| Total    | 53.00%          | 90.07%          | 54.32 | 61.29 | 45.20 | 58.27 | - | - | - | - |

Table 9. Assessment results for cases H1–H4.

| Criteria | Wi | H1 | H1*Wi | H2 | H2*Wi | H3 | H3*Wi | H4 | H4*Wi |
|----------|----|----|-------|----|-------|----|-------|----|-------|
| (2-1-1)  | 15.39% | 9.27 | 1.39 | 9.27 | 1.39 | 7.21 | 1.08 | 9.27 | 1.39 |
| (2-1-2)  | 10.94% | 6.12 | 0.66 | 7.14 | 0.77 | 6.12 | 0.66 | 6.12 | 0.66 |
| (2-1-3)  | 12.46% | 5.05 | 0.62 | 5.05 | 0.62 | 4.04 | 0.30 | 5.05 | 0.62 |
| (2-1-4)  | 11.21% | 8.16 | 0.90 | 9.18 | 1.01 | 6.12 | 0.67 | 8.16 | 0.90 |
| (2-2-1)  | 15.87% | 8.08 | 1.27 | 9.09 | 1.43 | 5.05 | 0.79 | 9.09 | 1.43 |
| (2-2-2)  | 10.96% | 5.88 | 0.66 | 6.86 | 0.77 | 5.88 | 0.66 | 6.86 | 0.77 |
| (2-2-3)  | 11.82% | 5.88 | 0.71 | 7.84 | 0.95 | 5.88 | 0.71 | 6.86 | 0.83 |
| (2-2-4)  | 11.35% | 5.88 | 0.68 | 6.86 | 0.79 | 4.90 | 0.57 | 6.86 | 0.79 |
| Total    | 54.32 | 6.89 | 61.29 | 7.73 | 45.20 | 5.63 | 58.27 | 7.39 |

ICOWA 0.3401 0.2018 0.2151 0.2430
\[ \tilde{S} = (Ex_1, Ex_2, He_k) \]

Schematic of the assessment results for case study H1-H4.
in pursuit of endless high-end material life, practitioners should also fully recognize their social responsibilities, and endeavour to achieve the goal of green design capable of coexisting with the environment (Akadiri et al., 2012; Chiang 2019; Shen et al. 2017). The use of construction waste management techniques which rely on recycle and reuse of materials has been proven to have economic benefits for the construction industry (Amponsah et al. 2012; Andrić et al. 2017). However, buyers’ participation in the design process is highly limited, and developers usually determine their planning and initial residential design strategies based on experience and intuition. The construction and renovation plans can be designed in a way that promotes environmental protection. Our experimental results provide a practical and unique model for deciding on an indoor environment. In response to environmental changes such as climate and lifestyle, its form, function, and arrangement have constantly evolved. The comfort of living environments can be achieved only through the planning and design of spaces, in which real designers and estate developers should consider the health of homebuyers and corporate social responsibility, thus establishing a corporate image: Some distinguished contributions of this study are as follows:

Based on literature review and experts survey in real estate and interior design industrial domains, we finalize the 16 decision-making factors for company’s users under each GID perspective. In addition, we also select the critical and meaningful decision-making factors by FDM. Initially, 10 decision-making factors under AHP perspective are considered for cloud service selection.

This paper proposed a hybrid GID Utility-Based Model for a cloud service selection using FDM, AHP and Cloud theory. We focus on selecting a GID among cloud services for consumer users.

This study adopts the concept of the green design and design quality indicator to develop a GID selection structure for companies’ users.

Experts agree that inappropriate space planning and energy decisions are a cause of wasted energy efficiency and that such bad decisions can negatively impact people landscapes and the indoor environment. Therefore, it is recommended when making plans related to future living indoor environments or land development projects, one should prioritize corporate social responsibility input, sustainability, and low-carbon emissions.

6. Conclusion

Sustainability, environmentalism, and low-carbon emissions are emphasized in urban development policies. The results of this study can guide policymakers in selecting a suitable GID cloud service compatible with the business strategies and objectives of companies. The findings are summarized as follows. The FDM was used to select key factors to widen and deepen processing according to the opinions of decision-makers. The AHP and cloud theory were then used to determine the weight of each criterion and decision-making factor. Additionally, the utility-based GID model was used to rank alternatives and to select the most favorable cloud service.

From the perspective of green design principles, we determined that the government currently requires developers to research and implement environmentally friendly plans and corporate social responsibility in many building development cases.

At the same time, developers must cater to the needs of residents of all ages, and integrate common design principles in addition to green ones during the planning and design stages in order to increase the comfort and safety of residents. While pursuing economic development, it is important to make decisions that are humane and promote environmental sustainability.

The GID Utility-Based Model is a critical decision support tools that can be utilized to promote and facilitate application in the industry.

This study only considered interior-design companies. Follow-up researchers may expand the scope of respondents to contractors, clients, and engineers to compare the diverse concerns regarding green building materials, automated industries, and smart systems. The government’s responsibility to first provide structured training support to obtain a comprehensive view of industrial development. Although the ultimate goal is similar, the challenges and problems encountered by various teams differ.

Disclosure statement

No potential conflict of interest was reported by the authors.

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