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Factor-analysis based questionnaire categorization method for reliability improvement of evaluation of working conditions in construction enterprises

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Abstract. This paper presents a factor-analysis based questionnaire categorization method to improve the reliability of the evaluation of working conditions without influencing the completeness of the questionnaire both in Taiwanese and Chinese construction enterprises for structural engineering applications. The proposed approach springs from the AI application and expert systems in structural engineering. Questions with a similar response pattern are grouped into or categorized as one factor. Questions that form a single factor usually have higher reliability than the entire questionnaire, especially in the case when the questionnaire is complex and inconsistent. By classifying questions based on the meanings of the words used in them and the responded scores, reliability could be increased. The principle for classification was that 90% of the questions in the same classified group must satisfy the proposed classification rule and consequently the lowest one was 92%. The results show that the question classification method could improve the reliability of the questionnaires for at least 0.7. Compared to the question deletion method using SPSS, 75% of the questions left were verified the same as the results obtained by applying the classification method.

Keywords: construction enterprise; expert system; factor analysis; questionnaire categorization; reliability improvement; working condition

1. Introduction

Questionnaires are widely used in surveys and data summarization. A good questionnaire must be of good reliability and validity. A questionnaire of good reliability is often of good consistency, stability, dependability, and predictability. Data obtained from several surveys using the same questionnaire, which is stable and dependable, should be consistent. Data collected using such a reliable questionnaire can be used for prediction. The proposed approach in this paper springs from the AI application and expert systems in structural engineering for real-life applications.

1.1 Tests for reliability

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There are many tests to measure reliability of questionnaires. Two common methods are discussed and illustrated below.

1. Stability Coefficient (Test-Retest Reliability)

Test-retest reliability is obtained by the product-moment correlation of two tests for the same respondents with the same questionnaire. Usually, the second test is conducted two weeks after the first one. In some cases, the time between the two tests can be one to several months. If the two tests are highly correlated then the questionnaire used is very stable. Generally, two tests are highly correlated when their correlation is between 0.7-0.9, moderately correlated when their correlation is between 0.4-0.6, and low correlated when their correlation is less than 0.4.

2. Coefficient of Internal Consistency (Cronbach's α and Split-Half Reliability)

If reliability is estimated with only data from one test, it is considered as reliability of internal consistency. The most common coefficient is Cronbach's α. The formula used to calculate this coefficient is described below:

If the content of a test is consistent, the obtained Cronbach's α should be high. Split-half reliability is another tool to measure internal consistency. In this method the questions are split into two halves in order to obtain two individual scores (usually, one score is obtained from answers to the odd-numbered questions, and another from even-numbered ones). Then the product-moment correlation of the two scores is computed. Because the questions are split-half, the reliability is often low. Therefore, adjustments could be required. The most common methods for adjustment were proposed by Spearman-Brown, Flanagan, and Rulon.

Nunnally (1978) and Devellis (1991, 1998) believed that α values over 0.7 are acceptable. DeVellis (1998) suggested not to accept when α values are under 0.6, better not to accept when α values are between 0.6 and 0.65, reluctantly accept when α values are between 0.66 and 0.70, accept α values are between 0.7 and 0.8, and well accept α values are between 0.8 and 0.9.

1.2 How to improve low reliability

To resolve the issue of low reliability, in addition to the adjustment formula mentioned above, another method, that most researchers also use, is the function provided by SPSS to delete questions at issue to increase reliability. However, deleting some questions from a questionnaire may somehow influence the completeness of that questionnaire. This study aims to improve reliability by categorizing questions. This study categorizes questions of a questionnaire according to the meanings of the words and using some mathematical models to make sure the reliability value of each category is above 0.7, so that categorized questions are highly consistent.

1.3 Data classification

Data classification has been applied to many research areas in science. Folino *et al*. (2006) presented an extension of the cellular genetic programming for data classification (CGPC) to induce an ensemble of predictors. The ensemble, with two algorithms, implemented the bagging and boosting techniques and compared with CGPC. Their approach could handle large data sets that did not fit in the main memory since each classifier was trained on a subset of the overall training data. Better classification accuracy was obtained at a significantly lower computational cost. Cheng *et al*. (2009) proposed techniques for classifying structural data with skewed distribution and partial feature coverage. Tseng and Lee (2009) proposed a novel pattern-based data mining method, namely classify-by-sequence (CBS), for classifying large temporal datasets,

possessing the merit of simplicity in implementation. Its pattern-based architecture could provide clear classification information to users. In addition, they designed a simulator to evaluate performance of CBS using datasets with different characteristics. The method discovers hidden patterns and classifies data effectively by utilizing the mined sequential patterns. Porro-Muñoz *et al*. (2011) introduced their use as a tool for classifying objects originally represented by two-dimensional (2D) arrays, where a 2D measure to compute the dissimilarity representation from spectral data with this kind of structure was proposed and compared to existing 2D measures in terms of the information that was taken into account with computational complexity.

Generally, new applications are derived from the classification method developed by some scholar. Drissi and Vilalta (2011) described a data classification method and apparatus for labeling unknown objects. Their data classification system employed an adaptive learning algorithm that improved through experience. Each rule of experience specified one or more characteristics for a domain dataset and a corresponding bias that could be utilized for data classification model if the rule was satisfied. The self-adaptive learning process becomes increasingly accurate as the rules of experience accumulate over time. To assist public sector to determine what would be a reasonable reserve price or award price, Lin *et al*. (2012) proposed a data classification system using fuzzy set theory. In their approach, for each category of classified data, multiple regression analysis was applied to the linear model, the power series model and the refined power series model to achieve low average relative error, i.e., 3% for final reserve price model and 9% for award price.

There were also studies regarding reliability improvement using the data classification method. To provide information about the reliability of the classification, Schleif *et al*. (2009) suggested an approach to enhance classifiers with reliability estimates in the context of prototype vector quantization. This enhancement is also used to optimize precision or recall of the classifier system and to determine items, which are not classifiable, leading to significantly improved classification results. The results were demonstrated on satellite remote spectral data but the method is applicable to a wider range of data sets. Alexander *et al*. (2010) established three classification systems that had "moderate" inter-observer reliability and "good" and "moderate" intra-observer reliability when classified solely on the basis of plain radiographs. After the addition of computed tomography (CT) scans inter-observer and intra-observer reliability significantly improved to "good" for all classifications.

2. Prime novelty statement

This paper presents a new method aimed to increase the reliability of questionnaires used for subjective evaluation of work. Certainly, the topic of the study is important. For example, we need highly reliable questionnaires for working condition evaluation. Two methods aimed to increase reliability were compared: (a) traditional method, according which questions not consistent with the rest of the questionnaire are deleted and (b) the proposed method, presented in this study, called the question classification method. The comparison proves that the proposed method is better than the traditional method because it achieves its goal, i.e., reliability improvement without sabotaging the completeness of questionnaires.

For a long time, several methods for questions classification have been available in statistics applied to social sciences. These methods allow distinguishing in an entire questionnaire measuring complex phenomena groups of items having similar content. These groups, called factors, usually have better consistency than the entire questionnaire. In factor analysis, factors are

distinguished-like in case of this study's method based on the analysis of responses given by respondents. Questions with similar response patterns are grouped or categorized into one factor. Items that form one factor have usually higher reliability than the entire questionnaire, especially in case when the entire questionnaire is complex and inconsistent.

A case study was conducted for this study with real questionnaires to prove that the proposed classification method could indeed improve reliability. The regular patterns of the classification method were found according to the results of the analyses, and the accuracy was at least 92%. In addition, the question classification method was compared with the question deletion method of SPSS. Moreover, the result of the comparison also proved that, without deleting any questions, the question classification method did help to increase the reliability to over 0.7. It is hoped that this study can offer future research in the area of reliability a benchmark referential index.

3. Materials and methods

The main purpose of this study is to increase reliability of the questionnaire. The proposed question classification method was compared with the question deletion method of SPSS and the advantages and disadvantages of both the methods were discussed.

3.1 Case data

The questionnaire was designed based on the "Job Diagnostic Survey (JDS)" by Hackman and Oldham (1975) and the sample questionnaires provided by the National Taiwan University. An actual questionnaire was used to explore the differences between the classification method and the question deletion method of SPSS.

1. The questionnaire consists of 2 parts, the employee part and the cadre part.
2. The employee part was used to obtain respondents' information regarding work value, and job performance and satisfaction.
3. The cadre part was used to obtain respondents' information regarding organizational management and organizational commitment and identification.

The "questionnaire of job characteristics" was used to conduct the survey. The actual questions from the questionnaire and the related coding are listed in Tables 1-4.

Table 1 The questionnaire for work values

Q1: New knowledge and technologies can be learned at work.
Q2: There are chances for advanced studies at work.
Q3: My own dream can be realized at work.
Q4: The quality of my life can be improved through my work.
Q5: My life becomes richer due to my work.
Q6: I can have the sense of achievement at work.
Q7: My boss at work is very understanding.
Q8: My colleagues always take care of each other.
Q9: My colleagues never attack each other for their own benefits.

Table 1 Continued

Q10: My colleagues g*et al*ong with each other well.
Q11: I can work in an environment which is not harmful to my body and mind.
Q12: I can arrange my own schedule properly because of the flexibility of my work.
Q13: When I am sick, the company takes good care of me.
Q14: The insurance system of the company is good.
Q15: I can get a raise or bonus of a proper amount.
Q16: The welfare system of the company is good.
Q17: My income is higher than that of others with the same conditions as me.
Q18: I never feel confused or scared while working.
Q19: There are many chances of promotion.
Q20: I devote myself to my work.
Q21: Even if there is no extra pay for working overtime, I would still work overtime to finish my work at night.
Q22: I usually go to work earlier to prepare the tasks I have to handle.
Q23: I am proud of my work.
Q24: I want to be perfect when it comes to my work.

Table 2 The questionnaire for work performance and satisfaction

Q1: I think my work ability is excellent.
Q2: I can always finish my work rapidly on time.
Q3: My boss thinks I am doing a great job at work.
Q4: My professional knowledge is enough to do my job.
Q5: I am highly cooperative with my team.
Q6: I am very satisfied with the welfare provided by the company I work for.
Q7: I am very satisfied with what this job has to offer to help improving my future development.
Q8: I am very satisfied with my salary.
Q9: I am very satisfied with my relationships with my colleagues.
Q10: I am very satisfied with the opportunities and the system of promotion.

Table 3 The questionnaire for organizational management

Q1: I think the employees of the company I work for are highly involved in decision making at work.
Q2: I think the company I work for does provide its employees the information required to complete their jobs.
Q3: If there is a training opportunity, the management of the company I work for usually encourages the employees to participate.
Q4: I think the trainings provided by the company I work for can meet the demands of the employees.
Q5: I think the company determines its employees' achievements based on their employees' performances at work.
Q6: The company I work for would communicate with its employees regarding their achievements and offer them suggestions.
Q7: I think the employees' salaries offered by the company are closely related to the employees' performances at work.
Q8: Compared with other companies in the same field, I think the salary and welfare offered by the company I work for are better.

Table 4 The questionnaire for organizational commitment and identification

Q1: I care about the future development of the company.
Q2: In order to stay employed by the company, I am willing to accept any assignment.
Q3: In order to help the company to be successful, I am willing to pay extra efforts.
Q4: It doesn't matter to work for another company as long as job content and conditions are similar.
Q5: I think the company I work for is a good company, and it's worthy to work hard for it.
Q6: The style of this company is close to my values.
Q7: Staying and working for this company doesn't do me any good.
Q8: I would leave this company as long as my job status is slightly changed.
Q9: I can identify myself with the company's policy for its employees.
Q10: I am glad that I decided to take this job instead of others.

3.2 Methodology

The measure usually taken to increase reliability of a questionnaire is to delete some questions from that questionnaire. However, deleting questions from a questionnaire means influencing the completeness of that questionnaire, and thus unnecessary human errors may occur. The data obtained from that questionnaire can may be influenced as well. Therefore, it is worthy to study the question classification method that which can be applied to a questionnaire to improve the reliability without deleting any questions, so that the questionnaire can still be complete. How the question deletion method of SPSS works and the concepts and theories of the classification method are illustrated below.

3.2.1 Question deletion method

About data deletion, Jia *et al*. (2014) established a simulation method (simple element deletion method was employed to simulate crack propagation) for the post buckling cracking process on the bases of formerly proposed fracture and plasticity models. Morone and Sezen (2014) addressed that existing reinforced concrete building was instrumented and tested by removing three columns from the first story. The building was modeled and analyzed to investigate its collapse behavior. Before scheduled demolition of the test building, the columns neighboring the removed columns were instrumented. During each column removal, distribution of loads from the removed column to the neighboring columns was monitored and recorded. Jia and Kuwamura (2014) proposed a simple element deletion model based on the concept of a damage index with only one model parameter to predict ductile fracture of structural steels. Widaman *et al*. (2013) indicated that difficulties arise in multiple-group evaluations of factorial invariance if particular manifest variables are missing completely in certain groups. Ad hoc analytic alternatives could be used in such situations (e.g., deleting manifest variables). Grierson (1992) showed that prior to calling the deletion routine, the rule establishes the minimum response ratio value for the current design cycle based on the absolute minimum {default=0.3) and maximum {default=0.8) deletion response ratios provided as input data in the context. Chung *et al*. (2009) used all-or-nothing element deletion approach of the modeling technique to analyze the elements. Yang and Soh (1998) addressed that member would be deleted when its cross-sectional area becomes zero. Will and Powell (1991) deleted the data that cannot identify outliers. Liang (2007) showed that using higher order finite elements or modifying the functional of a finite element model could get the initial

deletion ratio of elements. Furthermore, many researches on structure field would first delete data that caused error and then did the analysis (Koike *et al*. 2007, Morshed and Kazemi 2005, Balling *et al*. 2006, Lin and Chen 2009, Lin 2010).

As the name suggests, the question deletion method deletes some questions to increase the alpha value of reliability. Steps to perform the question deletion method, using SPSS, are as below:

1. Click on "Scale" under "Analyze" to open the "Reliability Analysis" window.
2. Select a set of questions on the left and add them to the "Items" area on the right. (Note: Select only one set of questions. Do not select questions from different sets.)
3. Click on "Statistics" to open a window and check the "Scale if item deleted" option.
4. Select "Alpha value" under "Model" and click on "OK" to begin the reliability analysis of SPSS.
5. Then the output report of the reliability analysis is generated. In the report, there is an Alpha value below. If this value is high, the reliability of this set of questions is high and the consistency of these questions is good. If the value is under 0.6, the reliability is too low and this set of questions should not be used.
6. When the alpha value is under 0.6, the first thing to do is to check the value of the "Alpha if Item Deleted", which represents the new alpha value after the corresponding question is deleted. With this value, it is possible to find out which questions should be deleted in order to increase the reliability while keeping the rest. In this study, only one question was deleted each time. The question, whose deletion would maximize reliability increase, would be selected for deletion. After several iterations, the reliability generally increased to a value over 0.7.
7. The "Corrected Item-Total Correlation" value shows the correlation among these questions. High value means high consistency among these questions. With this value, it is possible to find the questions that are less consistent than others are.

See "The questionnaire for work performance and satisfaction of Taiwanese" as an example in Table 5.

Table 5 The questionnaire for work performance and satisfaction of Taiwanese

Reliability Statistics				
Cronbach's Alpha	N of Items			
.548	10			
Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q1	31.2586	11.458	.372	.480
Q2	31.4138	11.896	.359	.488
Q3	31.3621	12.867	.171	.541
Q4	31.5690	13.127	.187	.535
Q5	31.1724	11.338	.341	.489
Q6	30.9483	13.418	.207	.531
Q7	31.1034	12.305	.228	.526
Q8	31.1897	14.472	-0.15	.572
Q9	30.7069	13.369	.114	.555
Q10	31.0172	11.315	.360	.482

The column "Cronbach's Alpha if Item Deleted" means when we delete this item, the α value constituted of remaining nine items. For example, when we deleted item "Q8", the original α value .548 raised to .572. Therefore, item "Q8" can be deleted.

3.2.2 The question classification method

Data classification has been applied to many research areas in science. For example, Lin *et al*. (2013) initially established an artificial intelligent multiple regression model using categorized data and then a prediction model using intelligent Kalman filtering. Rezakhani (2011) described the data classification and development of a fuzzy risk analysis model to assess the risks associated with construction projects. Juaim and Hassanain (2011) interviewed with a group of design professionals and owner's representatives for the purpose of identifying the factors that influence the process of developing and implementing the architectural program for building projects. This resulted in the identification of 28 factors, which were classified into several groups. Chokshi *et al*. (2013) presented a comparison of fly-ash bricks and clay bricks. Based on Fly-ash bricks and clay bricks for data classification, then analysis could be done by using statistical methods (SPSS Software). Kim *et al*. (2011) used the concept of data classification to recover lost data. Hurtado and Alvarez (2003) treated the reliability problem as a classification task and not as the computation of an integral. To this purpose, a kernel method was used for classification. In a classification analysis method, Park *et al.* (2002) addressed the problem of assigning an object to one of a number of possible groups based on observations made on the objects. O'Connor *et al.* (2009) showed that the probability-based classification of the structure served as an example of how probability-based assessment of railway bridges could be applied to reduce maintenance costs through avoidance of unnecessary repair/rehabilitation and/or to optimize those repairs shown to be necessary. Sun and Chang (2004) developed statistical pattern classification method based on wavelet packet transform (WPT) for structural health monitoring. Lin (2011) and Chiou *et al*. (2011) applied Hilbert-Huang transform to classify signals. Other researchers have studied classification of data followed by pattern analysis (Lin 2012, Xu and Chen 2012, Chen *et al*. 2012, Shih *et al*. 2012).

Although the measure usually taken to increase the reliability of a questionnaire is to delete some questions from that questionnaire, deleting questions from a questionnaire generally influences the completeness of that questionnaire. This can not only cause unnecessary human errors but also influence data obtained from the questionnaire. Therefore, it is worthy to study the question classification method, which improves questionnaire reliability without deleting question(s) thereby not influencing the completeness of the questionnaire. By classifying questions according to the meanings of the words used in them and responded scores of questions, reliability could be increased; that is, the parts of questions with alpha values below 0.7 were classified until the alpha values of all the groups of questions were above 0.7, so that categorized questions are highly consistent.

The patterns in the questions could be found using the data-editing program of SPSS. The scores of each question in the work characteristics questionnaire were from 1-5. After a respondent answers first question of a group, the answers to the remaining questions in the same group should not be more than 1 point different from the first answer. For example, if the answer to question C_1 in group C was 3, the answers to all the other questions in group C should be 2, 3, or 4. Similarly, if the answer to C_1 was 3 and that to C_2 (in the same group C) was 2, then the answers to the rest of the questions in the group should be 2 or 3. If for all the respondents this rule is satisfied, then these questions indeed belong to the same group. Hence, the formula for the classification method

Table 6 The organization chart using the question classification method for work values of Taiwanese

Self-improvement *R*=0.506	Learning opportunities *R*=0.809 Q1 Q2	
	Ideals and achievements *R*=0.594 Q3 Q4 Q5 Q6	Quality of life *R*=0.719 Q4 Q5
Job involvement *R*=0.667	Self-discipline *R*=0.854 Q20 Q23 Q24	
	Overtime system *R*=0.938 Q21 Q22	
Work values of Taiwanese Reliability *R*=0.366		
Work factors *R*=0.653	Getting along with colleagues *R*=0.750 Q7 Q8 Q9 Q10	
	Environmental factors *R*=0.745 Q11 Q12	
Welfare security *R*=0.693	Income security *R*=0.875 Q13 Q14 Q15 Q16 Q17	
	Future promotion *R*=0.836 Q18 Q19	

Table 7 The organization chart using the question classification method for work performance and satisfaction of Taiwanese

	Work performance *R*=0.678	Self-affirmation *R*=0.778 Q1 Q2 Q4
		Superintendent and team *R*=0.761 Q3 Q5
Work performance and satisfaction of Taiwanese Reliability *R*=0.548		
	Work satisfaction *R*=0.600	Working situation R=0.752 Q7 Q9 Q10
		Salary and welfare *R*=0.759 Q6 Q8

is written as

$$\text{Group C}=〔\,C_1, C_2, C_3, \ldots, C_n\,〕 \tag{1}$$

$$\text{IF}\quad 0 \leqq |\ \text{scores of } C_i - C_j\ | \leqq 1 \quad i \text{ or } j=1, 2, 3, \ldots n;\ i \neq j \tag{2}$$

$$\text{Then } C_i \text{ and } C_j \text{ belong to Group C} \tag{3}$$

4. Case study

In this study, the data used for analysis was obtained using real questionnaires in Tables 1-4. The consequent outcomes were analyzed and used the organization charts to show the

Table 8 The organization chart using the question classification method for organizational management of Taiwanese

	Employee's degree of involvement in making decisions at work *R*=1.000 Q1
	Trainings and information provided by company *R*=0.732 Q2 Q3 Q4
Organizational management of Taiwanese Reliability *R*=0.589	
	Employee's performance appraised by company *R*=0.757 Q5 Q6
	Salary and welfare offered by company *R*=0.803 Q7 Q8

Table 9 The organization chart using the question classification method for organizational commitment and identification of Taiwanese

	Commitment to organization *R*=0.757 Q1 Q2 Q3	
Organizational commitment and identification of Taiwanese Reliability *R*=0.563		
	Identification with organization *R*=0.693	Leaving organization for a reason *R*=0.729 Q4 Q7 Q8
		Identifying with organization's current status *R*=0.734 Q5 Q6 Q9 Q10

Table 10 The organization chart using the question classification method for work values of Chinese

	Self-improvement *R*=0.743	Learning opportunities *R*=0.889 Q1 Q2	
		Ideals and achievements *R*=0.841 Q3 Q4 Q5 Q6	Quality of life *R*=0.852 Q4 Q5
	Job involvement *R*=0.740	Self-discipline *R*=0.876 Q20 Q23 Q24	
		Overtime system *R*=0.935 Q21 Q22	
Work values of Chinese Reliability *R*=0.513			
	Work factors *R*=0.709	Getting along with colleagues *R*=0.791 Q7 Q8 Q9 Q10	
		Environmental factors *R*=0.761 Q11 Q12	
	Welfare security *R*=0.723	Income security *R*=0.923 Q13 Q14 Q15 Q16 Q17	
		Future promotion *R*=0.837 Q18 Q19	

Table 11 The organization chart using the question classification method for work performance and satisfaction of Chinese

	Work performance *R*=0.749	Self-affirmation *R*=0.869 Q1 Q2 Q4 Superintendent and team *R*=0.831 Q3 Q5
Work performance and satisfaction of Chinese Reliability *R*=0.606		
	Work satisfaction *R*=0.695	Working situation *R*=0.719 Q7 Q9 Q10 Salary and welfare *R*=0.932 Q6 Q8

Table 12 The organization chart using the question classification method for organizational management of Chinese

	Employee's degree of involvement in making decisions at work *R*=1.000 Q1 Trainings and information provided by company *R*=0.797 Q2 Q3 Q4
Organizational management of Chinese Reliability *R*=0.540	
	Employee's performance appraised by company *R*=0.812 Q5 Q6 Salary and welfare offered by company R=0.758 Q7 Q8

Table 13 The organization chart using the question classification method for organizational commitment and identification of Chinese

	Commitment to organization R=0.757 Q1 Q2 Q3	
Organizational commitment and identification of Chinese Reliability *R*=0.616		
	Identification with organization R=0.645	Leaving organization for a reason R=0.806 Q4 Q7 Q8 Identifying with organization's current status R=0.785 Q5 Q6 Q9 Q10

classification with layers of detailed questions. The classification stopped when the corresponding alpha value was over 0.7. The principle for classification was that 90% of the questions in the same classified group must satisfy the formula shown in Eqs. (1)-(3). In this study, among the group percentages of questions satisfying Eqs. (1)-(3), the lowest one was 92%. As for the question deletion method, the number of questions deleted to ensure the alpha value of 0.7 was presented. Then the two methods were compared. The organization charts for the question classification method are illustrated in Tables 6-9 for responses from Taiwanese and in Tables

10-13 for responses from Chinese, with both kinds of employees working in the same company. Based on the above classifications, the branches were separated according to meanings of words and responded scores of questions, and the alpha values were higher at the nodes closer to the ends of the branches. The comparison of the question deletion method used in SPSS and the question classification method is illustrated in Tables 14-15.

Table 14 The comparison of the question deletion method and the question classification method for responses of Taiwanese

Item	How many questions had to be deleted so that the alpha value could be over 0.7?	What is the highest alpha value achievable? And how many questions had to be deleted to achieve that value?	Was the final alpha value higher than that obtained using the classification method?	Were the questions left after deletion the same as those in the groups obtained from the classification method?
Work values of Taiwanese	Q21→Q22→Q1→Q2→Q4→Q5→Q3→Q6→Q19→Q18→Q12→Q11→Q16→Q13→Q14 15 questions in total	Q21→Q22→Q1→Q2→Q4→Q5→Q3→Q6→Q19→Q18→Q12→Q11→Q16→Q13→Q14→Q15→Q17 17 questions in total with the alpha value being 0.746	The alpha value was higher than those of "ideals and achievements" and "environmental factors"	Yes. The questions left were the same as those in the groups "self-discipline" and "getting along with colleagues"
Work performance and satisfaction of Taiwanese	Q8→Q9→Q6→Q7→Q10→Q3→Q5 7 questions in total	Q8→Q9→Q6→Q7→Q10→Q3→Q5 7 questions in total with the alpha value being 0.778	The alpha value was higher than those of "work situation", "salary and welfare", and "superintendent and team"	Yes. The questions left were the same as those in the group "self-affirmation"
Organizational management of Taiwanese	Q5→Q7 2 questions in total	Q5→Q7→Q8→Q6 4 questions in total with the alpha value being 0.732	No	Yes. The questions left were the same as those in the group "trainings and information provided by company"
Organizational commitment and identification of Taiwanese	Q2→Q3→Q1→Q6 4 questions in total	Q2→Q3→Q1→Q6 4 questions in total with the alpha value being 0.702	No	No. The questions left were Q4 Q5 Q7 Q8 Q9 Q10 not the same as any of the groups

Table 15 The comparison of the question deletion method and the question classification method for responses of Chinese

Item	How many questions had to be deleted so that the alpha value could be over 0.7?	What is the highest alpha value achievable? And how many questions had to be deleted to achieve that value?	Was the final alpha value higher than that obtained using the classification method?	Were the questions left after deletion the same as those in the groups obtained from the classification method?

Table 15 Continued

Work values of Chinese	Q7→Q19→Q18→ Q10→Q9→Q8→ Q12→Q11→Q22→ Q21 10 questions in total	Q7→Q19→Q18→ Q10→Q9→Q8→Q12 →Q11→Q22→Q21→ Q24→Q23→Q20→ Q2→Q1→Q6→Q3→ Q5→Q4→Q13→Q17 →Q14 22 questions in total with the alpha value being 1.000 Or 19 questions in total with the alpha value being 0.923	The alpha value was higher all the alpha values obtained using the classification method	Yes. The alpha value was 1.000. The questions left were the same as those in the 2 sub-groups under "income security". Or Yes. The alpha value was 0.923. The questions left were the same as those in the group "income security".
Work performance and satisfaction of Chinese	Q5 1 question in total	Q5→Q3→Q7→Q9→ Q10→Q8→Q6→Q4 8 questions in total with the alpha value being 0.907 Or 7 questions in total with the alpha value being 0.869	The alpha value was higher than those of "work situation", "self-affirmation", and "superintendent and team"	Yes. The alpha value was 0.907. The questions left were the same as those in the 2 sub-groups under "self-affirmation". Or Yes. The alpha value was 0.869. The questions left were the same as those in the group "self-affirmation"
Organizational management of Chinese	Q5→Q6→Q3→Q2 →Q4 5 questions in total	Q5→Q6→Q3→Q2→ Q4→Q8 6 questions in total with the alpha value being 0.791	The alpha value was higher than that of "salary and welfare offered by company"	No. The questions left were Q1 and Q7, which were not the same as any of the groups.
Organizational commitment] and identification of Chinese	Q2→Q9 2 questions in total	Q2→Q9→Q6→Q5→ Q3→Q8→Q1 7 questions in total with the alpha value being 0.806	The alpha value was higher than those of "identifying with organization's current status", and "commitment to organization"	Yes. The questions left were the same as those in the group "leaving organization for a reason"

5. Conclusions

This study presented a new method aimed to increase reliability of questionnaires for subjective evaluation of work for the AI application and expert systems in structural engineering. Certainly, the topic of the study is important-we need highly reliable questionnaires to evaluate working conditions. Two methods aimed to increase reliability were compared: one traditionally used, according to which items not consistent with the rest of the questionnaire are deleted and second-of this study-the question classification method. The proposed method is showed to be a better one because it achieves its goal, i.e., reliability improvement without sabotage of the

completeness of a questionnaire.

According to the analysis shown in this manuscript, in order to improve the reliability to a value above 0.7, about one third of the questions had to be deleted using the question deletion method of SPSS. However, this value (0.7) was achieved using the proposed classification method based on the meanings of the words and responded scores of questions. The regular patterns of the classification method were found according to the results of the analyses, and the accuracy was at least 92%. Further, for six of the eight questionnaires, when the question deletion method was applied and the corresponding alpha values were maximized, the questions left were the same as the results obtained by applying the classification method. Therefore, using the classification method to improve reliability of questionnaires was indeed feasible without influencing the completeness of those questionnaires. The classification method can be applied in other fields as well. Some domestic and foreign scholars have spent a lot of efforts studying data classification, so that people can handle data more easily and conveniently.

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