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An empirical study on using multi-criteria decision making method in enterprise to adopt RFID assessment criteria

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ABSTRACT

The research introduces the multiple criteria decision making (MCDM) method. Through domestic and international literature review and the employment of Modified Delphi Method (MDM) and Analysis of Hierarchy Process (AHP), the study constructed the "Choice model of business adopting RFID". The model construction employed "Literature Review Method" to analyze the study results of related scholars and summarized the assessing model that is suitable for business to adopt information system. MDM is then employed to select the assessment criteria with high degree of consensus under professional consideration according to "expert questionnaire", and the multi-criteria decision-making tool-AHP is employed for professional assessment. At the same time, the inconsistency of experts' opinions are reviewed and amended, and finally, the relative weight of various assessment criteria with advantage is obtained. Taiwan Sugar Corporation (TSC) is the empirical study case of the study, the Optimal Division among the 8 divisions, Hypermarket Business Division, Marketing Business Division, Animal Industry Business Division, Agriculture Business Division, Biotechnology Business Division, Sugar Business Division, Petroleum Business Division and Leisure Business Division for TSC to adopt RFID is analyzed and explored. The empirical result shows: (1). 5 dimensions and 21 assessment criteria which are suitable for business to adopt RFID and use as business decision-making reference. (2). "Hypermarket Business Division" should be the priority introduction choice for TSC to adopt RFID technology.

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KEYWORDS

RFID assessment criteria;
Multi-criteria decision making method;
Modified delphi method;
Analysis of hierarchy process.

INTRODUCTION

Along with the rapid change of technology, the dissemination of information through internet is faster, which has also changed the past lifestyle. To meet with the fierce market competition and challenge, business operation strategy must make immediate adjustments along with the market pulse, because of this, new technology and application tools must be more positively assessed and adopted to speed up the process and analyze the

related data to further improve operational performance and decision-making quality.

The development of RFID technology was early. Currently, this technology has been employed in many areas, such as Taiwan MRT EASYCARD, Taiwan Highway ETC pre-paid card, the vehicle identity, the automation of manufacturing industry and distribution industry, pet chips, access control, library management, and medicine management. Therefore, for business, due to being involved with the regeneration of business process and the integration of back-end information system, the assessment of RFID introduction is a critical work. The study wishes to construct a set of thorough and appropriate model for business to adopt RFID in decision-making and procedure, and further adopt the RFID application field that meets business demand the most in the most appropriate time with the most beneficial cost.

This study goes through RFID study reports and journal articles to analyze and summarize the current situation of domestic and international literatures that employed RFID, and wishes to construct a set of selection assessment for business adopting RFID.

In empirical study, due to TSC has cut across many different industries, and has an extensive production line, the study then analyzes the impact of users' RFID application attitude, intention and behavior focusing on the 8 divisions of TSC, and further explores the feasibility of adopting RFID system to TSC. The optimal division for adopting RFID system is selected and used as the decision-making reference for business adopting RFID.

To sum up, the study purpose is as follows:

1) Propose the assessment dimensions and criteria which are suitable for business to adopt RFID and use as business decision-making reference.
2) Propose the assessment dimension and criteria importance priority which are suitable for business to adopt RFID and use as business executives decision-making reference.
3) Evidently employ MDM and AHP in adopting RFID to TSC's optimal selection of the 8 divisions.

Literature review

The development and application of RFID

In recent years, many companies have gradually invested in passive tag and reader system R&D, and RFID has the cost advantage, therefore it has replaced the traditional barcode-type tag and became the new favorite.

RFID is a tag that is embedded with a chip which can send radio waves; it is mainly formed by Tag and Reader0Middleware System. RFID system is a technology which can read or collect data without any contact, and do not need to aim on the Bar Code (non-line-of-sight). Along with RFID technology continues to mature and progress, it has been gradually and extensively employed by the business industry in different fields, as shown in Figure.1.[1, 2]

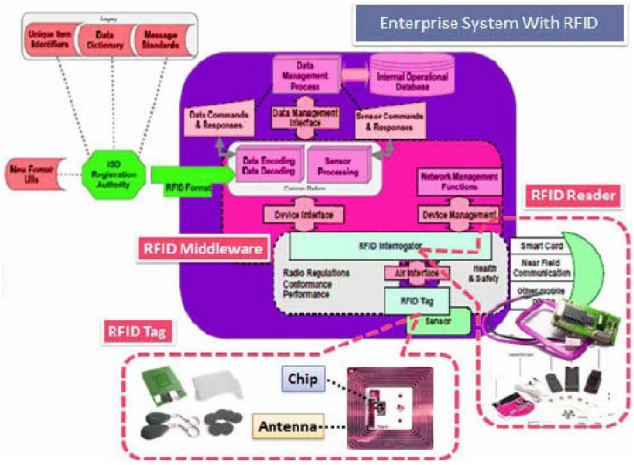

Figure 1 : RFID system architecture

Assessment criteria

It is necessary to include factors of product functions and technical terms and those relevant to providers with relation to assessment and selection of an adequate ERP system. Regarding said criteria, a variety of items are stated, e.g. Scholar H. K. Wang and C. L. Hung,[3] C. L. Chui and K. C. Chia,[4] Y. T. Chen and S. C. Lung (2006),[5] W. P. Lo, S. Y. Lin and Y. C. Liu.,[6] W. L. Chou and A. G Jiang,[7] Y. S. Su and C. C. Jen (2007),[8] etc.

In the selection of comprehensive assessment criteria for business to adopt information technology by Scholar Z. Y.Wu[9] as basis and divided the various RFID decision-making model assessment criteria into 5 major dimensions according to their attributes, and summarized to a total of 38 assessment criteria as the study's assessment indicators, as shown in TABLE 1.

TSC history and development

Cane sugar is an important native product of Tai-

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TABLE 1 : RFID assessment criteria

Major dimensions	Assessment criteria
Technology acceptance	Perceived usefulness, perceived ease of use, attitude of use, willingness of use, actual use, technology compatibility, technology perfection, and technology advantage.
Cost economy	Equipment and construction cost, labor cost, equipment maintenance cost, employee training cost, inspection and control cost, inventory cost, technology update cost, and production capacity utilization rate.
Human resource	Collaboration between employees, company and employee relationship, full support from high-level personnel, executive and managing ability of the team in charge, employee morale and loyalty, benchmarking, and establishing industry technical personnel information.
Customer and market oriented	Customer education service, decision-making ability to grasp market trend, customer satisfaction management, customer order planning, innovation compatibility, technology effectiveness, customer focus, customer communication, and long-term relationship.
Process management	Information transmission management, organizational operation, production risk control, transportation and warehousing management, perceived risk, and supplier quality management.

wan. TSC has a more than 300 years history. The highest record of cane acreage before the inauguration in the period of Taiwan under Japanese rule was 162,000 hectares, and the sugar production was 1,420,000 tons. There were 46 sugar factories, the cane acreage has once reached 120,000 hectares, sugar production has reached 1 million tons, and the highest foreign exchange earnings has once reached US$ 135 million. For a consecutive 17 years, sugar was Taiwan's leading export commodity and accounted for 79 percent of the nation's total foreign exchange earnings at its peak, therefore, sugar and rice were the major economic pillars.

In Taiwan's economic development, Annually TSC manufactured sugar and by-products worth hundreds of millions of U.S. dollars, and paid a considerable amount of taxes and, in turn, promoted the modernization of Taiwan's agriculture. TSC has contributed a lot to Taiwan's agricultural economy by effectively utilizing land resources and providing many job opportunities to the farmers. In production technology, TSC has first innovatively adopted new technologies, such as well-digging, salt improvement, soil and water conservation, mechanical farming, enterprise pig farming, the application of herbicide and compound fertilizer, and agricultural co-operation. Originally, TSC only focused on sugar industry, in recent year, TSC has been actively diversifying its businesses, and completed the construction of the 8 major business divisions, hypermarket business division, marketing business division, animal industry business division, agriculture business division, biotechnology business division, sugar business division, petroleum business division and leisure business division in 2004.[10]

RESEARCH METHODS

In this research, the RFID Assessment Criteria is a multiple criteria decision making (MCDM) problem and has a strategic importance for many commercial companies. In practical environments, the evaluators face a variety of adopting RFID technology service that is often vague from human beings' subjective judgments. These problems may not be properly evaluated by the conventional models. In order to overcome the situation of uncertainty among the evaluated criteria in real problem, in this study, the two MCDM methods (i.e., modified Delphi method, MDM and analytic hierarchy process, AHP) are utilized to derive the final appraisal values from which one can choose the best option and determine the preferred order according to these values.

The study goes through literature review and exploration, and has summarized the related assessment

factors. The group of scholars and experts employed the "modified Delphi assessment model" to process the first stage selection of assessment factors, it is hoped to propose the suitable assessment criteria for business to adopt RFID and provide as reference for business decision-making. The second state expert questionnaire survey is to employ "AHP analysis model" for analyzing the weight level of the assessment factors, obtaining the weight of the assessment factors, providing the decision-maker a set of objective and with quantitative data analysis decision-making reference, and further applying AHP to the adoption of RFID in business assessment program, and processing the optimal decision-making.

Modified delphi method (MDM)

Murry and Hammons (1995)[11] proposed a method to modify traditional Delphi method, which is called the "modified Delphi method". The "modified Delphi method" retains the spirit and advantage of the Delphi method, and appropriately simplify the complicated questionnaire process (which is to omit the opened questionnaire implementation) according to a large amount of related literature data, after the pretest modifications, structural questionnaire or experts interview is developed to replace the first stage investigation tool.[12]

The study has applied MDM to process the Delphi method questionnaire implementation, and the calculation method is described as follows:

If in the t-th Delphi method survey result, the score of the h-th expert gave to the j-th item is shown as X_{jht}; then the mean and SD of the score of the r-th expert gave to the j-th item in the t-th survey will be respectively shown as $\overline{X}_{jt}$ and S_{jt}:

$$\overline{X}_{jt} = \frac{1}{r}\sum_{h=1}^{r} X_{jht}, \forall j,t \quad (1)$$

$$S_{jt} = \sqrt{\frac{1}{r-1}\sum_{h=1}^{r}\left(X_{jht} - \overline{X}_{jht}\right)^2}, \forall j,t \quad (2)$$

The Coefficient of Variation (CV) can be employed as the criteria to evaluate whether or not the expert determination has reach a consensus. Therefore, the CV of the t-th survey on the j-th item is shown as CV_{jt}:

$$CV_{jt} = \frac{S_{jt}}{\overline{X}_{jt}}, \forall j,t \quad (3)$$

When smaller the CV_{jt}, the smaller variance of each average score is, which is the opinions of r experts are more consistent. As the measuring scale is [0, S], in this scale, the greater $\overline{X}_{jt}$ the score, the smaller the CV_{jt} is, and the smaller $\overline{X}_{jt}$ the score, the greater the CV_{jt} is. Therefore the impact of scale size must be eliminated. The greatest average score is employed for adjustment, and the following consensus deviation index (CDI) is defined:

$$DC_{jt} = 1 - CDI_{jt}, \forall j,t \quad (4)$$

The smaller the CDI, the higher the experts' Degree of Consensus (DC) is. Therefore, DC can be defined as follows:

$$CDI_{jt} = CV_{jt}\frac{\overline{X}_{jt}}{\max_j\left\{\overline{X}_{jt}\right\}}, \forall j,t \quad (5)$$

When the scores of r experts are all the same, $CDI_{jt}=0$, $DC_{jt}=1$, then it refers to having 100% consensus. It is not easy to reach 100% consensus, therefore, the planning unit can preset the threshold ε of consensus deviation, such as ε=0.1 or ε=0.05, and as long as CDI_{jt} is smaller than ε, then it refers to the t-th survey has reached consensus. For the Delphi method survey, it also used variance or quartile as the convergence criteria, the smaller the Quartile Deviation (QD).[13]

Analytic hierarchy process (AHP)

The purpose of AHP development is to systemize complicated problems, the hierarchy is divided from different perspectives, the context is found through quantitative determination, then evaluated to provide the decision-maker to select the sufficient information of suitable plan, and at same time lower the risk of decision-making errors. The application is divided into two parts, the establishment of hierarchy, and the assessment of hierarchy.

Establishment of hierarchy

The hierarchy of AHP is as shown in Figure 2.[14] In the Figure, A refers to the goal that wants to be reached, B refers to the subject, and C is the assessment criteria to form the hierarchy of the decided project. Hierarchy

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amount is set according to question analysis. However, there should not be too many factors in a hierarchy, as a rule, it should not be more than 7-9 factors.

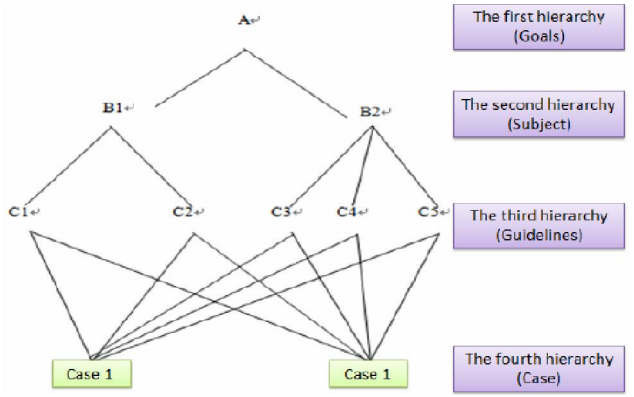

Figure 2 : AHP hierarchy diagram

Assessment of hierarchy

AHP is to give a complicated problem to experts and scholars to assess the elements, and then shown in simple hierarchy. Use scale assessment for pair comparison and establish the matrix, obtain the eigenvectors, then compare the priority of hierarchy element, and inspect the consistency of pair comparison matrix. If the consistency is met, then the priority value represented by the eigenvector then can be used as reference for evaluating the decision-making.

In the consistency test, Saaty's (1980)[15] recommendation is followed, Consistency Index (consistency index, C.I.) and Consistency Ratio (consistency ratio, C.R.) are used for the testing, and the relative weight between each element is calculated, which are respectively described as follows:

1) C.I. is the difference between the biggest eigenvalue (λmax) and order (n), which can be used as the assessment criteria to determine consistency level. The calculation method is C.I. = (λmax-n)/n-1, the smaller the C.I., the higher the consistency is; if C.I. ≦0.1, then it refers to the pair comparison matrix has satisfying consistency.
2) C.R. refers to the size of C.I. will be impacted by the matrix order and rating scale, which is C.R.= C.I./R.I.。R.I.(random index, R.I.). R.I. is random index; it is randomly created by the Positive Reciprocal Matrix. R.I. value will be greater along with the increasing matrix order, if C.R. ≦0.1, then it refers to the rating of the pair comparison is acceptable. Each order comparison item amount n and the relative R.I. value are shown as TABLE 2.[15]

TABLE 2 : Comparison item amount n and the relative R.I. value in AHP

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0.0	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	1.59

After passing the consistency test, obtain by multiplying the weights of each hierarchy, and then calculate the priority of each plan. The bigger the value, the higher priority of being adopted is. To understand the importance order of various evaluation dimensions and criteria, and allow the study result to have more empirical value, the study adopted AHP to obtain the priority of each plan.

EMPIRICAL RESULT ANALYSIS

Result analysis of MDM

5 assessment dimension and 38 assessment criteria are summarized to design the questionnaire according to the previous literatures. The questionnaire response data applied quantitative data to present experts' opinion, and applied semi-opened questionnaire and Likert Scale as the indicators to present experts' opinion, and obtain the modification and consistent agreement of adopting RFID in TSC evaluation dimension and criteria.

The questionnaire was implemented between March and May 2010, and all questionnaires have been recovered, the implementation frequency of questionnaire should depend on whether the experts' opinions have reached a consensus. There are a total of 50 questionnaires issued, and 42 effective questionnaires have been recovered, the effective response rate is 83%.

After the questionnaire is recovered, consensus test must be processed to determine whether experts' opinions are consistent, the study applied QD as the standard of consensus test. According to the standard set by scholar Young, I-Chen and Chou, Chien,[16] if the QD value:

1) Is smaller or equal to 0.60, then it refers to the experts' opinion has reached a high-degree of consensus.
2) Falls in between 0.60 and 1.00 or equal to 1.00,

then it refers to the experts' opinion has shown a moderate consensus.

3) Is bigger than 1.00, then it refers to the experts have not reached a consensus for the question, so the index should be modified.

Finally, after the entire questionnaire has passed a consensus test, Scholar Mead, Donna M.[17] thinks if there are more than 80% experts have the same opinion, it is regarded as the experts have reached a consensus on the overall questionnaire opinion, which is the assessment hierarchy we needed.

The questionnaire result retains that the experts have all reached a moderate or high-degree consensus, which meets the standard proposed by Scholar Mead, Donna M.[17], so it has established the assessment hierarchy of "adopting RFID in enterprise", 5 assessment dimension and 21 assessment criteria as shown in TABLE 3.

TABLE 3 : Delphi method questionnaire consensus degree

Delphi method questionnaire consensus degree					
Hierarchy		Evaluate dimension criteria	Quartile deviation	The consensus degree of experts on each	Overall questionnaire consistency test
2	5 assessment dimensions	Technology acceptance	0.50	High-degrees	
		Cost economy	0.75	Moderate	
		Human resource	0.75	Moderate	
		Customer and market oriented	0.50	High-degrees	
		Process management	0.50	High-degrees	
3	Technology acceptance	Perceived usefulness	0.50	High-degrees	
		Perceived ease of use	0.25	High-degrees	
		Attitude of use	0.50	High-degrees	
		Willingness of use	0.75	Moderate	
		Actual use	0.75	Moderate	
3	Cost economy	Equipment and construction cost	0.50	High-degrees	
		Labor cost	0.50	High-degrees	84%
		Equipment maintenance cost	0.00	High-degrees	
		Employee training cost	0.25	High-degrees	
3	Human resource	Collaboration between employees	0.00	High-degrees	
		Company and employee relationship	0.25	High-degrees	
		Full support from high-level personnel	0.00	High-degrees	
		Executive and managing ability of the team in charge	0.50	High-degrees	
3	Customer and market oriented	Customer education service	0.50	High-degrees	
		Decision-making ability to grasp market trend	0.50	High-degrees	
		Customer satisfaction management	0.50	High-degrees	
		Customer order planning	0.50	High-degrees	

Result analysis of AHP

The study designs AHP expert questionnaire according the TABLE 3. The evaluation hierarchy of "adopting RFID in business". The purpose is to investigate the relative weight of experts on the "selection of adopting AHP in the adoption of RFID to TSC division plan".

The questionnaire design mainly bases on the AHP proposed by Tomas L.Saaty [15], it employs the pair comparison method, and the rating scale is divided into five levels (9 scales), which are equal important, slightly important, important, relatively important, and absolutely important, they are respectively given the measurement value of 1, 3, 5, 7, and 9. The mailing and response of the questionnaire employs email or personal delivery with the agreement of all interviewed experts. There are 102 questionnaires issued, and 89 effective samples are obtained, the effective response rate is 87%. All the questionnaires were recovered between June to July 2010.

The study applied "Expert Choice 2000" decision-making support software to calculate the weight between the hierarchies. A conclusion is obtained with the aforementioned questionnaire processing feasibility analysis focusing on TSC's 8 divisions adopting RFID system, the assessment dimension and assessment criteria result is shown as TABLE 4.

TABLE 4 : Result of applying AHP in the adoption of RFID in TSC

Ultimate goal	Assessment dimensions	Dimension criteria	Hierarchy weight	Overall weight
The evaluation hierarchy of "adopting RFID in business"	Technology acceptance	Perceived usefulness	0.417	0.052
		Perceived ease of use	0.152	0.019
		Attitude of use	0.103	0.013
		Willingness of use	0.197	0.024
		Actual use	0.131	0.016
	Cost economy	Equipment and construction cost	0.298	0.102
		Labor cost	0.372	0.128
		Equipment maintenance cost	0.207	0.071
		Employee training cost	0.123	0.042
	Human resource	Collaboration between employees	0.135	0.017
		Company and employee	0.178	0.022
		Full support from high-level personnel	0.495	0.062
		Executive and managing ability of the team in charge	0.192	0.024
	Customer and market oriented	Customer education service	0.198	0.039
		Decision-making ability to grasp market trend	0.378	0.074
		Customer satisfaction management	0.277	0.054
		Customer order planning	0.147	0.029
	Process management	Information transmission management	0.325	0.069
		Organizational operation	0.141	0.030
		Production risk control	0.217	0.046
		Transportation and warehousing management	0.317	0.067

Result analysis of adopting RFID in TSC

In response to the adoption of RFID system can more rapidly and accurately obtain data, and the con-

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sideration of related adoption factors, in the diversified TSC divisions, the related information is summarized through experts' opinions, and the relative comparison weight of adopting RFID system to TSC divisions can be calculated with AHP, which can all be used as reference for TSC's decision-making to adopt RFID system. The study result shows, it is suggested that TSC's "Hypermarket Business Division" should be the priority RFID adopting division, as shown in TABLE 5.

TABLE 5 : Result of applying AHP in the adoption of RFID in TSC

TSC's decision-making to adopt RFID system	Business Division (BD)	Plan weight	Wercentage	Order
	Hypermarket (BD)	0.187	18.7	1
	Marketing (BD)	0.179	17.9	2
	Animal Industry (BD)	0.164	16.4	3
	Agriculture (BD)	0.161	16.1	4
	Biotechnology (BD)	0.104	10.4	5
	Sugar (BD)	0.079	7.9	6
	Petroleum (BD)	0.066	6.6	7
	Leisure (BD)	0.060	6.0	8

CONCLUSION

To ensure the assessment factors that need to be considered when establishing the selection model of "business adopting RFID", the study has divided the questionnaire design into 2 stages. Stage 1 applies the MDM expert questionnaire to ensure the selection of the assessment factors, and stage 2 applies AHP expert questionnaire to ensure the weight level of various assessment factors, to allow the experts to process the optimal decision-making focusing on the feasibility industry plan of adopting RFID in business. The empirical result is described as follows:

1) Dimension hierarchy analysis: The study result shows the five assessment dimensions are respectively: technology acceptance, cost economy, human resource, customer and market oriented, and process management and the weights are respectively 0.123, 0.344, 0.126, 0.196 and 0.211. Therefore, the importance of the dimensions is "cost economy" prior than other dimensions.
2) Criteria hierarchy analysis: The assessment result of assessment criteria is shown as TABLE 6. The study result shows, the importance of the assessment criteria is "labor cost (0.128)" is most important than other criteria.
3) The analysis of optimal division for the adoption of RFID: According the study data, the weight percentage of hypermarket business division, marketing business division, biotechnology business division, and animal industry business division are over 15%. Therefore, the "Hypermarket Business Division" is the most priority adoption division.

CONTRIBUTION

The following conclusions can be obtained after summarizing the study result:

1) Propose the 5 dimensions and 21 assessment criteria that are suitable for business to adopt RFID as business decision-making reference.
2) Empirically propose the assessment dimension and criteria importance order that is suitable for business to adopt RFID, the result can provide as reference for business executives' decision-making.
3) In assessment model of business adopting RFID, the importance order of the five dimensions are "cost economy" prior than other four dimensions; and the importance order for assessment criteria is "labor cost" being more important than other 20 criteria.
4) The empirical result shows that: The "Hypermarket Business Division" should be the priority adoption selection for TSC to adopt RFID technology.

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