國立交通大學

資訊管理研究所

碩 士 論 文

以 GIS 爲基礎之選擇最理想學校的決策支援系統

A GIS-Based Decision Support System for the Optimal Selection of Universities

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摘　要

企業的競爭力在業界中是一個很重要的成功因素；這在學術界也是一樣。每年一些知名的組織都會提供各教育機構的排名及評比。然而，這些資料僅能提供參考卻沒法提供與協助決策者最佳的決策。有鑑於此，本研究旨在提議如何建立一個不但可以有效率地整理及搜尋含有大量資料的資料庫，而且同時是一個能根據決策者的需求及偏好來選出最理想結果的決策支援系統。爲了能合理地產生最理想的結果，數學模組會被應用在計算過程中。最後，各物件的空間性關係會由 GIS 介面呈現出來。

關鍵字：　　決策支援系統、最佳化模組、地理資訊系統

A GIS-Based Decision Support System for the Optimal Selection of Universities

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Abstract

Competitiveness is a critical success factor for an organization in the business world; and this is also applicable to the academic world. There are rankings and comparisons for academic institutes produced by renowned organizations each year; however, this information is mere reference and unable to assist users to obtain the optimal decisions. Thus, this research aims to propose a tool that not only re-arranges the vast amount of data for viewing and searching in a more convenient manner, but also acts as a decision support system to generate the most suitable results according to users' specifications and requirements. In order to produce the optimal results scientifically, mathematical models will be applied in the calculation. Moreover, the spatial relationships between different subjects can be displayed by using a geographic information system (GIS).

Keywords: Decision Support System (DSS), Optimization Model, Geographic Information System (GIS)

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Kit-Yan Wong

July 2004 at NCTU

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Chapter 1 - Introduction

1.1 Research Motivation

Competitiveness has been used to compare different countries' advantages or disadvantages in selling their products in international markets. It acts as a reference to users of which country is more favourable in terms of living and/or having businesses. A similar measure is applied for universities and business schools in the world, so that students, parents and educators are able to compare the standards and resources of various schools. In order to portray the comparison, various organizations have formulated different rankings in this regards.

Rankings are formulated by renowned universities and organizations every year. For instance, Shanghai Jiao Tong University has formulated a ranking for the top 500 universities in the world; Financial Times produces ranking for the top 100 business schools in the world every year; and Asia Inc. has done a ranking for the top 10 business schools in East Asia. All these provide guidelines and comparisons to both students and universities for school selection and improvement needs.

However, these rankings can only act as a guideline and when a prospective student or a lecturer wishes to compare different schools in more details or with particular preferences; these would be insufficient to provide the necessary results. Therefore, some organizations, such as the Graduate Management Admission Council (GMAT), provide websites to allow students and educators to generate comparisons according to their requirements.

With these information provided as guidelines, students and educators might still have difficulties in finding the most favourable or suitable institute because these are insufficient to make the "best" solution with respect to all the requirements. Therefore, there should be a tool to assist them to input all the available information and to generate decisions with simulation and analysis.

1.2 Research Objectives

In order to provide a tool to students and educators for better comparison and decision making, a system is proposed in this research; which combines rankings and essential information for more accurate comparisons, and simulation methods to generate a more suitable decision according to their preferences and requirements. The objectives of the proposed system are elaborated below:

(a) Knowledge management

The amount of information available from different organizations and universities is vast, users may not be able to obtain all the information they require. This system plans to provide a more complete database of information for users to generate a more complete selection.

(b) Simulation methods

Besides providing necessary information, simulation methods are provided to allow users to simulate results according to their preferences. These are able to provide a more suitable result which in turn assist them in the decision making process.

(c) Mathematical model

A mathematical model, namely LINGO, is implemented into this system to calculate the most suitable result(s). The use of mathematical formulas is aimed to provide an accurate and scientific way to generate decisions.

(d) Map display

The geographical locations of different schools are often important for considerations. Very often, students and educators might not know where exactly an institute is; so map display will be provided with the use of GIS tools to provide a reference in locations.

Chapter 2 - Literature Studies

2.1 Selection Process of Universities

Magazines such as U.S. News often provide guidelines for prospective students to select the most suitable institute(s) according to their specifications and preferences. These guidelines often provide basic information, such as location, cost, campus size, programs, etc, for students to evaluate different schools. Figure 2.1 illustrates the steps that the students can follow when they are choosing an institute (adapted from U.S. News, 2004):

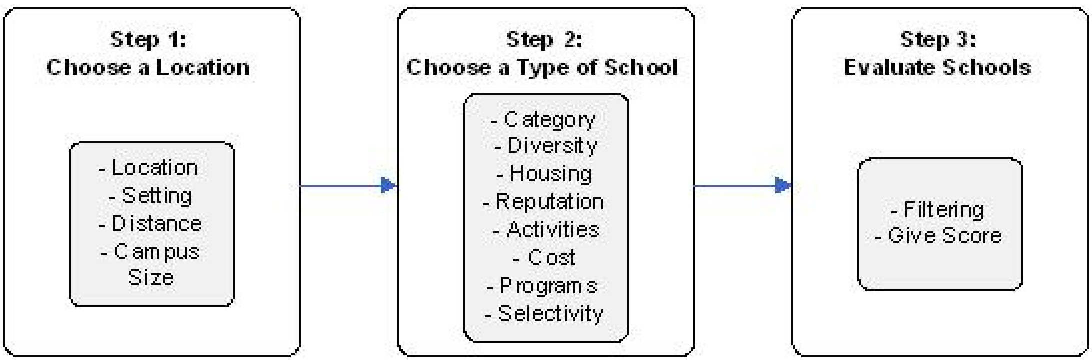

Figure 2.1 Student's Selection Process of Schools

Prospective students can give each criterion a score, according to the preference and important of each of them, to identify which school(s) is/are the most suitable. An example of a score sheet for calculating the scores of different schools is attached in Appendix A.

2.2 Admission Process of Universities

It is time-consuming but yet crucial for students to select the institute that is suitable for them to study further. Some magazines often publish guidelines and references to allow prospective students to acquire the necessary information on the requirements and processes of applying for an institute. Figure 2.2 shows the admission process suggested by Kaplan Inc.

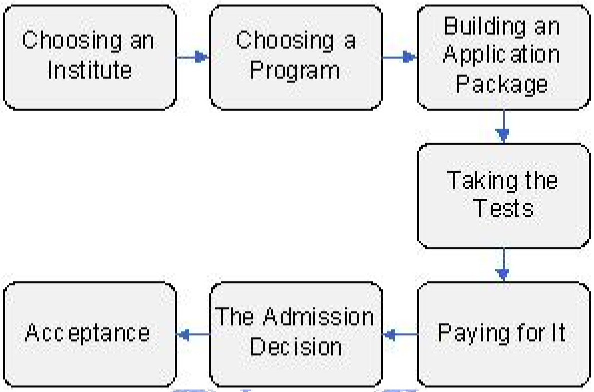

Figure 2.2 Admission Process

(a) Choosing an Institute

There are a huge number of institutes nationally and internationally. Students may find it difficult to decide on where to study further, especially if they consider studying overseas, there are even more options. An institute can be chosen according to the location, reputation, tuition fees, requirements and other factors.

(b) Choosing a Program

After an institute is selected, a program has to be chosen. Beside personal interests of the prospective student, there are some issues of the program that can also be taken into consideration. There issues are culture, rankings, average starting salary, salaries at the 5-year mark, placement rate, location, campus, class profile, cost, specialized and general curriculum, class size and grading policy (Kaplan Inc., 2004).

(c) Building an Application Package

An application package implies all the necessary information that may help the student to complete the application successfully. This includes the complete application form, recommendation letters, academic reports, motivation letter, etc.

(d) Taking the Tests

When applying for an institute overseas, students are usually required to write language tests and/or related tests. Besides entrance tests required by the specific institutes, other tests such as TOEFL, GMAT or GRE are required according to the institute's requirements.

(e) Paying for It

The tuition fee is one of the main concerns when a student is selecting an institute. When the student is studying away from home, extra costs such as accommodation and transportation have to be considered as well. Thus, student can also consider applying for scholarships and financial aids when necessary.

(f) The Admission Decision

A selection procedure will take place in the institute where possible acceptances are collected. These applications will be considered in more detail so that the most suitable students can be chosen. After this process, a limited number of students will be chosen and will be contacted by the institute.

(g) Acceptance

The students who are accepted will receive confirmation letters from the institutes. After this, students should begin to prepare for the necessary documents and materials, and anything that may be useful.

2.3 Existing Sources of Information

Information on schools rankings and comparisons is produced by renowned universities and organizations in the world on a regular basis. As mentioned earlier, a ranking for the top 500 universities in the world is formulated by Shanghai Jiao Tong University; rankings for the top 100 business schools in the world is produced by Financial Times each year; and recently a ranking for the top 10 business schools in East Asia is done by Asia Inc.. Organizations, such as the Graduate Management Admission Council (GMAT), also provide information and websites for students and educators to search for and compare the business schools in the world. These sources of information can be categorized into two major types:

(a) Information on rankings

Financial Times produces one of the most accredited rankings for the top 100 business schools in the world each year. Research is done on three broad areas: alumni career progress, diversity and idea generation; and each area contributes a specific percentage towards the total scores. (See Appendix B1) The information produced by Financial Times is broadly used by students and educators around the world as a reference.

Shanghai Jiao Tong University in China has also produced a ranking for the top 500 universities in the world. Scores are given to each university by various renowned organizations and an overall score is given to each of them in order to formulate the final ranking. (See Appendix B2)

Lastly, Asia Inc. preformed a ranking for the top 10 business schools in East Asia. Three main areas, namely peer-reputation ranking, school and faculty quality, and student quality, are considered which contribute 20%, 45% and 35% of the final score respectively. (See Appendix B3)

(b) Search Engines

The Graduate Management Admission Council (GMAT) provides a comprehensive search engine online to allow prospective students and educators to search for and compare different business schools around the world. They can specify the requirements of the business school(s) that they are looking for and the database will generate the matching results for them. In this way, they are able to obtain more details of the business schools that they are interested in. (See Appendix B4)

2.4 Competitiveness of Schools

According to the IMD World Competitive Yearbook, there are four dimensions that shape a competitiveness environment. These are attractiveness vs. aggressiveness, proximity vs. globality, assets vs. processes, and individual risk taking vs. social cohesiveness. (IMD, 2003) Although these dimensions are applied to countries in the yearbook, they can also be applied to the competitiveness of schools.

(a) Attractiveness vs. aggressiveness

Some universities are attractive to students and educators because of their fames and resources. They are often recognized around the world and prospective students would like to study there because of their recognition and accreditation. If other universities that are less well-known want to attract more students and educators, they may need to provide more benefits and facilities to attract them.

(b) Proximity vs. globality

Proximity determines the services and facilities that a university provides to its students and prospective students locally; while globality determines its international recognition and resources. Undoubtedly, a university's competitiveness will increase if it is internationally recognized; but this may take time and effort to achieve.

(c) Assets vs. processes

Some universities are rich in assets such as advanced technologies, renowned professors and huge resource base. These provide professional resources to students to assist them in studying. Universities that have fewer assets focus on processes such as skills in order to maintain their positions.

(d) Individual risk taking vs. social cohesiveness

Many universities carry out joint programs with other universities so that both universities are able to provide high quality education and resources. Other universities prefer to improve their standards and resources individually so that they can focus more on what is lacking.

2.5 Decision Support System (DSS)

Decision support system is an information system that collects data, manipulates and analyzes them with the aids of models and calculations, and finally displays the results in a manner to help decision makers to generate the most suitable decisions. DSS can be divided into two general categories: data-oriented systems and model-oriented systems (Alter, 1980). Designed to support different purposes, data-oriented systems provide functions for data retrieval, analysis and presentation while model-oriented systems provide calculation, simulation or optimization models for decision making. (Bennett, 1983) *(a) Structure of a DSS*

During the design of a DSS, there are a number of issues that should be considered. First, a DSS should be designed to support multiple processes because there are different types of decision making processes. Second, a DSS should also support different types of decisions because different types of decisions have different data processing requirements. Third, because decision makers make decisions by relying on conceptualizations, a DSS should provide familiar display tools, such as charts and graphs, to assist in conceptualization and presentation. Forth, a DSS should provide controls to allow decision makers to make decisions directly and according to their own requirements and preferences. (Bennett, 1983)

A high-level structure of a DSS is shown in Figure 2.3. There are five major modules in a DSS. In order to minimize computation time and enhance efficiency, the number of module is kept as minimal so that the system will be more effective for both the developers and users. (Bennett, 1983)

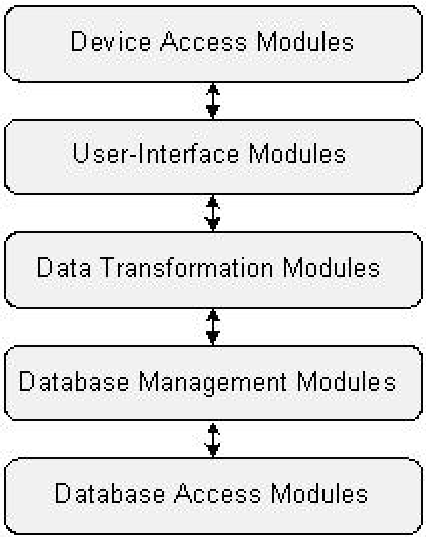

Figure 2.3 Program Structure for a DSS

(b) Decision Making Process

The process of decision making is usually influenced by the external environment and the decision maker's cognition. The decisions are often subjective because it is generated according to the existing circumstances and the decision maker's preference. However, in order to make a decision effectively, there are a few steps that can be taken. These steps are: (1) problem definition, (2) information gathering, (3) information assessment, (4) choice of decision making, (5) behavioural action and (6) review (MSU Counselling Centre, 2003).

When a decision maker is required to make a decision, he/she usually has to go through a number of processes. The relationship between these processes is shown in Figure 2.4 (Adapted from ISC, 2004).

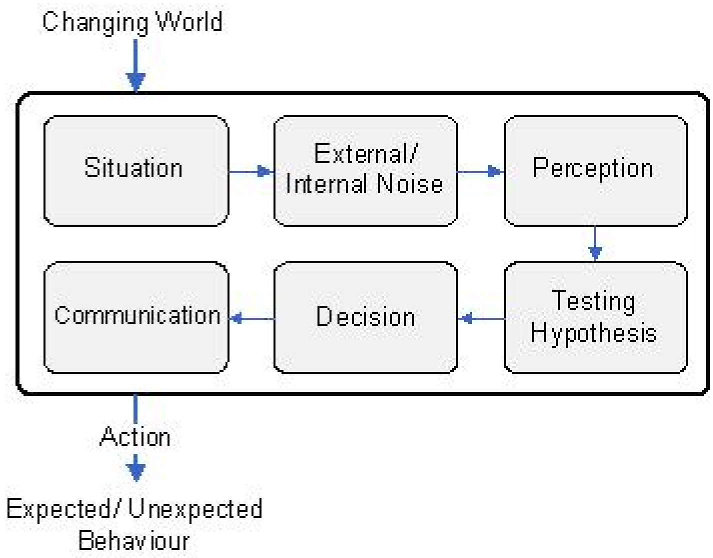

Figure 2.4　　Decision Making Process

Because of the turbulent environment, a decision maker has to adapt to the current situation through different noises. These noises come from both the environment and the mind of the decision maker; and these affect their perceptions of what is happening in the surroundings. In order to make an appropriate decision, the decision maker should consider different possibilities and create hypothesis to test various assumptions. This process helps to eliminate the possibilities until the final decision is reached. Then the decision maker can communicate with the others who may be influenced by the decision. Finally, actions can be taken to put the decision into practice. (ISC, 2004)

2.6 Optimization Model

The idea of optimization is often addressed when decisions have to be made. In order to provide a scientific approach for formulating optimal or best solutions, industrial engineers and mathematicians have begun to build models and investigated for new techniques. When the number of available alternatives is small, simulation methods can be used to generate a meaningful evaluation effectively without too much simplification on each alternative (Murty, 1995).

As there are various optimization models available, it is important to select the one which is the most suitable in describing and solving the specific problem. In order to achieve this, there are five criteria that should be considered. They are performance, realism/complexity, computational costs, information requirements and ease of use (Mulvey, 1979).

With performance, the usefulness of the solution generated by the model is considered. The model should be able to provide information that helps to improve the current problem effectively. Realism or complexity is used to determine how closely related is the model to the real situation. It is to ensure that the model represents the reality appropriately. Hence, the more realism usually requires more complexity in the model. The computational costs imply the money and time that have to be spent for a problem. Ideally, the cost and time spent for computing the problem should be kept as minimal. The amount of information needed to solve the problem is the information requirements of the model. The more information available, the better results the model can produce. However, it is also important to identify and use the information that is critical to the decision making process. Too much unnecessary data can hinder the efficiency and increase the costs of the calculation. Lastly, ease of use ensures that the model is flexible and easy to use for different kinds of problem. When the criteria of the problem are altered, the model should be able to adapt the changes accordingly. (Bennett, 1983)

(a) LINGO

LINGO is a form of mathematical programming that uses mathematical procedures to determine optimal allocation of scarce resources. In order to optimize a problem, two requirements are considered; they are limited resources and activities. The use of LINGO allows users to effectively input a model formulation, and solve and modify it until it gives the desired results.

There are five steps in the model formulation process when a problem needs to be optimized. The processes are shown in Figure 2.5 (LINDO, 1999):

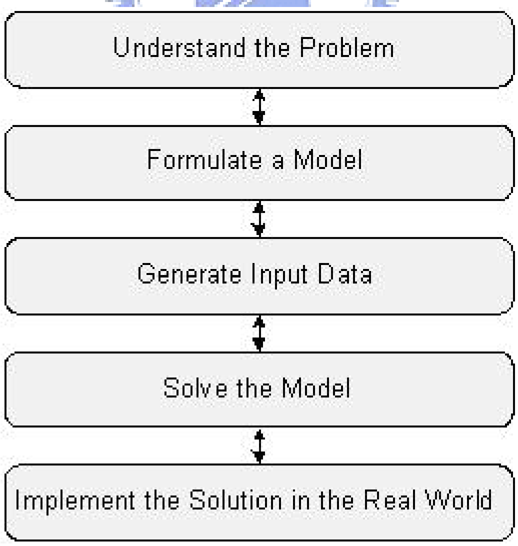

Figure 2.5 The Overall Process of Model Formulation

2.7 Geographic Information System (GIS)

By definition, a geographic information system (GIS) is a computer-based information system that captures, models, manipulates, retrieves, analyzes and presents geographically referenced data (Worboys, 1995). GIS is applied widely in fields such as business, communication, defence, education, engineering, government, natural resources, health, transportation and utilities (ESRI, 2004). In Taiwan, GIS is mostly used in disaster prevention and transportation planning. In business environment, when decisions have to be made with reference to geographical information, a system called spatial decision support system (SDSS) will be evolved.

A SDSS allows users to interact with the system via a user interface; operations are done within the system and the final results will be shown in graphical or tabular forms. Inside the system, a database management system (DBMS) is the core that stores and manipulates data. There are also modelling techniques embedded in the system to retrieve the necessary data. The required outcomes are then generated and displayed. A SDSS architecture is shown in Figure 2.6. (Armstrong *et al.*, 1986)

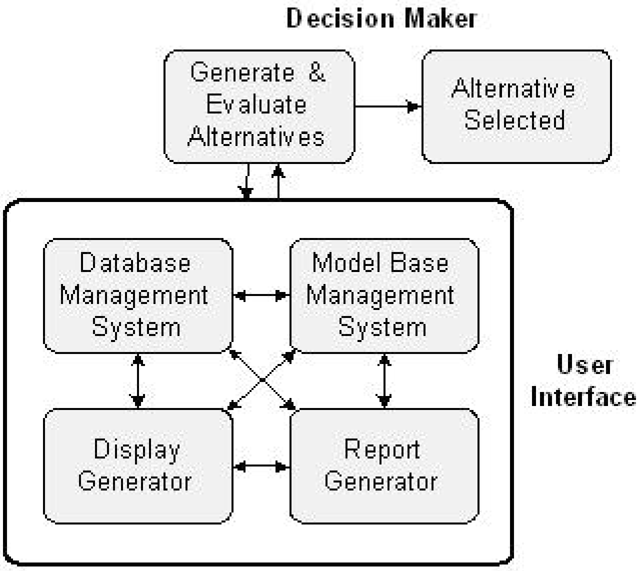

Figure 2.6 Architecture for a SDSS

2.8 Summary

In summary, although rankings and information are provided by various institutes and organizations, these can only be seen as guidelines when a prospective student or an educator is making a decision. This information is formulated statistically; however, it may be too objective for someone to base his/her decision on. Very often, the best in ranking does not imply the most suitable and favourable for a prospective student. He/She may be more concern with the academic environment or tuition fees, which are often not considered and less critical in statistical research; or some criteria may be more important than the others to him/her but it is not the case in general research data. Moreover, although there are guidelines from books and magazines to assist students to select the suitable schools, these are not efficient as students are required to generate the results themselves. So, there is a need for a tool that allows students and educators to manipulate data and make decisions according to their preferences.

Thus, this research aims to propose a system that does not only store and retrieve the required data, but also provides simulation and optimization for users to generate results that are most suitable and favourable according to their requirements and preferences. For geographical references and comparisons, a GIS is implemented to provide interaction and display for geographic data and results.

In the following sections, the structure of the proposed system will be discussed in detail. Chapter 3 will discuss the mathematical model behind the optimization process. Chapter 4 will discuss the structure of the system while Chapter 5 will demonstrate the actually operations of the system. Conclusion and suggestions for future development will be discussed in the final chapter.

Chapter 3 – Mathematical Model

Besides the provision of results according to the specifications and requirements of the users, the system should also be able to generate objective results accordingly. An objective solution usually implies a result that is generated scientifically and mathematically; so that it can be seen as a guideline or reference for users to make a decision.

In this research, a mathematical modelling tool called LINGO will be applied to calculate the optimal solutions for each user's selection. In the entire optimization process, two models will be used for the calculation. These models are formulated by the professor and fellow students of the Operations Research Lab at National Chiao Tung University, Taiwan.

In a brief summary, the first model calculates the common weight for each criterion chosen by the user; while the second model calculates the x-, y- and z-coordinates for each subject so that it can be mapped onto a sphere with other subjects for comparison. The mapping of the results will show the relationship between each subject and its dissimilarity with the ideal solution.

3.1 Common Weight Model

The common weight model aims to generate the weights for all the criteria mathematically, so that the users are able to obtain an objective result of weightings for each criterion without calculating it manually. The model is illustrated as follows:

Variable	Meaning
m	Total number of subjects
n	Total number of criteria
$\overline{C_k}$, $\underline{C_k}$	Maximum and minimum values of criterion k
$C_{i,k}$	Criterion k of subject i
w_k	Weight of criterion k
M	Predefined constant

Table 3.1 Variables for the Common Weight Model

$$Min \quad \sum_{i=1}^{m} \sum_{j \neq i}^{m} t_{i,j}$$

subject to

$$\sum_{k=1}^{n} \left(w_k * \left(\frac{C_{i,k} - \underline{C_k}}{\overline{C_k} - \underline{C_k}} \right) \right) + \left(M * t_{i,j} \right) \geq \sum_{k=1}^{n} \left(w_k * \left(\frac{C_{j,k} - \underline{C_k}}{\overline{C_k} - \underline{C_k}} \right) \right) . \quad \forall \ i, j \ and \ j \neq i$$

$$\sum_{k=1}^{n} w_k = 1$$

$$w_k \geq \varepsilon, \quad \forall \ k$$

$$t_{i,j} \in \{0,1\}$$

$$t_{i,j} + t_{j,i} \leq 1, \quad \forall \ i, j < i$$

During the calculation, a matrix of binary numbers will return. The summation of each row in the matrix represents its rank. The goal of the objective function, $Min \sum_{i=1}^{m}\sum_{j\neq i}^{m} t_{i,j}$, is to minimize the sum of *t* for each row in order to maximize the rank of each subject. Thus, the smaller the sum of *t*, the higher the rank of the specific subject.

For each $t_{i,j}$, if $t_j > t_i$, then t_{ij} will equal to 1. If $\sum_{k=1}^{n}\left(w_k * \left(\frac{C_{i,k} - \underline{C_k}}{\overline{C_k} - \underline{C_k}}\right)\right)$ is greater than $\sum_{k=1}^{n}\left(w_k * \left(\frac{C_{j,k} - \underline{C_k}}{\overline{C_k} - \underline{C_k}}\right)\right)$, $t_{i,j}$, will be 0. However, if $\sum_{k=1}^{n}\left(w_k * \left(\frac{C_{i,k} - \underline{C_k}}{\overline{C_k} - \underline{C_k}}\right)\right)$ is smaller than $\sum_{k=1}^{n}\left(w_k * \left(\frac{C_{j,k} - \underline{C_k}}{\overline{C_k} - \underline{C_k}}\right)\right)$, $t_{i,j}$, will be 1 and $M * t_{i,j}$ will be non-zero.

The constraint, $\sum_{k=1}^{n} w_k = 1$, ensures that the sum of all the criteria equals to 1; while $w_k \geq \varepsilon, \quad \forall \; k$ ensures that the weights are greater than 0, which makes the calculation of the criteria meaningful. The constraint, $t_{i,j} + t_{j,i} \leq 1, \; \forall \; i, j < i$, ensures that if i is better than j, then the opposite relationship will not occur.

3.2 Spherical Model

After the rankings and scores are calculated by the model described in previous section, another model will be applied to calculate the x-, y- and z-coordinates for each subject so that the results can be displayed on a sphere for a clear representation and comparison of the results.

On the sphere, the ideal solution is projected on the North Pole. The ideal solution implies the optimal solution that carries the maximum values for each criterion. Thus, the closer a subject is to this ideal point, the more favourable it is to the decision maker.

The following table first explains the meaning of each variable in the model.

Variable	Meaning
m	Total number of subjects
n	Total number of criteria
$\overline{C_k}$, $\underline{C_k}$	Maximum and minimum values of criterion k
$C_{i,k}$	Criterion k of subject i
w_k	Weight of criterion k
S_i	Score of subject i
$D_{i,j}$	Dissimilarity between subjects i and j
X_i, Y_i, Z_i	x, y and z coordinates of subject i

Table 3.2 Variables for the Spherical Model

The spherical model is illustrated as follows:

$$MIN \quad \sum_{i=1}^{m}\sum_{j>i}^{m}\left|(X_i - X_j)^2 + (Y_i - Y_j)^2 + (Z_i - Z_j)^2 - D_{i,j}^2\right|$$

subject to

$$S_i = \sum_{k=1}^{n}\left(w_k * \left(\frac{C_{i,k} - \underline{C_k}}{\overline{C_k} - \underline{C_k}} \right) \right)$$

$$D_{i,j} = \sqrt{2} * \sum_{k=1}^{n}\left(w_k * \left(\frac{\left|C_{i,k} - C_{j,k}\right|}{\overline{C_k} - \underline{C_k}} \right) \right)$$

$$X_i^2 + Y_i^2 + Z_i^2 = 1 \;, \quad \forall \;\; i$$

$$Y_i = 2S_i - S_i^2 \;, \quad \forall \;\; i$$

This model assumes that the dissimilarity between two subjects is the distance between them. Dissimilarity is the degree of difference between subjects. It is calculated by minimizing the difference between the straight-line distances of two subjects.

First of all, $S_i = \sum_{k=1}^{n}\left(w_k * \left(\frac{C_{i,k} - \underline{C_k}}{\overline{C_k} - \underline{C_k}} \right) \right)$ calculates the score of each criterion. Then, $D_{i,j} = \sqrt{2} * \sum_{k=1}^{n}\left(w_k * \left(\frac{\left|C_{i,k} - C_{j,k}\right|}{\overline{C_k} - \underline{C_k}} \right) \right)$ calculates the dissimilarity between i and j; and the largest possible value for $D_{i,j}$ is $\sqrt{2}$.

Constraint $X_i^2 + Y_i^2 + Z_i^2 = 1 \;, \; \forall \; i$ ensures that all the points are projected onto the surface of the sphere. The last constraint,

$Y_i = 2S_i - S_i^2$, $\forall \ i$, defines the relationship between the y-coordinates and the scores.

3.3 Summary

The use of the mathematical models helps prospective students or lecturers to obtain an objective result on the scores of the universities and the selected criteria. The results can be considered as the optimal solution formulated scientifically. During this process, students or lecturers do not need to worry about the influence of their preferences; and the formulated results can be best used to compare the universities in different dimensions.

Moreover, the display of results on a sphere allows students or lecturers to visualize the results for better comparison and interpretation. The North Pole of the sphere represents the ideal location of the result. Thus, the closer a subject is to the North Pole, the better the result is. The display on the sphere also illustrates an important feature of the results; that is the similarity of the results. Results that are similar in terms of their scores and weightings will cluster together on the sphere; while dissimilar results will situate away from the others. In this way, comparison between different schools can be achieved visually.

Chapter 4 - System Design

4.1 System Architecture

The system proposed in this research comprises of three modules. They are the optimization module, data query module and GIS module. In a nutshell, the system allows users to select the schools and criteria for comparison, set weights for each criterion, and input them into the optimization model to formulate an objective optimal result. Users are also able to query the most suitable results according to their specifications and requirements from the database management system (DBMS). For a visual display of the spatial relationships between different schools, a GIS tool is used to put the information onto a map.

There are four functions within the system. Firstly, it stores all the information in a database management system (DBMS). The information includes details of the universities, such as their names, origins, co-ordinates and descriptions; types of criteria, their descriptions and calculation methods; as well as score data in which it describes the scores of each criterion of a university. Secondly, it provides selection mechanisms for users to choose the kind of criteria and the specific schools the users would like to view and compare. They could also set different weightings for each criterion according to what they think would be more critical in making decisions. Thirdly, there are calculation mechanisms to simulate and/or optimize the results according to the previous selections. On one hand, to simulate results, the system calculates total scores according to the score of each criterion with its predefined weighting. On the other hand, the selected information can be input in a mathematical model, namely LINGO, to simulate an optimized solution and the solution will be displayed on a sphere for a clear visual presentation. Lastly, the locations of different universities are displayed on a map using a GIS tool for geographical references; and the locations of the universities generated by simulation and optimization models can also be displayed as a reference.

The following tools will be used during the development of the system:

- Borland Delphi, for the overall system
- LINGO, for the mathematical models
- MapInfo, for the vector maps of the GIS functions

Figure 4.1 shows the flow of the system. There are a number of processes within the system. Users are able to input their preferences before calculation is done, and results are generated in the forms of reports, spheres or maps.

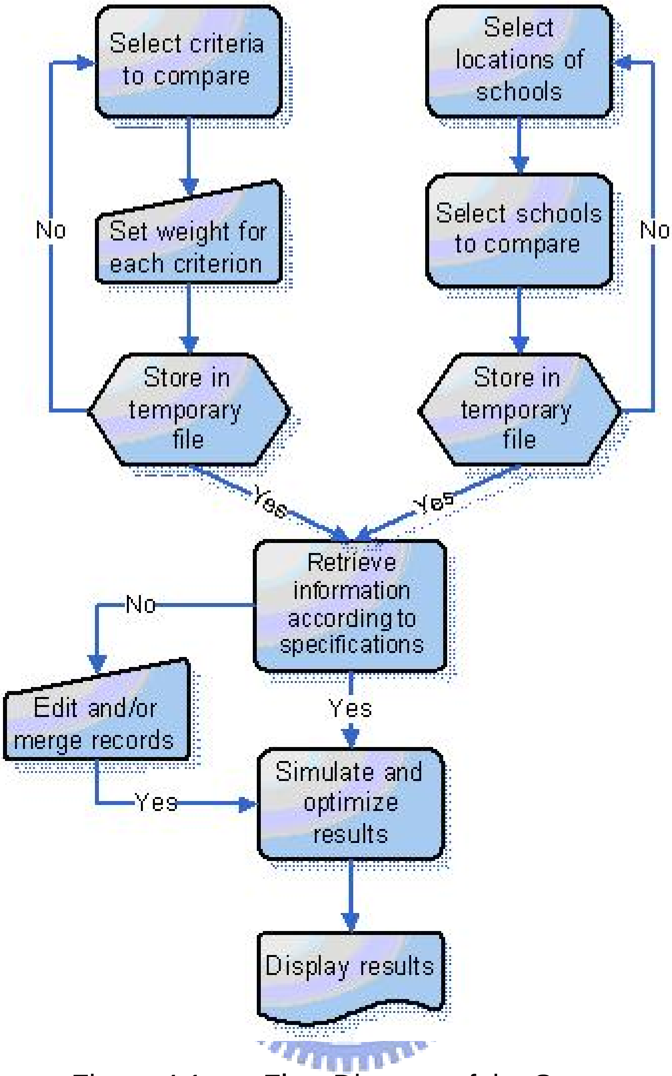

Figure 4.1 Flow Diagram of the System

The architecture of the system is presented in Figure 4.2 (adapted from Hall *et al*., 1997). Inside the system, the graphical user interface (GUI) acts as a medium for users to interact with the system. It is connected to the database management system (DBMS) that manipulates the data, which is transferred to the mathematical calculator and the optimization model for simulation. Geographical data, such as maps, is stored in the spatial model base and will be retrieved by the GIS model for modelling and display in a later stage. The DBMS and spatial model base is linked so that the simulated results can be linked to their geographical data and be displayed when required. Finally, maps are produced by GIS modelling, and reports and graphs are produced by the simulated and optimized results.

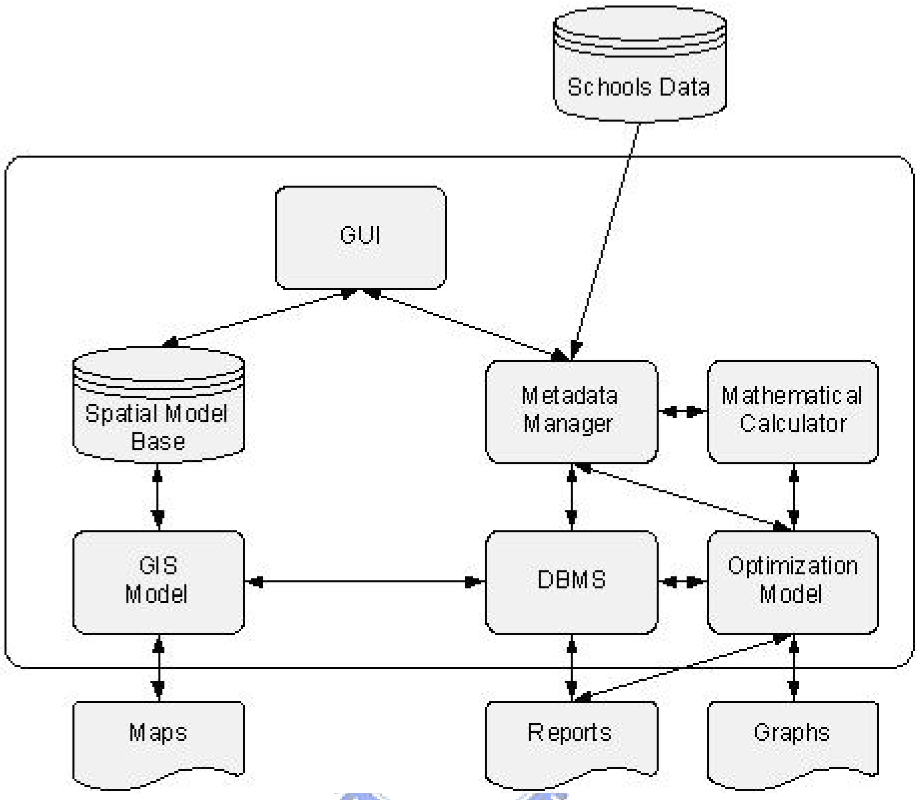

Figure 4.2 Proposed Architecture of the System

4.2 Database Structure

The structure of the database is presented in Figure 4.3. The database consists of 4 main types of data: school data, criteria types, descriptions of schools and scores of various criteria of each school.

A unique code is assigned to each school record. Each record consists of the name of the university (Name), its location (Locations_Code), its descriptions (Descriptions_Code), its x- and y-coordinates, as well as its vision and mission statements. In this table, the Locations_Code is a foreign key from another table called Locations that stores the various possible locations of a university. These locations are Africa, Asia, Australia, Europe, Middle East, North America and South America. Each location is assigned to a unique code in this table. The Descriptions_Code is a foreign key from another table in the database called Descriptions that includes information about a particular school such as the type of school, programs it offers, the cost, campus size, etc. Each description is assigned to a unique code in this table.

The Criteria table simply stores the names of each criterion and its descriptions. A unique code is also assigned to each criterion. During the simulation and optimization processes, the scores of the criteria may need to be combined with the scores of other criteria. Some scores can be added together while the other may require obtaining an average score. So, an attribute (CalMethod) is added with the value of 0 implies addition and 1 implies an average.

The last table is the Score table, which stores the scores of the criteria of each university. There are two foreign keys, namely School_Code and Criteria_Code, which identify each criterion of a particular university. The scores of the criteria are included in this table.

A more detailed database schema of this database is included in Appendix C for reference.

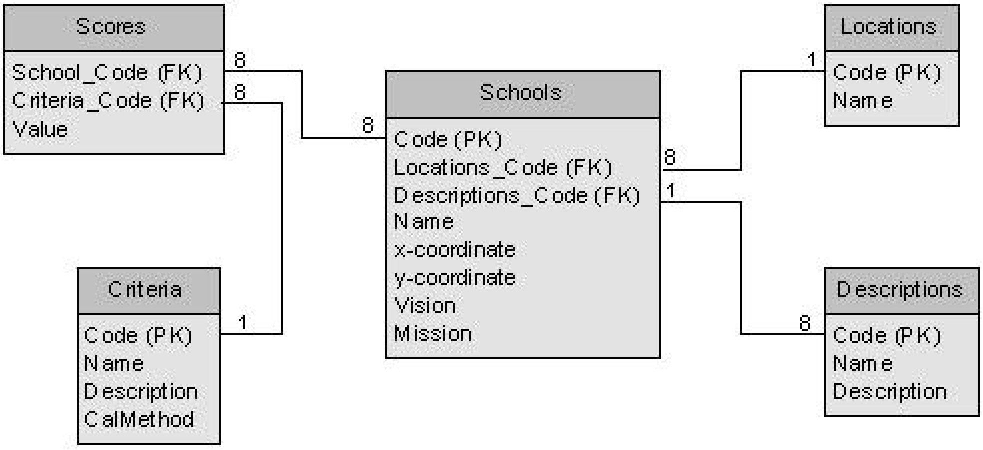

Figure 4.3 Entity Relationship Diagram of the Database

4.3 Mathematical Models

There are two types of calculations in the system, which have been entailed in Chapter 3. The first calculation is a simulation of the total score with user-defined weightings. The system allows users to select the criteria they would like to compare and set a weight from 1 to 5 to each criterion according to their preferences. So, the more important a criterion is, the higher the weight will become, and the more it counts towards the total score. The second calculation is done with a spherical DEA model that will produce the optimal results and can be displayed on a sphere for visual representation. This model is able to calculate outputs with the given weights and scores, and produces dissimilarity and the coordinates for each record. Details of the two calculation methods are described in the following:

The following table explains the meanings of various variables used in the two formulas:

Variable	Meaning
m	Total number of schools
n	Total number of criteria
$\overline{C_k}$, $\underline{C_k}$	Maximum and minimum values of criterion k
$C_{i,k}$	Criterion k of school i
w_k	Weight of criterion k
M	Predefined constant
S_i	Score of school i
$D_{i,j}$	Dissimilarity between schools i and j
X_i, Y_i, Z_i	x, y and z coordinates of school i

Table 4.1 Explanation of Various Variables

(a) Simulation model

As explained earlier, the simulation process takes the score of each criterion and its weighting given by the users into consideration. The following formula explains how the calculation will be formulated:

$$S = \sum_{i=1}^{n} (W_i \ X \ C_i)$$

where S is the total score calculated; c_i is the criterion; w_i is the weight assigned to criterion i; and n is the total number of criteria in the calculation.

(b) Optimization model

There are two steps in the optimization process. The first step is to optimize the ranking of the selected schools. It is calculated by the following formula, as mentioned in Chapter 3:

$$Min \quad \sum_{i=1}^{m}\sum_{j\neq i}^{m} t_{i,j}$$

subject to

$$\sum_{k=1}^{n}\left(w_k * \left(\frac{C_{i,k}-\underline{C_k}}{\overline{C_k}-\underline{C_k}}\right)\right)+\left(M * t_{i,j}\right) \quad \geq \quad \sum_{k=1}^{n}\left(w_k * \left(\frac{C_{j,k}-\underline{C_k}}{\overline{C_k}-\underline{C_k}}\right)\right). \quad \forall \ i, j \ and \ j \neq i$$

$$\sum_{k=1}^{n} w_k \quad = \quad 1$$

$$w_k \geq \varepsilon, \quad \forall \ k$$

$$t_{i,j} \in \{0,1\}$$

$$t_{i,j} + t_{j,i} \leq 1, \quad \forall \ i, j < i$$

After the ranking of the schools is formulated, the second step is to put the results onto a sphere for visual representation. The following formula is used to generate the coordinates of each result on the sphere. On the sphere, the North Pole represents the best possible result of each school. Thus, the closer the school is to the North Pole, the more favourable the school is according to the user's requirements. Beside the comparison of scores, the sphere can also display the idea of similarity of results. When there are results that are similar to each other, it implies that their scores are similar and/or their criteria carry more or less the same importance. So, when these results are shown on the sphere, they will be located close to each other. In other words, the sphere is able to show the groupings of similar results. The following formula has been introduced in Chapter 3:

$$MIN \qquad \sum_{i=1}^{m}\sum_{j>i}^{m}\left|(X_i - X_j)^2 + (Y_i - Y_j)^2 + (Z_i - Z_j)^2 - D_{i,j}^2\right|$$

subject to

$$S_i = \sum_{k=1}^{n}\left(w_k * \left(\frac{C_{i,k} - \underline{C_k}}{\overline{C_k} - \underline{C_k}}\right)\right)$$

$$D_{i,j} = \sqrt{2} * \sum_{k=1}^{n}\left(w_k * \left(\frac{\left|C_{i,k} - C_{j,k}\right|}{\overline{C_k} - \underline{C_k}}\right)\right)$$

$$X_i^2 + Y_i^2 + Z_i^2 = 1 \;,\quad \forall \; i$$

$$Y_i = 2S_i - S_i^2 \;,\quad \forall \; i$$

4.4 GIS Architecture

The GIS architecture of the system is built in a hybrid approach. This means the spatial data is stored independently from the non-spatial data. (Worboys, 1995) In the system, geographical data such as the countries and landmarks are stored in a number of spatial data files; and they are linked to the relational database described in Section 4.2. The architecture of the hybrid approach is demonstrated in Figure 4.4.

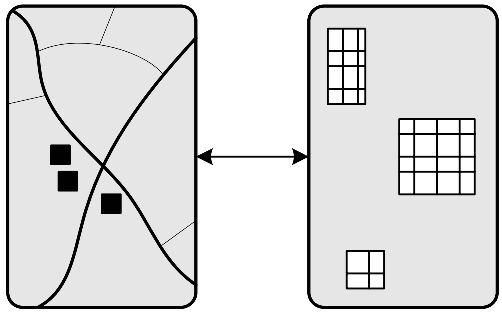

Figure 4.4 Hybrid GIS Architecture

Due to the difference in nature between spatial data files and relational databases, the hybrid architecture helps to manage the two components separately so that performance can be optimized. In order to link the two components, pointers are used to connect the records in the files that have the unique identifiers of tuples in the database.

Spatial data is created in vector formats, where features are represented in terms of points, lines and polygons. In order to manage the data efficiently, different features are drawn in different layers. In other words, the schools are drawn in point layers while the countries are drawn in a polygon layer. As the number of schools is large, it is more convenient to categorize and put them in different layers according to their locations. This is demonstrated schematically in Figure 4.5.

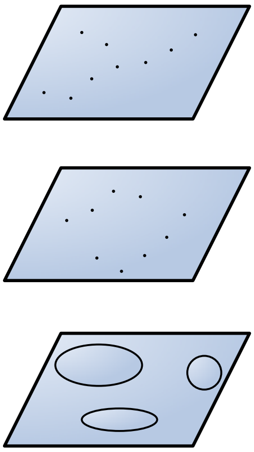

Figure 4.5 Schematic Representation of Spatial Data Files

Spatial data is geo-referenced; in other words, the information represented on the layers is geographically accurate. Because the locations of the schools may be too fine to plot onto the map, their locations will be considered according to the cities, provinces or countries where they are situated. The projection of the map uses the Universal Transverse Mercator (UTM), which is one of the most common projection types available.

Chapter 5 - System Implementation

The system is built according to the design specifications described in the earlier chapters. In order to demonstrate the functionalities and actual implementation of the system, an example will be used below. The example that will be used in the following is the scores of the top 500 universities in the world provided by Shanghai Jiao Tong University this year. The illustration will show how the system functions and responds to users' selections, as well as the results generated by simulation and optimization in the forms of maps or spheres.

As the user enters the system, the following screen will appear:

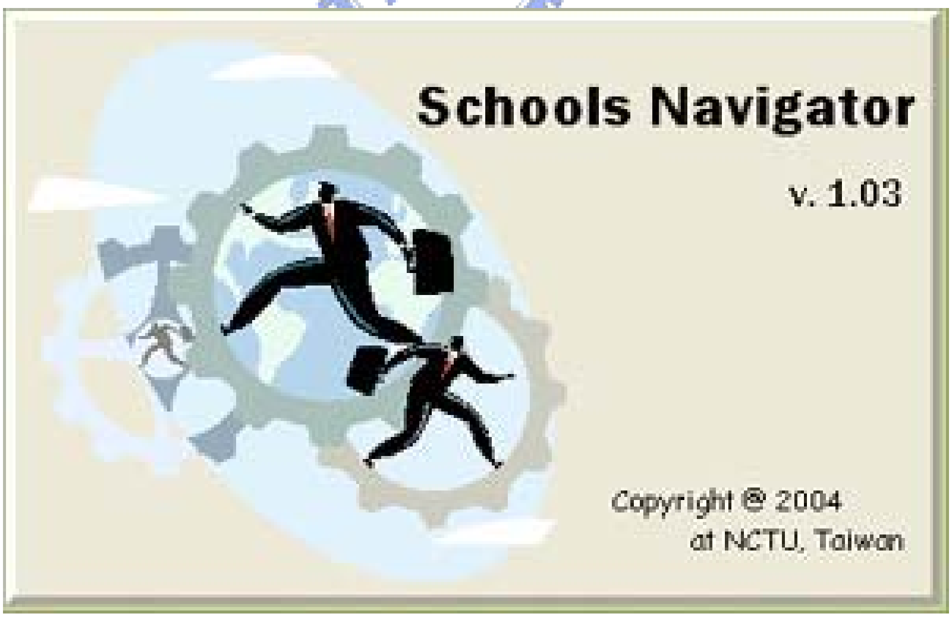

Figure 5.1　　Welcoming Screen

After this screen, the user will enter the main system where the application will begin. The entire operation will be demonstrated in the following sections.

5.1 Setting Criteria

The first step of the operation requires the user to select the criteria he/she would like to view and compare. After the specification the criteria, the user has to set the weight for each criterion according to the importance of it in his/her decision making process. The following screenshots illustrate these operations:

(a) Select the criteria

In this example, there are five criteria available for the users to choose from. Suppose the user selects three criteria, namely Score_on_HiCi, Score_on_NS and Score_on_SCI. The screen will look as follow:

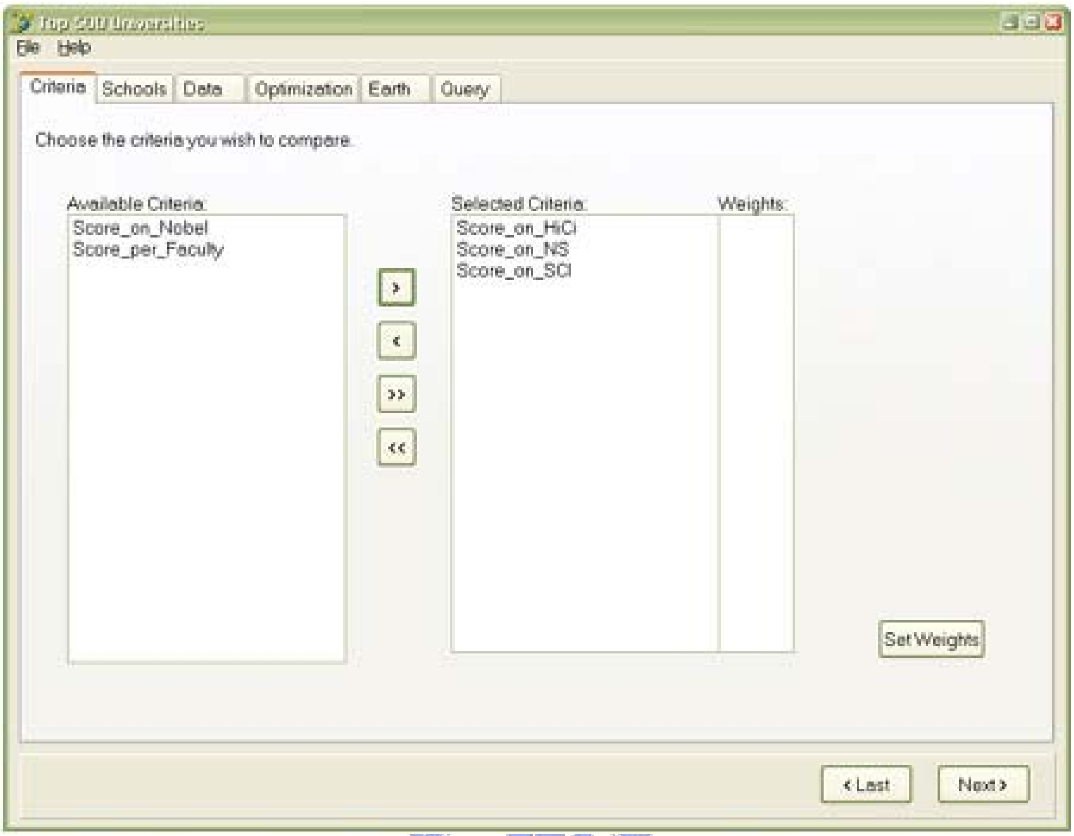

Figure 5.2 Select Criteria

(b) Set the weights

After the criteria are chosen, the user is required to set the weight for each criterion according to his/her preference. Click "Set Weights" and the following will be shown:

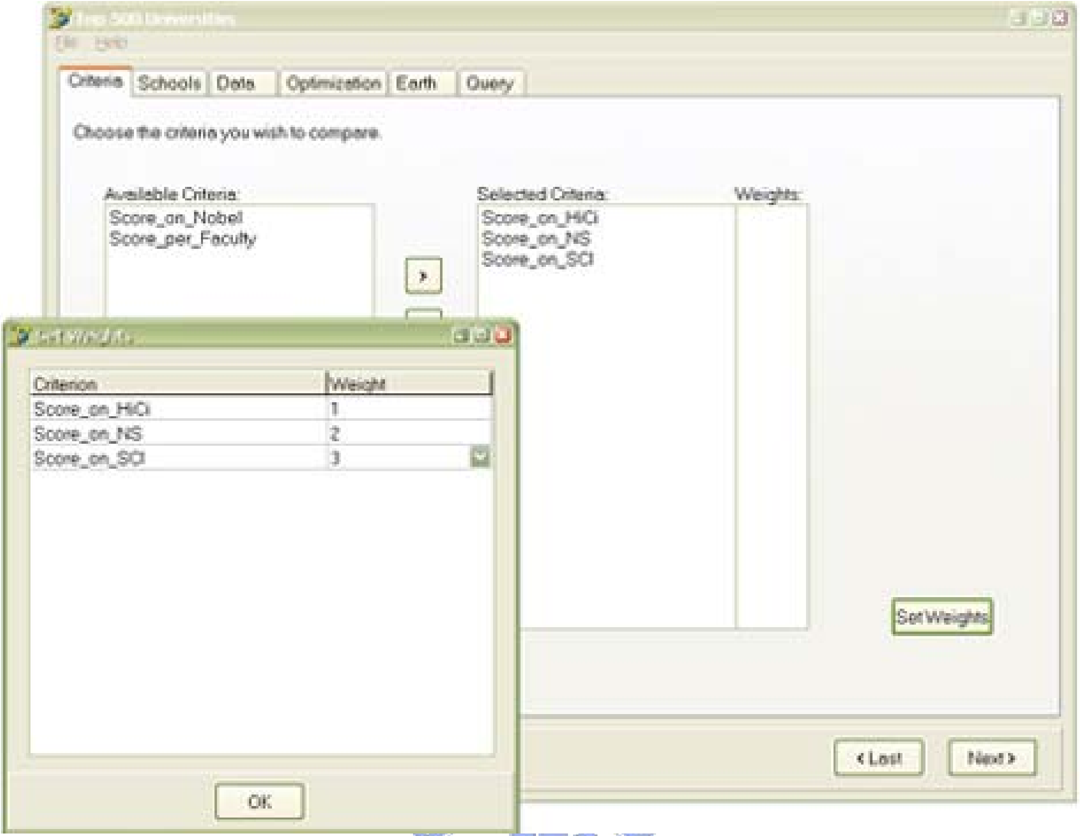

Figure 5.3 Set Weights

Click "OK" and the weights will be reflected in the main screen as follow:

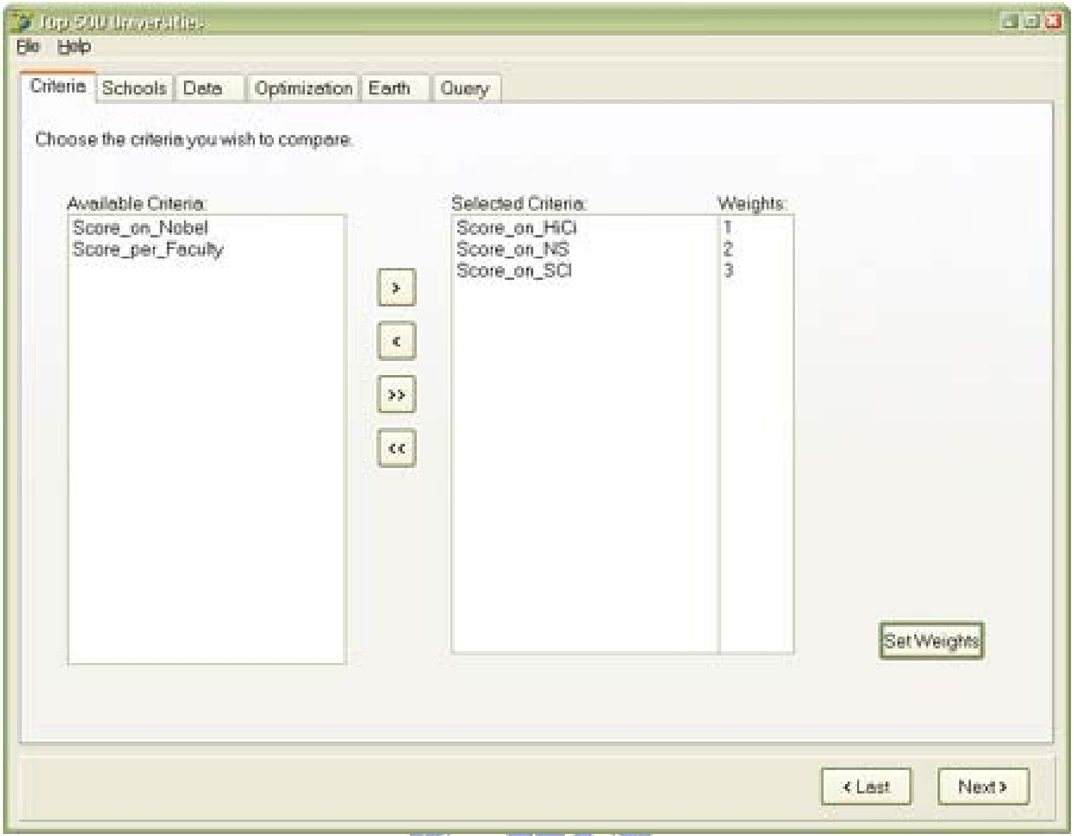

Figure 5.4 The Weights are Set

5.2 Select Schools

The second step is to select the schools the user would like to compare. Schools are categorized into six groups, including Africa, Asia, Australia, Europe, Middle East, North America and South America. The user is able to choose all the locations in one time, or choose one or more locations at a time. Assume that the user would like to compare the schools in Taiwan available in the database; it would look like the following:

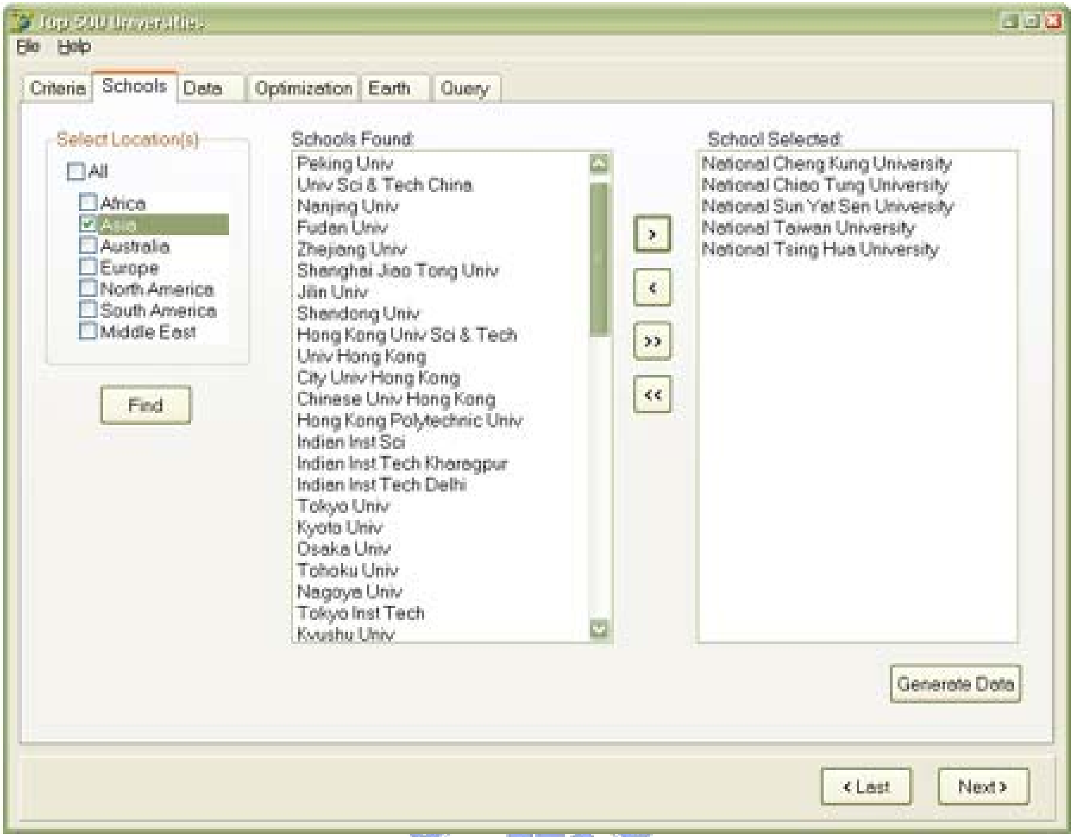

Figure 5.5 Select Schools

5.3 Generate Basic Information

After the selection process is completed, the data required will be generated and displayed when "Generate Data" is clicked:

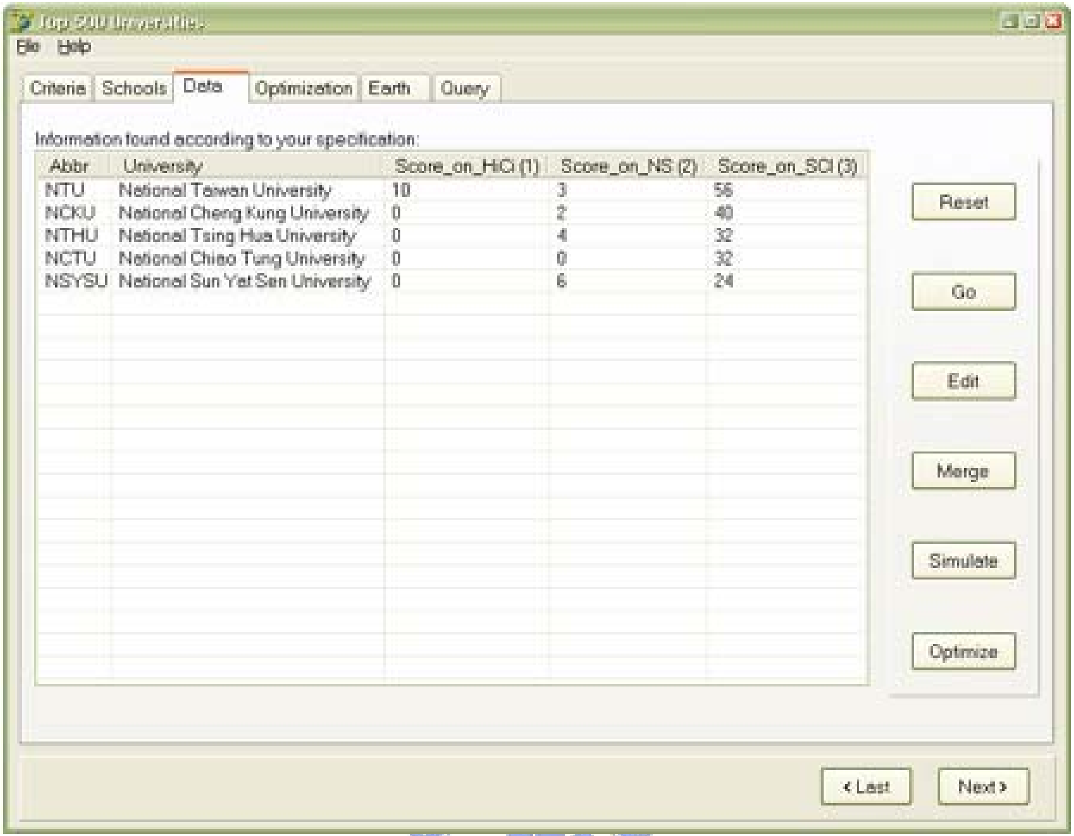

Figure 5.6 Generate Data According to User’s Specifications

(a) Edit Records

At this point, the system carries a number of important functions, which will be discussed later in the following sections. However, before these functions are performed, the user is allowed to alter the displayed data where necessary. He/She can edit the data of a record such as the following:

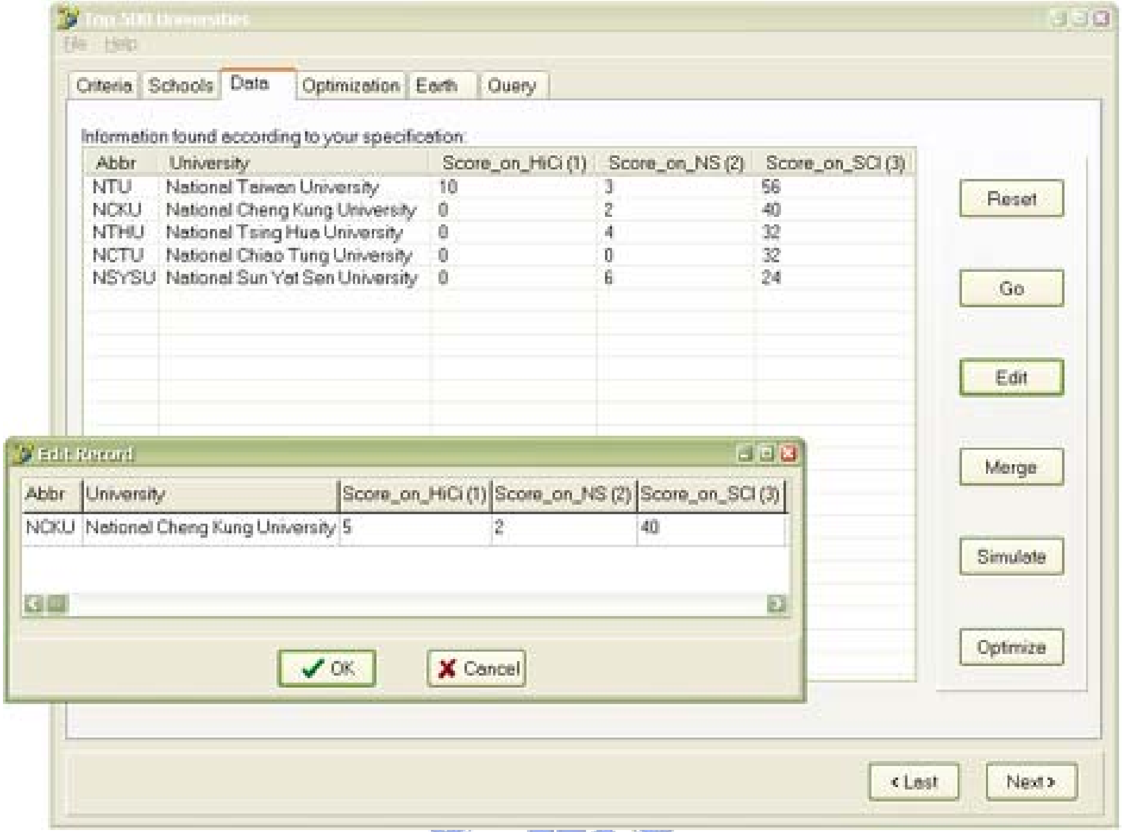

Figure 5.7 Edit a Record

The change(s) will be reflected afterwards:

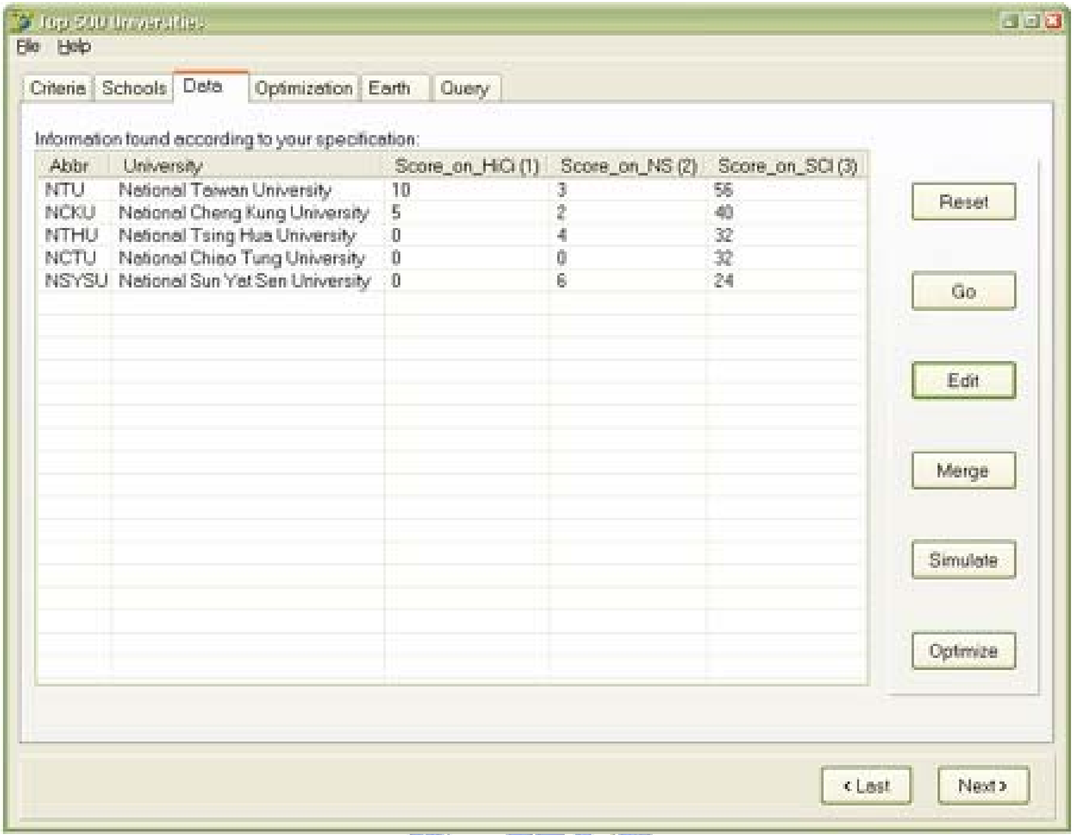

Figure 5.8 Record Edited

(b) Merge Two or More Records

Besides editing records, the user is also allowed to merge the data of two or more schools for simulation of results. Click “Merge” and the following will be shown:

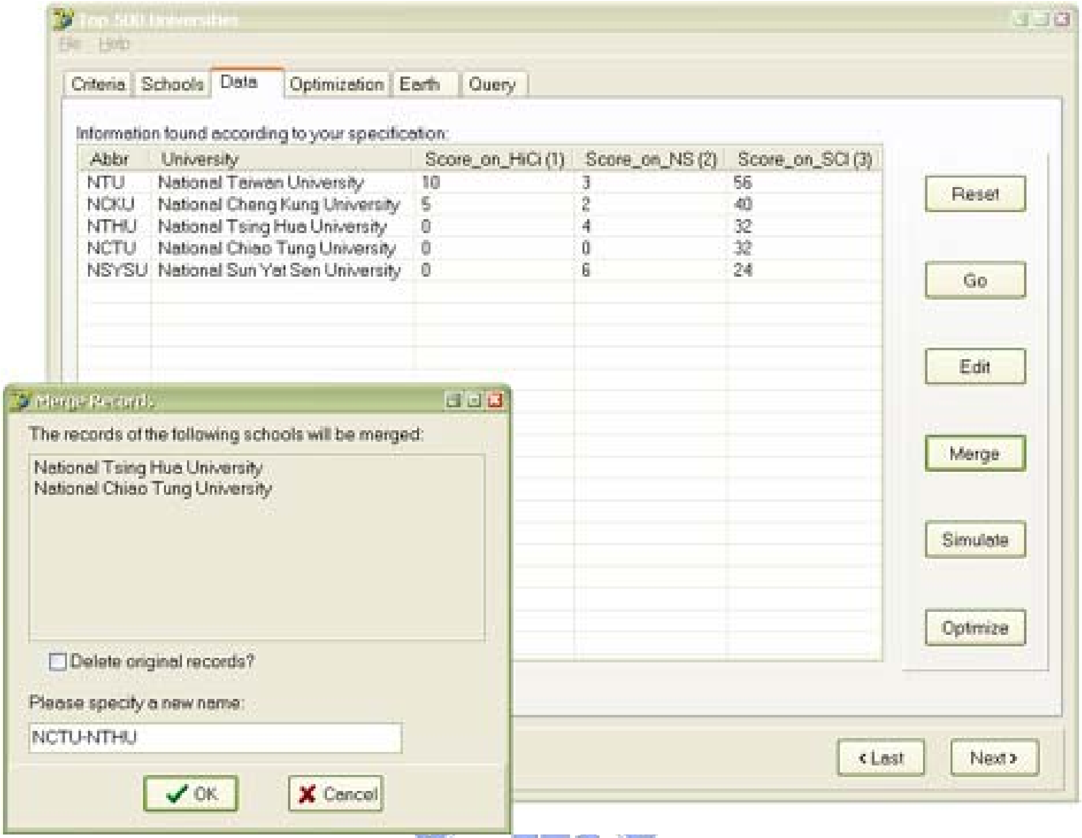

Figure 5.9 Merge Two Records

The user can either delete the records combined or leave them for comparison. When this process is completed, a new record will be added into the table and the scores for different criteria will be calculated.

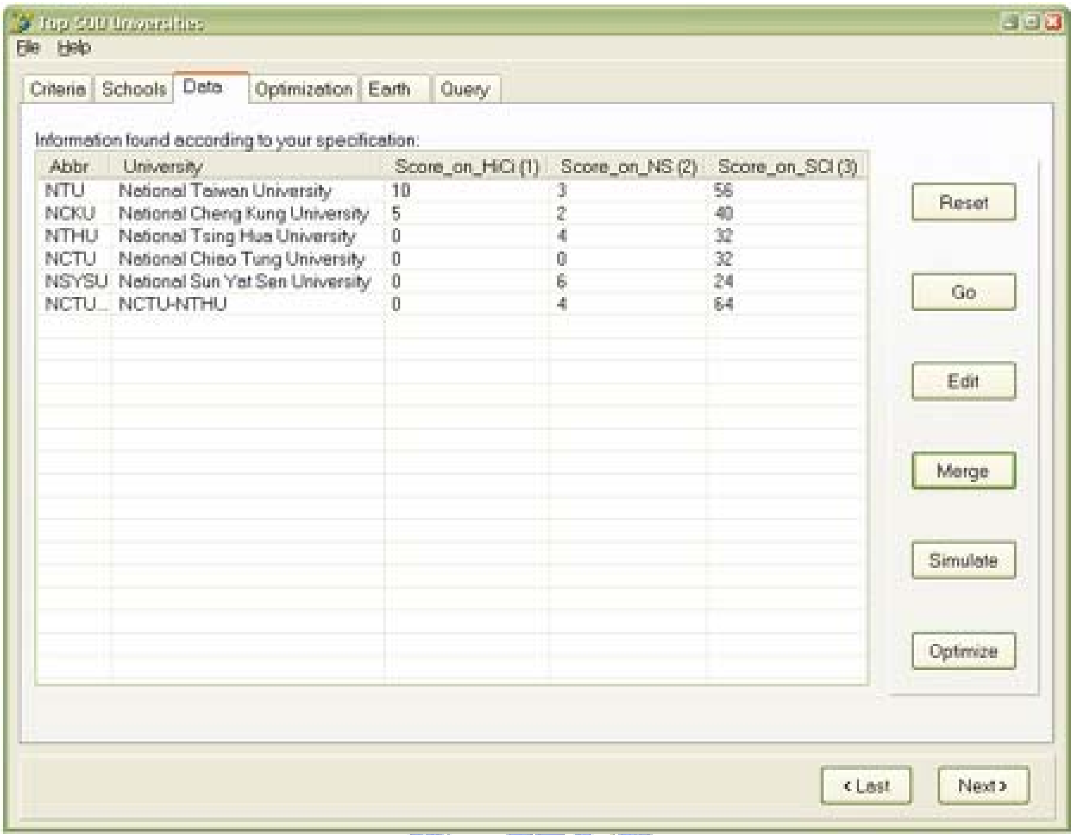

Figure 5.10 Addition of a New Record

5.4 Simulate Results

When the required information is generated, the total scores of the records can be simulated with the formula described in Section 4.3(a). After the calculation, the records can be sorted in descending order so that the user is able to obtain the “ranking” of the results and see more clearly which school is the most favourable according to his/her selection and calculation.

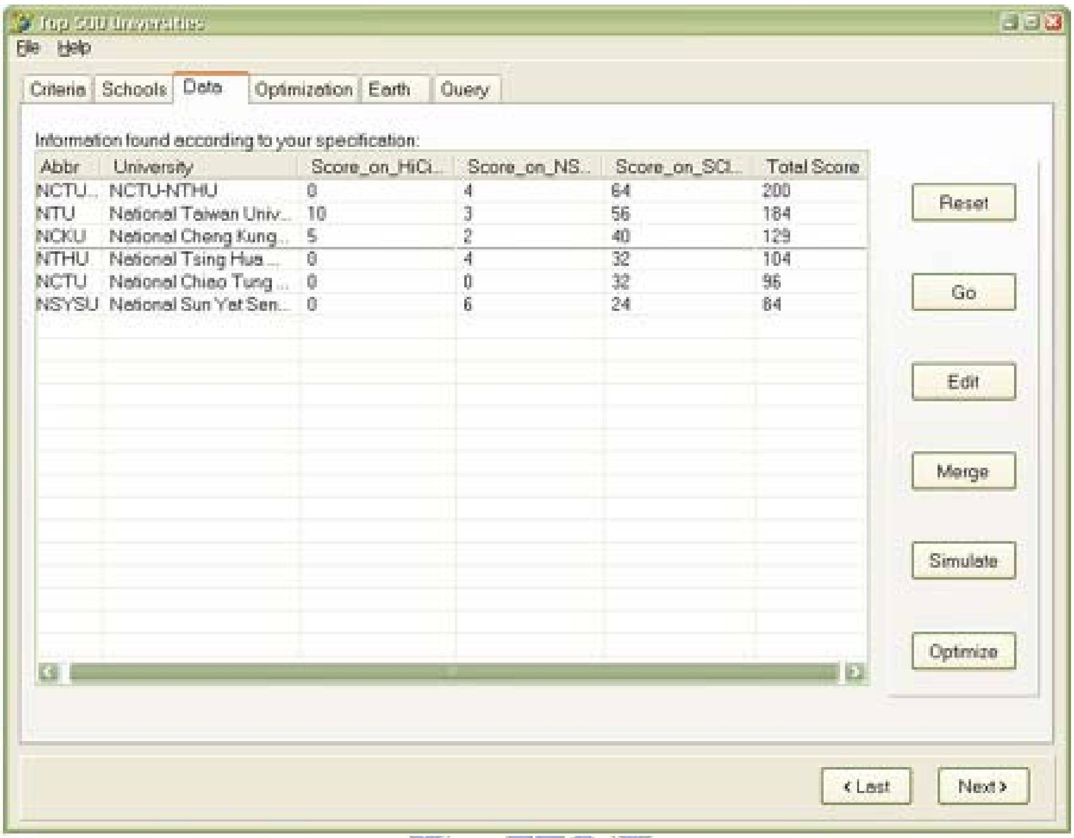

Figure 5.11 Simulate Results

5.5 Optimize Results

Results simulated by the above section provide a subjective solution according to the user's specific requirements. Weights are set according to the importance with regards to the user. However, a more objective result can be formulated by using the optimization models described in Section 4.3(b). In this model, weights are calculated by the model in order to show the importance of the criteria to the overall scores. Score of each criterion and score of each school are calculated and displayed as shown in Figure 5.12.

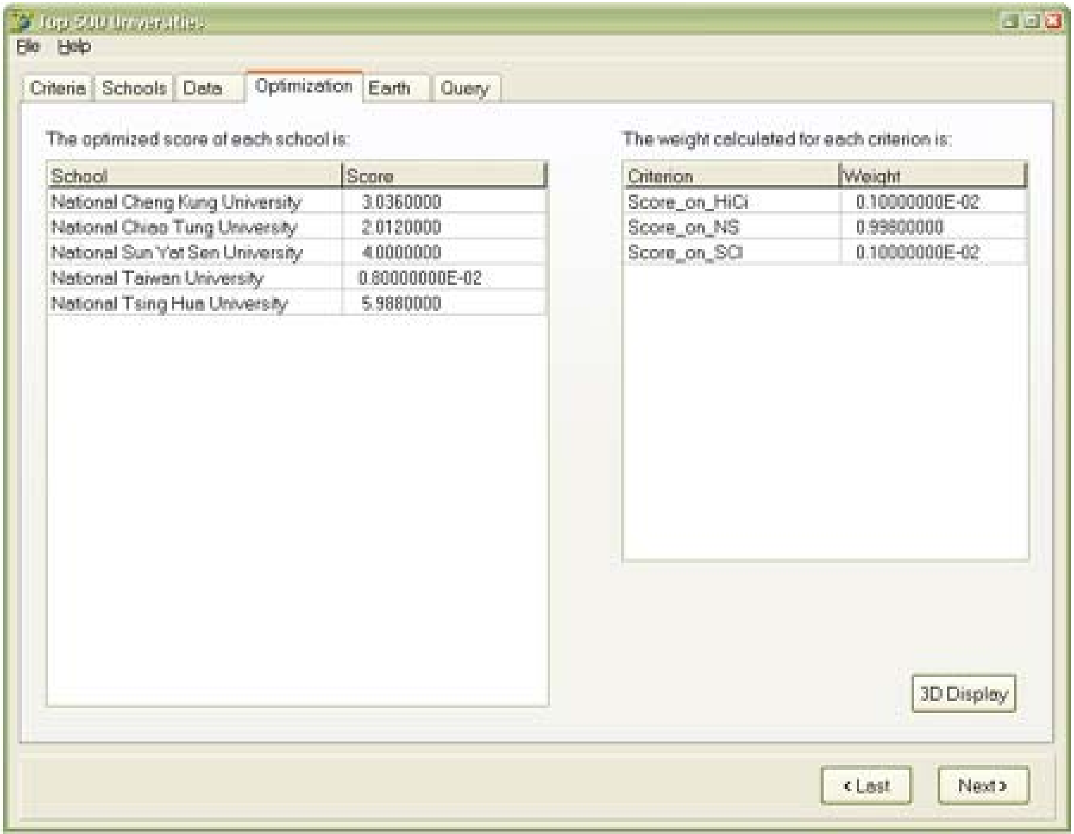

Figure 5.12 Optimize Results

After the scores are calculated, dissimilarity between different schools can be calculated by the model. Based on the three calculated factors, namely the weight, score and dissimilarity, the model will perform the final calculation where the x-, y- and z-coordinates of a specific school are calculated. The results will be displayed on a sphere for better visual representation. Figure 5.13 shows how the results are shown on a sphere.

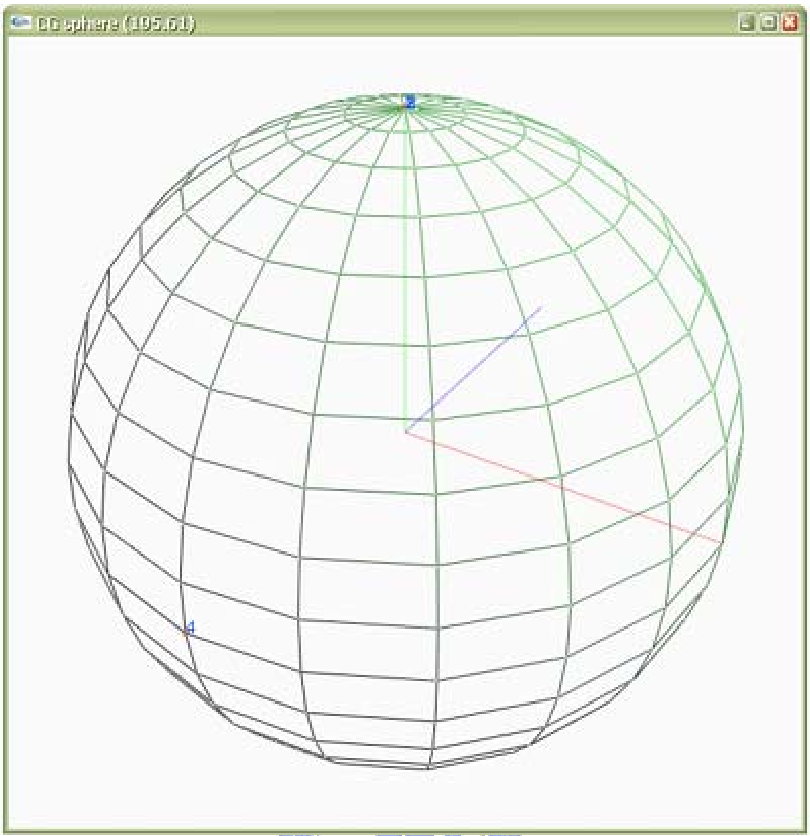

Figure 5.13 Display with a Sphere

On the sphere, point 0 (the North Pole) is the ideal solution of the calculation. Thus, the close the point to point 0, the more favourable the school is. Furthermore, the display also shows the similarity between various schools. The schools that have similar characteristics will cluster together on the sphere.

5.6 GIS Display

In order to allow users to have an idea of where the schools are, the schools are plotted onto a map using GIS tool. For better display and easier management of data, schools are plotted in different layers according to where they are located. The eight layers include schools in Africa, Asia (excluding Taiwan), Australia, Europe, Middle East, North America, South America and Taiwan. The users are able to view one or more or all of those layers at the same time. They are also able to view the data of a specific layer in a table form by selecting the desired layer. As the schools are displayed on the map as points, users cannot view the details of a particular school. There is an “InfoTool” (i) that allows users to click on any point and its data will be shown in the “School Selected” section on the right. This is shown in Figure 5.14.

Figure 5.14 GIS Display

The selected school is marked on the map, in order to view its location clearly, the map can be zoomed in for a clearer result:

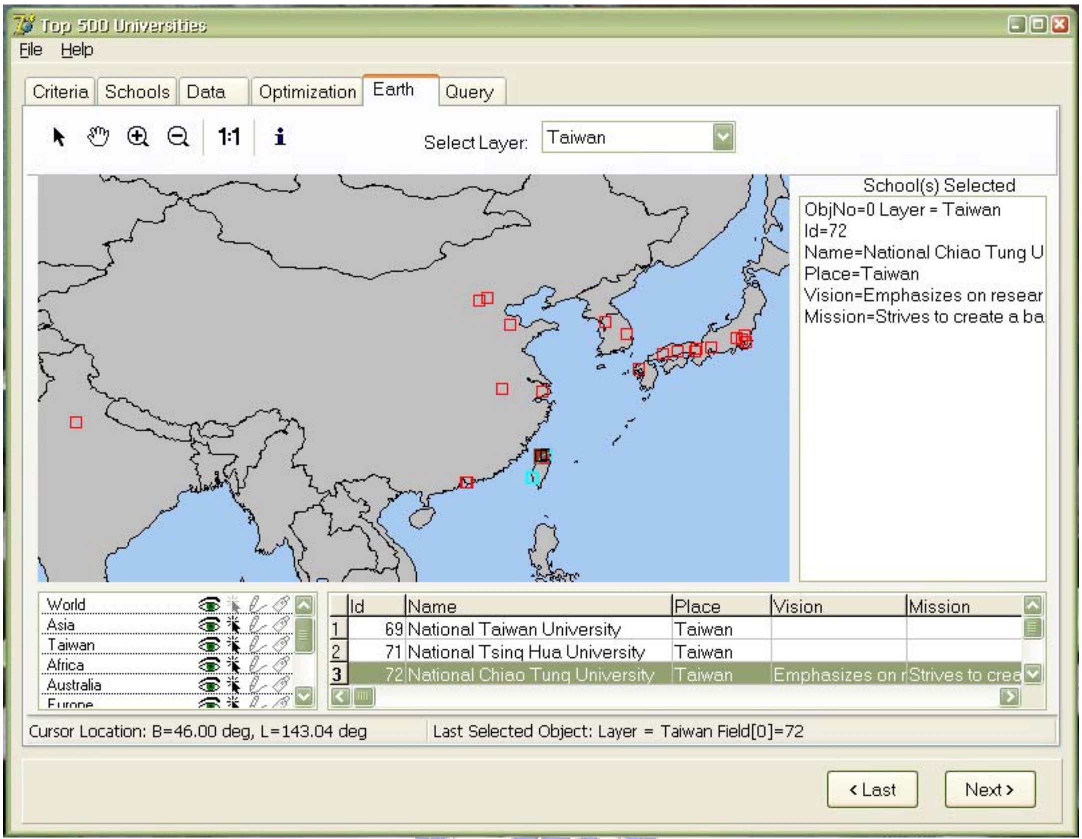

Figure 5.15 A Closer Look of the Selected School

5.7 Data Query

Finally, users are able to ask the system to generate the schools that are the most suitable according to their specifications and preferences. They can choose the location, campus size, category, diversity, housing option, cost, reputation and selectivity process of different schools and the system will generate the results that fulfil all the requirements. The process is illustrated in Figure 5.15.

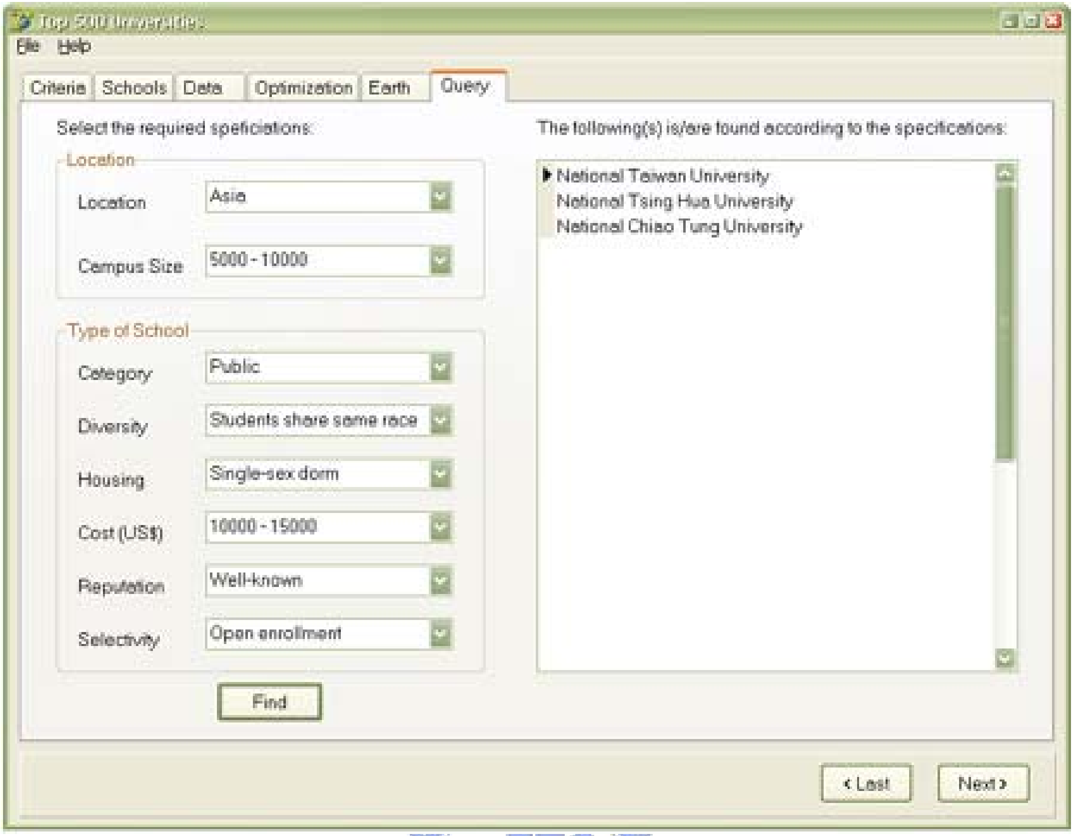

Figure 5.16 Query According to User's Specifications

Chapter 6 - Conclusion and Future Research

6.1 Conclusion

This research aims to propose a system that is easy to use and user-friendly so that users can follow the step-by-step procedures and generate the most favourable results according to their requirements and preferences. Users are only required to select the criteria and the subjects they wish to compare, and the results will be simulated. The initial goals of this research are to provide a tool that combines rankings and essential information for better comparison and decision making, and also to use simulation methods to generate a more suitable decision according to users' preferences and requirements.

(a) Advantages

The system is easy to use. The interfaces are designed such that they are simple and easy to understand. Users are only required to select what they wish to compare and in what forms they wish to see the results.

It provides a medium to store all the necessary information in a DBMS. Data can be retrieved easily with simple selection procedures. However, it is not a mere database, it provides simulation and optimization mechanisms for users to generate results to assist them in decision making.

In order to optimize results, mathematical models are implemented so that it provides precise and logical results according to users' preferences. Results can also be shown on maps which allow users to obtain a visual comparison of subjects and where the subjects are situated.

The system is flexible because it can be applied to any subjects. It can be used in fields such as real estates, selection of location for any new construction, etc. There is no limitation for the subjects as long as there are different criteria to be taken into consideration.

(b) Disadvantages

Although the database can store a large number of data within the system, the mathematical model may not be able to calculate a large number of data at one time. If the number of data in the calculation is too large, it may take a long computation time for the model to generate the optimal results.

Users are unable to create new criteria or subjects. This is done to protect the original dataset so that the original research data can be maintained.

(c) Summary

In summary, the system has achieved what was proposed in the beginning of this research. It has provided a tool that combines essential information from different sources in a DBMS and provides simulation and optimization mechanisms to generate the most favourable results for the users. It applies mathematical models to calculate accurate solutions and GIS tool to provide a visual representation of locations.

6.2 Future Development

As mentioned earlier, the system can be applied to other applications besides schools selection and comparison. When it does apply to other applications, alterations might be required to adapt to the specific application.

However, there are still rooms for enhancements in the system. For instance, the mathematical models can be re-evaluated to provide more effective and efficient calculations. The GIS section can be more interactive where users are allowed to add or remove features from the maps. The system can be more flexible so that users are able to add more criteria and/or subjects during the selection and comparison processes.

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Appendix A Selection of Schools for Students

This score sheet allows prospective students to evaluate each potential school. Various factors are provided and students can rank each of them on a scale of 1 to 5, with 5 being the highest score and 1 being the lowest. The school with the highest overall score will be considered as the most suitable selection.

The score sheet is adapted from U.S.News, 2004.

School: ______________________________

Location	**Score (1-5)**	**Notes**
Region		
Setting (urban, suburban, rural)		
Distance from home		
Academics		
Rigor of coursework		
Choice of majors		
Class size and student/faculty ratio		
Academic facilities		
Quality of professors		
Access to professors		
Campus Life		
Size of student body		
Diversity of student body		
Student attitudes about the school		
Social life		
Extracurricular activities		
Housing options		
Atmosphere		
Costs		
Affordability		
Access to grant/aid		

Career Preparation		
Range of internships Quality of career services		
Other Factors		
Total Score		

Appendix B Rankings and Comparisons of Schools

1. Financial Times MBA2004 – The top 100 full-time international MBA programs (Financial Times, 2004)

The following page shows a complete research result of the top 100 full-time international MBA schools in 2004 formulated by the Financial Times.

FINANCIAL TIMES MBA 2004

The top 100 full-time global MBA programmes

Rank in 2004	Rank in 2003	Rank in 2002	3 Year average rank	School name	Country	Audit year*	Alumni career progress: Salary today (US$)	Weighted salary (US$)	Salary increase (%)	Value for money rank	Career progress rank	Aims achieved rank	Placement success rank	Employment at three months (%)	Alumni recommend rank	Diversity: Woman faculty (%)	Woman students (%)	Woman board (%)	International faculty (%)	International students (%)	International board (%)	International mobility rank	International experience rank	Languages**	Idea generation: Faculty with doctorates (%)	FT doctoral rank	FT research rank	Rank in 2004
1	1	1	1	University of Pennsylvania: Wharton	USA	2003	157,199	151,726	182	52	23	32	18	86	1	17	33	8	30	39	52	64	30	0*	100	3	2	1
2	2	2	2	Harvard Business School	USA	2003	163,834	162,149	150	71	26	47	19	87	2	24	35	14	35	33	21	53	96	0	98	9	1	2
3	3	3	3	Columbia Business School	USA	2003	157,747	142,781	196	55	75	31	13	87	8	14	30	9	51	31	36	47	61	0*	98	12	6	3
4	6	6	5	Insead	Fra/Sing	2003	129,181	133,619	124	1	31	17	43	70	5	15	24	6	86	88	69	7	7	2	98	50	10	4
4	7	9	7	London Business School	UK	2004	126,033	125,167	165	85	33	16	55	65	7	11	23	6	74	88	60	3	18	1	98	36	19	4
4	5	3	4	University of Chicago GSB	USA	2002	151,372	140,310	182	81	40	39	8	87	6	13	29	16	42	27	12	58	36	0*	98	20	4	4
7	4	3	5	Stanford University GSB	USA	-	149,124	150,291	138	94	17	12	25	85	3	16	35	13	35	35	18	63	64	0	99	13	3	7
8	8	8	8	New York University: Stern	USA	2003	130,897	124,340	185	93	54	20	11	80	16	19	34	13	40	28	5	57	56	0	99	3	12	8
9	10	6	8	MIT: Sloan	USA	2003	134,397	139,526	144	79	34	8	9	88	9	16	26	10	21	33	25	37	80	0	96	5	9	9
10	11	11	11	Dartmouth College: Tuck	USA	2003	148,830	144,623	174	65	77	19	1	90	11	21	24	15	29	29	6	50	69	0	96	78	15	10
11	9	10	10	Northwestern University: Kellogg	USA	2002	133,920	139,169	147	100	39	15	7	86	4	21	28	10	24	28	6	51	26	0	97	22	5	11
12	13	14	13	IMD	Switz.	2003	137,941	142,626	99	2	3	2	17	91	17	10	16	2	100	96	77	2	54	0	95	78	75	12
13	18	25	19	Iese Business School	Spain	2003	96,490	99,470	187	61	25	55	40	96	21	12	25	4	29	70	78	12	9	1	99	52	71	13
13	12	12	12	Yale School of Management	USA	2003	129,821	129,280	194	75	36	30	21	73	26	12	29	17	31	24	7	59	92	0	98	69	37	13
15	26	35	25	Instituto de Empresa	Spain	2003	97,440	98,257	149	5	1	9	36	80	71	34	38	22	44	72	80	5	11	1	82	78	79	15
16	19	13	16	Cornell University: Johnson	USA	2003	118,617	129,604	159	89	87	53	14	77	25	29	27	15	27	35	40	56	71	0	94	66	22	16
17	17	25	20	Georgetown Uni: McDonough	USA	2004	116,372	121,240	179	91	38	28	69	83	41	28	30	19	27	38	9	48	48	0*	91	78	50	17
17	23	20	20	Uni of N Carolina: Kenan-Flagler	USA	2004	114,079	117,639	163	58	90	66	12	71	19	16	27	11	25	25	4	36	34	0	92	30	13	17
19	14	16	16	University of Virginia: Darden	USA	2004	127,760	137,012	171	63	68	14	6	65	13	23	27	13	8	25	7	66	75	0	98	69	83	19
20	15	19	18	Duke University: Fuqua	USA	2004	116,111	122,244	148	96	88	26	2	80	12	20	30	11	37	32	5	72	35	0	92	44	11	20
21	21	31	24	University of Toronto: Rotman	Canada	2002	103,039	98,285	161	14	60	13	65	77	23	24	31	42	56	39	50	61	74	0	93	44	36	21
22	29	31	27	Emory University: Goizueta	USA	2004	113,544	116,310	152	72	48	18	22	81	30	32	24	16	24	29	6	79	60	0	95	78	7	22
22	28	27	26	Rotterdam School of Management	Neth.	-	101,785	107,305	142	36	13	96	84	79	42	11	17	9	31	97	27	10	2	0	96	34	56	22
22	15	15	17	UC Berkeley: Haas	USA	-	120,765	120,379	126	70	22	34	35	81	14	24	24	17	31	32	11	43	41	0*	98	11	16	22
22	22	31	26	York University: Schulich	Canada	2002	84,480	85,734	158	3	29	85	90	82	45	23	36	19	53	69	48	8	55	0*	99	58	44	22
26	35	28	30	University of Oxford: Said	UK	2004	122,098	122,098	122	4	27	23	47	81	44	15	21	12	40	88	40	9	37	0	90	68	59	26
27	33	29	30	University of Maryland: Smith	USA	2004	97,883	97,323	175	48	99	43	47	85	47	21	34	5	10	34	32	49	91	0	100	26	17	27
28	23	21	24	Carnegie Mellon University	USA	2003	115,637	118,604	155	87	70	50	5	80	24	14	22	8	33	25	8	76	84	0	90	7	25	28
29	22	18	23	University of Western Ontario: Ivey	Canada	2002	101,668	106,010	165	29	64	38	73	70	20	22	21	13	34	40	43	29	40	0	92	52	41	29
30	43	31	35	SDA Bocconi	Italy	2003	95,583	92,411	164	11	80	35	30	80	47	30	22	47	17	44	27	30	13	2	80	10	87	30
30	25	23	26	University of Michigan	USA	2002	115,463	121,754	135	99	57	22	4	81	10	24	24	22	33	27	4	77	63	0	95	25	18	30
32	20	16	23	UCLA: Anderson	USA	-	118,552	126,388	130	90	81	36	10	74	15	10	33	10	23	24	11	74	23	0	100	44	8	32
32	34	36	34	Warwick Business School	UK	2004	103,160	103,984	112	12	52	3	72	87	29	37	22	21	34	74	32	35	12	1	84	1	61	32
34	30	22	29	University of Cambridge: Judge	UK	2004	105,706	110,801	110	22	37	57	59	79	56	26	33	35	43	87	35	19	39	0	88	8	70	34
35	38	42	38	University of Rochester: Simon	USA	2002	106,011	104,661	164	92	61	61	31	83	62	14	24	9	36	46	35	40	76	0	94	55	40	35
36	45	38	40	University of South Carolina: Moore	USA	2004	90,586	96,071	183	59	73	93	88	65	55	15	29	8	14	29	3	41	8	0*	90	37	57	36
37	44	48	43	Manchester Business School	UK	2004	98,994	98,287	145	27	6	77	86	80	32	16	28	0	32	72	0	21	3	0	80	30	88	37
38	31	30	33	Uni of S California: Marshall	USA	-	105,527	107,117	149	88	91	60	23	84	46	23	27	12	26	21	20	78	42	0	85	55	14	38
39	37	36	37	McGill University	Canada	2003	81,245	82,243	136	50	16	51	75	66	36	29	30	10	71	61	30	16	25	0	96	58	49	39
40	39	55	45	Ohio State University: Fisher	USA	-	94,856	94,856	150	49	7	83	61	88	53	20	21	11	21	23	0	85	27	0	94	26	21	40
40	49	57	49	Uni of Illinois at Urbana-Champaign	USA	-	80,467	83,198	157	54	100	69	62	85	70	24	28	15	30	57	0	96	58	0	100	2	29	40
42	68	81	64	City University: Cass	UK	2004	96,175	95,113	136	6	11	88	85	95	74	18	33	23	36	70	25	18	31	0	61	20	81	42
42	49	41	44	Washington University: Olin	USA	-	96,752	96,569	156	84	30	90	37	71	39	17	24	9	45	37	0	67	70	0	90	65	20	42
44	48	55	49	Pennsylvania State: Smeal	USA	2003	92,395	93,408	168	39	72	41	46	67	62	22	29	11	16	34	0	62	81	0	84	43	35	44
44	35	24	34	Vanderbilt University: Owen	USA	-	108,151	115,270	160	67	86	33	24	80	34	24	25	8	19	25	8	93	53	0	98	75	72	44
46	47	43	45	Purdue University: Krannert	USA	-	92,251	96,968	151	43	76	49	15	75	36	11	21	14	17	38	2	69	65	0	95	17	31	46
46	32	40	39	Uni of Texas at Austin: McCombs	USA	-	103,083	111,366	138	66	97	59	27	70	18	25	23	16	18	24	0	83	66	0*	90	15	23	46
48	40	38	42	Rice University: Jones	USA	-	103,374	106,265	145	62	58	58	33	85	35	27	28	10	31	25	2	94	96	0	98	78	28	48
49	56	49	51	College of William and Mary	USA	2004	97,834	97,834	172	42	49	81	74	82	65	22	28	9	18	44	2	68	88	0	100	78	80	49
49	52	49	50	University of Iowa: Tippie	USA	-	88,587	88,587	172	40	83	68	26	82	98	18	28	17	20	39	0	71	73	0	95	48	60	49
51	60	71	61	Michigan State University: Broad	USA	2002	87,162	87,462	157	38	98	42	3	80	52	21	28	16	5	29	4	79	93	0	98	13	34	51
52	40	46	46	Queen's School of Business	Canada	2002	94,463	94,463	141	31	28	1	51	70	31	23	22	20	42	31	20	46	96	0	85	73	64	52
53	69	67	63	Australian Graduate School of Mgt	Australia	-	97,701	98,763	111	32	95	48	28	73	43	23	21	17	51	50	19	27	15	0	96	57	26	53
53	90	92	78	Ceibs	China	-	65,093	61,556	194	80	50	45	20	96	75	18	33	10	71	11	50	100	5	0	88	78	85	53
53	62	67	61	HEC Paris	France	2003	94,893	94,701	121	25	9	63	57	54	40	15	18	11	22	78	74	15	29	2	75	42	84	53
56	45	45	49	Indiana University: Kelley	USA	-	99,509	108,262	141	73	66	62	16	71	28	27	27	7	15	30	2	87	51	0	76	26	42	56
56	72	53	60	University of Pittsburgh: Katz	USA	2003	86,020	85,008	157	16	94	75	87	86	98	19	30	4	17	42	0	28	94	0*	93	37	53	56
56	69	60	62	University of Wisconsin - Madison	USA	-	91,770	91,770	144	44	53	82	44	70	56	25	36	26	22	26	3	88	85	0	100	44	33	56
59	53	49	54	SMU: Cox	USA	-	101,524	101,524	164	77	82	73	42	78	51	22	24	13	15	24	4	75	21	0	89	78	62	59
60	64	52	59	Arizona State University: Carey	USA	-	91,308	91,308	145	60	42	67	56	92	33	15	30	20	15	23	5	73	78	0	92	26	32	60
60	40	63	54	University of California at Irvine	USA	-	91,902	92,040	130	76	56	44	39	82	72	34	32	13	32	34	15	89	67	0	98	58	27	60
60	81	71	71	University of Minnesota: Carlson	USA	-	88,822	88,822	146	74	69	56	41	93	53	23	24	11	25	27	2	60	59	0	91	50	30	60
63	57	53	58	Babson College: Olin	USA	2003	106,513	108,280	137	98	20	72	53	80	38	31	30	24	17	30	9	81	72	0	94	78	46	63
63	62	74	66	Boston University School of Mgt	USA	2003	97,743	97,743	133	97	4	91	79	87	67	25	33	15	27	47	15	44	45	0	80	49	43	63
63	54	44	54	Cranfield School of Management	UK	2004	111,070	120,661	107	9	21	11	54	62	22	22	19	42	13	62	25	33	90	0	58	16	94	63
63	60	60	61	Virginia Tech: Pamplin	USA	2004	75,557	75,557	172	30	65	7	63	84	96	21	20	8	2	45	0	69	96	0	92	37	68	63
67	73	87	76	Universiteit Nyenrode	Neth.	-	88,156	88,156	111	21	15	5	82	78	78	20	34	0	27	80	63	4	14	0	80	72	95	67
67	73	60	67	University of British Columbia: Sauder	Canada	-	78,257	78,257	121	19	14	64	81	89	56	17	29	16	68	59	8	34	20	0	90	30	51	67
69	59	47	58	Hong Kong UST Business School	China	-	62,089	62,089	84	69	79	6	52	89	77	14	48	33	88	82	94	52	1	1	100	61	24	69
69	-	-	-	Lancaster University Mgt School	UK	2004	71,616	73,164	113	17	45	29	80	91	82	21	53	45	24	78	36	31	24	0	82	6	82	69
71	83	79	78	Esade Business School	Spain	2003	70,409	70,409	144	83	5	46	32	74	47	16	25	22	17	70	89	25	6	2	71	71	92	71
72	64	84	73	Melbourne Business School	Australia	-	100,717	100,717	106	34	44	78	78	69	56	24	24	17	44	76	8	13	16	0	96	76	86	72
73	57	57	62	Thunderbird	USA	-	85,029	92,033	126	51	63	76	64	37	27	33	27	12	39	51	17	17	17	0*	94	78	76	73
73	76	57	69	Tulane University: Freeman	USA	-	89,019	89,019	156	86	85	94	95	82	81	18	26	7	24	36	4	32	68	0*	89	61	54	73
75	51	63	63	Brigham Young University: Marriott	USA	-	85,624	85,624	181	18	84	21	45	84	47	7	14	7	2	12	1	99	82	0*	92	78	55	75
75	78	85	79	Imperial College London: Tanaka	UK	2004	101,174	102,313	106	15	59	25	58	44	65	19	32	36	40	56	45	39	86	0	83	37	78	75
75	54	65	65	University of Notre Dame: Mendoza	USA	-	98,572	101,144	153	64	96	74	66	78	60	20	19	13	8	26	1	86	47	0	93	78	39	75
78	83	96	86	Ipade	Mexico	-	67,112	67,112	223	37	2	52	70	70	76	7	20	15	10	10	19	82	19	1	30	78	96	78
79	69	82	77	Texas A & M University: Mays	USA	-	82,118	82,118	137	20	93	40	38	96	62	25	19	7	9	24	0	54	43	0	88	22	47	79
80	78	73	77	University of Georgia: Terry	USA	2004	86,720	86,720	147	28	55	24	76	81	72	19	22	0	13	33	0	97	89	0	87	22	63	80
80	64	65	70	Wake Forest University: Babcock	USA	2004	91,200	91,365	159	68	24	71	68	86	67	10	30	12	5	21	4	95	83	0	95	78	58	80
82	-	-	-	Brisbane Graduate Sch of Bus, QUT	Australia	-	51,203	51,203	165	35	8	100	28	87	95	38	33	38	21	76	25	11	62	0	56	78	90	82
82	95	89	89	University of Durham Bus School	UK	2004	82,434	82,434	107	24	42	89	98	83	82	23	35	13	45	81	19	14	79	1	93	63	93	82
84	64	77	75	Case Western Reserve: Weatherhead	USA	2002	86,712	86,945	123	95	71	95	47	78	67	16	28	17	37	41	4	90	38	0	97	35	38	84
84	89	74	82	University College Dublin: Smurfit	Ireland	-	92,228	92,228	93	13	10	99	99	96	87	23	26	11	27	52	60	23	44	1	90	64	74	84
86	85	-	-	Bradford School of Mgt/Nimbas	UK/Nth/Ger	2004	79,728	79,728	92	23	35	27	83	92	89	34	31	36	30	80	27	26	32	0	68	17	73	86
86	-	-	-	Incae	Costa Rica	-	41,559	44,899	171	53	45	97	89	57	82	9	25	8	57	78	85	45	4	1	91	78	96	86
86	86	76	83	Trinity College Dublin	Ireland	-	92,012	92,012	93	10	18	37	91	85	82	33	20	33	30	60	33	6	77	0	77	76	91	86
89	-	-	-	University of Tennessee at Knoxville	USA	-	90,392	90,392	140	7	92	80	50	64	78	19	36	19	4	18	0	91	95	0	89	52	77	89
90	86	70	82	University of Arizona: Eller	USA	-	78,814	78,814	133	56	78	79	60	84	98	26	17	20	15	27	3	98	96	0	95	19	52	90
91	-	92	-	University of California: Davis	USA	-	93,735	93,735	97	82	19	4	70	86	87	19	32	11	38	15	0	84	46	0	100	78	48	91
92	88	-	-	IAE Management and Bus School	Argentina	-	62,845	62,845	156	57	32	54	77	70	89	9	27	0	33	27	57	24	10	1	51	78	96	92
93	73	77	81	Edinburgh University Mgt School	UK	2004	76,395	76,395	93	26	62	70	94	84	89	19	30	25	31	75	50	42	50	1	82	41	69	93
94	-	85	-	Georgia Institute of Tech: DuPree	USA	2004	85,438	85,438	126	46	89	98	34	70	60	13	31	13	17	31	0	92	57	0	100	66	65	94
95	95	97	96	Ashridge	UK	2004	108,375	111,353	74	41	12	10	100	100	78	26	8	60	37	42	40	55	22	0	37	78	66	95
95	91	89	92	University of Bath School of Mgt	UK	2004	77,684	77,934	86	33	74	65	92	81	82	24	48	16	22	69	21	38	49	0	78	30	67	95
97	100	-	-	University of Alberta	Canada	-	65,135	65,135	103	45	51	92	93	93	96	14	39	24	61	47	17	65	52	0	93	73	45	97
98	82	99	93	ESCP - EAP	France	2003	82,468	82,468	69	47	41	87	96	52	89	23	43	9	34	86	70	22	28	2	78	78	89	98
98	-	-	-	Theseus International Mgt Institute	France	2003	86,701	86,701	101	8	67	84	97	71	89	14	25	20	86	62	80	20	87	0	14	78	96	98
100	92	92	95	ENPC MBA Paris	France	2003	76,801	76,801	72	78	47	86	67	40	89	13	37	7	63	66	21	1	33	1	63	78	96	100

Footnotes

* KPMG reported on the results of obtaining evidence and applying specified audit procedures relating to selected data provided for the Financial Times 2004 MBA survey ranking for selected business schools. Inquiries in the process can be made by contacting Michelle Podhy and Patrick Gaudet of KPMG by email at mpodhy@kpmg.ca. The specified audit procedures were carried out during November and December 2003. The audit date denotes the survey for which the specified audit procedures were conducted.

**These schools run additional courses for MBA students for which additional language skills are required. These figures are included in the calculations for the ranking but are not represented on the table to avoid confusion.

Although the headline ranking figures show several changes in the survey this year, what is equally significant is the pattern of clustering among the schools. Almost 200 points separate the top school from the school ranked number 100. The top 12 schools, from Wharton to IMD, form the premier league of business schools. The second group is headed by Iese and Yale, in joint thirteenth position, and includes the University of Rochester ranked 35. The third group is the largest, and includes schools ranked from to 36 to 78. Just 31 points separate these 43 schools, and schools in this group could easily move up or down by 10 places with few changes in the data. The fourth group includes schools ranked from 79 to 100, which are separated by 48 points.

2. Shanghai Jiao Tong University – The top 500 universities in the world

The following table shows the first 55 universities with the highest overall scores calculated in this ranking by Shanghai Jiao Tong University.

School	Country	Overall Score	Score on Nobel	Score on HiCi	Score on N&S	Score on SCI	Score per Faculty
Harvard Univ	USA	100	100	100	100	100	68.7
Stanford Univ	USA	83.5	76.2	88.2	73.8	72.2	80.5
California Inst Tech	USA	76.3	72.9	68	64.1	52	100
Univ California - Berkeley	USA	74	75	70.3	76.1	72.8	51.8
Univ Cambridge	UK	73.4	91.1	58	56.4	69.3	68.7
Massachusetts Inst Tech	USA	70.6	79.4	67.3	66.3	63.9	53.5
Princeton Univ	USA	62.5	60.5	60.7	51.9	47	72.4
Yale Univ	USA	61.1	49.2	57.1	58.1	63.5	58.2
Univ Oxford	UK	59.5	53.3	45.9	57.2	66.2	55.6
Columbia Univ	USA	59.1	64.5	49.2	50.9	68.5	43.4
Univ Chicago	USA	57	87.1	43.5	45.3	54.2	36.6
Cornell Univ	USA	56.9	57.3	57.1	46	66.6	39.2
Univ California - San Francisco	USA	55.3	41.6	57.1	60.1	60.9	39.2
Univ California - San Diego	USA	54.4	14.2	58	59.8	67.5	55.2
Univ California - Los Angeles	USA	53.8	37.3	58	48	78	30.3
Univ Washington - Seattle	USA	50.3	34.4	57.1	46.6	76.7	20.5
Imperial Coll Sci Tech Med	UK	50.1	42.2	41	37.4	66.9	46.9
Univ Pennsylvania	USA	50	39.8	41	43.1	71.4	38.5
Tokyo Univ	Japan	49.4	18.3	22.9	52.6	91.1	46.2
Univ Coll London	UK	48.9	28.5	45.9	42	66.8	45.8
Univ Michigan - Ann Arbor	USA	48.8	21.4	61.5	45.7	75.9	23.8
Washington Univ - St. Louis	USA	47.8	30.5	41	43.1	54.7	54.3
Univ Toronto	Canada	45.8	21.7	32.4	41.1	76.3	42.9
Johns Hopkins Univ	USA	45.7	21.8	50.2	53.3	72	16.6
Swiss Fed Inst Tech - Zurich	Switzerland	45.6	39.9	34	44.8	51.9	42.7

Univ California - Santa Barbara	USA	45.3	32.7	47	40.3	42.5	49.4
Univ Wisconsin - Madison	USA	45	24.6	50.2	47.4	68	20.4
Rockefeller Univ	USA	44.8	64	32.4	44.1	27.2	41.9
Northwestern Univ	USA	44.4	21.4	48.1	36.7	56.1	45.4
Kyoto Univ	Japan	43.6	24.7	27.1	35.8	75.5	40.8
Univ Colorado - Boulder	USA	40.9	33	42.3	37	46.8	32.3
Vanderbilt Univ	USA	40.4	33.4	35.5	20.8	48.7	50.9
Duke Univ	USA	40.4	0	42.3	44.6	60.8	41.6
Univ Texas Southwestern Med Center	USA	39.5	41.4	29	40.6	40.5	33.5
Univ British Columbia	Canada	38.2	21.4	30.8	31.8	59.1	35.8
Univ California - Davis	USA	38.1	0	52.3	34.6	65.1	26.4
Univ Minnesota - Twin Cities	USA	37.8	0	54.3	36.4	71.1	15.1
Rutgers State Univ - New Brunswick	USA	37.2	22.5	34	35.4	47.2	34.8
Karolinska Inst Stockholm	Sweden	36.8	30.9	34	23.1	49.6	34.4
Pennsylvania State Univ - Univ Park	USA	36.5	0	54.3	39	59.1	18.5
Univ Utrecht	Netherlands	36.5	23.6	27.1	28.2	57.6	34.2
Univ Southern California	USA	36.5	30.2	37	23.4	53	27
Univ Edinburgh	UK	36	18.9	29	37.9	49.1	33.7
Univ California - Irvine	USA	35.9	27.6	29	27.6	45	38.8
Univ Illinois - Urbana Champaign	USA	35.2	20.1	35.5	34.1	58.5	16.8
Univ Zurich	Switzerland	35.2	30.2	20.5	32.4	48.7	33
Univ Texas - Austin	USA	35	18.9	45.9	31.8	51.7	15.7
Univ Munich	Germany	34.1	23.2	14.5	33.5	56.7	32
Brown Univ	USA	33.9	15.3	29	28.5	40.8	45.1
Australian Natl Univ	Australia	33.9	14.2	44.7	25.6	42.4	31.7
Case Western Reserve Univ	USA	33.2	12.9	22.9	24.8	46.3	48.3
Univ North Carolina - Chapel Hill	USA	33.1	0	34	34	60	27
Osaka Univ	Japan	33	0	20.5	31.4	71.8	30.9
Univ Pittsburgh	USA	33	0	37	26.8	65.1	25.5
Univ Arizona	USA	32.7	0	35.5	37.9	55.9	23.8

3. Asia Inc. – Asia's best MBA schools (Asia Inc., 2004)

	香港中文大學 MBA Program	香港大學 Faculty of Business & Economics	香港科技大學 School of Business & Management	日本 International 大學 Graduate School of International Management	上海交通大學 Aetna School of Management	日本青山大學 Graduate School of International Management	北京工業大學 Guanghua School of Management	南韓 KAIST Graduate school of Management	台灣政大大學商學院	台灣交大大學管理學院
Tuition: Resident (US$)	17135	20192	22500	34200	9700	19723	8500	25000	4000	6648
Tuition: Non-Res (US$)	17135	20192	22500	NA	12000	NA	12000	25000	4000	6648
No. of Applicants (2003/2004)	202	159	244	453	507	91	2139	576	NA	3654
% Accepted	29	41	36	19	19	74	12	35	NA	11
Total Full-Time Students	65	48	94	117	95	25	380	371	650	344
Total Enrolment	608	108	489	117	810	155	1427	678	1926	666
% Women Students	39	37	10	20	0	27	18	8	48	35
% Foreign Students	14	48	10	75	1	6	3	1	2	2
Avg. Age of Full-Time Students (yrs)	29	29	27	28	28	33	28	31	25	23
Avg. Work Experience (yrs)	4.8	6	5	5	5.9	3	5.8	5.5	1	3
Avg. GMAT Scores	629	631	630	595	NA	NA	640	NA	NA	NA

Total MBA Teaching Staff	107	56	53	29	157	45	117	62	166	170
% Full-Time MBA Staff	93	79	96	59	57	47	74	74	78	54
% MBA Staff with PhD	90	96	100	62	59	36	68	76	95	82
% Staff with 10 Yrs Experience	83	100	75	93	87	91	42	58	75	86
Student-Faculty Ratio	0.7	1.1	1.8	6.9	1.1	1.2	4.4	8.1	5	3.8
Avg. Class Size	45	36	45	60	43	20	60	27	15	27

4. Graduate Management Admission Council – School Search (GMAT, 2004)

This is an example of school search with three business schools in Asia.

Institution	China Europe International Business School (CEIBS)	Hong Kong University of Science and Technology	Indian Institute of Management, Bangalore
School	China Europe International Business School (CEIBS)	School of Business and Management	Indian Institute of Management, Bangalore
Program URL	http://www.ceibs.edu	http://www.bm.ust.hk/mba	http://www.iimb.ernet.in
Location	People's Republic of China	Hong Kong (SAR of China)	India
Type of Program	Full-Time Accelerated	Full-Time Accelerated	Full-Time Traditional Two-Year
Length of Program	Less than 18 Months	Less than 18 Months	18 to 24 Months
Concentrations	General Management	Finance, Information Systems/Technology, Other: "China Business"	Accounting, Consulting, E-Commerce, Economics, Entrepreneurship, Finance, General Management, Human Resource Management, Information Systems/Technology, International Business, Leadership, Manufacturing and Technology Management, Marketing, Operations Management, Organizational Behavior, Portfolio Management, Supply Chain

			Management
Joint Degrees	NA	NA	NA
Costs	NA	NA	NA
Residents			
Non-Residents			
(In US Dollars)			
Financial Aid	NA	NA	NA
Domestic Students			
Loans			
Scholarships			
International			
Loans			
Scholarships			
New Entrants	NA	38	176
Offers of Admission	NA	NA	NA
Completed Applications	NA	NA	NA
Application Requirements	NA	NA	NA
Entry Points	NA	Total: 1 July	Total: 1 April
GMAT Scores	NA	NA	NA
Mean			
Median			
Middle 80% Range			
Work Experience (Years)	NA	NA	NA
Demographics	NA	NA	NA
% International			
% Female			
Class Size	NA	NA	NA
Required Courses			
Elective Courses			
US SubGroups	NA		NA

Appendix C Description of the Database Schema

Table name: Locations

Function: To store the various locations and the codes given to them.

Attribute	Type	Description	Remarks
Code	Integer (5)	A unique code given to each location.	PK
Name	String (20)	The name of the location.	--

Table name: Descriptions

Function: To store the descriptions of a school and the codes given to them.

Attribute	Type	Description	Remarks
Code	Integer (5)	A unique code given to each description.	PK
Name	String (20)	The description of the location.	--

Table name: Criteria

Function: To store the criteria available and the codes given to them.

Attribute	Type	Description	Remarks
Code	Integer (5)	A unique code given to each criterion.	PK
Name	String (20)	The name of the criterion.	--
Description	String (50)	Description of each criterion.	--
CalMethod	Integer (2)	The calculation method for each criterion. The value of '0' means addition and '1' means average.	--

Table name: Schools

Function: To store the data of the schools.

Attribute	Type	Description	Remarks
Code	Integer (5)	A unique code given to each criterion.	PK
Name	String (50)	The name of the school.	--
Place	String (15)	The country where the school is located.	--
Locations_Code	Integer (5)	The code of the location given in the Locations table.	FK
Descriptions_Code	Integer (5)	The code of the location given in the Descriptions table.	FK
x-coordinate	LongInt	The x-coordinate of the school on a map.	--
y-coordinate	LongInt	The y-coordinate of the school on a map.	--
Vision	String (100)	The vision of the school.	--
Mission	Blob	The mission statement of the school.	--

Table name: Scores

Function: To store the various scores of each school.

Attribute	Type	Description	Remarks
School_Code	Integer (5)	The code of the school given in the Schools table.	FK
Criteria_Code	Integer (5)	The code of the criterion given in the Criteria table.	FK
Value	LongInt	The score of a specific criterion of each school.	--