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ABSTRACT

A study was conducted to develop the electronic technical competencies of duty and task analysis by using a revised DACUM (Developing a Curriculum) method, a questionnaire survey, and a fuzzy synthesis operation. The revised DACUM process relied on inviting electronics trade professionals to analyze electronic technology for entry-level electronics technicians. The questionnaire survey focused on electronics factories and companies, and opinions of various occupants were obtained from managers, engineers, and technicians. Then, fuzzy synthesis operation of "importance rank" and "future need" was used to analyze items of the duty and task technical competencies. Finally, those entry-level technical competencies for electronics technicians graduates from institutes of technology were analyzed and proposed. The study provides an important source of reference for implementing new curricula in electronics departments in institutes of technology and narrows the gap between theory and practice for electronics technical education. (Contains 13 references.) (Author/KC)

An Application of Fuzzy Theory to Technical Competency Analysis for the Entry-level Electronic Technician

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Abstract. The purpose of this study was to develop the electronic technical competencies of duty/task profile by way of revised DACUM method, questionnaire survey, and fuzzy synthesis operation. The revised DACUM relied on inviting electronic trade professionals to analyze electronic technology for entry-level electronic technicians. The questionnaire survey focused on electronic factories and companies, and opinions of various occupants were obtained from managers, engineers, and technicians. Then, fuzzy synthesis operation of "importance rank" and "future need" was used to analyze items of above duty/task technical competencies. Finally, those entry-level technical competencies for the electronic technician graduated from institute of technology were analyzed and proposed. The main contributions of the study not only provide an important source of reference for the new curriculum implementation of electronic department in institute of technology, but also narrow down the gap between theory and practice for electronic technical education.

keywords: **fuzzy theory, fuzzy composite evaluation, technical competency analysis**

A. Preface

Our education program for junior colleges is concentrated on applied science and technical competency, and the training of practical professional people. Students of these colleges receive effective lessons and vocational practices, with main focus on the knowledge and expertise needed by our industries, so that they may readily join up the line of production workers and service men in various sectors of our industries upon graduation. However, according to CHEN wen-tsun's report at the 4th Electronics, Information and Communication Strategic Convention (1994), inadequate manpower in electronics, computer and telecommunication industries is closely linked to problems in our education system, with possible causes delineated below:(1) Educational programs unable to keep up with the fast pace of technological Developments;(2) Emphasizing too much on theories but not enough on practice;(3) Learning process and curriculum not coordinated, lack of well balanced native teaching materials[1].It is necessary and urgent to analyze the technical competency of electronics technician students in junior colleges for setting our country's technical education programme, curriculum design and development, with an eye to meeting our educational goals for junior colleges.

At the present, most papers relating to technical competency analysis adopt either one of the following methods: (1)DACUM, (2)V-TECS, (3)DELPHI, or(4) revised or a combination of the above three methods[2-6]. Their selection of one technical analysis method over the other is influenced not only on the type of topic chosen, but also on the researcher's subjective perception. Basically, all these four methods have their foundation on qualitative descriptive analysis, but in the process of analysis, comparison, synthesis, sorting, induction, and deduction are involved, as well as some quantitative statistic analysis, in finding out what kinds of technical competencies are required of the students? how significant are the technical competencies to the technical students? what will be the future demand of the identified technical competency? However, as regards to comparative analysis on the importance level and future demand among all technical competences inclusive, we have seldom seen efforts expended in their quantitative analysis. Therefore, it is worthwhile to do research, like this one, in this area, to enhance further development in technical competency analysis.

B. FUZZY COMPOSITE EVALUATION

Fuzzy composite evaluation literally means to conduct a full-scale evaluation on a certain object such as a product or a person. Since the object could possess multiple characteristics and under multiple influences, we need to consider all the factors which could influence the object by a comprehensive evaluation, so called the composite evaluation. Since the evaluation process involves fuzzy factors, so we call it fuzzy composite evaluation[7]. The method and procedures for conducting this fuzzy composite evaluation are as follows [8,9]:

(1) Let the set of causing factors as U, U has a finite boundary. where $\mathbf{U} = \{u_1, u_2, \cdots, u_n\}$, $\bigcup_{i=1}^{n} u_i = \mathbf{U}, u_i \cap u_j = \varnothing, i = j$,

(2) Give every factor evaluation comment to be set V, where $\mathbf{V} = \{v_1, v_2, \cdots, v_m\}$,

(3) Let fuzzy relation matrix $\tilde{\mathbf{R}}$, where $\tilde{\mathbf{R}}$ is the relation between u_i and u_j, in a matrix form as below:

$$\tilde{\mathbf{R}} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}$$

(4) Give every element in factor set U a distributed weight, making up a fuzzy victor set $\tilde{\mathbf{A}}$, i.e. $\mathbf{A} \equiv \{a_1, a_2, \cdots, a_n$, also satisfy $a_i \geq 0, \sum_{i=1}^{n} a_i = 1$.

(5) List out fuzzy composite evaluation model: $\tilde{\mathbf{Y}} = \tilde{\ } \cdot \tilde{\mathbf{R}} = (y_1, y_2, \cdots, y_m)$,after normalization, we get results for each factor $\tilde{\mathbf{Y}} = (y_1/y, y_2/y, \cdots y_m/y$, $y = \sum_{j=1}^{m} y_j$,

(6) Use different algorithms, for example, greater than and small than denoted by $\mathbf{M}(\wedge, \vee)$. weighted average denoted by $\mathbf{M}(.,+)$,

(7) For many factors to be considered and in multiple levels, divide the factors into several levels, as if many factors need to be considered and many levels between the factors, we can divide them into many levels according to its characteristics, first start with each level composite evaluation and then go to higher level composite evaluation, steps as follows:

1.Partition the factors into many subsets:

$U = \{U_1, U_2, \cdots\cdots, U_n\}, U_1 = \{U_{i1}, U_{i2}, \cdots\cdots, U_{in}\}, i = 1, 2, \cdots\cdots$

2.For every K_i factors in U_i, do composite evaluation. let every factor in U_i with weighted distribution becomes A_i, U_i 's fuzzy evaluation matrix be $\tilde{R}_i$, result in $\tilde{B}_i = \tilde{A}_i$ $\tilde{R}_1 = \{b_{i1}, b_{i2}, \cdots\cdots, b_{in}\}, i = 1, 2, \cdots\cdots$;

3. $U = \{U_1, U_2, \cdots\cdots, U_n\}$, U_i's composite evaluation result as n number of individual evaluations in U,with new weighted distribution A', therefore, total fuzzy relation matrix becomes:

$$\tilde{R} = \begin{bmatrix} \tilde{B}_1 \\ \tilde{B}_2 \\ \vdots \\ \tilde{B}_n \end{bmatrix} = (b_{ij})_{n \times m}$$

4.By means of fuzzy composite algorithm $\tilde{B} = \tilde{A} \circ \tilde{R}$. i.e. $U_1, U_2, \cdots\cdots, U$ composite evaluation result, also to be composite evaluation results for all factors in U.

C. DACUM METHOD

DACUM is the abbreviation for Developing A CurriculUM, invented by a group of scholars in economic development department of the New Start Company in Canada's Nova Scotia. In the process of DACUM analysis, researchers first form a committee with 8 or 12 members, including one competency analysis expert, a number of technicians and administrators. And in a period of 2 to 4 days, by means of brain storming, they complete a list called the competency profile. Please note that technical experts currently holding a teaching post in vocational schools cannot be selected as committee member, because of subjectivity and bias in the analysis process, thus positions are filled by experts from the industries. At present, DACUM has been widely used in every profession, including professional competencies, technical competencies, skilled competencies and semi-skilled competencies. DACUM is based on 3 philosophical foundations[10]: (1) skilled technicians in the industries know best what they need most in terms of skill and competence; (2) a technician from the industry is capable of telling what are the necessary competences required for his trade; (3) competence includes operating skills, feelings, and perceptions overall. Generally, members in the DACUM committee is free from external pressures in discussing and analyzing, according to the following procedure[11]:

(1) The chairman gives an introduction and job description for every designated job function;

(2) All committee members proceed with duty analysis under the guidance of the chairman. Duty analysis means the major responsibilities and acitivities to be performed for an individual job function.

(3) As the duties have been assigned, then all members are filed in order and each give a description of the tasks involved from their duty analysis. Task means the smallest work unit of an individual worker, with specific purpose and logical steps in its implementation.

(4) As task analysis has been completed, regarding all the duties, the chairman reviews them , reorganizes them , deletes some, and modifies some until completion.

The end result is usually a competency profile, with 8 to 12 duties and 50 to 200 tasks, representing all the necessary skills required to perform a certain job function well.

D. TECHNICAL COMPETENCY ANALYSIS

This analysis is a revised version of DACUM, analyzing what level of competency is needed by students of junior colleges of electronic technology when they enter the job market. After reviewing all documents and discussing in conferences on the topic of DACUM technical competency, a total of 12 duties and 73 tasks are chosen which are delineated as follows[12]:

DUTY	TASK
DUTYA: select electronic components	TASK1: select basic passive parts.
	TASK2: select basic active parts.
	TASK3: select analog IC parts.
	TASK4: digital IC parts.
	TASK5: select ADC/DAC parts.
	TASK6: select sensor/transducer parts.
	TASK7: select peripheral parts.
	TASK8: select connection parts.
	TASK9: select consumable material.
DUTYB: use electronic instruments	TASK1: operate R.L.C.meter.
	TASK2: operate DVM.
	TASK3: operate function.
	TASK4: operate counter.
	TASK5: operate IC tester.
	TASK6: operate digital/analog scope.
DUTYC: construct analog circuits	TASK1: combine DC low-voltage circuits.
	TASK2: combine low-frequency amplifier circuits.
	TASK3: combine high-frequency amplifier circuits.
	TASK4: combine power amplifier circuits.
	TASK5: combine low-frequency oscillation circuits.
	TASK6: combine high-frequency oscillation circuits.
	TASK7: combine filter circuits.
	TASK8: combine wave-shaping circuits.
	TASK9: combine driver circuits.
DUTYD construct digital circuits	TASK1: combine combinational logic circuits.
	TASK2: combine sequential logic circuits.
	TASK3: combine counter/timer circuits.
	TASK4: combine display/driver circuits.
	TASK5: construct logic control circuits.
	TASK6: construct EPLD/FPGK firmware.
DUTYE. construct microprocessor system circuits	TASK1: select microprocessor parts.
	TASK2: select memory IC parts.
	TASK3: interface IC parts.
	TASK4: establish memory circuits.
	TASK5: establish microprocessor interface circuits.
	TASK6: construct microprocessor system circuits.
	TASK7 familiarize assemble language.

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DUTYF: design software	TASK1: operate DOS. TASK2: operate WINDOWS. TASK3: operate UNIX. TASK4: familiarize a high-level language. TASK5: familiarize a low-level language.
DUTYG: construct telecommunication circuits	TASK1: combine AM emmiter circuit. TASK2: combine AM acceptor circuit. TASK3: combine FM emmiter circuit. TASK4: combine FM acceptor circuit. TASK5: combine ultrasonic wave accepter circuit. TASK6: combine ultrasonic acceptor circuit. TASK7: combine ultrared ray emmiter circuit. TASK8: combine ultrared ray acceptor circuit.
DUTYH: apply computer-assisted drawing	TASK1: use basic drawing. TASK2: use electronic drawing. TASK3: operate drawing software. TASK4: operate PC board software.
DUTYI. fabricate project	TASK1: investigate new product and technology. TASK2: analyze new product and technology. TASK3: construct prototype products. TASK4: operate instruments and equipments. TASK5: write technical reports. TASK6: declare new products.
DUTYJ: use applied software	TASK1: use document processing software. TASK2: use management software. TASK3: use statistic software. TASK4: use publishing software.
DUTYK: monitor production management	TASK1: maintain safe work. TASK2: maintain sanitary work. TASK3: control production sequences. TASK4: manage production quality.
DUTYL conduct technical services	TASK1: use troubleshooting skill. TASK2: maintain product function. TASK3: analyze product market. TASK4: establish sale market.

E. APPLICATION OF FUZZY COMPOSITE EVALUATION

After the technical competency analysis, our research has developed a composite evaluation model as shown in figure 1, comparing the importance and future demand of 12 duties(duty A ~ duty L), for future designing and developing technical education curriculum. To be objective in doing so, our research group itemizes technical competency by duties and tasks, and categorize them by level of importance(very important, important, and not important) and future demand(increased, unchanged, decreased) and each carrying a weighted factor in technical competency evaluation. Based on this, we develop a fuzzy technical competency questionnaire and send them to 180 selected manufacturers of electronics and computer-related products, with a hope of collecting comments from their technical people. From a total of 180 questionnaires sent, we received 166 pieces of reply, a response rate of 92.2%.

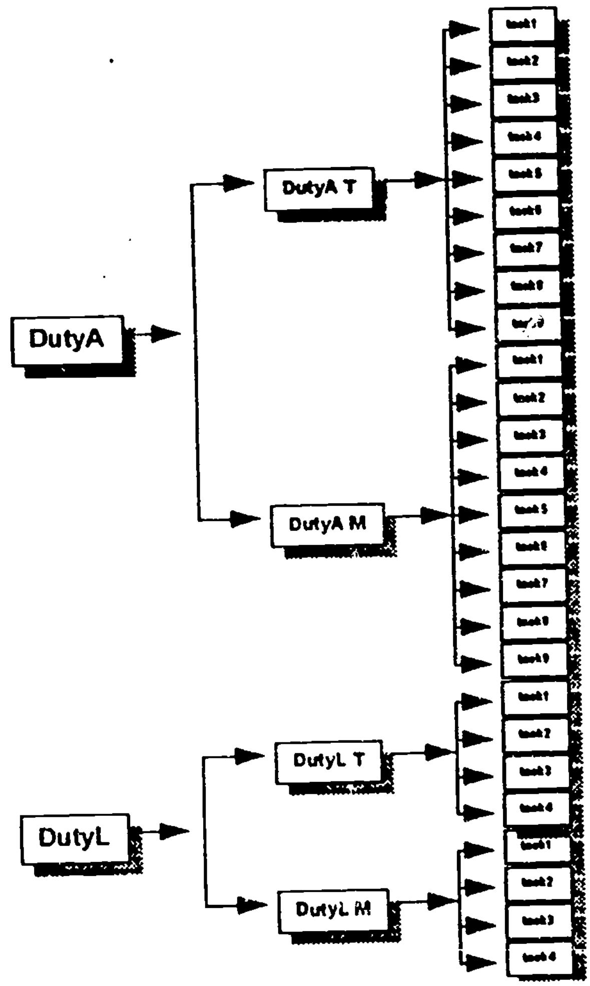

Figure 1 The model of technicalcompetency composite evaluation

After collecting the returned questionnaires, tabulating the data and reprocessing the numbers in unitized format, we build a second level of fuzzy relation matrix for technical people $\tilde{\mathbf{R}}_T$, and then multiply with second level weighted distribution $\tilde{\mathbf{A}}_1$ with fuzzy mathematics operation(using greater than or less than function) with final result $\tilde{\mathbf{F}}_T = \tilde{\mathbf{A}}_1 \circ \tilde{\mathbf{R}}_T$, also an identical matrix for managment people, resulting in $\tilde{\mathbf{F}}_M = \tilde{\mathbf{A}}_1 \circ \tilde{\mathbf{R}}_M$. Then combining the two factors from technical people $\mathbf{F}_T$ and from management people $\mathbf{F}_M$ into a first level fuzzy relation matrix $\tilde{\mathbf{R}}$, then multiply with the first level weighted distribution $\tilde{\mathbf{A}}_2$ (again using greater than or less than function), composite evaluation result as $\tilde{\mathbf{F}} = \tilde{\mathbf{A}}_2 \circ \tilde{\mathbf{R}}$. inally, unitize the numbers again, apply fuzzy operation, compare the level of importance and future demand.

(1) LEVEL OF IMPORTANCE(very important, important, and not important)

I. From information in returned questionnaire, after normalization, we get $\tilde{\mathbf{R}}_T$ and $\tilde{\mathbf{R}}_M$, after fuzzy operation derive $\tilde{\mathbf{F}}_T$ and $\tilde{\mathbf{F}}_M$.

$$\tilde{\mathbf{R}}_T = \begin{bmatrix} 0.37 & 00.50 & 0.13 \\ 0.40 & .0.49 & 0.11 \\ 0.38 & 0.51 & 0.11 \\ 0.38 & 0.57 & 0.10 \\ 0.21 & 0.59 & 0.20 \\ 0.16 & 0.63 & 0.21 \\ 0.28 & 0.54 & 0.18 \\ 0.26 & 0.60 & 0.14 \\ 0.22 & 0.53 & 0.25 \end{bmatrix} \qquad \tilde{\mathbf{R}}_M = \begin{bmatrix} 0.36 & 0.51 & 0.13 \\ 0.37 & 0.51 & 0.12 \\ 0.31 & 0.62 & 0.07 \\ 0.43 & 0.50 & 0.07 \\ 0.24 & 0.60 & 0.16 \\ 0.22 & 0.62 & 0.16 \\ 0.20 & 0.68 & 0.12 \\ 0.17 & 0.68 & 0.15 \\ 0.14 & 0.63 & 0.23 \end{bmatrix}$$

$$\tilde{\mathbf{A}}_1 = \begin{bmatrix} 0.11 & 0.11 & 0.12 & 0.12 & 0.12 & 0.14 & 0.12 & 0.08 & 0.08 \end{bmatrix}$$

therefore,

$$\tilde{\mathbf{F}}_T = \tilde{\mathbf{A}}_1 \circ \tilde{\mathbf{R}}_T = \begin{bmatrix} 0.11 & 0.11 & 0.12 & 0.12 & 0.12 & 0.14 & 0.12 & 0.08 & 0.08 \end{bmatrix} \circ \tilde{\mathbf{R}}_T$$
$$= \begin{bmatrix} 0.14 & 0.14 & 0.14 \end{bmatrix}$$
$$\tilde{\mathbf{F}}_M = \tilde{\mathbf{A}}_1 \circ \tilde{\mathbf{R}}_M = \begin{bmatrix} 0.11 & 0.11 & 0.12 & 0.12 & 0.12 & 0.14 & 0.12 & 0.08 & 0.08 \end{bmatrix} \circ \tilde{\mathbf{R}}_M$$
$$= \begin{bmatrix} 0.14 & 0.14 & 0.14 \end{bmatrix}$$

II. Combining the two factors $\tilde{\mathbf{F}}_T$ from technical people and $\tilde{\mathbf{F}}_M$ from management people, result as fuzzy relation matrix $\tilde{\mathbf{R}}$, multiply by first level weighted distribution matrix $\mathbf{A}_2$, lead to composite evaluation $\tilde{\mathbf{F}}$ matrix.

$$\tilde{\mathbf{R}} = \begin{bmatrix} \tilde{\mathbf{F}}_T \\ \tilde{\mathbf{F}}_M \end{bmatrix} = \begin{bmatrix} 0.14 & 0.14 & 0.14 & 0.14 \\ 0.14 & 0.14 & 0.14 & 0.14 \end{bmatrix}$$

$$\tilde{\mathbf{A}}_2 = \begin{bmatrix} 0.6 & 0.4 \end{bmatrix}$$

$$\tilde{\mathbf{F}} = \tilde{\mathbf{A}}_2 \circ \tilde{\mathbf{R}} = \begin{bmatrix} 0.6 & 0.4 \end{bmatrix} \begin{bmatrix} 0.14 & 0.14 & 0.14 \\ 0.14 & 0.14 & 0.14 \end{bmatrix} = \begin{bmatrix} 0.14 & 0.14 & 0.14 \end{bmatrix}$$

III. Via normalization process: $\tilde{\mathbf{F}}^* = \begin{bmatrix} 0.33 & 0.33 & 0.33 \end{bmatrix}$ This result reflects the importance of (duty A:choose Electronics Component Group): with 33% of the people thinks it is very important, 33%, could be important, and the other 33%, not important at all.

IV. Solve fuzzy matrix: weighted average(3 for very important,2 for important, 1 for not important)

$$Q = \tilde{\mathbf{F}}^* \circ \lambda^T = \begin{bmatrix} 0.33 & 0.33 & 0.33 \end{bmatrix} \begin{bmatrix} 3 \\ 2 \\ 1 \end{bmatrix} = 1.98$$

(2) FUTURE DEMAND(increased, unchanged, and decreased)

I. From tabulated questionnaire data and then unitize the numbers to get $\tilde{\mathbf{R}}_T'$ and $\tilde{\mathbf{R}}_M'$, after fuzzy operation (using greater th... or less than), result in $\tilde{\mathbf{F}}_T'$ and $\tilde{\mathbf{F}}_M'$.

$$\tilde{R}_T' = \begin{bmatrix} 0.39 & 0.55 & 0.06 \\ 0.42 & 0.54 & 0.04 \\ 0.41 & 0.53 & 0.06 \\ 0.57 & 0.42 & 0.01 \\ 0.44 & 0.52 & 0.04 \\ 0.42 & 0.51 & 0.07 \\ 0.46 & 0.47 & 0.07 \\ 0.42 & 0.15 & 0.08 \\ 0.23 & 0.70 & 0.07 \end{bmatrix} \qquad \tilde{R}_M' = \begin{bmatrix} 0.26 & 0.69 & 0.05 \\ 0.29 & 0.65 & 0.06 \\ 0.45 & 0.52 & 0.03 \\ 0.55 & 0.40 & 0.04 \\ 0.49 & 0.43 & 0.08 \\ 0.50 & 0.44 & 0.06 \\ 0.37 & 0.58 & 0.05 \\ 0.35 & 0.58 & 0.07 \\ 0.32 & 0.57 & 0.11 \end{bmatrix}$$

$$\tilde{A}_1' = \begin{bmatrix} 0.11 & 0.11 & 0.12 & 0.12 & 0.12 & 0.14 & 0.12 & 0.08 & 0.08 \end{bmatrix}$$

therefore,

$$\tilde{F}_T' = \tilde{A}_1' \circ \tilde{R}_T' = \begin{bmatrix} 0.11 & 0.11 & 0.12 & 0.12 & 0.12 & 0.14 & 0.12 & 0.08 & 0.08 \end{bmatrix} \circ \tilde{R}_T'$$
$$= \begin{bmatrix} 0.14 & 0.14 & 0.08 \end{bmatrix}$$

$$\tilde{F}_M' = \tilde{A}_1' \circ \tilde{R}_M' = \begin{bmatrix} 0.11 & 0.11 & 0.12 & 0.12 & 0.12 & 0.14 & 0.12 & 0.08 & 0.08 \end{bmatrix} \circ \tilde{R}_M'$$
$$= \begin{bmatrix} 0.14 & 0.14 & 0.08 \end{bmatrix}$$

II.Combining factor of technical people $\tilde{F}_T$ and factor of management people $\tilde{F}_M$, and get fuzzy relation matrix $\tilde{R}'$, and multiply with first level weighted distribution set $\tilde{A}_2$, result in $\tilde{F}'$ matrix.

$$\tilde{R}' = \begin{bmatrix} \tilde{F}_T' \\ \tilde{F}_M' \end{bmatrix} = \begin{bmatrix} 0.14 & 0.14 & 0.08 \\ 0.14 & 0.14 & 0.08 \end{bmatrix}$$

$$\tilde{A}_2 = \begin{bmatrix} 0.6 & 0.4 \end{bmatrix}$$

$$\tilde{F}' = \tilde{A}_2 \circ \tilde{R}' = \begin{bmatrix} 0.6 & 0.4 \end{bmatrix} \begin{bmatrix} 0.14 & 0.14 & 0.08 \\ 0.14 & 0.14 & 0.08 \end{bmatrix} = \begin{bmatrix} 0.14 & 0.14 & 0.08 \end{bmatrix}$$

III. Normalization the numbers, $\tilde{F}'^{\bullet} = \begin{bmatrix} 0.39 & 0.39 & 0.22 \end{bmatrix}$ indicating that for duty A, 39% of the people thinks that it is very important, 39% thinks it is important, and 22% thinks it is not important.

IV. Solve fuzzy matrix: using weighted average(3 for increased, 2 for unchanged, and 1 for decreased)

$$Q' = \tilde{F}'^{\bullet} \circ \lambda^T = \begin{bmatrix} 0.39 & 0.39 & 0.33 \end{bmatrix} \begin{bmatrix} 3 \\ 2 \\ 1 \end{bmatrix} = 2.17$$

(3) The level of importance and demand in future for each duty according to composite evaluation results listed as in Table1 below:

Table 1. the comparative result of importance demand and future need

DUTY DESCRIPTION	IMPORTANCE DEMAND	FUTURE NEED
DUTYA:select electronic components	8(1.98)	8(2.17)
DUTYB:use electronic instruments	7(2.06)	7(2.20)
DUTYC:construct analog electronic circuits	8(1.98)	11(2.05)
DUTYD:construct digital electronic circuits	6(2.08)	2(2.26)
DUTYE:construct microprocessor system circuits	4(2.11)	8(2.17)
DUTYF:design software	8(1.98)	2(2.16)
DUTYG:construct telecommuncation circuits	8(1.98)	12(1.98)
DUTYH:apply computer-assisted drawing	2(2.13)	5(2.23)
DUTYI:fabricate project	2(2.13)	5(2.23)
DUTYJ:use applied software	8(1.98)	8(2.17)
DUTYK:monitor production management	1(2.23)	1(2.32)
DUTYL:conduct technical service	5(2.09)	2(2.26)

E. CONCLUSIONS

In this research, we combine the use of fuzzy composite evaluation, revised DACUM methods and questionnaire survey, apply quantitative and qualitative analysis on electronics technicians graduated from junior colleges, find out what technical competencies they need, and also compare the level of importance and future demand of these technical competencies by tasks, a very effective way of analyzing new technical competency. In analyzing the results of composite evaluation, we know that, in the order of importance and future need, duty G(construct telecommunication circuits) is last in the list, probably due to (1) that task could not reflect future demand, such as personal communications and cabled TV technical competence,(2) few samples taken from telecommunication manufacturers, (3) the majority of manufacturers engage in information-related industries, not involved in communications. We therefore suggest further research with narrower scope to meet our country's growing demand in wireless communications.

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