Applying Multi-Criteria Method to the Decision of Assessment Tools for High-care Student Groups

Chen-Feng Wu[1], Chun-Ta Lin[1] and Pei-Min Wang[2]

[1]*Department of Information Management, Yu Da University*
No 168, Hsueh-fu Rd, Chaochiao Township, Miaoli County, 361 Taiwan
[2]*Chung Hsing Commercial & Industrial Vocational High School*
No.211, Daying Rd., Zhunan Township, Miaoli County 35051, Taiwan
[1]*{cfwu, maxlin}@ydu.edu.tw,* [2]*cindy613@ms10.hinet.net*

Abstract

An effective assessment tool can prevent student dropout problems that are a continuous concern in the educational world in advance. If students can be screened before dropping out and offered preventive counseling, their risk behaviors will be more effectively controlled than if they are found and returned to school. Researchers are diligently developing efficient and effective assessment tools in the name of "prevention over treatment." A multi-criteria decision making method that is the analysis hierarchy process (AHP) is applied for professional counselors and uses questionnaires to select a series of key criteria for high-care group assessment tools that can be adopted in school counseling units in this paper, and it is a multi-criteria decision method and is also used to establish a model for selecting assessment tools for high-care students groups in vocational high schools. The proposed model can offer counseling units in vocational high schools in Taiwan an objective and effective method for selecting optimal assessment tools.

Keywords: *Assessment tools, multi-criteria decision making, analysis hierarchy process (AHP), high-care group*

1. Introduction

Dropping out of school and defiant behaviors are closely associated with criminal behavior. A study of education dropouts and juvenile criminals reported that among 218 juvenile delinquents, 65% had dropped out of education. In other words, more than three-fifths of the juvenile offenders were education dropouts [1]. Another study also showed that the crime rate among education dropouts was nearly four times higher than that for general students [2]. Multiple factors influence students to leave education. Statistical analysis of dropout data indicates that the main factors influencing students to leave education are personal, family, school, and peer-related factors.

According to domestic and foreign literature, dropping out of school can increase the crime rate [2], increase government expenditure on social welfare [3], and increase feelings of alienation among dropouts. Statistical analysis of juvenile delinquency conducted in 2001 by the Criminal Research Center of the Ministry of Justice stated that the total number of

criminals was 14,727 [4], of which, 35.14% were high school dropouts and 52.54% were between 16 and 18 years of age. These data demonstrate that dropping out of school can is a significant concern for personal development and social stability. For society as a whole, dropping out of education is a waste of social and educational resources. Students that dropout are also likely to engage in defiant or even criminal behavior, thereby affecting social order. Additionally, dropouts may have insufficient living skills because of their interrupted education; consequently, they may be trapped in the bottom social class and a life of crime. Therefore, the belief that dropping out of education not only leads to crime but is also a major social concern has received significant attention from scholars in various fields.

According to a Ministry of Education survey, the number of first-year students in higher vocational schools was 119,296 in 2005, the number of students who graduated from higher vocational schools in 2008 was 103,064, and the number of students that dropped out was 16,232, for a dropout rate of approximately 13.6% [5]. Based on the 13.6% dropout rate for students enrolled in higher vocational schools, more than 10,000 students drop out of higher vocational schools every year. Although the number of dropouts accounts for a small proportion of the total students of the same age, it is critical to domestic juvenile delinquency. Using information technology, this study analyzes and compares four assessment tools, namely, a checklist, a self-report questionnaire for predicting dropout probability, a statistical prediction model, and teachers as predictors [6] to identify the appropriate assessment tools for predicting potential dropouts. This enables the at-risk population to be identified and appropriate counseling to be provided to prevent the population from dropping out of school.

The problems encountered by the at-risk population at higher vocational schools differ from those experienced at secondary or primary schools. Therefore, indices must be established to evaluate the assessment tools for identifying the at-risk population at higher vocational schools. The objective of this study is to determine the most suitable assessment tool for identifying which students of higher vocational schools are at risk of dropping out. The identification of an optimal assessment tool enables counseling units to provide counseling to higher vocational school students to prevent the population from dropping out of school. This assessment tool can also be employed to evaluate schools and provide a reference for education units researching juvenile issues.

2. Literature Review

Multiple factors influence students to leave school. Most previous studies concerning dropouts mention both the conceptual model for dropouts developed by Tinto [7] and that developed by Miller [8] subsequently; these two models are essentially the same. Both models emphasize that the academic and social performance of students with different background characteristics can influence their perceptions at the psychological level, and these perceptions affect students' decisions to remain in education [9].

Multi-criteria strategy has been applied to several fields, and the most adopted one is analytic hierarchy process (AHP) developed by Saaty in 1971. With constant modifications and verifications, by 1978, the AHP method had matured. AHP has a wide range of theoretical applications; the amount of literature on AHP is substantial. The research methods of AHP theory [10] are explained and classified below.

2.1. Overview of AHP theory

AHP is a method that systematizes and simplifies complex problems by analyzing problems in different hierarchies. In other words, a problem is decomposed into tree-like structural hierarchies, and hierarchies with mutual influences are established. The weights of each hierarchy and factor are then determined through pairwise comparison. Finally, the advantages and disadvantages of an objective are assessed through comprehensive evaluation to provide a reference for decision makers.

2.2 AHP procedures

The use of AHP to establish a selection model involves the following six steps:

(1) Describe the problem

(2) Establish hierarchical relationships

(3) Establish a pairwise comparison matrix at each level

(4) Calculate eigenvectors and eigenvalues and identify the relative weights of factors in every hierarchy level

(5) Consistency test

(6) Select an alternative

Education units have gradually adopted AHP for various practical applications related to decision making. For example, AHP is used to assist students with making decisions concerning pursuing further education and seeking employment, to compare students' professional competence indices, to predict students' test results or grades, to evaluate the risks of students enrolling in school departments for further education, to assess the allocation of teachers, to decide requirements for teachers, and to appraise the performance of school administrative units [11, 12].

The methods frequently used by domestic and foreign education units to predict student dropouts include checklists, self-report questionnaires for dropout probability, statistical prediction models, and teacher assessments [6]. These four methods use different subjects, approaches, durations, and data presentation; the appropriate sample size for these methods also differs. However, each method has unique advantages and disadvantages. Table 1 shows a summary of the advantages and disadvantages of the four assessment tools based on existing studies [13-20].

Table 1. Comparison of Assessment Tools

Assessment tools	Advantages	Disadvantages
Checklist	1. Simple and clear. 2. Easy to use. 3. Saves time and prevents errors caused by students misunderstanding questions, answering casually, or refusing to answer questions.	1. Differences between students' problems are not easily distinguished. 2. Accurate identification of problems can be difficult if teachers do not understand or know the students well enough.
Self-report questionnaire for dropout probability	1. Students can answer the inventory themselves. 2. Numerous students can be assessed simultaneously. 3. This approach does not increase teachers' load.	1. Students may refuse to answer questions or provide false answers. 2. Disabled students may be unable to answer.
Statistical prediction model	1. Frequently used in domestic and foreign studies; therefore, the amount of related data and literature is substantial.	1. Both disadvantages of the self-report questionnaire for dropout probability also hold true for this model. 2. Professional training is required to use this tool. 3. Only a list of names is provided; the outcome of this method does not benefit follow-up counseling strategies.
Teacher assessments	1. Extremely convenient. 2. Time-consuming checklists and data analysis are not required; additionally, no costs are incurred.	1. This approach is likely to be affected by teachers' personal preferences and teacher-student relationships. 2. Counseling units are still required to conduct subsequent assessments.

3. Methodology

Research procedures that support the study theme were formulated as shown in Figure 1. The targets of this study were first-year students of higher vocational schools. The assessment tools included a checklist, a self-report questionnaire for dropout probability, a statistical prediction model, and teacher assessments. Other assessment tools were not included in this study.

3.1. Description of hierarchical factors

AHP was adopted in this study and structured various evaluation factors in hierarchical order using a top-down inductive method. We also collected and evaluated criteria discussed

in literature, incorporating critical factors into criteria based on their properties. Four main criteria are summarized and described below.

1. Accuracy

Although validity and reliability are required for an assessment tool to fulfill its function, a more critical indicator is the prediction accuracy rate. Accurate predictions rely on screening rate, teacher-student relationship, and student factors.

(1). Screening rate

For counseling units, counseling and case monitoring is continuous. However, because the counseling units of educational institutions are responsible for an excessive amount of tasks, the counselors hope that the lists they receive actually contain at-risk students who genuinely require counseling.

(2). Teacher-student relationship

For assessment tools in which subjects are teachers, teachers' personal subjective evaluations rely on teacher-student relationships and whether teachers can objectively evaluate students. This tool is more likely to be influenced by personal preference and teacher-student relationships.

(3). Student factors

For assessment tools in which subjects are students, the evaluation may be invalid because students can refuse to answer or provide false answers because of psychological factors. Specifically, at-risk students are more likely to refuse to discuss their problems or may be unable to answer because of other capability limitations.

2. Convenience

An assessment tool is more likely to be adopted if it is easy to use, does not require professional training, does not increase workloads excessively, and the content is easy to understand.

Regarding convenience, the factors considered are the ease of operation and workload.

(1). Ease of operation

Checklists do not require extensive textual descriptions and the questions primarily concern phenomena that can be easily observed or understood by teachers and that exist in schools. If checklist instructions are provided, minimal training is necessary to employ this tool.

(2). Workload

Numerous students are screened using self-report inventories and statistical prediction models, which can be a burden to counseling staff. Additionally, direct intervention is not necessary for all surveyed cases; thus, the timely prevention of education dropouts can be difficult.

3. Speed

An assessment tool is more likely to be adopted if both tests and analyses can be completed in a relatively short time.

Regarding speed, factors considered are the number of test participants and the operation duration.

(1). Number of respondents

If the respondents of a self-report questionnaire are students, teachers are not required to understand the students well and a significant number of students can be surveyed.

(2). Operation duration

Assessment tools that can be completed within 10 to 20 minutes are more likely to be employed.

4. Practicality

For the counseling units that take over operations after testing, assessment results that allow immediate identification of at-risk students or provide information that can identify the problems students experience are extremely helpful for the transfer of test results to counselors. Therefore, practicality is also a key factor when selecting an assessment tool.

Regarding practicality, the factors considered are data analysis and transitional function.

(1). Analysis of personal information

Personal information enables teachers to concretize their vague perceptions of students and understand the various risk factors faced by students. This information also facilitates the planning of subsequent counseling and critical tasks for a specific student after teachers or counselors have identified the student's situation.

(2). Transitional functionality

Counselors and mentors who are not directly involved in the assessment procedure should be able to take over assessed cases relatively rapidly after obtaining detailed assessment result.

3.2. Establishing and applying models

The establishment of a selection method in this study involves six steps. AHP was adopted to determine the weights of selection criteria and construct a selection model. The results are described below.

1. Analysis and establishment of research architecture

(1). Problem description: We first conducted problem analysis for the theme and goal of this study before collecting relevant information to fully understand objectives. Next, we differentiated the causal relationships among the secondary objectives to facilitate the partitioning of subsequent hierarchical structure.

(2). Establishment of hierarchical structure: Several populations were defined by analyzing the study goal. Each population was further divided into several subpopulations; the hierarchical structure is shown in Figure 2.

We followed Saaty's suggestion that a hierarchy level should contain a maximum of seven factors (to avoid influencing hierarchical consistency); we also placed factors with similar properties in the same hierarchy level.

2. Calculation of factor weights for each hierarchy level

The weights for evaluating assessment tools for at-risk populations at higher vocational schools were established by calculating the geometric means and summarizing the composite score determined by expert groups according to weights defined by experts. Once the hierarchy levels were established, pairwise comparisons were performed on the factors in each level. Higher hierarchy levels were set as the target for pairwise comparisons of the factors in the lower hierarchy levels to evaluate the importance between the paired factors. Relative weights among factors were identified by calculating the eigenvectors and eigenvalues using the theoretical foundation for eigenvectors (1), (2) based on the obtained pairwise comparison matrix A. w_1 represented accuracy, w_2 represented convenience, w_3 represented speed, and w_4 represented practicality.

$$A\bar{w} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & w_1/w_3 & w_1/w_4 \\ w_2/w_1 & w_2/w_2 & w_2/w_3 & w_2/w_4 \\ w_3/w_1 & w_3/w_2 & w_3/w_3 & w_3/w_4 \\ w_4/w_1 & w_4/w_2 & w_4/w_3 & w_4/w_4 \end{bmatrix} \cdot \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \end{bmatrix} \quad \textbf{(1)}$$

That is, $(A - 4I)\bar{w} = 0$ **(2)**

3. Calculation of eigenvectors and eigenvalues

The weights for factors in each hierarchy level were obtained from a pairwise comparison matrix of the primary and secondary criteria using eigenvector equations ((3) and (4)). The pairwise comparison matrix A was multiplied by the weight vector x of a factor equaling nx; thus, $(A - nI)x = 0$. x is considered the eigenvector of eigenvalue n. Because a_{ij} is the value provided by decision makers based on their subjective judgment during pairwise comparisons, this value differed from the real W_i/W_j value; therefore, $Ax = n.x$ is inaccurate. Saaty suggested replacing n with the maximum eigenvalue $\lambda_{\max}$ in matrix A.

$$\lambda_{\max} = \sum_{j=1}^{n} a_{ij} \frac{W_j}{Wi} \quad \textbf{(3)}$$

If A is a consistency matrix, the eigenvector X can be calculated using the following equation:

$$(A - \lambda_{\max} I)X = 0 \quad \textbf{(4)}$$

4. Consistency test

According to the basic assumption of AHP theory, matrix A is assumed to be a matrix that conforms to a consistency matrix. However, matrix A may not conform to a consistency matrix because of respondents' subjective judgments. Nonetheless, the evaluation results must pass a consistency test to verify that the respondents' judgments were consistent; otherwise, the questionnaire is considered invalid. Therefore, Saaty suggested verifying the consistency of a pairwise comparison matrix using a consistency index (CI) and consistency ratio (CR).

(1). Consistency index

The CI uses the difference between the $\lambda_{\max}$ obtained using the eigenvector method and n (matrix dimension) as the baseline for determining the degree of consistency.

$$CI = (\lambda_{\max} - n)/(n-1) \quad \textbf{(5)}$$

CI = 0 indicates that judgments are consistent. By contrast, CI > 0 indicates that judgments are inconsistent. Saaty considered CI < 0.1 a tolerable error.

(2). Consistency index

According to a study conducted at Oak Ridge National Laboratory and the Wharton School, the CI generated from a positive reciprocal matrix obtained from assessment scales 1 to 9 in different orders is known as a random index (RI) (Table 2).

The ratio of CI and RI in a matrix of similar order is known as CR.

$$CR = CI / RI \quad \textbf{(6)}$$

If the CR is less than 0.1, the consistency of the matrix is satisfactory.

Table 2. Random index (data source: Saaty, 1980)

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

5. Calculation of the relative weights in each hierarchy level

After calculating the weights of factors in each hierarchy level, the weights of the overall hierarchy were calculated, and then, calculations for the overall hierarchy were conducted. Saaty believed that under rational assumptions, geometric mean can be used as an integrative function.

6. Calculation of weights for the overall hierarchy and selection of the optimal assessment tool

The most appropriate alternative for the research goal can be determined by calculating the weights of factors in each hierarchy level. Microsoft Excel and AHP software were used to process and analyze information.

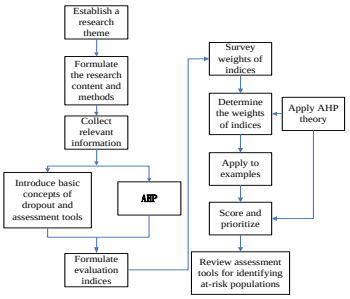

Figure 1. Research procedure

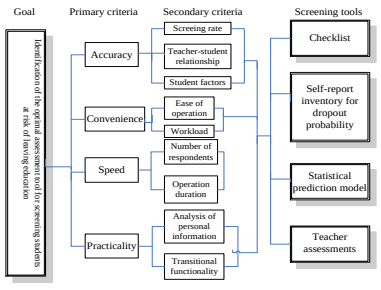

Figure 2. Hierarchical structure

4. Results and Discussion

To evaluate the assessment tools selected by counseling units for identifying at-risk populations, we drafted an index set after reviewing literature and conducting a questionnaire. We also developed the indices required for this study by conducting interviews and mentor meetings, inviting students, mentor teachers, and counseling units to adjust the index set. The weights of various factors were assessed using AHP to explore the alternatives and strategies that should be used for selecting assessment tools.

4.1. Weights of the factors in each hierarchy level

In this study, we analyzed the questionnaires using the AHP method; the process can be divided into three parts. The first part involves primary criteria that influence the alternatives for assessment tools; these criteria include accuracy, convenience, speed, and practicality. The second part involves secondary influential criteria that include the screening rate, teacher-student relationship, student factors, ease of operation, workload, number of participants, operation duration, analysis of personal information, and transitional functionality. The third part is the decision-making hierarchy; this part involves prioritizing the four assessment tools, namely, the checklist, self-report questionnaire for dropout probability, statistical prediction model, and teacher assessments, and the selection of an optimal tool.

First, the results of expert questionnaires regarding the primary criteria were analyzed. The experts' judgments on the primary criteria of alternative assessment tools were compared in pairs. The resulting pairwise comparison matrix is shown in Table 3.

Table 3. The importance of the primary criteria of the optimal assessment tool for identifying at-risk populations

Primary criteria	Accuracy	Convenience	Speed	Practicality	Geometric Mean	Weight	Priority
Accuracy	1	5	9	3	$\sqrt[4]{1*5*9*3} = 3.4087$	$\frac{3.4087}{5.6944} = 0.5986$	1
Convenience	0.20	1	3	0.50	$\sqrt[4]{0.2*1*3*0.5} = 0.7401$	$\frac{0.7401}{5.6944} = 0.1300$	3
Speed	0.11	0.33	1	0.30	$\sqrt[4]{0.11*0.33*1*0.3} = 0.3247$	$\frac{0.3247}{5.6944} = 0.0570$	4
Practicality	0.33	2.00	3.33	1	$\sqrt[4]{0.33*2*3.33*1} = 1.2209$	$\frac{1.2209}{5.6944} = 0.2144$	2
λ_{max} = 4.0408; CI = 0.0136; and CR = 0.0151. ※ C.I. = 0.0136 < 0.1, indicates that the pairwise comparison is consistent					Total = 5.6944		

The consistency of the pairwise comparison matrix for the important factors of primary criteria was calculated using (2). The value of W' can be calculated using (3); relevant descriptions are as follows:

$$\lambda \max = \left(\frac{1}{m}\right) * \left(W_1^{'} / W_1 + W_2^{'} / W_2 + ... W_m^{'} / W_m \right)$$

$$= \left(\frac{1}{4}\right) * \left(\frac{2.4048}{0.5986} + \frac{0.5279}{0.1300} + \frac{0.2312}{0.0570} + \frac{0.8639}{0.2144}\right)$$
$$= \mathbf{4.0408} \quad \mathbf{(7)}$$

$$\mathbf{CI} = (\lambda \max - m)/(m-1)$$
$$= \frac{4.0408 - 4}{4-1}$$
$$= \mathbf{0.0136} \quad \mathbf{(8)}$$

The calculation result shows that $C.I. = 0.0136 < 0.1$, indicating that the pairwise comparisons of primary criteria are consistent. After AHP analysis, in the expert questionnaires, where the respondents consider various decision-making factors that can influence the alternative assessment tools, counselors attached greatest importance to the criterion accuracy; the weight for accuracy was 0.5968. The criterion practicality was ranked second and its weight was 0.2144, followed by the criterion convenience with a weight of 0.1300. The criterion speed was considered the least important with a weight of 0.0570. Based on their weights, accuracy is the primary consideration for most professional counseling personnel when selecting an assessment tool. The results of expert questionnaires indicate that most respondents consider accuracy significantly more important than practicality, convenience, and speed.

The weights of criteria in each hierarchy level can be calculated from the pairwise comparison matrix of the primary and secondary criteria using eigenvector formulae; the results are shown in Table 4. For example, the weights of the primary criteria accuracy and the secondary criteria screening rate were multiplied to achieve 5986*0.6483 = 0.388.

Table 4. Weights of eigenvectors for primary and secondary criteria

Criteria	Weights of criteria	Secondary criteria	Weights of secondary criteria	The two weights multiplied
Accuracy	0.5986	Screening rate	0.6483	0.3880
		Teacher-student relationship	0.1220	0.0730
		Student factors	0.2297	0.1374
Convenience	0.1300	Ease of operation	0.7500	0.0975
		Workload	0.2500	0.0325
Speed	0.0570	Number of respondents	0.3333	0.0189
		Operation duration	0.6667	0.0380
Practicality	0.2144	Analysis of personal information	0.7500	0.1608
		Transitional functionality	0.2500	0.0536

Regarding the single factors judged by experts, the screening rate was the most important factor of accuracy, ease of operation of convenience, operation duration of speed, and

analysis of personal information of practicality. As shown in Table 4, among the four criteria, the screening rate of the accuracy criterion was the most important factor and has a combined weight of 0.3880. The analysis of personal information of the practicality criterion is ranked second and has a combined weight of 0.1608. Student factors, also from the accuracy criterion, is ranked third and has a combined weight of 0.1374. The respondents attached relatively minimal importance to the factor number of participants in the speed criterion; the combined weight of this factor was only 0.0189. This result indicates that experts consider the most important factor to be the screening rate. The primary purpose of assessment tools is to identify or screen for the students at high risk of leaving education. Therefore, the screening rate is the most critical index of an assessment tool. If not all of the identified students require direct intervention, with the limited human resources in counseling units, investing effort in monitoring numerous students can negatively affect their efficacy.

4.2. Selecting the optimal assessment tool by calculating the weights of the overall hierarchy

The composite score for the four assessment tools was obtained by organizing the weights of various criteria obtained from questionnaires completed by counseling personnel. The composite score of the factors that influence the respondents' choice of assessment tool for identifying at-risk populations are shown in Table 5.

Table 5. Selection of assessment tools for counseling units

Decision factors	Primary criteria	Secondary criteria	Combined weight	Priority
Checklist	0.32429	1.30762	0.3286	1
Self-report questionnaire for dropout probability	0.28409	0.874815	0.2516	3
Statistical prediction model	0.09732	0.73678	0.1351	4
Teacher assessments	0.2943	1.080785	0.2846	2

In summary, under various influences, the assessment tool most preferred by counseling personnel, according to AHP analysis, was, from most to least preferred, checklists, teacher assessments, self-report questionnaires of dropout probability, and statistical analysis models. The primary criteria for checklists scored 0.32429, which was higher than scores for the three other assessment tools. Checklists also received relatively high scores for the secondary criteria analysis of personal information and transitional functionality. This result indicates that counseling personnel value test outcomes when selecting assessment tools. Additionally, they consider whether assessment outcomes can be transferred for use in counseling, which is the practical aim of this study.

5. Conclusions

Education units are concerned with students' school attendance and have proposed multiple measures to reduce the number of dropouts. However, specific actions that evaluate assessment tools for identifying at-risk students at higher vocational schools have not been conducted. Therefore, this study proposed methods for selecting assessment tools that can

effectively identify the students who are likely to leave education. We created indices to evaluate assessment tools for identifying at-risk populations at higher vocational schools based on the properties of the assessment tools. We also calculated the weights of the indices according to performance evaluating questions using AHP to determine the relative importance of each index.

Additionally, the method we developed to evaluate assessment tools for identifying at-risk populations at higher vocational schools was applied to the four assessment tools commonly employed by educational institutions. In practice, the four assessment tools are evaluated and prioritized according to the conditions of actual cases. This is done to allow counseling personnel to adopt the most appropriate assessment tools according to the individual situations they face and to rapidly and effectively identify at-risk students at higher vocational schools. The learning characteristics of higher vocational school students differ from those of students in other education systems. Therefore, the indices used to evaluate the assessment tools for identifying at-risk populations and the collected items for these tools should be adjusted according to the characteristics of higher vocational school students.

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Authors

Chen-Feng Wu. He received the B.S. degree in Computer Science and Engineering, Feng-Chia University in 1993 and his M.S. and Ph.D. in Computer Science and Engineering, Tatung University in 1998, and 2007, respectively. Currently, He is the associate professor of the Department of Information Management, Yu Da University, Taiwan. His research interests include wireless networks, parallel and distributed systems, embedded systems, high speed switching architectures and education of Information Technology.

Chun-Ta Lin has received his Ph.D. in Industrial Engineering and Management at the Yuan Ze University in 2007. Since 2010 he has been working as Associate Professor in Department of Information Management at Yu Da University. His research interests include supply chain management related issues and heuristic algorithm development.

Pei-Min Wang. She received the B.S. degree in Industrial Management, Chung-Hua University in 2001, and her M.S. degree from the Yu Da University (YDU), Maioli, in 2012, in information management. She is currently a math teacher, Chung-Hsing Commercial Industrial Vocational High School. Her research interests include wireless network, WCDMA and System for Mobile Communications wireless transmission technology.