南華大學九十五學年度 博士班 招生考試試題卷

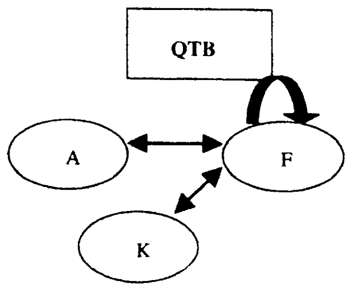
系所別：管理科學研究所 博士班	科目編號：C2-01-01
科　目：管理論文評析(一)　【第一篇 /共二篇】	試題紙第 1 頁共 13 頁

管理論文評析(一)
(請用中文回答下列各題，否則不予計分)

1. 請以列舉方式說明本文作者認為 ANP-Delphi with MAH 方法之優點或優勢為何？(10 分)

2. 請說明下列方法之用途。
   (a) Analytic Network Process。(5 分)
   (b) Maximise Agreement Heuristic。(5 分)

3. 請詳細說明下圖所代表的意義(節錄自本文圖 4 中)。(10 分)



4. 請依 Firm no.3 的數據資料(見附錄 A 中之 Table A.1)，試將本文中之 Table 3 重新計算與完成。(10 分)

5. 若將附錄 B 中 Table B.2 的 Firm no. 4 的 Ranking 資料修改如下表所示，請重新計算並完成 Table B.3 與 Table B.4。(10 分)

Firm no.	Ranking
1	1,2,3
2	1,2-3
3	3-1,2
4	**3-1-2**
5	1,2-3

A framework for group decision support systems: An application in the evaluation of information technology for logistics firms☆

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Abstract

The objective of this research is to propose a framework to enable decision-makers to achieve an overall consensus by using a group decision support system in the evaluation of information technology. The framework consists of a series of steps beginning with individual rankings of criteria by applying the analytic network process (ANP), through to a consensus ranking by utilising Delphi and Maximise Agreement Heuristic (MAH) methods. The contribution of this research lies in the methodology for integrating ANP, Delphi and MAH in order to perform quantitative and qualitative analysis in-depth to achieve the overall consensus ranking in association with a programme developed by the authors. The model assessment and its limitations using five logistics firms in Thailand are also presented.

Keywords: Analytic network process; Delphi; Maximise agreement heuristic

1. Introduction

The objective of this research is to present a framework to enable decision-makers (DMs) to work as a group and achieve an overall consensus in the evaluation of information technology (IT) proposals. An explanation was given to each DM as to precisely what was meant by each IT alternative proposed. The DMs usually indicated that the explanation of the problem, and the analytic network process (ANP), were helpful in enabling them to articulate their decision criteria. They were not sure, however, how to manage different individual ratings of the relationships between all IT alternatives, to reach a reasonable consensus. This paper attempts to deliver a solution for that requirement, based upon DMs

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from logistics businesses, by using the Delphi and the Maximise Agreement Heuristic (MAH) method, using a programme developed by the authors.

Before going into details of the decision model, it is necessary to clarify the rationale of the decision support system, ANP, Delphi and MAH. Riddle and Williams (1987) state that technology selection, particularly IT selection, is the process of determining which (new or old) methods, techniques, and tools satisfy criteria reflecting specific target community's IT requirements. IT selection requires several capabilities: the ability to *identify* a set of candidates to be considered, the ability to *evaluate* (either comparative or in isolation) the candidates, and the ability to *choose* from amongst the candidates based upon the evaluations. They also examine IT selection as the key to technology improvement and transfer. It is the critical first step in improving practice and it can identify the need for new acquisition, integration, propagation techniques, and perhaps even suggest the general nature or operational details of these techniques. The requirements above can be achieved by the assistance of a decision support system.

Morton (1971) first articulated the concepts involved in "decision support systems" (DSS) within the term "management decision systems". DSS can be characterised as *interactive* computer-based systems which *help* a decision-maker utilise *data* and *models* to solve *unstructured* problems (Fick and Sprague, 1980; Sprague and Sprague, 1996; Sauter, 1997). The other meaning may be an interactive system under user control that provides data and models to assist the discussion and solution of unstructured problems (Laudon and Laudon, 1995).

There are a number of applications of DSS in the literature. For example, Pandey and Kengpol (1995) apply a multi criteria decision method for selecting the best possible automated inspection device used in flexible manufacturing systems. They face the difficulty of justifying the value of this advanced technology, particularly in financial terms. Kengpol and O'Brien (2000) develop a decision support tool for the selection of advanced technology by using the Analytic Hierarchy Process (AHP), costs and benefits and statistical analyses to assess the value of investment. However, there is a need to achieve an overall consensus amongst DMs.

Elfvengren et al. (2002) state that groups have an advantage in combining talents and providing innovative solutions to possibly unfamiliar problems; the fact that a group possesses a range of skills and knowledge over and above an individual is a distinct strength in favour of the group. The objective of group decision support system (GDSS) is to support the interface amongst users in order to improve productivity of decision making meetings either by speeding up the decision making process or by improving the quality of the decision results (Ellis et al., 1991).

The department of Industrial Engineering and Management at Lappeenranta University of Technology (LUT) has a full scale GDSS laboratory which is used extensively for teaching and collaborating research within research teams or amongst industries. The mass of publications resulting from the GDSS laboratory at LUT include, for example, Elfvengren et al. (2002); Kärkkäinen et al. (2001); Piippo et al. (1999) and Ojanen et al. (2000).

This paper proposes a framework to evaluate quantitative and qualitative aspects of benefits, costs and risks from the investment in IT, enhanced by using GDSS to achieve an overall consensus. The general model links strategic criteria to provide for the evaluation in a multi-attribute decision analysis. The Analytical Hierarchical Process (AHP) introduced by Saaty (1990) is one of the frequently used approaches to aid such analysis. In AHP, a hierarchy considers the distribution of a property (goal) amongst the elements being compared, and judges which element has a greater influence on that property (Korpela et al., 2002; Korpela and Tuominen, 1996; Kivijarvi and Tuominen, 1991). In reality, we need a holistic approach in which all criteria and alternatives involved are connected in a network system that accepts various dependencies (Saaty, 1996). Several decision problems cannot be hierarchically structured because they involve the interactions and dependencies in higher/lower level elements. Not only does the importance of the criteria determine the importance of the alternatives as in AHP, but the importance of the alternatives themselves also influences the importance of the criteria. In this paper, the overall goal is to find the optimal investment in IT by considering the benefits, costs, risks and other sub-criteria. An approach is needed that can accommodate the above requirements. Saaty (1996) introduced an approach called the "ANP", which no longer depends upon a linear top-to-bottom form of hierarchy but looks more like a network with the ability to consider feedback and to connect clusters of elements. ANP applications have been noticeably limited when compared with AHP, due to its complexity and time consuming nature. Examples of its application include "decision methods on a breast cancer patient" (Carter et al., 1999), "evaluating environmentally conscious business practices" (Sarkis, 1998), "strategic analysis of logistics and supply chain" (Meade and Sarkis, 1998), "energy policy planning" (Hämäläinen and Seppäläinen, 1986), "information system project selection" (Lee and Kim, 2002) and "product planning" (Karsak et al., 2002).

2. Criteria for the selection of information technology

Not much research has dealt directly with the criteria for the selection of advanced technology or IT. Almost all of it has dealt with the decision-making theory. Souder (1972); Baker (1974); and Baker and Freeland (1975) report some strengths and limitations of a number of quantitative R&D selection and resource allocation models.

Forman (1985) argues that the executive DMs are involved in establishing goals and criteria, and integrating information relevant to the goals and criteria. Therefore they need guide parameters that allow them to structure and incorporate subjective as well as objective factors, and integrate their expertise as well.

The most interesting criteria for selection of advanced technology come from Liberatore (1987, 1988). He presents criteria and sub-criteria for project proposal evaluation. Four categories are listed: manufacturing criteria, technical criteria, marketing and distribution criteria, and financial criteria. All suggested criteria and sub-criteria are as illustrated in Table 1.

Nowadays most major companies are still struggling with their conventional investment justification procedures because they are either misunderstood or the information for the calculations is inadequate for such a complex problem (Canada and Sullivan, 1989). Sambasivarao and Deshmukh (1997) explain that decision making in advanced manufacturing technology (AMT) becomes quite complex because this technology encompasses quality, flexibility, lead times, manufacturing capability, time to market and others.

According to Fig. 1, the ANP advantages are in being able to articulate the decision criteria and in ensuring that *each* of their weights and preferences is internally consistent. However, the limitation of ANP is in managing different individual ratings of the relationships in order to reach a reasonable consensus. The Delphi model can provide a reliable consensus of opinion amongst a group of experts in the form of average preference weights. The MAH model is capable of accommodating the consensus logic rather than only the average of preference weights. As illustrated in Fig. 1, the integration of ANP, Delphi and MAH can demonstrate a methodology with more insight

Table 1
R&D project selection criteria

- Capability of manufacturing the product.
- The ability of meeting the facility and equipment requirements.

Technical criteria, pertaining to R&D and engineering
- Probability of technical success
- Total R&D and Engineering costs
- Amount of time required to complete all tasks
- Availability of required R&D and Engineering resources

Marketing and distribution criteria
- Size of potential market
- Capability to market product
- Market trends and growth
- Financial criteria
- Profitability, as measured in cash flow
- Capital investment required
- Return on Investment

Source: Liberatore (1988).

than overall mean scores to closely represent the consensus view. (The literature of Delphi and MAH are explained in Section 4.)

3. Analytical model for the selection of IT

In evaluating which of various alternatives to choose, four distinct groups, or clusters, are considered to have an influence on the decision

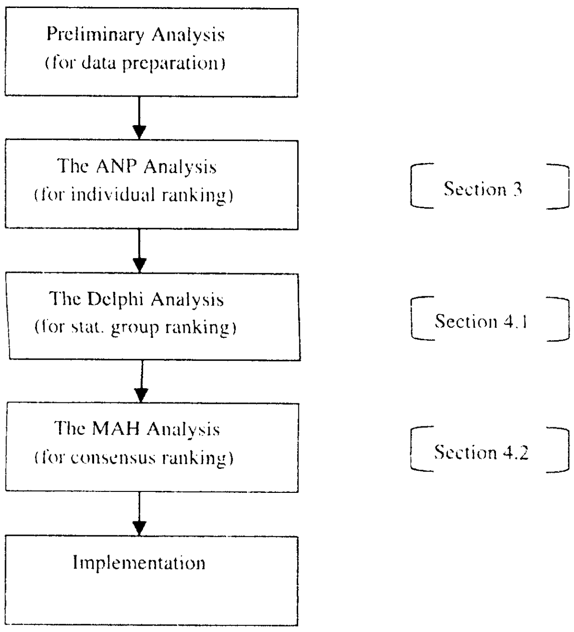


Fig. 1. The decision support system (DSS) model.

process (Fig. 3). There are different elements within each cluster. These clusters and the elements are not necessarily included in each or every sub-criteria (Fig. 4). The criteria, sub-criteria and cluster relationships given from selected literature, for example, Kengpol and O'Brien (2000); Saaty (1996) and Liberatore (1988), and from interviews with reputable logistics companies in Thailand in order to represent general internal and external characteristics of the firm. Within this research, there is only one DM, who is the logistics manager, participating from each logistics firm. The following will serve as a foundation for the ANP model.

3.1. Control hierarchy in feedback network

As illustrated in Fig. 2, the control hierarchy contains the *overall goal*, *control criteria* (benefits, costs and risks) with further *control sub-criteria* for evaluation under each criterion. *Quantitative benefits* (from investment in IT) are related to the potential monetary gain from adopting IT e.g. raw material savings, energy savings, reduction in waste treatment, etc. *Qualitative benefits* are the knowledge and creative skills gained from IT technology and include problem-solving skills that develop while learning. *Quantitative costs* are defined in terms of money spent in the implementation of IT, for example in the programme, staff training budget and other overhead budgets. *Qualitative costs* can be thought of as the mental efforts imposed on their staff: for example, from

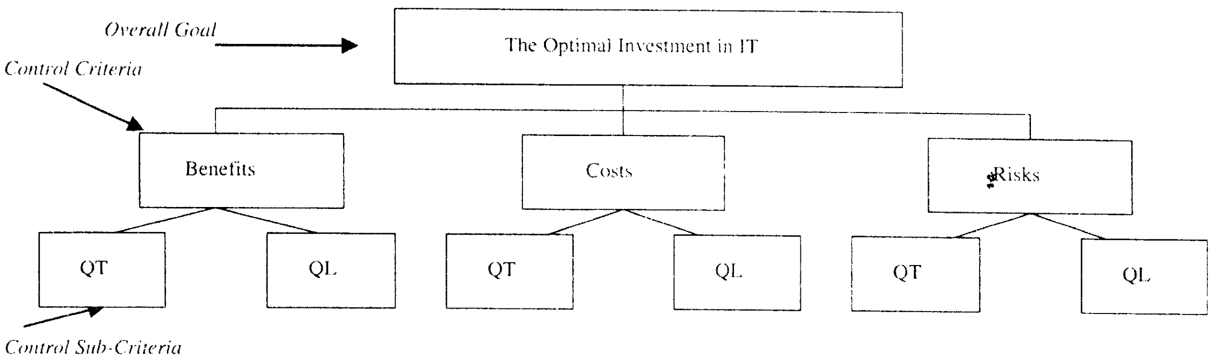


Fig. 2. Control hierarchy. Remarks: QT = quantitative, QL = qualitative.

the interviews there was a concern that the previous job efficiency of the staff chosen to work within IT may reduce due to their needs to learn and acquire new skills in the implementation of IT. *Quantitative risks* are about the return on investment in the implementation of IT. Competitor investment in IT may be a crucial factor in favouring a firm to invest in IT if they want to be in the forefront of the business. *Qualitative risks* are of increasing concern to most of the large manufacturing firms, from losing their staff after they have been trained to developing knowledge skills, practice skills and problem solving skills.

3.2. Stakeholders

As illustrated in Fig. 3, there are four clusters of stakeholders identified in this model. Each cluster is further sub divided into several elements. Firstly, the *technical cluster* (T): there are three elements in this cluster, namely: time to implement (T1) means length of time from the beginning until the firm can run IT in full; skills requirement (T2) means how much each particular alternative requires skills to achieve IT competence; resource requirement (T3) means how much of each particular resource are specifically required. Secondly, the *financial cluster* (F): this cluster has two elements, namely expenses (F1) which means the total expected cost for a specific period to obtain IT including cost of machine, training, material and overhead, etc., and incomes (F2) means total expected incomes to the firms, for example new incomes from new markets. Thirdly, the *marketing cluster* (K) means there are better chances of having more new customers (K1: create new market). Finally, the *alternatives cluster* (A): this could be ways of achieving IT performance in the logistics business; for example, (A1) is the fully integrated computerised IT system, (A2) is the semi-integrated computerised IT system, and (A3) is the manual integrated IT system.

3.2.1. Cluster relationships and the ANP model

Fig. 4 illustrates six cluster relationships that are associated with the control hierarchy (Fig. 2) and the cluster and elements of stakeholders (Fig. 3). The interrelationships (outer dependence) between clusters are represented by unidirectional or bi-directional arrows. The direction of each arrow indicates a direct influence between clusters. Inner dependence within a cluster may occur if the cluster is itself dynamically influenced by the control sub-criteria (such as the influence of the financial cluster on the quantitative benefits which comes from the more savings in budget, the more budget spent on new options). Each element of cluster in each control sub-criterion will be subjected to pairwise comparison. Therefore, for the control hierarchy illustrated in Fig. 2 we need to generate more than a hundred matrices from a total of more than 400 pairwise comparisons to construct the supermatrix for analysis. The details and explanations of the solution of a supermatrix can be found in Saaty (1996) and Sarkis, (1998).

3.2.2. Results and discussions

All ratings for the alternative IT proposals, compared through the responses of five logistics firms, are shown in Appendix A, Table A.1, and at

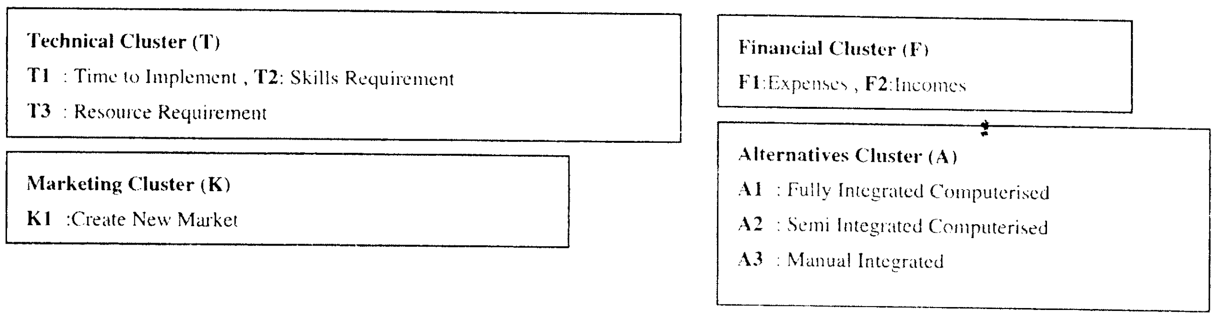


Fig. 3. Clusters and elements of stakeholders.

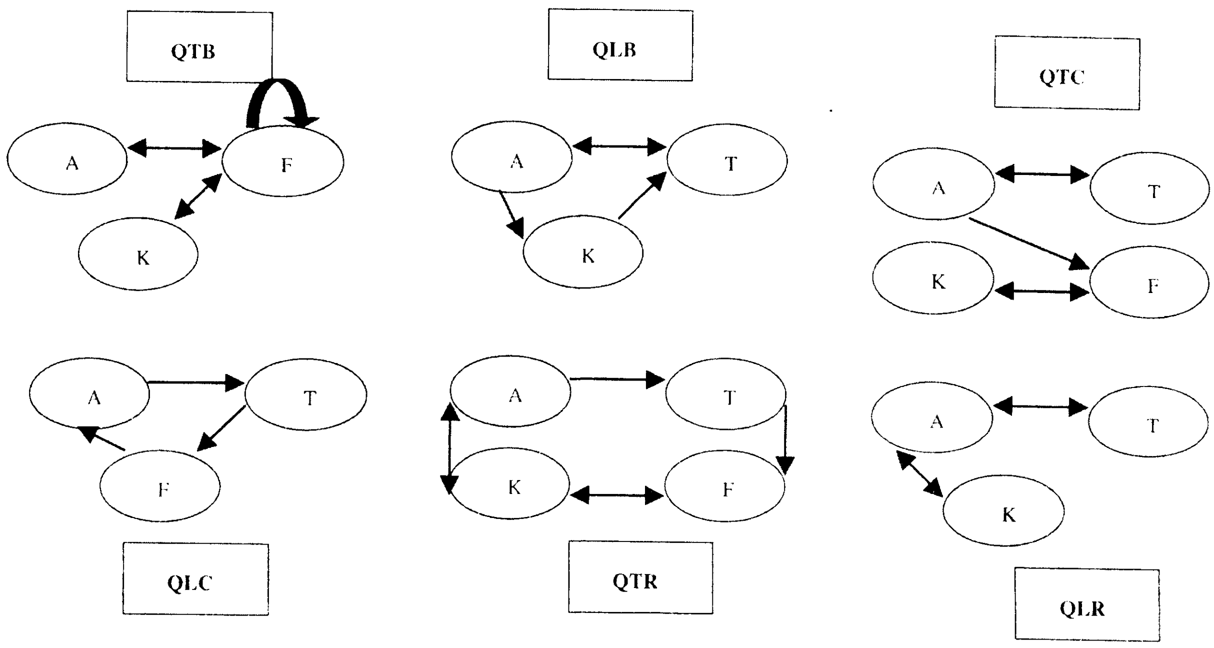


Fig. 4. Cluster relationships. Remark: QT = quantitative, QL = qualitative, B = benefits, C = costs, R = risks.

Table 2 in this section which illustrates only the responses from the firm no.1. This indicates that there is an equal weight (0.33) to the *benefits*, *costs* and *risks*. In terms of *benefits*, the DMs give highest priority to the *quantitative benefits* (0.60), which would lead the majority to select the fully integrated system. On the other hand, the manual integrated system is the only preferred technology in every sub-criterion of *costs*. Surprisingly, both the *quantitative and qualitative risks* are equal in priority (0.50), giving preference only to the semi-integrated IT system.

Table 3 summarises the overall results and gives the ranking of benefits/(costs*risks) for firm no. 1. This combines the three sets of derived priorities into a single index that expresses the overall utility of the strategies. This combination is meaningful because the derived priorities are ratio scales and the product and quotient of ratio scales can also be expressed as a ratio scale (Saaty, 1994). The benefit/cost ratio indicates that the fully integrated IT system is the most appropriate but, when we include the *risks* criteria, we find that the semi-integrated IT system becomes the most appropriate. This indicates that the semi-integrated IT system is preferred due to its having the lowest associated *risks* and being in the middle rating of *benefits* and *costs*.

Table 2
Firm no. 1: priorities and synthesised results of benefits, costs and risks

	Benefits QT	(0.33) QL	Costs QT	(0.33) QL	Risks QT	(0.33) QL
IT Priority	0.60	0.40	0.60	0.40	0.50	0.50
Fully integrated	0.42	0.36	0.38	0.32	0.36	0.38
Semi-integrated	0.35	0.39	0.35	0.38	0.25	0.28
Manual-integrated	0.23	0.25	0.27	0.30	0.39	0.34

Whilst ANP ensures internal consistency amongst individual DMs, however, it does nothing to provide logic consensus within a group of DMs. Moreover, ANP presented criteria does not ensure that group consensus would prevail in the ultimate ranking of the elements of the control criteria. This is a limitation of ANP in group decision making.

Table 3
Firm no. 1, overall results (with sub-criteria priorities)

	Benefits	Costs	Risks	Benefits/costs		Benefits/(costs*risks)	
Fully integrated	0.396	0.356	0.37	**1.11**	**1**	3.006	2
Semi-integrated	0.366	0.362	0.265	1.01	2	**3.815**	**1**
Manual-integrated	0.238	0.282	0.365	0.84	3	2.11	3

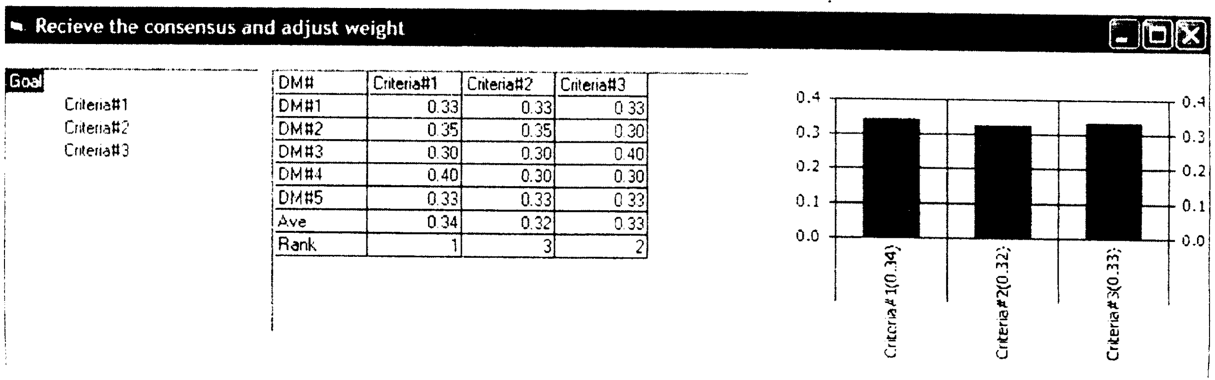


Fig. 5. Preference weights of the element (round 1). Remark: Criteria#1 = benefits, Criteria#2 = costs, Criteria#3 = risks.

The following sections describe processes that respond to such limitations in association with a programme developed by the authors.

4. Enhancement from applying group decision making

4.1. The statistics ranking

The first response to the awareness of DMs is to apply the principle of a review of their individual judgements by an anonymous group, based upon the control level criteria (benefits, costs, and risks). Whilst there are several techniques in practice, the Delphi method developed by the Rand Corporation (Dalkey and Helmer, 1963) is amongst the most practical (Tavana et al., 1996). Its objective is to obtain the most reliable consensus of opinion of a group of experts without direct confrontation. The Delphi method is composed of three essential processes: firstly, to achieve judgements from individual DMs; secondly, to collate and statistically summarise the individual judgements; finally, to feed the collated information back to individual DMs without revealing their identity and seek for a revision in their judgements, if any.

Theoretically, the sequence of collating, feedback and revision is repeated over several rounds until no further change is achieved. At this stage, the ranking of information relating to the benefits/costs/risks of adopting IT, which come from interviews with the individual DMs of the five companies in Thailand, is the first process considered in the Delphi method because this level is of most concern to the DMs. Therefore, the next sections are related to the second and the third processes.

4.1.1. Group decision making (round 1)

The individual ranking of preference weights and mean of the element relationships, which come from the five collaborating companies based upon benefits, costs and risks control criteria of adopting IT systems .s calculated by the programme developed by the authors, are shown in Fig. 5.

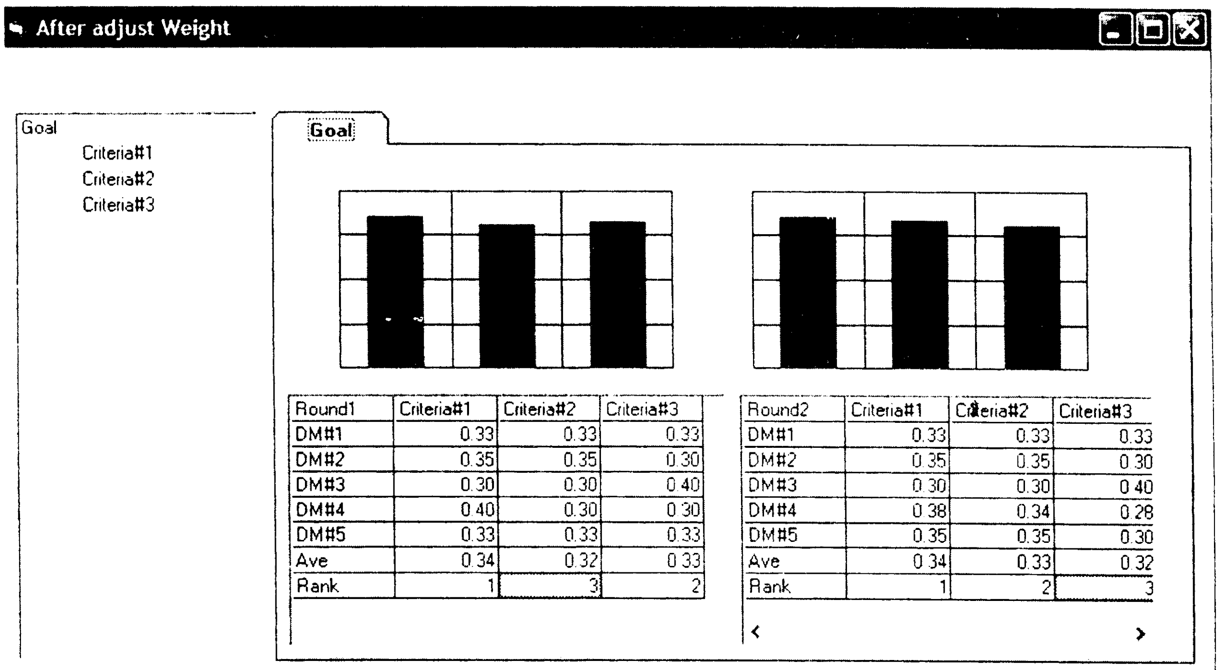
Fig. 5 illustrates the mean rankings from Appendix A, Table A.1 of the control criteria level of logistics firms no.1–5, which indicates that benefits (0.34) is the most important criteria over costs and risks. However, benefits achieves nearly the same amount of preference as the others, which means the DMs have given all the criteria nearly equal weight to the costs and risks of IT. The summary from the first round is that benefits from establishing IT is of most concern, and risks of competitors having the technology are the next important. Competitor investment in the technology is a crucial factor, and the knowledge and creative skills gained from the technology are also of importance. The next process is to submit the results from Fig. 5 to all the DMs, who are encouraged to reconsider their earlier pairwise comparisons of the criteria. These revisions constitute the second round.

4.1.2. Group decision making (round 2)

Fig. 6 illustrates the revised preference weights from all the firms, in which only firms no. 4 and 5 have changed their weights. The new and previous ranking preference and mean are also shown in Fig. 6.

Based upon the ranking of the preference weights in Fig. 6, Benefits is still the most important, with the calculation of overall mean score = 0.34. The second most important is costs, and then comes risks This can happen only because in round 2, the DMs improved their earlier pairwise comparisons of the criteria without introducing potential bias from interpersonal interaction. In this case, the monetary gain and potential market from acquiring IT are more important (benefits) than budget spending on the technology investment (costs), and the least important is the risks from competitors having the IT.

In this study, the Delphi processes are stopped after only round 2, due to the time availability from the DMs. One suggestion from the DMs was that ANP with Delphi and overall mean scores cannot provide a reasonable consensus ranking because it should accommodate the consensus logic rather than only the average of preference weights. There is a need to provide a method with more insight than overall mean scores to closely represent their consensus view



Round1	Criteria#1	Criteria#2	Criteria#3
DM#1	0.33	0.33	0.33
DM#2	0.35	0.35	0.30
DM#3	0.30	0.30	0.40
DM#4	0.40	0.30	0.30
DM#5	0.33	0.33	0.33
Ave	0.34	0.32	0.33
Rank	1	3	2

Round2	Criteria#1	Criteria#2	Criteria#3
DM#1	0.33	0.33	0.33
DM#2	0.35	0.35	0.30
DM#3	0.30	0.30	0.40
DM#4	0.38	0.34	0.28
DM#5	0.35	0.35	0.30
Ave	0.34	0.33	0.32
Rank	1	2	3

Fig. 6. Preference weights of the elements (round 2), compared with round 1.

(real ranking). The next section deals with this suggestion.

4.2. The consensus ranking

Group decision-making processes and optimal aggregation techniques for ordinal individual rankings have been studied by a number of researchers. Amongst them (Beck and Lin, 1983) develop two methods called "MAH and "minimising regret heuristic" (MRH) which are simple and more practical than those complex approaches. In particular, MAH is distinguished by its simplicity, flexibility and general performance (Tavana et al., 1996). Therefore, MAH is chosen in this research to apply to the ranking in Delphi round 2 (at Fig. 6). The MAH algorithm can be seen in Beck and Lin (1983).

4.2.1. Applying MAH with preference weights in round 2

According to Appendix B, the ANP-Delphi ranking order from Fig. 6 (in Section 4.1.2) can be represented in another way, with the symbols in Table B.1 and ranking in Table B.2 which will be the information to create an agreement matrix in Tables B.3 and B.4 based upon the theory of MAH. At Table B.3, agreement matrix 1 is the first agreement matrix based upon the data in Table B.2 above. At a particular control criterion in agreement matrix 1, it shows the number of times each criterion is preferred by the DM. For example at agreement matrix 1, using the individual rankings provided in Table B.2 at criteria row 1 compared with column 2, only *one* firm prefers benefits (1) to costs (2). Then, the number of preferences in each row P_i and column N_i are added and calculated to get the total agreement and disagreement for each control criteria. The differences in total DM agreement and disagreement $(P_i - N_i)$ are then calculated. The greatest positive difference is at benefits $(1) = 3$ and, therefore, this control-criterion is the most important. Following this placement, benefits (1) is deleted from the matrix 2, and the MAH is repeated again until the achievement of the rank 2 and 3 is discovered, as in matrix B4, which can also be seen in Appendix C at Fig. C.2.

Table 4
Comparison between ranking of overall mean scores and MAH

Rank	Preference ranking from Delphi round 2	Preference ranking from MAH
1	Benefits	Benefits
2	Costs	Costs
3	Risks	Risks

Table 4 illustrates the comparison between the Delphi ranking (round 2) of overall mean scores (from Fig. 6) and the MAH ranking. All the MAH matrix calculation has been shown in Appendix B and the ranking (from Appendix B) result is illustrated in Table 4.

Refering to Table 4, there is no change of preference ranking from the MAH result. It represents exactly the ranking in Delphi round 2 and overall mean score at Fig. 6. However, if the result were different, based upon the integration of Delphi and MAH, the DMs can be satisfied with the explicit way of deriving the rankings from Delphi and MAH rather than only the single result from Delphi.

5. Conclusions and recommendations

The objective of this research is to present a framework to enable DMs to work as a group and achieve reasonable consensus. The contribution of this research lies in the methodology for integrating ANP, Delphi and MAH in order to perform in-depth quantitative and qualitative analysis which can be implemented in a real industry to achieve consensus ranking. The DSS model (as illustrated in Fig. 1) is the combination of a number of models, beginning with the ANP which recognises the preference given to elements by individuals: then the Delphi with MAH which provide feedback about inconsistencies between DMs, and the logic consensus to achieve the desired result. The integration of ANP, Delphi and MAH can increase in-depth analysis and contribute to providing a higher quality decision.

The model for reaching a group consensus (ANP—Delphi with MAH) can benefit two groups of users. The first group can use the model for guidance and adapt it for their own groups of management for choosing information technologies. It will take a longer time to reach a consensus, which may be similar to the majority rankings shown in Table 3 above. Alternatively the user can duplicate the rankings in Table 3 for IT selection and immediately use them in their own rankings, because they come from experienced DMs.

The advantage of this research is that the model can include the qualitative data as well as the quantitative data because using quantitative data alone can mislead and be inadequate (Kengpol and O'Brien, 2001), and therefore there is a need to utilise quantitative and qualitative analysis together. This can also be seen from the case presented. Another advantage of ANP--Delphi with MAH is that in a group setting, status differences can reduce the willingness of group members to participate, and it is possible a few individuals can dominate the decision process. In ANP–Delphi with MAH, DMs are questioned systematically and feedback is provided anonymously. The logical structure of the approach and the impersonal feedback of Delphi reduce the inhibitory effects of status differences and the potential domination of the group by a few individuals. In addition, with MAH, a DM can be satisfied with the explicit way of deriving the rankings.

In terms of limitations, in the experience of the authors this kind of research is most appropriate if there are no more than 10 DMs because it will consume too much time in the processing of the research. There is also a need to have a person who has a good understanding about the model concept to eliminate bias and error. It is possible that a very new logistics firm that is totally inexperienced with any IT system may have difficulty in using the model.

Although the data gathered from the research are insufficient to represent general business trends, it has nevertheless thrown up some interesting responses. The authors hope that the findings from this research can benefit users in both developed and developing countries. Complex decision models such as in Kengpol (2004a, b), etc. are increasingly needed across global industries, therefore, a system of comprehensive justification in a new decision-making process is desperately needed.

Acknowledgement

The authors are grateful to the Finnish Government and the Department of Industrial Engineering and Management, Lapeenranta University of Technology, Finland in providing grants for this research, and the KMITNB in providing opportunities. The authors would like to express sincere gratitude to those logistics companies in Thailand who provided valuable time and information for the research but whose names unfortunately cannot be revealed because of the confidentiality agreement. The authors are very appreciative of all of the anonymous reviewers for their valuable comments.

Appendix A

Firm no. 1–5: priorities and synthesised results of benefits, costs and risks are given in Table A.1.

Appendix B

Control criteria and the symbol used in the agreement matrix are given in Table B.1.

Round 2 ANP ranking of the control subcriteria are given in Table B.2.

Agreement matrix 1 to achieve rank 1 is given in Table B.3.

Agreement matrix 2 to achieve ranks 2 and 3 are given in Table B.4.

Appendix C

See Fig. C.1 and C.2.

Table A.1
Firm no. 1–5: priorities and synthesised results of benefits, costs and risks

Firm no. 1	Benefits 0.33		Costs 0.33		Risks 0.33	
	QT 0.60	QL 0.40	QT 0.60	QL 0.40	QT 0.50	QL 0.50
Fully integrated	0.42	0.36	0.38	0.32	0.36	0.38
Semi-integrated	0.35	0.39	0.35	0.38	0.25	0.28
Manual-integrated	0.23	0.25	0.27	0.30	0.39	0.34
Firm no. 2	Benefits 0.35		Costs 0.35		Risks 0.30	
	QT 0.50	QL 0.50	QT 0.50	QL 0.50	QT 0.50	QL 0.50
Fully integrated	0.38	0.35	0.28	0.33	0.35	0.36
Semi-integrated	0.30	0.29	0.47	0.38	0.37	0.40
Manual-integrated	0.32	0.36	0.25	0.29	0.28	0.24
Firm no. 3	Benefits 0.30		Costs 0.30		Risks 0.40	
	QT 0.65	QL 0.35	QT 0.50	QL 0.50	QT 0.50	QL 0.50
Fully integrated	0.31	0.31	0.35	0.30	0.39	0.33
Semi-integrated	0.39	0.42	0.36	0.31	0.29	0.31
Manual-integrated	0.30	0.27	0.29	0.39	0.32	0.36
Firm no. 4	Benefits 0.40		Costs 0.30		Risks 0.30	
	QT 0.60	QL 0.40	QT 0.50	QL 0.50	QT 0.65	QL 0.35
Fully integrated	0.40	0.40	0.29	0.33	0.29	0.31
Semi-integrated	0.38	0.30	0.45	0.43	0.29	0.24
Manual-integrated	0.22	0.30	0.26	0.24	0.42	0.45
Firm no. 5	Benefits 0.33		Costs 0.33		Risks 0.33	
	QT 0.60	QL 0.40	QT 0.60	QL 0.40	QT 0.50	QL 0.50
Fully integrated	0.45	0.37	0.60	0.38	0.36	0.40
Semi-integrated	0.32	0.47	0.20	0.26	0.25	0.29
Manual-integrated	0.23	0.16	0.20	0.35	0.39	0.31

Table B.1
Control criteria and the symbol used in the agreement matrix

Control criteria	Symbol
Benefits	1
Costs	2
Risks	3

Table B.2
Round 2 ANP ranking of the control sub-criteria

Firm no.	Ranking
1	1,2,3
2	1,2–3
3	3–1,2
4	1–2–3
5	1,2–3

Remark: "," means equal ranking.
"–" means different ranking e.g. 1–2–3 means 1 weighted higher than 2 and 2 weighted higher than 3.

Table B.3
Agreement matrix 1 to achieve rank 1

Criteria	1	2	3	Pi	Pi–Ni	
1	0	1	3	4	3	Rank 1
2	0	0	3	3	1	
3	1	1	0	2	−4	
Ni	1	2	6			

Table B.4
Agreement matrix 2 to achieve ranks 2 and 3

Criteria	2	3	Pi	Pi–Ni	
2	0	3	3	2	Rank 2
3	1	0	1	−2	Rank 3
Ni	1	3			

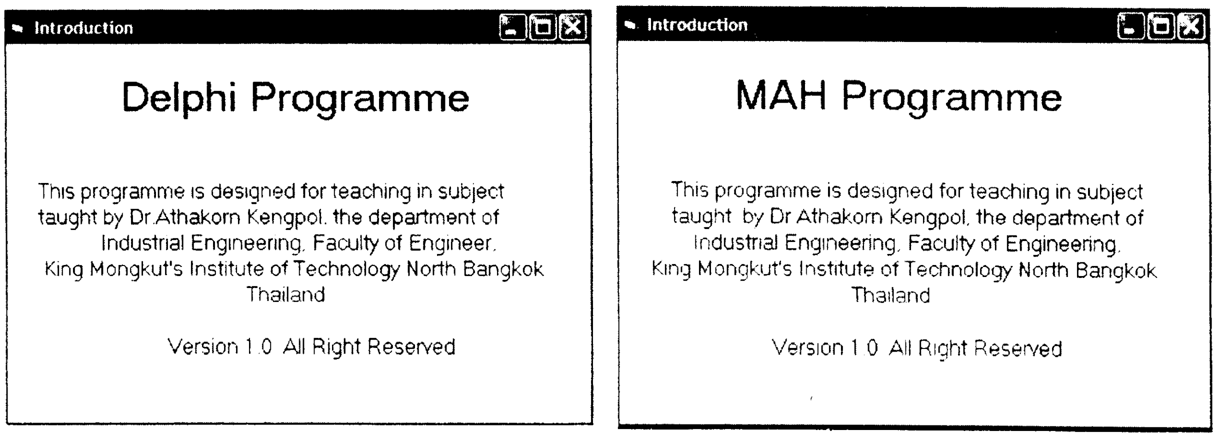


Fig. C.1. Front of the programme.

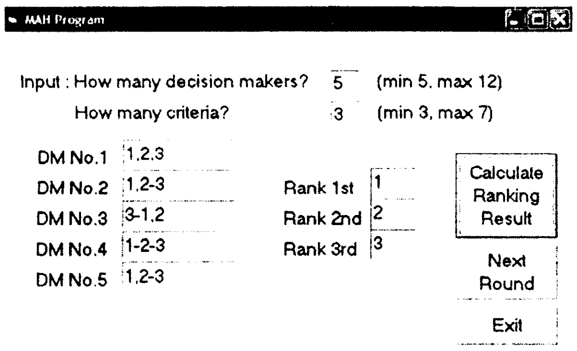


Fig. C.2. Result of the MAH programme.

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