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Exploring the Relevance of Regionalism to the Sustainable Building Assessment Model in Taiwan: Through GBTool2005 Version

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Abstract: From the year 1997, the work for the assessment methods of building environmental performance was prepared by ISO TC 59 SC 17 "Sustainability in building construction". It's definite that the international standard of building environmental performance is a current trend in the overall sustainable buildings. Besides, it provides a reference as a common basis between stakeholders, building owners, design teams, contractors and suppliers, et cetera. This article undertakes the AHP (Analytic Hierarchy Process) method to investigate the international demonstration sustainable building assessment tool, by compiling and completing an experts' questionnaire of professionals, the Government, professors, et cetera, in Taiwan. In addition, this study is aimed at exploring the differences between "different professionals" and "localized characteristics" of the regional effect factor, it applies the ANOVA method to clarify which is regional effect factor correlated with the assessment issues and categories. The result purposes to suit the measure to local conditions, and provide advantageously an information-bed for sustainable building assessment strategies in the future Taiwan as well.

Keywords: Sustainable building, assessment, regionalism, gbtool2005, analytic hierarchy process.

1. INTRODUCTION

Assessment methods are implicitly a synthesis of current environmental knowledge related to buildings, and they can focus a broad range of research through a common filter into a useful framework for design [1, 2]. If sustainable development is to flourish in practice, it must be responsive to the particular context of environmental, social, political, economic and cultural pressures in each region. There are many frames of reference and a multiplicity of issues that cannot all be resolved by one approach [3]. Therefore, using an accepted credible assessment framework can serve as a test-bed for comparing and contrasting the effectiveness of new methods and for setting performance benchmarks [4]. It also provides a way of communicating these issues to building owners and managers, architects, builders, interior designers, landscape architects, community planners, and others interested in the built environment [5]. As well in 1997, within the scope of ISO TC 59 SC 17 "Sustainability in building construction," the International Organization for Standardization tried to standardize criteria and indictors for the performance of buildings; various working groups are presently dealing with questions concerning building performance measurement [6].

In Taiwan, the Government (Architecture and Building Research Institute, Ministry of the Interior, Taiwan) established the "Green Building Evaluation and Labeling System" in 1999 to promote the so-called EEWH system and was regarded as a standard evaluation method for green buildings [7]. As the new EEWH system carried out projects since the year 2005, it is believed to be very reliable, practical and localized for green building evaluation and each indicator has its respective separately-calculating formula [8]. From the evaluated result of utilizing the EEWH system, it still hard to be exchanged region-specific topics with other assessment tools for lacking a common assessment structure, formation and issues, et cetera.

The Green Building Challenge (GBC) process, which involves several countries in the development and testing of a common framework for the assessment of sustainable performance, is of vital importance [9-12]. At the Tokyo SB05 conference, there were 25 teams involved in "the assessment case study session" to achieve the appraisal of many buildings. GBTool2005 is the mass of the sustainable building assessment tools in "the assessment case study session", and it as a reference and basis for developing a domestic assessment method [5, 13, 14]. Therefore, this paper is based on the use of GBTool2005 to carry out the expert questionnaire of the professional, the government and the academia of construction fields in Taiwan, and the application of the ANOVA method to validate a relevance of regionalism to the sustainable building assessment. It is aimed at proposing the critical effect factor of the sustainable building assessment model, and specifically to suit the measuring of Taiwan's conditions.

2. QUESTIONNAIRE METHODOLOGY

There are three steps in this paper, they include: the AHP method (Analytic Hierarchy Process), Normal Distribution,

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and Analysis of Variance (ANOVA). The first step is a survey phase: application of the AHP method to express quantification of the human opinions according to the GBTool2005 system [15]. The following step: employment of "Normal Distribution" to test the validity of investigated weighting values that set up by classifying groups, and then decide weights of respective groups. The final test step is through a basic knowledge of analysis of variance (ANOVA) method to measure the differences of respective groups. The methodology is shown in Fig. (**1**).

2.1. AHP Method (Analytic Hierarchy Process)

In order to express quantification of the human opinion and perception, this paper utilizes the AHP method [16-18]. The AHP modeling process involves four phases: structuring the decision problem, measurement and data collection, determination of normalized weights, and synthesis-finding solutions to the problem [19-23]. Namely, it includes decomposition of the decision-making problem into elements according to their common characteristics and the formation of a hierarchical model having different levels. Each level in the hierarchy corresponds to the common characteristic of the elements in that level.

The hierarchical structure used in formulating the AHP model can enable all members of the evaluation team to visualize the problem systematically in terms of relevant criteria and sub criteria. The team can also provide input to revise the hierarchical structure, if necessary, with additional criteria. Furthermore, using the AHP, the evaluation team can systematically compare and determine the priorities of the criteria and sub criteria.

Forming a Hierarchical Model

This research applied the nominal scale measure to form the AHP hierarchical model according to the GBTool2005 system [24] which consisted of more than three levels. The topmost level is the "total weighted result" of the GBTool2005 system. The second, third and fourth levels correspond to "Issues", "Categories" and "Criteria," but the "Criteria" level contains about 119 items. Therefore, the hierarchical structure positively take the highest three levels in the AHP model for the efficient judgment of the expert questionnaire. The AHP model is shown in Fig. (**2**), and each issue is respectively subdivided into several categories, that is, these categories are classified into the independent issue to set up the hierarchy.

Weighting Method

The issues and categories can be assessed using the basic AHP approach of pairwise comparisons of elements in each level with respect to every parent element located one level above. The nominal-ratio scale of pairwise comparison among the Categories represented as the score from 1 to 9 was adopted, which was filled in a positive reciprocal matrix to calculate the eigenvector and eigenvalue [25]. For each issue and category, the weighting value is obtained by the geometric mean (GMM) of experts' questionnaires, and combining the individual pairwise comparison judgment matrices to obtain the consensus pairwise comparison judgment matrices for the entire team [26, 27]. The investigated weights at the 'Issue' and 'Category' level are calculated according to equation 1 below:

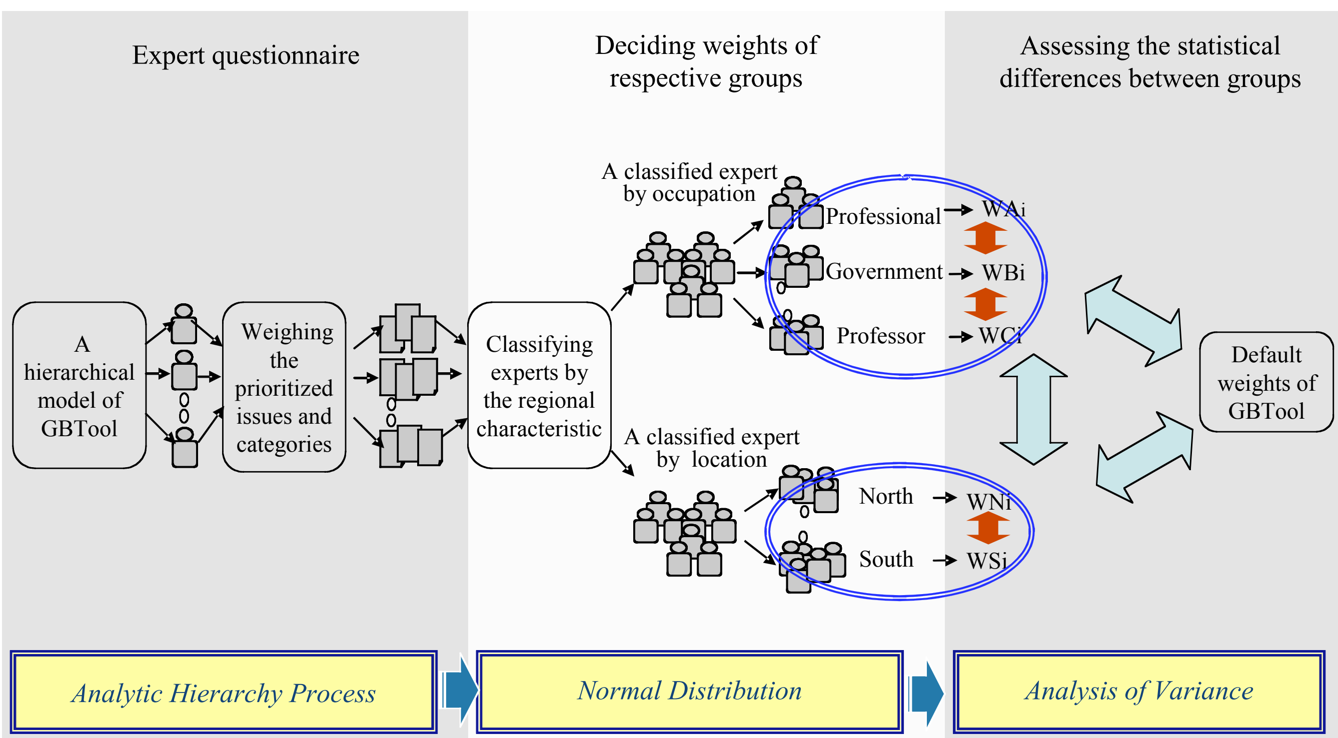

Fig. (1). The methodology of this research.

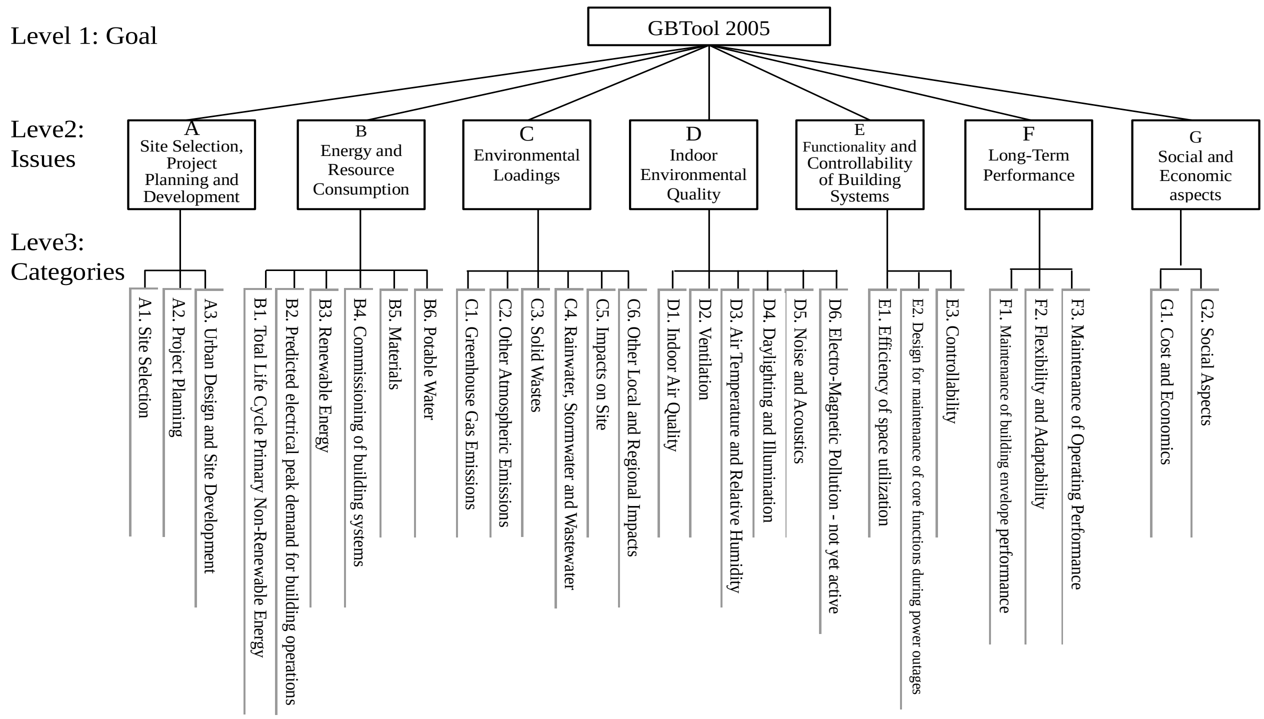

Fig. (2). The AHP model for assessment elements of GBTool2005.

$$W_{A,\,i} = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}}, \text{ for i, j=1, 2, 3…., n} \qquad (1)$$

GMM=$\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}$, where the index A and n implies “Issue” or “Category” level, and the number of “Issue” or “Category”, and $\sum_{i=1}^{n} W_{A,i} = 1$. (this section partially extracted from the published paper of [28])

2.2. Study Group

Sampling Design

Sampling characteristics represent the nature of the sample employed in measure validation research [29]. This research adopts an expert appraisal method that assumed more experience and perhaps more education in filling out questionnaires. Therefore, this sampling design belongs to a “judgment sampling”, also known as purposive selection, of “nonprobability sampling”. Namely, it can be suitable to a small sample from a population and can fulfill the research subject.

Expert Groups

It is important to study the opinions of experts from different fields on an identical platform. Thus, the expertise is involved with “architects and professionals”, “government” and “academia and professors” expert groups, for they play a dominant role in shaping the sustainable building development and drawing up the construction policy in Taiwan.

2.3. Classifying the Expert Questionnaire Results

It is important to explore the influence of the regional characteristic on the sustainable building assessment model. Thus, this study groups the expert questionnaire results according to the effect factor of “occupation” and “location”

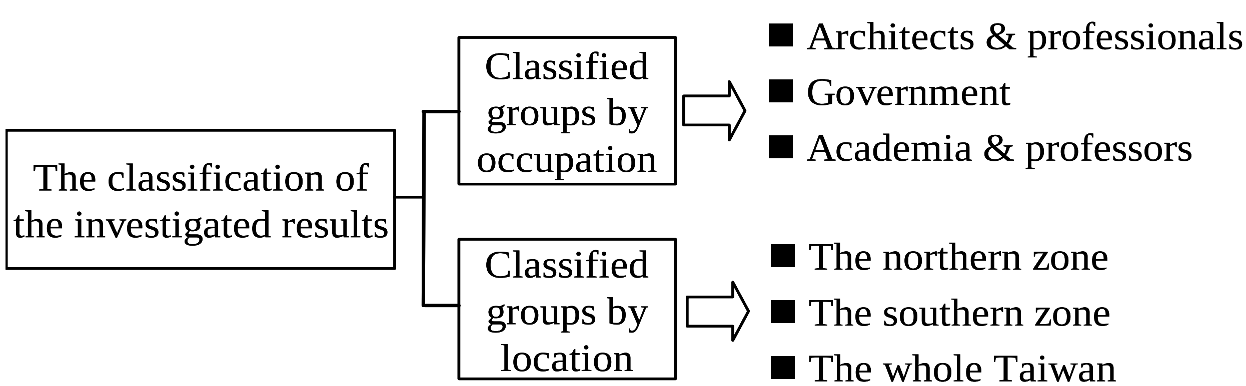

Fig. (3). The classification of the investigated results.

respectively. The classification of the investigated results is shown in Fig. (**3**).

Classified Groups by Occupation

Firstly, classifying all investigated results consistent with the survey expert fields of "architects and professionals", "government," and "academia and professors" groups, in order to point out the differences between Taiwan and other countries on the sustainable building policy, construction development, and current market demand, et cetera.

Classified Groups by Location

The classification of the location factor refers to administrative division of Taiwanese building technique regulations and on the basis of the climatic characteristic, and then can be sorted into three analyzed types by "the Tropic of Cancer": the northern zone, the southern zone and the whole Taiwan. This purpose is to validate the weighting value of building assessment whether partitioned into the northern weighting value, the southern weighting value and the whole Taiwan value, or adopting directly the default weighting value of the GBTool2005 system.

3. APPLYING STATISTICAL QUANTITATIVE ANALYSIS

Are the questionnaire results of psychological tests replicable or repeatable? From recent articles, investigating the reliability and validity of measures has called for explicit attention in marketing research [30]. Accordantly, this paper applies with the reliability estimate and the validity estimate to obtain a proper and valued questionnaire result, and carry out a stable and precise achievement [29].

3.1. Reliability Estimate and Validity Estimate

In research, the term "reliability" means "repeatability" or "consistency." Reliability estimate is the extent to which an experiment, test, or any measuring procedure yields the same result on repeated trials. A measure is considered reliable as low reliability is less detrimental to the performance pretest. But reliability is a necessary but not sufficient condition for validity.

Therefore, "validity" refers to which a study accurately reflects or assesses the specific concept that the researcher is attempting to measure. While "reliability" is concerned with the accuracy of the actual measuring instrument or procedure, "validity' is to measure the results that have the appearance of truth or reality, and provide a useful scheme for assessing the quality of research conclusions.

3.2. Reliability Estimate of Questionnaire Development Procedure

A careful measure development procedure that included defining the domain, searching a variety of sources for items, and specifying and then empirically investigating dimensionality, would increase a measure's reliability [30]. Thus, the reliability estimate of the questionnaire development procedure in this phase included: forming a tool, sampling, and measurement characteristics, etc...

Therefore, based on the GBTool2005 system which was developed by an ad hoc method and generally discussed in the international sustainable building conference, then, can present the relative reliability of forming a tool. In regard to the sampling and measurement characteristics, the sampling design adopts an expert appraisal method that could lead to less measurement error, and the measuring uses the AHP method (Analytic Hierarchy Process) to structure the questionnaire. Accordingly, the questionnaire development pro-

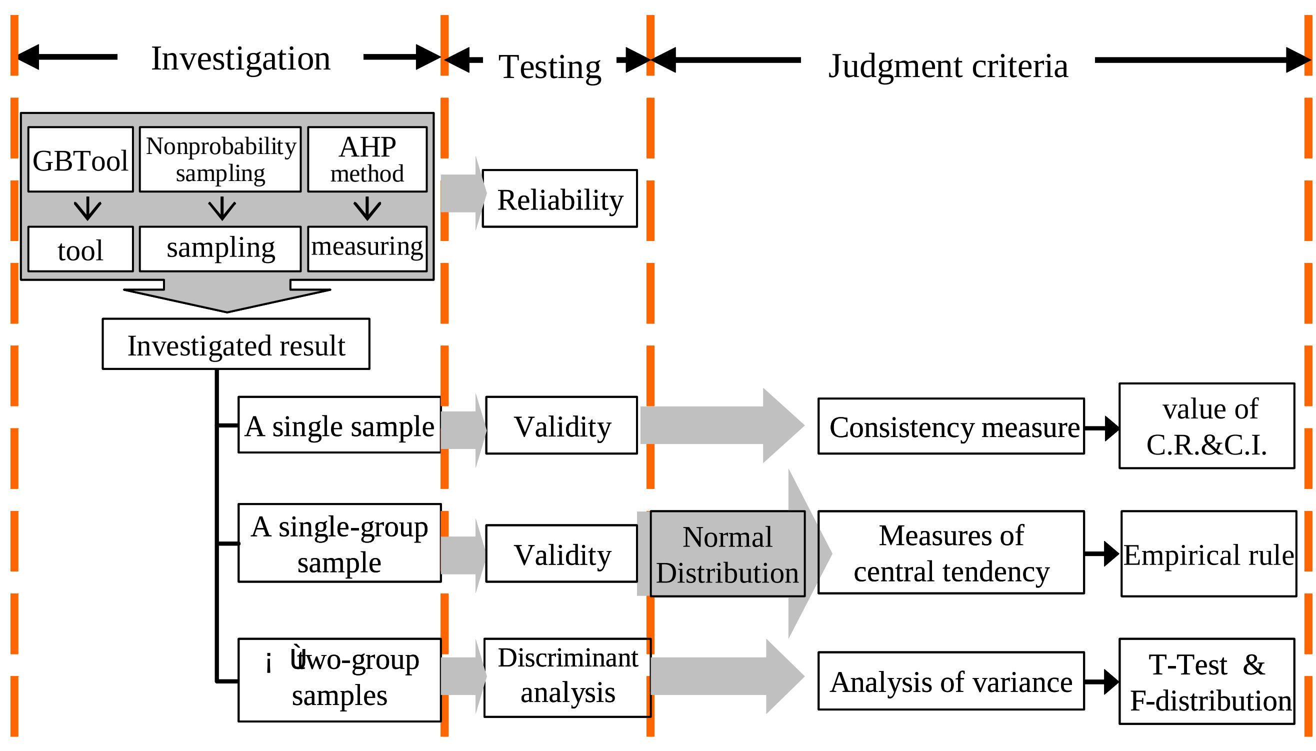

Fig. (4). The methodology of statistical test in this research investigation.

cedure clarifies a high "reliability."

3.3. Validity of Questionnaire Result

The testing analysis of questionnaire result is rested with the exploring cause, which grouped the questionnaire results to the primary types of a single sample, a single-group sample, and beyond two-group samples.

A Single Sample

In order to test the validity of a single questionnaire result, it utilizes the consistency index (C.I.) of AHP method as a judgment criterion. The consistency ratio was obtained to filter out the null questionnaire when the C.I. value was greater than 0.1.

A Single-Group Sample

Considering the research subject, the questionnaire results classified to several single-group samples. Then, this study adopts a statistical inference of "normal distribution" which involved the judgment criteria of "empirical rule", examining the validity of the group questionnaire results.

Beyond Two-Group Samples

After the foregoing sifting of the validity of the single-group samples, this paper proceeds to a discriminant analysis among beyond-two-group samples. Therefore, it utilizes ANOVA of T-test and F-distribution method as a judgment criterion to examine the difference among the grouped questionnaire results. The methodology of the statistical test is shown in Fig. (**4**).

3.4. Normal Distribution

The normal distribution is the most used statistical distribution. The principal reasons are: Normality arises naturally in many physical, biological, and social measurement situations.

All normal distributions are symmetric and have bell-shaped density curves with a single peak. In general, the normal distribution curve is described by the following probability density function. Therefore, the normal density of investigated weights can be actually specified by means of equation 2. The height of the density at any weighting value x can be formulated by:

$$f\ (x)\ =\frac{1}{\sigma\sqrt{2\pi}}\ e^{-\frac{1}{2}\left[\frac{x-\mu}{\sigma}\right]} \qquad (2)$$

where the index μ and σ implies the mean that peak of the density occurs, and the standard deviation.

Specifically, if the data appears to follow a normal distribution, then the empirical rule is preferred as it is more positive.

Empirical Rule

The empirical rule is a handy quick estimate of the data given the mean(μ) and standard deviation(σ) of a data set that follows the normal distribution.

If a variable is normally distributed, according to the rule: within one standard deviation of the mean there will be approximately 68% of the data, i.e. in the interval $\mu \pm\sigma$; within two standard deviations of the mean there will be approximately 95% of the data, i.e. in the interval $\mu \pm2\sigma$; and within three standard deviations of the mean there will be approximately 99.7% of the data i.e. in the interval $\mu \pm3\sigma$. Then, the data distribution can fill a measure of central tendency.

Therefore, this study will apply the criteria of the empirical rule as a measure of central tendency to examine the validity of several single-group questionnaire results.

4. TESTING THE INVESTIGATION RESULT OF ASSESSMENT WEIGHTING VALUES

This study sent out 50 copies to investigative experts, and received back 43 copies, which gives a response rate of 95%. This section subsequently estimates the validity of "a single questionnaire result" and "a single-group questionnaire results."

4.1. Measuring the Validity of a Single Questionnaire Result

After filtering out the null questionnaire by the value of C.R. and C.I. that internal consistency measure of AHP method, there were 36 expertise copies that belonged to the valid questionnaire. The number of experts under consultation is 36, inclusive of twelve professionals, nine government, and professors. The total valid questionnaire experts also can be split into eighteen experts of the northern zone and eighteen experts of the southern zone according to the location factor. The expert distribution of the valid questionnaire results is shown in Fig. (**5**).

4.2. Measuring the Validity of a Single Group Result on the Issue Level

With regard to the AHP expert questionnaire of the "Issues" level of the GBTool2005 system, this part applies the criteria of Empirical Rule to examine the validity of several single-group questionnaire results via "normal distribution" and "the central tendency test."

Measuring a Central Tendency of All Expert Questionnaire Results

Table **1** depicts a group test analysis on the investigated result of all experts by Empirical Rule, and all calculations of the "Issue" level conform to a measure of central tendency.

Measuring a Central Tendency of Classified Groups by a Location Factor

The major portion of issues obtained from the southern expert results conforms to a measure of central tendency. Just "B Energy and Resource Consumption" which 56% of the data are lie in the interval $\mu \pm \sigma$ displays the entire southern expert result has a low validity on this issue at the present Taiwan. However, the whole issues of the northern expert results all filled to a measure of central tendency. (Table **2**) shows a group test analysis on the investigated result of the location classified experts by Empirical Rule.

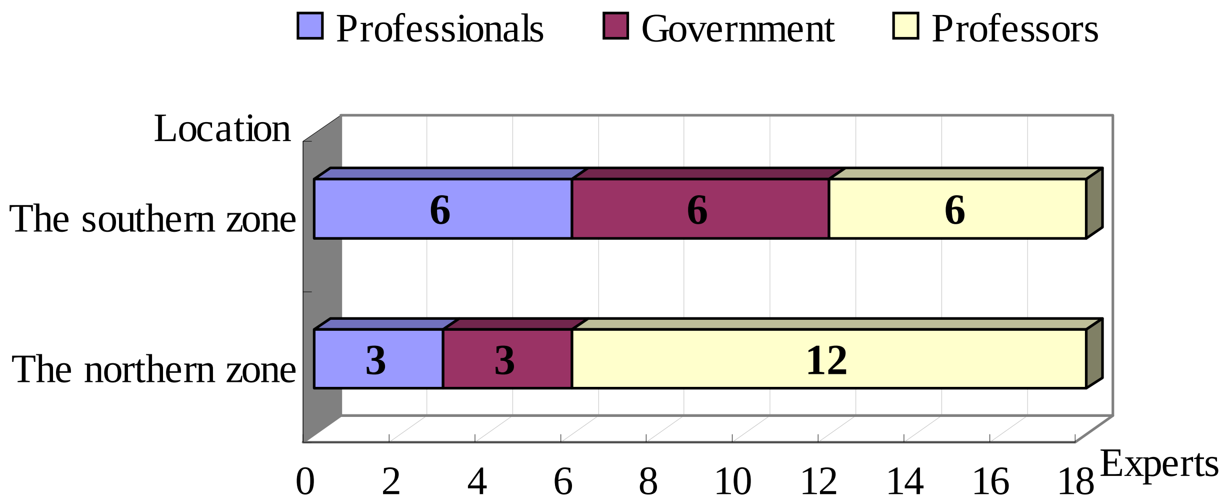

Fig. (5). The expert distribution of the valid questionnaire results.

Measuring a Central Tendency of Classified Groups by an Occupation Factor

With regard to the professional expert results, there are three issues that contain "A Site Selection, Project Planning and Development," "D Indoor Environmental Quality" and "E Functionality and Controllability of Building Systems" which can not fall in the interval $\mu \pm \sigma$, and also display a dispersive judgment in the present Taiwan. Moreover, there are two issues: "E Functionality and Controllability of Building Systems" and "G Social and Economic aspects" of the government expert results which display an invalid central tendency. However, the academics experts merely have one issue: "B Energy and Resource Consumption" that is 61% of the data in the interval $\mu \pm \sigma$, and do not have a marked central tendency. The central tendency test of three groups on the investigated result of issues is given in Table **3**.

4.3. Measuring the Validity of a Single Group Result on the Category Level

Overall questionnaire experts, only the "E Functionality and Controllability of Building Systems" issue that possessed of above 50% "invalid" category items, and then this issue display an invalid measure of central tendency. About

Table 1. A Group Test on the Investigated Result of All Experts by Empirical Rule

Issues of GBTool2005	All Experts	Criteria
A Site Selection, Project Planning and Development	89%	Examining values between $\mu \pm \sigma$
	validity	Measuring a central tendency
B Energy and Resource Consumption	81%	Examining values between $\mu \pm \sigma$
	validity	Measuring a central tendency
C Environmental Loadings	83%	Examining values between $\mu \pm \sigma$
	validity	Measuring a central tendency
D Indoor Environmental Quality	81%	Examining values between $\mu \pm \sigma$
	validity	Measuring a central tendency
E Functionality and Controllability of Building Systems	68%	Examining values between $\mu \pm \sigma$
	validity	Measuring a central tendency
F Long-Term Performance	72%	Examining values between $\mu \pm \sigma$
	validity	Measuring a central tendency
G Social and Economic aspects	69%	Examining values between $\mu \pm \sigma$
	validity	Measuring a central tendency

Table 2. A Group Test on the Investigated Result of the Location Classified Experts by Empirical Rule

Issues of GBTool2005	18 Experts of the Northern Zone	18 Experts of the Northern Zone	Criteria
A Site Selection, Project Planning and Development	72%	83%	Examining values between μ ± σ
	validity	validity	Measuring a central tendency
B Energy and Resource Consumption	68%	56%	Examining values between μ ± σ
	validity	invalidity	Measuring a central tendency
C Environmental Loadings	78%	72%	Examining values between μ ± σ
	validity	validity	Measuring a central tendency
D Indoor Environmental Quality	72%	68%	Examining values between μ ± σ
	validity	validity	Measuring a central tendency
E Functionality and Controllability of Building Systems	83%	72%	Examining values between μ ± σ
	validity	validity	Measuring a central tendency
F Long-Term Performance	83%	83%	Examining values between μ ± σ
	validity	validity	Measuring a central tendency
G Social and Economic aspects	78%	78%	Examining values between μ ± σ
	validity	validity	Measuring a central tendency

Table 3. A Group Test on the Investigated Result of the Occupation Classified Experts by Empirical Rule

Issues of GBTool2005	9 Experts of Professional	9 Experts of Government	18 Experts of Professor	Criteria
A Site Selection, Project Planning and Development	**56%**	68%	89%	Examining values between μ ± σ
	invalidity	validity	validity	Measuring a central tendency
B Energy and Resource Consumption	68%	68%	72%	Examining values between μ ± σ
	validity	validity	validity	Measuring a central tendency
C Environmental Loadings	68%	78%	**61%**	Examining values between μ ± σ
	validity	validity	**invalidity**	Measuring a central tendency
D Indoor Environmental Quality	**56%**	78%	78%	Examining values between μ ± σ
	invalidity	validity	validity	Measuring a central tendency
E Functionality and Controllability of Building Systems	**44%**	**Not a normal distribution**	83%	Examining values between μ ± σ
	invalidity		validity	Measuring a central tendency
F Long-Term Performance	89%	78%	78%	Examining values between μ ± σ
	validity	validity	validity	Measuring a central tendency
G Social and Economic aspects	78%	**56%**	78%	Examining values between μ ± σ
	validity	**invalidity**	validity	Measuring a central tendency

the northern and southern zone expert groups: all categories of the northern zone expert results completely conform to a measure of central tendency; but the southern zone expert results involve of three issues display an invalid measurement that each issue contains above 50% "invalid" category items. With regard to the professional expert questionnaire, there are three issues that each issue contains above 50% "invalid" category items which represent an untrue measure of central tendency as well. However, the measurements of the professor and government only have one issue which

Table 4. A Group Test Analysis on the Investigated Result on the Category level by Empirical Rule

Assessment Categories \ Each expert group result		All experts	Location classified experts		Occupation classified experts		
			North	South	Professor	Professional	Government
A	Site Selection, Project Planning & Development						
A1	Site selection	Validity 72%	Validity 78%	*Invalidity 61%*	Validity 94%	*Invalidity 66%*	Validity 68%
A2	Project planning	Validity 72%	Validity 89%	*Invalidity 61%*	Validity 72%	*Invalidity 66%*	Validity 68%
A3	Urban design and site development	Validity 75%	Validity 83%	Validity 68%	Validity 68%	*Invalidity 66%*	Validity 100%
B	Energy and Resource Consumption						
B1	Total life cycle primary non-renewable energy	Validity 81%	Validity 83%	Validity 72%	Validity 78%	Validity 68%	Validity 68%
B2	Predicted electrical peak demand for building operations	Validity 81%	Validity 89%	Validity 89%	Validity 72%	Validity 89%	Validity 89%
B3	Renewable energy	Validity 68%	Validity 72%	*Invalidity 56%*	*Invalidity 61%*	Validity 68%	*Invalidity 22%*
B4	Commissioning of building systems	Validity 78%	Validity 78%	Validity 78%	Validity 68%	Validity 89%	Validity 78%
B5	Materials	Validity 78%	Validity 83%	*Invalidity 56%*	Validity 72%	*Invalidity 66%*	Validity 68%
B6	Potable water	Validity 78%	Validity 83%	Validity 78%	Validity 72%	Validity 78%	Validity 78%
C	Environmental Loadings						
C1	Greenhouse gas emissions	Validity 72%	Validity 83%	Validity 68%	*Invalidity 61%*	Validity 68%	Validity 68%
C2	Other atmospheric emissions	Validity 82%	Validity 68%	Validity 68%	*Invalidity 61%*	Validity 89%	Validity 68%
C3	Solid wastes	Validity 83%	Validity 89%	Validity 72%	Validity 78%	Validity 78%	Validity 78%
C4	Rainwater, stormwater and wastewater	Validity 72%	Validity 72%	Validity 72%	*Invalidity 56%*	Validity 78%	Validity 78%
C5	Impacts on site	Validity 72%	Validity 78%	Validity 83%	*Invalidity 61%*	Validity 68%	Validity 89%
C6	Other local and regional impacts	Validity 78%	Validity 78%	Validity 68%	*Invalidity 61%*	Validity 68%	Validity 100%
D	Indoor Environmental Quality						
D1	Indoor air quality	Validity 72%	Validity 78%	Validity 72%	*Invalidity 61%*	*Invalidity 44%*	Validity 78%
D2	Ventilation	Validity 75%	Validity 83%	Validity 78%	Validity 72%	*Invalidity 66%*	Validity 78%
D3	Air temperature and relative humidity	Validity 78%	Validity 68%	Validity 89%	*Invalidity 61%*	Validity 78%	Validity 68%
D4	Daylighting and illumination	*Invalidity 58%*	Validity 78%	Validity 68%	Validity 78%	*Invalidity 66%*	Validity 68%
D5	Noise and acoustics	Validity 82%	Validity 78%	Validity 89%	Validity 78%	Validity 89%	Validity 78%
D6	Electro-magnetic pollution - not yet active	Validity 78%	Validity 83%	Validity 72%	Validity 83%	Validity 78%	Validity 78%
E	Functionality & Controllability of Building Systems						
E1	Efficiency of space utilization	*Invalidity 56%*	Validity 78%	Validity 68%	Validity 72%	*Invalidity 66%*	Validity 78%
E2	Design for maintenance of core functions outside of planned design conditions	*Invalidity 64%*	Validity 78%	*Invalidity 44%*	Validity 68%	*Invalidity 66%*	Validity 78%
E3	Controllability	Validity 81%	Validity 89%	*Invalidity 61%*	Validity 83%	Validity 78%	Validity 78%

Table 4. (Contd….

Assessment Categories \ Each expert group result		All experts	Location classified experts		Occupation classified experts		
			North	South	Professor	Professional	Government
F	Long-Term Performance						
F1	Flexibility and adaptability	Validity 81%	Validity 94%	Validity 78%	*Invalidity 61%*	Validity 78%	Validity 78%
F2	Maintenance of operating performance	Validity 81%	Validity 78%	Validity 72%	Validity 72%	Validity 78%	Validity 72%
G	Social and Economic aspects						
G1	Cost and economics	Validity 75%	Validity 94%	*Invalidity 61%*	Validity 72%	Validity 78%	*Invalidity 66%*
G2	Social aspects	Validity 81%	Validity 78%	*Invalidity 56%*	Validity 72%	Validity 78%	*Invalidity 66%*

Illustrated issue contains above 50% items of the category that cannot past the central tendency test.

Table 5. A Group Test Analysis on the Investigated Result on the Issue Level and the Category Level of GBTool2005 by Empirical Rule

Assessment Issues	All experts	Location classified experts		Occupation classified experts		
		North	South	Professor	Professional	Government
A. Site Selection, Project Planning & Development	●○	●○	●	●○		●○
B. Energy And Resource Consumption	●○	●○	○	●○	●○	●○
C. Environmental Loadings	●○	●○	●○		●○	●○
D. Indoor Environmental Quality	●○	●○	●○	●○		●○
E. Functionality & Controllability Of Building Systems	●	●○	●	●○		○
F. Long-Term Performance	●○	●○	●○	●○	●○	●○
G. Social And Economic Aspects	●○	●○	●	●○	●○	

● Validity issue via the central tendency test; ○Validity category via the central tendency test.

cannot fill a measure of central tendency respectively. Table **4** displays a group test analysis of the investigated result.

4.4. Summarizing a Central Tendency Measure of the Investigation Result

On the basis of the foregoing examining the validity of the group questionnaire results, the issues and the categories of GBTool2005 correspond to the Empirical Rule test in the majority, and still have some items of the southern zone expert and the professional expert group which have not yet reached the judgment of a central tendency measure yet. A group test analysis as shown in Table **5**.

4.5. The Investigation Result of Assessment Weighting Values

This AHP approach derives the weights of the different expert groups indicated that the experts empirically express their opinions on the practical aspects of the recent period and the domestic situation.

The weighting value of all experts is listed in sequence: "C Environmental Loadings" (0.211), "B Energy and Resource Consumption" (0.186), "D Indoor Environmental Quality" (0.162), "A Site Selection, Project Planning and Development" (0.118), "F Long-Term Performance" (0.111), "G Social and Economic aspects" (0.107), "E Functionality and Controllability of Building Systems" (0.105). The location classified group experts of the northern zone and the southern zone, of which the priority weighting value are: "C Environmental Loadings" (0.211) and "B Energy and Resource Consumption" (0.207) respectively. The occupation classified group experts of professors and professionals, of which the priority weighting value are also: "C Environmental Loadings" (0.234) and "B Energy and Resource Consumption" (0.197) respectively.

Interestingly, the weighting value of the three issues: "C Environmental Loadings", "B Energy and Resource Consumption", and "D Indoor Environmental Quality" obviously exceeded the other four issues which the weighting value are approximate 0.1. It means that "C Environmental Loadings", "B Energy and Resource Consumption", and "D Indoor Environmental Quality" are the critical issues of the sustainable building assessment in Taiwan.

Fig. (**6**) illustrates the investigated weight of the "Issues" level according to the group expert pattern. In addition, the complete investigated weight of the "Issues" and "Categories" is shown in Table **6**.

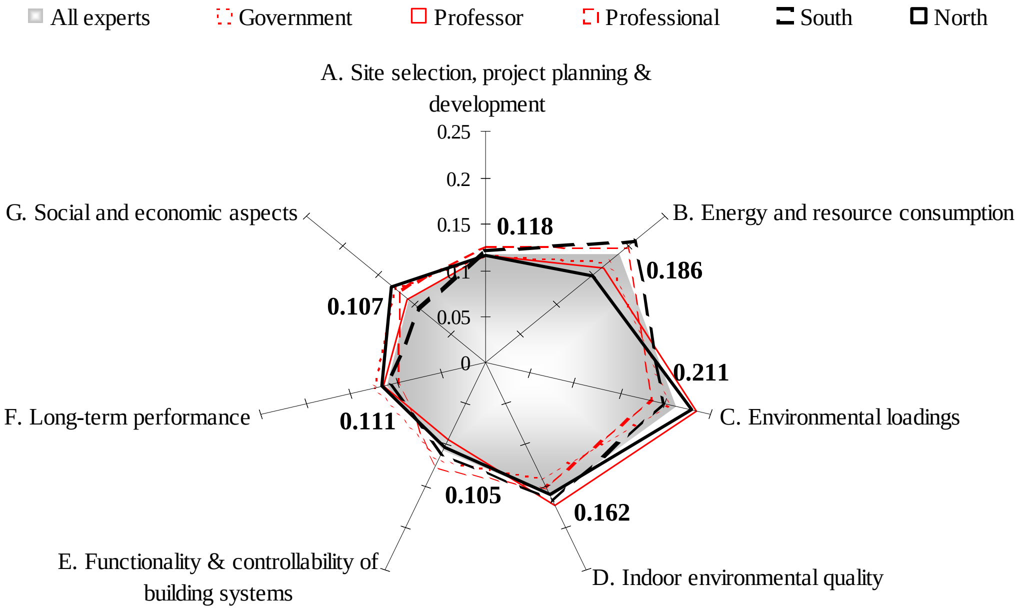

Fig. (6). The investigated weight of the different group expert patterns on the "Issues" level.

5. ANALYZING A RELEVANCE OF A CRITICAL REGIONAL FACTOR TO THE ASSESSMENT ISSUES

The foregoing is the majority of the single group test analysis on the Issue level and the Category level of GBTool2005 which consist with the validity of a central tendency measure. Therefore, the subsequent analysis based on "T-test" and "F-distribution" of ANOVA approach to assess the statistical differences of the investigated values between "without and within classified groups", and compare with default weights of GBTool2005. Aiming to identify whether "location effect" or "occupation effect" is the most influential parameter of classification.

5.1. An Analysis of "Location"

Comparison Between the Northern Experts and the Southern Experts

The analysis of variance between the investigated values of the northern expert group and the southern expert group is: "B Energy and Resource Consumption" and "G Social and Economic aspects" both present T-value> | Critical value | . The T-test is significant at P-value <α(0.05), and then the null hypothesis that there are no differences between the northern experts and the southern experts on these two issues should be rejected. Thus it should use different weighting values for the northern zone and the southern zone on the two issues when appraising buildings by GBTool2005. The T-test result is shown in Table **7**.

Table **8** reports the contrast between the default weights of GBTool2005 with the investigated weight of the northern experts and the southern experts respectively. The ANOVA analysis between the investigated values of the southern expert group and the default weights included: "E Functionality and Controllability of Building Systems", "F Long-Term Performance" and "G Social and Economic aspects" present T-value> | Critical value | . The T-test is significant at P-value <α(0.05), that is, the null hypothesis is rejected that there is significantly large different between the default weights of GBTool2005 and the southern experts on these three issues. The ANOVA analysis between the investigated values of the default weights and northern expert group is: "B Energy and Resource Consumption" and "F Long-Term Performance" present T-value> | Critical value | . The T-test is significant at P-value <α(0.05), and the null hypothesis that there is significantly large difference between the default weights and the northern experts on the two issues.

5.2. An Analysis of "Occupation Effect"

Comparison Among the Occupation Classified Expert Groups

Consider these occupation classified expert groups composed of three independent samples: professional, government, and professor. The next step utilizes F-test involving the examination of the difference. In Table **9** it is seen that F-value> | Critical value | , and the calculation proves the null hypothesis that there is no differences among the three occupation classified expert groups is true.

The comparison of the default weights of GBTool2005 with three investigated weights of professional, government, and professor respectively is shown in Table **10**.

The ANOVA test between the investigated values of the default weights and the professional expert group presents that T-value> | Critical value | at the "E Functionality and Controllability of Building Systems" issue. It means the construction professional pays more attentions on "E Functionality and Controllability of Building Systems."

The analysis of variance between the default weights and the government expert group is: "B Energy and Resource Consumption" and "F Long-Term Performance" present T-value> | Critical value | . However, the investigated weight of "F Long-Term Performance" is higher than the default weight of GBTool2005. Namely, it indicates the government highlights the importance of the "F Long-Term Performance" issue on the current sustainable construction field.

Table 6. The Investigated Weights of Each Expert Group on "Issues" and "Categories" Level

Assessment Issues \ Investigated weights	All experts	Location classified experts		Occupation classified experts		
		North	South	Professor	Professional	Government
A. Site selection, project planning & development	**0.118**	**0.116**	**0.121**	**0.125**	**0.116**	**0.116**
A1.Site selection	0.315	0.343	0.305	0.315	0.315	0.315
A2. Project planning	0.330	0.320	0.334	0.320	0.327	0.355
A3. Urban design and site development	0.355	0.337	0.361	0.365	0.363	0.330
B. Energy and Resource Consumption	**0.186**	**0.148**	**0.207**	**0.197**	**0.171**	**0.164**
B1. Total life cycle primary non-renewable energy	0.174	0.168	0.180	0.185	0.195	0.205
B2. Predicted electrical peak demand for building operations	0.138	0.142	0.135	0.099	0.126	0.157
B3. Renewable energy	0.184	0.175	0.190	0.191	0.214	0.180
B4. Commissioning of building systems	0.164	0.168	0.160	0.172	0.134	0.175
B5. Materials	0.145	0.131	0.160	0.187	0.155	0.123
B6. Potable water	0.195	0.216	0.175	0.166	0.176	0.160
C. Environmental Loadings	**0.211**	**0.228**	**0.197**	**0.183**	**0.204**	**0.234**
C1. Greenhouse gas emissions	0.183	0.164	0.210	0.167	0.223	0.178
C2. Other atmospheric emissions	0.123	0.124	0.126	0.100	0.127	0.137
C3. Solid wastes	0.172	0.175	0.171	0.178	0.175	0.168
C4. Rainwater, stormwater and wastewater	0.172	0.163	0.186	0.18	0.184	0.166
C5. Impacts on site	0.175	0.192	0.152	0.195	0.148	0.175
C6. Other local and regional impacts	0.175	0.182	0.155	0.180	0.143	0.176
D. Indoor Environmental Quality	**0.162**	**0.16**	**0.166**	**0.152**	**0.14**	**0.172**
D1. Indoor air quality	0.222	0.217	0.225	0.231	0.213	0.221
D2. Ventilation	0.214	0.203	0.24	0.214	0.215	0.216
D3. Air temperature and relative humidity	0.164	0.175	0.158	0.156	0.187	0.168
D4. Daylighting and illumination	0.165	0.153	0.177	0.180	0.165	0.154
D5. Noise and acoustics	0.135	0.135	0.123	0.134	0.120	0.131
D6. Electro-magnetic pollution - not yet active	0.100	0.117	0.077	0.085	0.100	0.110
E. Functionality & Controllability of Building Systems	**0.105**	**0.102**	**0.109**	**0.125**	**0.117**	**0.092**
E1. Efficiency of space utilization	0.334	0.343	0.329	0.423	0.494	0.346
E2. Design for maintenance of core functions outside of planned design conditions	0.336	0.324	0.352	0.265	0.249	0.361
E3. Controllability	0.330	0.344	0.319	0.312	0.258	0.294
F. Long-Term Performance	**0.111**	**0.115**	**0.109**	**0.097**	**0.124**	**0.114**
F1. Flexibility and adaptability	0.449	0.469	0.435	0.417	0.513	0.467
F2. Maintenance of operating performance	0.551	0.531	0.565	0.583	0.487	0.533

Table 6. Contd….

Assessment Issues \ Investigated weights	All experts	Location classified experts		Occupation classified experts		
		North	South	Professor	Professional	Government
G. Social and Economic aspects	**0.107**	**0.131**	**0.091**	**0.121**	**0.128**	**0.108**
G1. Cost and economics	0.509	0.465	0.556	0.503	0.502	0.531
G2. Social aspects	0.491	0.535	0.444	0.497	0.498	0.469

Table 7. T-Test for the Southern Expert Group and the Northern Expert Group on the Investigated Weight of "Issue"

Assessment Issues	Weights of the southern experts	Weights of the northern experts	T-value	DF*	P-value (two-tailor)	Critical value	Statistically significant
A Site Selection, Project Planning and Development	0.121	0.116	0.071	34	0.944	±2.0336	No
B Energy and Resource Consumption	0.207	0.148	2.938	34	0.006	±2.0336	Yes
C Environmental Loadings	0.197	0.228	-1.334	34	0.191	±2.0336	No
D Indoor Environmental Quality	0.166	0.160	0.924	34	0.362	±2.0336	No
E Functionality and Controllability of Building Systems	0.109	0.102	0.391	34	0.698	±2.0336	No
F Long-Term Performance	0.109	0.115	-0.444	34	0.660	±2.0336	No
G Social and Economic aspects	0.091	0.131	-2.445	34	0.020	±2.0336	Yes

* DF=Degree of freedom; n= (North sample18) + (South sample18)-2=34.
Comparison with the default weights of GBTool2005.

Table 8. T-test for the Default Weights of GBTool2005 with the Investigated Weight of the Northern Experts and the Southern Experts on the "Issue" Level

Assessment issues	GBTool2005 (default)	Critical value (α=0.05)	Experts of the southern zone*			Experts of the northern zone*		
			weights	T-value	Statistically significant	weights	T-value	Statistically significant
A Site Selection, Project Planning and Development	0.125	±2.110	0.121	-0.0311	No	0.116	-0.0669	No
B Energy and Resource Consumption	0.208	±2.110	0.207	-0.2184	No	0.148	-6.0879	Yes
C Environmental Loadings	0.208	±2.110	0.197	-1.0985	No	0.228	0.8375	No
D Indoor Environmental Quality	0.167	±2.110	0.166	-0.3230	No	0.160	-0.8361	No
E Functionality and Controllability of Building Systems	0.083	±2.110	0.109	2.3401	Yes	0.102	1.5972	No
F Long-Term Performance	0.083	±2.110	0.109	2.1900	Yes	0.115	2.3069	No
G Social and Economic aspects	0.125	±2.110	0.091	-2.6691	Yes	0.131	1.1819	Yes

* DF=Degree of freedom; n= (North sample18) or (South sample18)-1=17.

Table 9. F-Distribution for Professional, Government and Professor Expert Groups on the Investigated Weight of "Issue"

Assessment Issues	Professional	Government	Professor	F-value	DF [*1]	Critical Value [*2]	Statistically Significant
A Site Selection, Project Planning and Development	0.125	0.116	0.116	0.110	33	3.293(0.051)	No
B Energy and Resource Consumption	0.197	0.171	0.164	1.689	33	3.293(0.051)	No
C Environmental Loadings	0.183	0.204	0.234	1.782	33	3.293(0.051)	No
D Indoor Environmental Quality	0.152	0.14	0.172	1.377	33	3.293(0.051)	No
E Functionality and Controllability of Building Systems	0.125	0.117	0.092	1.820	33	3.293(0.051)	No
F Long-Term Performance	0.097	0.124	0.114	0.927	33	3.293(0.051)	No
G Social and Economic aspects	0.121	0.128	0.108	0.226	33	3.293(0.051)	No

*1 DF=Degree of freedom; n= (Total sample36)-3=33.
*2 Critical value: F-value < 3.293 or F-value > 0.051, there is significant difference among theses three independent samples.
Comparison with the default weights of GBTool2005.

Table 10. T-test for the Default Weights of GBTool2005 with the Investigated Weight of Professional, Government and Professor Expert Groups on the "Issue" Level

Assessment Issues	GBTool2005 (default)	Professional [*1]			Government [*1]		Professor [*2]		
		Critical value (α=0.05)	T-value	Statistically significant	T-value	Statistically significant	Critical value (α=0.05)	T-value	Statistically significant
A Site Selection, Project Planning and Development	0.125	±2.306	-0.021	No	0.186	No	±2.101	0.183	No
B Energy and Resource Consumption	0.208	±2.306	-0.038	No	-2.573	Yes	±2.101	-3.972	Yes
C Environmental Loadings	0.208	±2.306	-1.596	No	-0.669	No	±2.101	1.146	No
D Indoor Environmental Quality	0.167	±2.306	-1.147	No	-2.180	No	±2.101	0.117	No
E Functionality and Controllability of Building Systems	0.083	±2.306	2.579	Yes	1.755	No	±2.101	0.791	No
F Long-Term Performance	0.083	±2.306	0.784	No	2.594	Yes	±2.101	1.861	No
G Social and Economic aspects	0.125	±2.306	-0.045	No	0.255	No	±2.101	-0.787	No

*1 DF=Degree of freedom; n= (Professional sample9) or (Government9)-1=8; Critical value=±2.306.
*2 DF=Degree of freedom; n= (Professor sample18)-1=17; Critical value=±2.101.

6. DETERMINE A CRITICAL REGIONAL FACTOR

6.1. "Location Effect" vs. "Occupation Effect" on the Issue Level

Refer to the aforementioned ANOVA measurements. From (Table **11**) it is clear that there is a significant variance between the southern expert group and the northern expert group on the two issues: "B Energy and Resource Consumption" and "G Social and Economic aspects". In addition, there is no difference among the occupation classified expert groups. Accordingly, the "location effect" is a critical regional factor to determine the sustainable assessment issues of GBTool2005 for appraising buildings in Taiwan.

6.2. The Investigated Weight vs. the Default Weight on the Issue Level

In Table **12** it is seen the calculation proves that there is a significant difference between the investigated average weights and the default weights on "B Energy and Resource Consumption", "E Functionality and Controllability of Building Systems" and "F Long-Term Performance". Specifically, the investigated weights of "E Functionality and Controllability of Building Systems" and "F Long-Term Performance" are both larger than the default weights. It indicates that Taiwan's experts suggest paying more attention to the two issues on the sustainable building assessment aspect.

6.3. A Discussion on the Assessment Categories

This phase still applies the ANOVA method to measure the variance within "the location classified expert groups" and "the occupation classified expert groups" respectively on the category level. However, there are no differences not only between the northern zone experts and the southern zone experts, and but also among professional, government, and professor. Thus, "location effect" and "occupation ef-

Table 11. The ANOVA Analysis for Comparison Between "Location Effect" and "Occupation Effect" on the "Issue" Level

Assessment Issues	Location Classified Experts		Occupation Classified Experts		
	Southern Experts	Northern Experts	Professional	Government	Professor
A Site Selection, Project Planning and Development	–	–	–	–	–
B Energy and Resource Consumption	▲	▼	–	–	–
C Environmental Loadings	–	–	–	–	–
D Indoor Environmental Quality	–	–	–	–	–
E Functionality and Controllability of Building Systems	–	–	–	–	–
F Long-Term Performance	–	–	–	–	–
G Social and Economic aspects	▼	▲	–	–	–

▲ It means the weighting value is significant higher by the ANOVA analysis.
▼ It means the weighting value is significant higher by the ANOVA analysis.
– It means the weighting value is no significant variance.

Table 12. T-test for the Default Weights of GBTool2005 with the Investigated Weight of All Experts on the "Issue" Level

Assessment Issues	GBTool2005 (Default)	All Experts (Taiwan)	T-Value	DF	Critical Value (α=0.05)	Statistically Significant
A Site Selection, Project Planning and Development	0.125	0.118	-0.0309	35	±2.0315	No
B Energy and Resource Consumption	0.208	0.186	-2.9762	35	±2.0315	Yes
C Environmental Loadings	0.208	0.211	0.0176	35	±2.0315	No
D Indoor Environmental Quality	0.167	0.162	-1.4239	35	±2.0315	No
E Functionality and Controllability of Building Systems	0.083	0.105	2.7895	35	±2.0315	Yes
F Long-Term Performance	0.083	0.111	3.2055	35	±2.0315	Yes
G Social and Economic aspects	0.125	0.107	-0.4331	35	±2.0315	No

fect" can not be regard as a classified treatment on the category level in Taiwan.

Table **13** reports a significant difference between all the investigated weights and the default weights such as these categories mostly within "B Energy and Resource Consumption", "C Environmental Loadings" and "D Indoor Environmental Quality" issues.

7. CONCLUSION

Based on the assessment framework of GBTool2005, this study can provide a regional customization of GBTool2005 in Taiwan, and announce a set of feasible weighting values applied to evaluate the performance of buildings. The results can be summarized in the following points:

(1) The AHP result of experts' opinions outlines the priority issues in Taiwan. They are: 'C. Environmental Loadings,' of which the weighting value is 21.1%, 'B. Energy and Resource Consumption,' of which the weighting value is 18.6%, and 'D Indoor Environmental Quality,' of which the weighting value is 16.2%.

(2) The ANOVA statistical inference clarifies that "location characteristics" is the critical factor to influence the assessment weighting value. Therefore, the default weights of GBTool2005 can be adapted regionally to three sets of the weighting value on the first-level "Issues": "the northern zone", "the southern zone" and "the whole Taiwan"; meanwhile, the second-level "Categories" can be grouped into one weighting value set of the whole Taiwan area shown as the marked area in Table **13**.

(3) Overall, (Fig. **7**) illustrates the simple formulation of the "Issues" level: "A. Site Selection, Project Planning and Development," "C. Environmental Loading" and "D. Indoor Environmental Quality" continue using the weighting value of GBTool2005; "B Energy

Table 13. T-Test for the Default Weights of GBTool2005 with the Investigated Weight of All Experts on the "Category" Level

Assessment Categories	GBTool2005 (Default)	All Experts (Taiwan)	T-Value	DF	Critical Value (α=0.05)	Statistically Significant
A. Site selection, project planning & development						No
A1.Site selection	0.333	0.315	-0.7438	35	±2.0315	No
A2. Project planning	0.333	0.330	-0.1505	35	±2.0315	No
A3. Urban design and site development	0.333	0.355	1.0064	35	±2.0315	No
B. Energy and Resource Consumption						No
B1. Total life cycle primary non-renewable energy	0.250	0.174	-4.0073	35	±2.0315	Yes
B2. Predicted electrical peak demand for building operations	0.150	0.138	-1.2553	35	±2.0315	No
B3. Renewable energy	0.150	0.184	2.0662	35	±2.0315	Yes
B4. Commissioning of building systems	0.150	0.164	1.0141	35	±2.0315	No
B5. Materials	0.150	0.145	-0.5161	35	±2.0315	No
B6. Potable water	0.150	0.195	2.2290	35	±2.0315	
C. Environmental Loadings						
C1. Greenhouse gas emissions	0.250	0.183	-5.3534	35	±2.0315	Yes
C2. Other atmospheric emissions	0.150	0.123	-2.1573	35	±2.0315	Yes
C3. Solid wastes	0.150	0.172	1.8030	35	±2.0315	
C4. Rainwater, stormwater and wastewater	0.150	0.172	1.8030	35	±2.0315	
C5. Impacts on site	0.150	0.175	2.1417	35	±2.0315	Yes
C6. Other local and regional impacts	0.150	0.175	2.1417	35	±2.0315	Yes
D. Indoor Environmental Quality						
D1. Indoor air quality	0.280	0.247	-3.6502	35	±2.0315	Yes
D2. Ventilation	0.220	0.238	1.7789	35	±2.0315	No
D3. Air temperature and relative humidity	0.170	0.182	0.9570	35	±2.0315	No
D4. Daylighting and illumination	0.170	0.183	0.9570	35	±2.0315	No
D5. Noise and acoustics	0.170	0.150	-2.4107	35	±2.0315	Yes
D6. Electro-magnetic pollution - not yet active	–	–	–	–	–	–
E. Functionality & Controllability of Building Systems						No
E1. Efficiency of space utilization	0.400	0.334	-0.9988	35	±2.0315	No
E2. Design for maintenance of core functions outside of planned design conditions	0.300	0.336	0.5841	35	±2.0315	No
E3. Controllability	0.300	0.330	0.3988	35	±2.0315	No
F. Long-Term Performance						No
F1. Flexibility and adaptability	0.500	0.449	-1.1590	35	±2.0315	No
F2. Maintenance of operating performance	0.500	0.551	1.590	35	±2.0315	No
G. Social and Economic aspects						No
G1. Cost and economics	0.500	0.509	0.4015	35	±2.0315	No
G2. Social aspects	0.500	0.491	-0.4015	35	±2.0315	No

and Resource Consumption", "E Functionality and Controllability of Building Systems", "F Long-Term Performance" and "G Social and Economic aspects" should be modified on the basis of the building's lo-

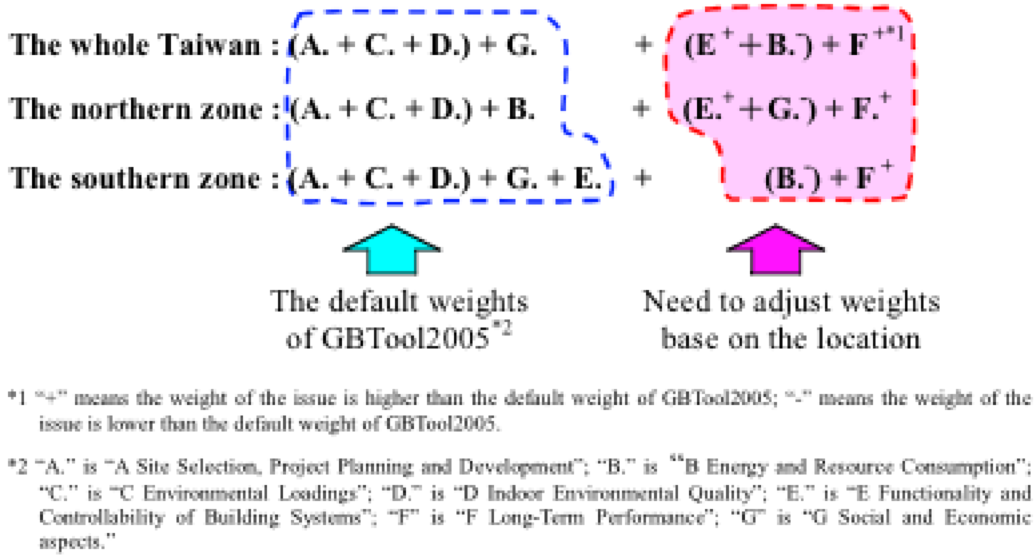

Fig. (7). The simple formulation of the weighting value on the "Issues" level of GBTool2005.

cation. In addition, "F Long-Term Performance" is a critical issue as the weight is significant "higher" than the default weight whatever the building is located. The "Category" level of "B. Energy and Resource Consumption," "C. Environmental Loading" and "D. Indoor Environmental Quality" select the average result of all experts' questionnaires; the rest categories use the default value of GBTool2005.

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