ScienceAsia 30 (2004): **317-326**

An Application of the Analytic Network Process (ANP) for University Selection Decisions

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Received 24 Dec 2003
Accepted 17 Aug 2004

Abstract: Choosing to attend the right university for first degree study is one of the most complex real-life problems for some prospective students and their guardians. In addition, the outcome of the decision will affect not only the decision-makers but also their family, society and ultimately all sectors of the country. As such, selecting the universities is a critical decision that is just as important as making business decisions. From statistical data, the dropout rate after first year of university and a rate of lateral transfer from one faculty to another in public university are high. Therefore, students need to have a framework to assist them in achieving their lifetime goals. The research methodology begins with investigating and determining the Key Performance Indicators (KPI) influencing university selection decisions from relevant sources. Then, the process of synthesis using Nominal Group Technique (NGT) is implemented with small expert group and grouping them to each main factor/cluster with Affinity Diagram Technique (ADT). The university ranking with a systematic framework, called Analytical Network Process (ANP), is constructed. The Delphi method and focus group are applied to elicit experts' opinion for identifying membership and relationship of the clusters/elements. Our objective is to test the ANP applicability with the process of selecting a university program. The paper proposes a framework to select universities for prospective students in order to achieve their different objectives and purposes. The framework consists of a series of steps that begin with the identification of the overall goal to achieve the desired result. Sensitivity analysis is also performed on multiple control criteria and sub-criteria. ANP is used to resolve this decision, rather than just the Analytic Hierarchy Process (AHP), which cannot accommodate the variety of interactions, dependencies and feedback between higher and lower level elements. According to priorities grouped under benefits, costs and risks within the control criteria, the results are based upon the relationships between clusters. Several scenarios are analyzed by varying different weights and ratings in the model to determine their effect on the results. Consequently, one can identify the most "satisfactory" university program on the basis of a number of both objective and subjective attributes and the proposed model is applied to the engineering discipline in Thailand.

Keywords: multiple-criteria decision making, Analytic Network Process (ANP), university selection.

Introduction

Higher education is one of the service industries that is growing rapidly at present, leading to intensive competition and a large number of suppliers. As a result, consumers can get the benefits, such as more alternatives, reduced prices, high quality, and improved student services. However, university selection decisions are also the most complex real-life problem. The effects of the decision will be felt by various stakeholders, ranging from the decision-makers, their families, society, to the country. In addition, selecting an appropriate university is also very important for the future of the student and his/her country. From statistical data[1], the dropout rate after the first year of university, and a rate of lateral transfer from one faculty to another in public university are high. Therefore, decision-making in selecting the university is of critical importance, on par with decision making in business. This paper proposes a framework for selecting the university, using the public universities offering engineering courses in the northeastern region of

Thailand as examples. For the purpose of this paper, the term "university" from now on refers to the university offering engineering courses. The general model links performance criteria to outcomes in university selection for multi-attribute decision-making. Analytic Hierarchy Process (AHP) introduced by Saaty[2] is one of the frequently used approaches to aid such an 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. In reality, we need a holistic approach in which all criteria and alternatives involved are connected in a network system that accepts various dependencies.[3] 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 alternatives themselves also influences the importance of the criteria.

The objective of the paper is to test the Analytical Network Process (ANP) applicability with the process for decision making in the selection of university program. Furthermore, the paper has developed a decision support model for university selection in order to find the appropriate university, with considerations for the benefits, costs, risks and other criteria. An approach is needed that can accommodate the above requirements. ANP, introduced by Saaty[4], does not depend upon 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. Although focusing on a decision process for the selection of university, this paper presents a generic model that decision-makers can adapt to their own organization and other disciplines in all educational levels.

Literature Review

A study of relevant literature on university selection or performance measurement problem concerning prospective students reveals shortcomings of the existing approach. Some studies did not specify explicitly the issue of who is doing the assessment and what the purpose of measuring university performance is for. A small number of studies referred to three different classes of stakeholders/customers for the purpose of evaluating universities: 1) the applicant 2) the institutions and 3) the state or government.[5,6,7] In addition, some studies addressed different perspectives of stakeholders, resulting from different missions and objectives within the sector, and leading to different purposes and criteria of performance measurement.[8]

The difficulty in making a decision arises from the fact that most of these factors are difficult to quantify even though they are extremely significant and meaningful. Several factors may be conflicting. At the same time, the complexity of various trade-offs among factors makes the decision even more difficult. University selection is one of the complex real-life decision-making problems. There are three important attributes to the university selection problem that contribute to the complication. They are multiple objectives and criteria, tangible and intangible factors and value tradeoffs. Although the features causing the complexity in specific problems may differ, the bottom line is that many of today's decision problems have the following characteristics: (1) high stakes, (2) complicated structure, (3) no overall experts, and (4) need to justify decisions.[9] However, Keeney[9] has omitted some important aspects of the complexity involving the interactions and dependencies between factors. In addition, there are a large number of studies worldwide involving the popular sources of information that attempt to make recommendations in choosing a university for potential students, for instance, the U.S. News & World Report in the USA, Good University Guides in Australia, Times Higher Education in the UK, Maclean's magazine in Canada, and the now-defunct source of Asiaweek in Asia. These approaches produce a ranking of universities using a single value system, which in some sense may rank the universities in terms of prestige, but is only one of the many perspectives on universities.[7]

There are some approaches that are of interest in the university selection problem. The first is the Data Envelopment Analysis (DEA) approach which copes with allowing a diversity of weights (for an introduction to DEA, see Boussofiane[10]) in measuring university performance.[11,12,13,14,8] The critical hypothesis proposed by Sarrico[7] involved university selection decision that different individuals may wish to apply their own values in selecting list of universities to apply to, rather than simply accept the ranking list from the single value system approaches. Moreover, the university performance and the potential student perspective were measured using DEA, and the outcome compared with the Times Good University Guide. It was found that the ranking system from the Times is only applicable for the most academically able students, but it is not useful in terms of assisting the choice of university for other categories of applicants (less able, mature, local, and less able overseas). However, DEA cannot handle qualitative data directly and have two inter-related problems. One problem involved weak discriminating power, which identified too many decision-making units as the efficient ones. The other problem with DEA was its unrealistic weight distribution, which results from linear programming.[15]

Another approach is Analytic Hierarchy Process

(AHP), which dealed not only with the weights diversity problem but also permitted the inclusion of subjective factors in order to arrive at a recommended decision.[2] For educational cases, AHP has been applied in various ways. For instance, AHP was modified for selecting undergraduate and postgraduate student projects to formalize the process of selection of 'hard' and 'soft' system components,[16] and for evaluating curriculum design alternatives.[17] In addition, Saaty[3] illustrated a practical example of how hierarchy can be applied to choosing a school and addressed how strongly a school is rated by students and parents in relation to the others and applied AHP to forward planning to describe the future of higher education in the United States from 1985 to 2000. In another example, Dalal and Thammaneewong[18] proposed AHP as a systematic and less subjective method for ranking business schools in the real world. However, decision making problems cannot be always hierarchically structured in practice because there are possible relationships or interactions and dependencies between the higher level elements and lower level elements.[4] Therefore, what is needed is to develop a holistic model that can directly accommodate complicated decision making problems without decomposing them into a simple form. The Analytic Network Process (ANP) model may be applied to fulfil such complex requirements. The ANP approach may be considered as a second generation AHP, which has been designed to overcome more complex problems. It replaces hierarchies with network systems that permit all possible elements and join them together in network structures. With its strength, the modeling of the interactions and dependencies among elements of the problem, ANP may be applied to generate a better in-depth analysis and to deliver a more accurate result than AHP. Examples of its applications can be found else where.[19,20,21,22,23,24] As stated earlier, such a complicated problem as an evaluation of the university performance for the potential students involves a complex set of relationships and dependencies among elements which are being considered in this paper.

A Conceptual Decision Model

In order to select a number of universities to meet the individual basic requirements, the following criteria have been established. These criteria will help to reduce the alternatives in the first place.

Step 1: Determination of Alternatives

The information used to narrow down alternatives may be specified as follows:

1. Location across the country, such as which parts or which city/province/state
2. Type of schools such as engineering, business, social science, etc.
3. Fields of study for undergraduate level, such as industrial, mechanical, electrical, chemical, etc.
4. Scholarship or financial aids to general students or athletes
5. Accessibility on the internet for all types of applications, such as admissions and finance aids
6. Types of services for high school students.
7. Diversity of courses, such as e-learning and distance learning programmes.

Step 2: Admission Consideration

This step screens potential applicants to check possibility of being admitted by university. The purpose of step 2 in the decision making process is to narrow down the alternatives from step one. The likelihood of university admission will be expressed in percentages, considering the academic ability of the applicant, which is represented by overall performance across high school's courses, the university requirement score, and the competition rate. To derive the results, mathematical model is formulated and regression analysis is applied to this problem.

Step 3: University Ranking

This university ranking process is formulated by a multiple criteria decision-making approach, in particular, ANP. Then, the university selection decision models are compared and the model suitable for the university selection problem is selected. The model comparison is performed by the experimental method with the expert decision makers, counselors in high schools and universities, academics, as well as existing students and alumni. As a result, the best appropriate models are modified to university selection decision for individuals.

It is hoped that both the framework and findings will benefit the potential students and their parents wishing to choose university, as well as the counselors in both high schools and university helping applicants in university selection. The framework can guide practitioners and decision-makers in analyzing and choosing the most appropriate university for study. The overview of the procedure for university selection decisions can illustrate in Figure 1.

The merit of the framework lies in its ability to quantify the value of performance, and choose the most appropriate university, based directly upon the complex relationships between decision constraints, without decomposing the problem into a hierarchical form. This paper especially focuses on the principle of applying ANP in the selection of universities for prospective students and also shows a type of model validation.

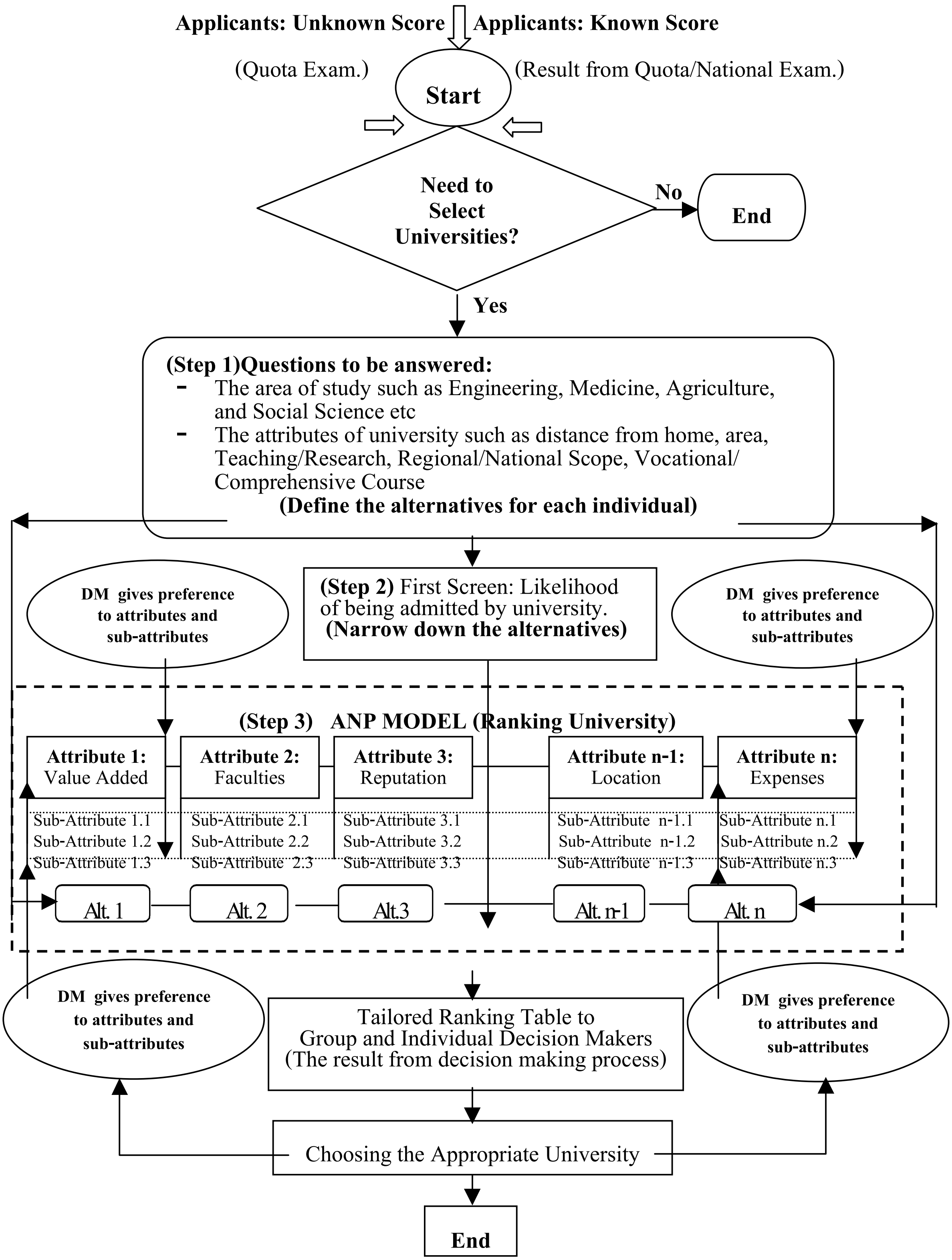

Fig 1. The procedure of university selection by the decision maker (DM).

Table 1. Component/Element Membership for Each Control Criterion.

Component or Cluster	Element	Benefits			Costs			Risks		
		Ec.	In.	So.	Ec.	In.	So.	Ec.	In.	So.
Alternatives (ALT)	1. Suranaree University of Technology(SUT)	x	x	x	x	x	x	x	x	x
	2. Khon Kaen University (KKU)	x	x	x	x	x	x	x	x	x
	3. MahaSarakarm University (MSU)	x	x	x	x	x	x	x	x	x
	4. UbonRatchathani University (UBU)	x	x	x	x	x	x	x	x	x
Admissions (ADM)	1. Entry Point *	x	-	-	-	x	-	-	-	-
	2. Yield Rate**	-	-	x	-	-	-	-	-	-
Financial Requirements (FR)	1. Tuition and fees	-	-	-	x	-	-	-	-	-
	2. Living Cost	-	-	-	x	-	-	-	-	-
	3. Financial Aid	x	-	-	-	-	-	-	-	-
Faculty Resources (FA-R)	1. Faculty Standard/Qualification	-	x	-	-	-	-	-	x	-
	2. Student: Faculty Ratio	x	x	x	-	x	x	x	x	x
	3. Faculty Publication	-	x	-	-	-	-	-	x	-
Academic Resources (AR)	1. Computer Availability	x	x	x	-	x	x	-	x	-
	2. Library Spending	x	x	-	-	x	x	x	x	-
Social Experiences (SE)	1. Participation of Student Activity	x	x	x	-	-	-	-	-	-
	2. Quality of Recreational, Sport Facilities and Membership Fee	x	x	x	-	-	-	-	-	-
	3. Student Accommodation's Allocation	x	-	x	x	x	-	-	-	x
	4. Campus Environment's Attractiveness	-	-	x	-	-	-	-	-	-
Outcomes (OUT)	1. Value Added	x	x	-	-	x	-	x	x	x
	2. Employment and Admission to Higher Study	x	-	-	-	-	-	-	-	-

* the average entry qualification required by the engineering school when admitting new students.
** percent of those admitted students who actually enrol.
Ec. = Economic, In. = intellectual, and So. = Social.

Analytical Model

In evaluating which of the four alternative universities to choose, six distinct groups, or clusters, are considered to have an influence on the decision process (Table 1). There are different elements within each group or cluster. These clusters and the elements are not necessarily included in each and every sub-criterion (Figure 3). The criteria and sub-criteria were obtained from investigation of relevant sources particularly the reports of Chansa-ngavej[25] and Thompson.[26] More over, a number of questionnaires and interviews with general professionals who have had experiences in university selection decisions in undergraduate level were conducted. These professionals are the counselors from high schools and universities, current students and their guardians in the northeastern region of Thailand The results of questionnaires and interviews show that the criteria and sub-criteria influence university selection decisions in practice. After that, specific criteria for university selection decisions are derived from a number of expert groups, including current students, academic staff and lecturers who have had previous experiences in university selection decisions, on the basis of teaching, learning and counseling aspects in faculty of engineering. The followings will serve as the foundation for the ANP model.

Control Hierarchy in Feedback Network

As illustrated in Figure 3, the Control Hierarchy contains the Overall Goal, Control Criteria (Benefits, Costs and Risks) with further Control Sub-Criteria for evaluation under each criterion.

Economic Benefits (from attending the appropriate university) are mostly related to gaining qualification that will lead to higher earning and more rewarding careers. The potential student desires to be accepted from a university firstly. Then he/she wants to gain the benefits across university courses, and lastly obtain that qualification. For example, the potential applicant firstly considers the likelihood of being admitted. He/she may require financial aid for both academic and non-academic activities. Then he/she may contemplate the career prospect and the expected income level after degree completion.

Intellectual Benefits are the knowledge, creative

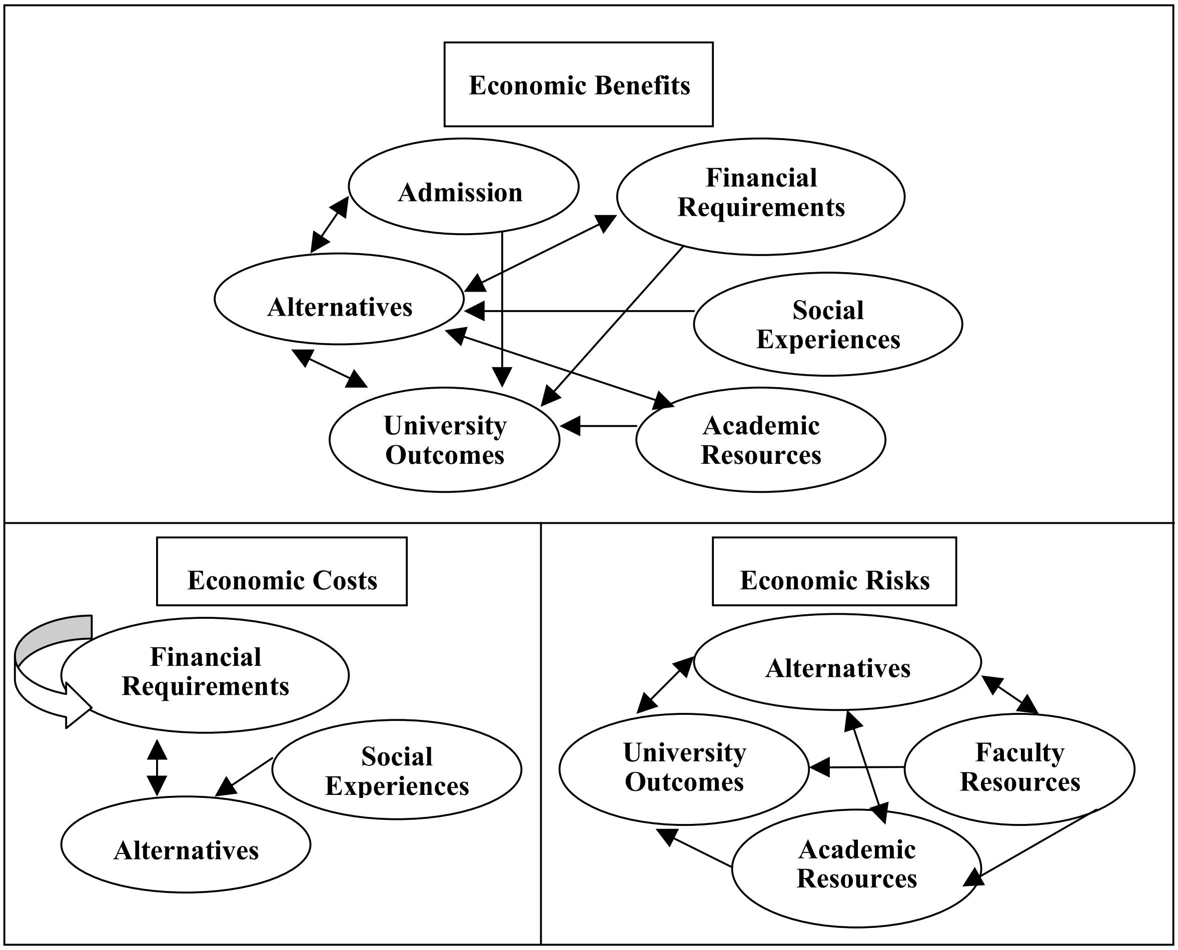

Fig 2. The examples of Cluster Relationship.

and problem-solving skills gained from completing such a university degree. For example, one could argue that one university has a greater intellectual benefit than another university.

Social Benefits are considered to be the interactive and networking opportunities provided by the university. The social benefits are different for each university depending on social support provided at each institution.

Economic Costs are defined in terms of money spent in the duration of study at the university.

Intellectual Costs have been referred to in the context that cost equals pain. The intellectual costs can be thought of as the mental strain imposed by a given course, for example, academic severity, and curriculum contents that are complex and difficult in their nature.

Social Costs are thought of as a function of time. Time spent in attending classes, preparing for classes, and meeting with project groups is time not available for purely social activities with family and friends.

Economic Risks are the return on investment. Studying at a particular university is considered a risky investment, both in terms of time and money spent, for students and their parents/relatives who support them, if the output is not as expected. Then a great loss is realized.

Intellectual Risks are gauged by the anticipated ability to utilize the knowledge and any skills obtained from the course to contribute to the success in the future. For instance, one university may be more intellectually risky to future employer than another university if their curriculum is not up-to-date or flexible and teaching and learning system is not modified to match with globalization.

Social Risks relate to perceptions of wasting or losing time. Examples of social risks may be the risk of less opportunity for networking if one university has emphasized academic aspect (self learning) more than teaching based.

Stakeholders

As illustrated in Table 1, there are seven

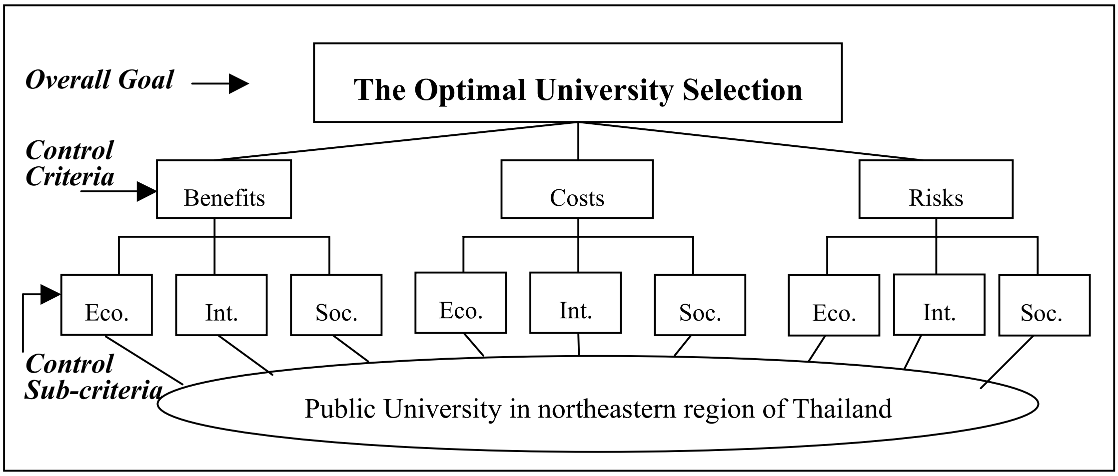

Fig 3. Control Hierarchy, Eco. = Economic, Int. = Intellectual, Soc. = Social.

components/clusters of stakeholders identified in this model. Each cluster is further sub-divided into several elements. The four public universities in the northeastern region of Thailand, namely Suranaree University of Technology (SUT), Khonkaen University (KKU), MahaSarakarm University (MSU), and UbonRatchathani University (UBU), are considered as alternatives. The components/clusters and elements in each control hierarchy are listed in Table 1 and their connections are given in Table 2. All elements in Alternatives Cluster are included in all the networks. However, some elements are not part of certain networks. Some clusters and elements uniquely belong to certain networks only. Figure 3 shows the connection between elements indicating the flow of influence. To organize our thinking about the flows, we can either indicate connections to the set of elements that are influenced by each element, or indicate connections from the elements that transmit influence to each element. Connecting two components gives a full connection among elements in these components. In this application we follow the first approach, and Table 2 indicates the elements that are influenced by each element in the left column.

Cluster Relationship and ANP Model

Figure 3 illustrates three examples out of ten cluster relationships as shown in Figure 2. The relationship (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 Admission Cluster and Academic Resources Cluster on the Economic Benefits). Each element of cluster in each control sub-criterion will be subjected to pair-wise comparison. Therefore, for the Control Hierarchy illustrated in Figure 3 we need to generate the matrices from many pairwise comparisons to construct the Supermatrix for analysis. The details and explanations of the solution of a Supermatrix may be found in Saaty.[4]

Results and Discussion

The model has been developed for both the quota and entrance admission systems. During the period of collecting the data, only the data of the quota admission system were available. As the result, these data have been used for the illustration. Suranaree University of Technology has different quota admission from others. Therefore Suranaree University of Technology was excluded from the experiment. Another modification was that Khonkaen University has two separate admission systems, one for the department of agricultural engineering and the other for department of common engineering. Therefore, the illustration was was carried out subject to these restrictions. The ratings for the university alternatives compared in this example are shown in Table 3. This indicates that there is an equal weight (0.333) given to the Benefits, Costs and Risks. In terms of Benefits, the decision-maker gives the highest priority to the Economic Benefits (0.22), which would lead the majority of the students to select the Khonkaen University. On the other hand, the UbonRatchathani University is the only preferred alternative in Intellectual and Social sub-criterion of Costs because UbonRatchathani University has simplified the curriculum. Surprisingly, the Intellectual Risk is of the most concern to the decision-maker (0.20) because of worries about utilizing the knowledge and any skills obtained from the course to contribute to the success of the future, giving preference mainly to

Table 2. Flows of Influence from Each Cluster/Element.

Influenced by Clusters/Elements that transmit influence	Clusters/Elements being influenced										
	Economic Benefits					Economic Costs		Economic Risks			
	ALT	ADM	FR	AR	OUT	ALT	FR	ALT	FA-R	AR	OUT
Alternatives (ALT)											
1. SUT	-	1	3	2	2	-	1	-	2	2	1
2. KKU	-	1	3	2	2	-	1	-	2	2	1
3. MSU	-	1	3	2	2	-	1	-	2	2	1
4. UBU	-	1	3	2	2	-	1	-	2	2	1
Admissions (ADM)											
1. Entry Point	All	-	-	-	2	-	-	-	-	-	-
2. Yield Rate	-	-	-	-	-	-	-	-	-	-	-
Financial Requirements (FR)											
1. Tuition and fees	-	-	-	-	-	All	2	-	-	-	-
2. Living Cost	-	-	-	-	-	All	3	-	-	-	-
3. Financial Aid and options	All	-	-	-	2	-	-	-	-	-	-
Faculty Resources (FA-R)											
1. Faculty Qualification	-	-	-	-	-	-	-	-	-	-	-
2. Student: Faculty Ratio	-	-	-	-	-	-	-	All	-	2	1
3. Faculty Publication	-	-	-	-	-	-	-	-	-	-	-
Academic Resources (AR)											
1. Computer Availability	-	-	-	-	-	-	-	-	-	-	-
2. Library Spending	All	-	-	-	2	-	-	All	-	-	1
Social Experiences (SE)											
1. Participation of Student Work	-	-	-	-	-	-	-	-	-	-	-
2. Quality of Recreational, Sport Facilities and participated	All	-	-	-	-	-	-	-	-	-	-
3. Student Accommodation's Allocation	All	-	-	-	-	All	-	-	-	-	-
4. Campus Environment's Attractiveness	-	-	-	-	-	-	-	-	-	-	-
U/EC Outcomes (OUT)											
1. Value Added	-	-	-	-	-	-	-	All	-	-	-
2. Employment and Admission to Higher Study	All	-	-	-	-	-	-	-	-	-	-

Department of Agriculture Engineering at Khonkaen University. (For Costs and Risks, a minimum value is considered the best.)

Table 4 summarizes the overall results from Table 3 above and gives the ranking of the Benefits/(Costs Risks). For example, at Table 4: the Department of Agriculture Engineering- Khonkaen University, Benefits = 0.0955 comes from $0.2161 \times 0.2812 + 0.0766 \times 0.3014 + 0.0407 \times 0.2855$. 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[2].

Table 3. Priorities and Synthesized Results of Benefits, Costs and Risks.

	Control Criteria								
	Benefits (0.33)			Costs (0.33)			Risks (0.33)		
	Econ.	Intcll.	Soc.	Econ.	Intell.	Soc.	Econ.	Intell.	Soc.
Priorities	0.22	0.08	0.04	0.10	0.18	0.05	0.10	0.20	0.0
Synthesized Results									
Agricultural Engineering- Khonkaen University	0.28	0.30	0.29	0.23	0.25	0.30	0.24	0.22	0.22
Common Engineering- Khonkaen University	0.28	0.24	0.27	0.23	0.29	0.30	0.29	0.26	0.27
MahaSarakarm University	0.18	0.23	0.21	0.26	0.25	0.28	0.26	0.23	0.26
UbonRatchathani University	0.25	0.23	0.23	0.27	0.21	0.12	0.22	0.29	0.25

Table 4. Overall Results.

	Control Criteria						
	Benefits	Costs	Risks	Benefits/Costs		Benefits/Costs × Risks	
Agricultural Engineering- Khonkaen University	0.09545	0.08405	0.07453	1.13574	2	**15.23931**	**1**
Common Engineering- Khonkaen University	0.09068	0.09108	0.08783	0.99557	3	11.33540	3
MahaSarakarm University	0.06549	0.08731	0.08001	0.75009	4	9.37470	4
UbonRatchathani University	0.08170	0.07091	0.08762	**1.15214**	**1**	13.14887	2

The Benefit/Cost ratio indicates that UbonRatchathani University is the most appropriate. However, when the Risks criteria are included, the Department of Agriculture Engineering at Khonkaen University becomes the most appropriate. This model shows that the Department of Agriculture Engineering at Khonkaen University is preferred due to its lowest associated Risks, highest Benefits and moderate Costs.

Sensitivity Analysis

Sensitivity analysis may be performed on the Control Criteria and Sub-Criteria by varying the different weights to determine when alternatives may become preferable. In the example of control hierarchy of Costs shown earlier, as the Economics, Intellectual and Social sub-criteria in the Costs are dominant in the priorities (0.0990, 0.1799, and 0.0545 in Table 3), raising the Economic and decreasing the Intellectual and Social criteria will not change the rankings of the alternatives. On the other hand if, the priority of the Economic criteria is reduced and the priority given to the Intellectual and Social criteria increased, the value of Benefits/(Costs × Risks) will change in favor of UbonRatchathani University as the most preferred university. In the same way, when control hierarchy of Risks is taken into consideration, the Economics, Intellectual and Social sub-criteria in the Risks are dominant in the priorities (0.1000, 0.2000, and 0.0300 in Table 3). Increasing the Economic and decreasing the Intellectual and Social criteria will change the value of Benefits/(Costs × Risks) in favor of UbonRatchathani University as the most preferred university. On the other hand if, for example, the priority of the Economic criteria is reduced and the priority given to the Intellectual and Social criteria increased, the rankings of the alternatives will not be changed.

Conclusion

This paper has proposed a systematic framework using ANP for the selection of universities that offer undergraduate program in engineering. An advantage of this approach lies in its ability to link, dynamically, economic, cost and risk factors associated with attending a particular university. The framework is not only applicable to the selection of preferred universities in the northeastern region of Thailand, but provides a structure for any applicant within their environment. Although, the ANP technique appears complicated, it can capture the complexity of real world evaluation of university selection.

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