Multiple Criteria Decision Making Techniques in Higher Education

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Abstract

Higher education has faced the problem of budget cuts or constrained budgets for the past 30 years. Managing the process of the higher education system is, therefore, a crucial and urgent task for the decision makers of universities in order to improve their performance or competitiveness. This paper reviews the literature which focuses on four major higher education decision problems. These are resource allocation, performance measurement, budgeting, and scheduling. Related articles appearing in the international journals from 1996 to 2005 are gathered and analyzed so that the following three questions can be answered: (i) What kind of decision problems was paid most attention to? (ii) Were the multiple criteria decision making techniques prevalently adopted? (iii) What are the inadequacies of these approaches? Based on the inadequacies, some improvements and possible future work are recommended, and a comprehensive resource allocation model is developed taking account these factors. Finally, a new knowledge-based goal programming technique which integrates some operations of analytic hierarchy process is proposed to tackle the model intelligently.

Keywords: Higher education; Resource allocation; Performance measurement; Budgeting; Scheduling; Multiple criteria decision making.

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1. Introduction

Intellectual capital is the major ingredient of successful companies or nations. The more intellectual capital a company or a nation possesses, the more competitiveness it has. In order to achieve this goal, a company may recruit experts from markets or train up its staff as professionals. Similarly, a nation may attract immigration of skilled personnel or allocate more resources to the education sector. Comparatively, university-level or higher education has been found to be more beneficial to the nations' growth than primary or secondary education (DePillis and DePillis, 2001). In higher education, students not only can become equipped with skills and knowledge through direct teaching (e.g., lecture) and indirect teaching (e.g., e-learning system), but also they can build up analytical and problem-solving skills through doing research projects. Nevertheless, resources allocated by governments for higher education have been reduced over the last 30 years due to the public pressure (Lee and Clayton, 1972). According to Liefner (2003), this continuous budget cutting makes universities such as in United Kingdom, United States, and the Netherlands change from traditional state-coordinated systems; that is, teaching and research programmes in universities are highly managed by government directives to market-oriented systems. This means that funding for universities mainly comes from the private sector rather than government. Universities have, therefore, to manage their systems optimally and keep up their performance so that enough funding can be raised to cover necessary expenses (Jongbloed and Vossensteyn, 2001). In the other words, the funding scheme is gradually changed from direct government support to performance-related.

Process management in the market-oriented system, as illustrated in Figure 1, is extremely important nowadays. The input or resources include public funding from government, private and public research grants and contracts from funding and research councils, tuition fees from students, and other income from the private sector, such as endowment income and gift. The university then needs to manage the processes, which include resource allocation, performance measurement, budgeting, scheduling, and so on, so that the performance in terms of teaching and research can be improved. In the market-oriented system, the funding is directly proportional to a university's performance or output. One can collect more funding provided that ones performance is superior to other competitors. For instance, teaching quality, entry quality, number of bachelor degree awarded, non-completion rate, and employment rate are amongst the performance indicators for teaching. To measure the performance of research, some indicators like research quality and quantity, numbers of MPhil and PhD awarded, numbers of research contracts and grants,

and award or reward from society can be applied. This can be regarded as a closed-loop system in which every part is interrelated and must be managed optimally. Under this performance-related funding scheme, teaching and research quality can definitely be increased to a certain extent. Consequently, the nations can be contributed as explained earlier. This scheme has a drawback, however, that faculties or staff members may not be willing to diversify their research fields especially those with high risk. In order to meet the research quality and particularly quantity, they may prefer investigating familiar research areas instead of exploring state-of-the-art topics.

take in Figure 1

Once the amount of input or the financial resources assigned to the system are known, the decision makers of a university have to optimize their choices with respect to the objectives, which are normally diverse and conflicting. For example, the university aims at increasing the teaching and research quality by employing experienced professors, while at the same time, aims at minimizing expenditure. For this reason, the multiple criteria decision making (MCDM) techniques should be adopted. Although it is difficult to handle the multiple conflicting objectives simultaneously, this approach coincides with the real situation faced by the university. Janis and Mann (1977) also stated that it is very difficult to determine how well a decision has worked out if there is only a single objective. This is the reason why this paper focuses on MCDM techniques. In this paper, the authors find whether MCDM techniques are commonly used to aid the process management in higher education throughout the period from 1996 to 2005 by surveying the publications in referred journals during this period. On completion of this survey, which MCDM techniques are commonly applied to which management process, and the inadequacies of the approaches adopted by previous researches can be known. Finally, some possible future research areas can be suggested based on the result findings.

This paper is organized as follows. Section 2 explains which databases and what searching criteria were used for finding the relevant journal articles. Section 3 describes the categories of MCDM techniques including multiple objective decision making (MODM) and multiple attribute decision making (MADM), and distinguishes their differences. Section 4 analyzes the results of the survey, and finds out the trends of the researches carried out in the past 10 years. Section 5 discusses the improvements on approaches proposed by previous researchers, and suggests some possible future work. Section 6 concludes the paper.

2. Methodology

One objective of this paper is to survey the application of MCDM techniques to higher education management process through a literature review and classification of international journal articles from 1996 to 2005. The reason for selecting this period is that Mustafa and Goh (1996) provided a detailed report on similar issues from 1972 to 1995. Nevertheless, they did not study the application of other quantitative techniques such as the mathematical modeling in operations research. These types of techniques are also considered in this paper because a quantitative analysis is extremely useful to decision makers, especially if the decision makers have little experience with similar problems or the problem is very sophisticated (Anderson et al., 2005).

Mustafa and Goh (1996) found that 62 articles including journal articles, conference papers, book chapters, and PhD theses proposed to use the MCDM techniques. It was observed that the MODM techniques (60%) such as goal programming (GP) are more commonly adopted than MADM techniques (40%) such as the analytic hierarchy process (AHP). Moreover, it was noticed that the most significant studied management process in higher education was resource allocation.

In this paper, we focus on international journal articles merely. Therefore, Emerald, Ingenta, MetaPress, ProQuest, ScienceDirect, and SwetsWise can be used for searching because these are large and comprehensive databases. In order to ensure the relevance of the journal papers, only title, abstract, and keywords fields in each of the above databases are filtered rather than the full-text searching. In addition to the query “higher education”, each of the following keywords is searched simultaneously:

- Resource Allocation
- Performance Measurement
- Budgeting
- Scheduling
- Multiple Criteria (or Multi-Criteria) Decision Making
- Multiple Objective (or Multi-Objective) Decision Making
- Goal Programming
- Multiple Attribute (or Multi-Attribute) Decision Making
- Analytic Hierarchy Process
- Operations Research
- Mathematical Model (or Modeling)

After topic filtering, there were 25 internationally refereed journal articles meeting the above criteria. The scope of these journal articles includes resource allocation, performance measurement, budgeting, and scheduling. Qualitative, quantitative, and both MCDM techniques including MODM and MADM have been applied in these journal articles based on our searching criteria.

3. Multiple Criteria Decision Making

A wide variety of quantitative approaches are available for making decisions. For example, the traveling salesman problem in the form of integer linear programming model can be constructed to determine the traveling sequence of a salesperson in which the salesperson cannot visit each city more than once, with an objective of minimizing the overall traveling distance/time. Besides, the quadratic assignment problem in the form of integer nonlinear programming model can be formulated to determine the assignment of which facility to which location so that the traveling distance/time of material flow is minimized. These kinds of quantitative approaches have been paid much attention to because they can be widely adopted to many situations like logistics scheduling, manufacturing facility location planning, and so on (Williams, 1999). The scheduling problem arising in higher education can also be tackled using these approaches (Johnson, 2001). Nevertheless, a single criterion or objective is considered in these prevalent approaches. Therefore, they may not suitable for managing some decision problems with multiple and conflicting criteria. To better describe such situations, multiple criteria decision making (MCDM) techniques should be used.

MCDM techniques are generally divided into two categories which are multiple objective decision making (MODM) and multiple attribute decision making (MADM). MODM techniques are a special extension of linear programming. A model is defined as a linear programming when the single objective function and the constraints involve linear expressions, and the decision variables are continuous. But, in MODM techniques, multiple objective functions are incorporated into the model simultaneously. On the other hand, MADM techniques aim at selecting from a population of feasible alternatives which characterized by multiple attributes.

3.1. Multiple objective decision making

Goal Programming (GP), invented by Charnes and Cooper (1961), is regarded as the most practical MODM technique (Mustafa and Goh, 1996) since it was most frequently used

to solve the higher education decision problems. It is indeed very similar to the linear programming model except that multiple goals are taken into consideration at the same time. The goals as well as their priority level (i.e., P_1, P_2, …, P_n) are identified by the decision makers. Goals with priority level P_1 are most important, followed by those with priority level P_2, and so on (i.e., $P_1 > P_2 > \ldots > P_n$). Those with a higher priority level are considered first. Once they have been satisfied with no further improvement, the next most important goals are then considered. Deviation variables (i.e., d_1^+, d_1^-, d_2^+, d_2^-, …, d_n^+, d_n^-) are included in each goal equation to represent the possible deviations from goals. Deviation variables with positive sign refer to over-achievement or mean that deviations are above the target value, whereas those with negative sign indicate under-achievement or reflect that deviations are below the target value. The objective function of a GP is to minimize deviations from desired goals. For each goal, there are three possible alternatives of incorporating deviation variables in the objective function, as shown in the following:

- If both over- and under-achievement of a goal are not desirable, then both d_i^+ and d_i^- are included in the objective function, or
- If over-achievement of a goal is regarded as unsatisfactory, then only d_i^+ is included in the objective function, or
- If under-achievement of a goal is regarded as unsatisfactory, then only d_i^- is included in the objective function.

In summary, six steps are used to develop a GP model, as shown in Figure 2. After formulating a GP model for a particular decision problem, commercial packages like LINDO and CPLEX can be used to solve the model to optimality. In cases where the model only consists of two decision variables, even the simple graphical method can be adopted. In order to illustrate what a GP model looks like, a typical GP model is formulated as:

$$\text{Minimize } z = \sum_i P_i \left(d_i^+ + d_i^- \right) \qquad (1)$$

subject to

$$\sum_j a_{ij} x_j \le b_i \qquad \text{for all } i. \qquad (2)$$

$$\sum_j a_{ij} x_j - d_i^+ + d_i^- = b_i \qquad \text{for all } i. \qquad (3)$$

$$\text{All } x_j, d_i^+, \text{ and } d_i^- \ge 0 \qquad (M1)$$

where

a_{ij} = coefficient;

b_i = right-hand side value;

d_i^+ = over-achievement of goal i;

d_i^- = under-achievement of goal i;

P_i = priority level of goal i

x_j = decision variable.

Model M1 can be regarded as the GP model. The objective function (1) is to minimize the total deviations from the goals, while subjecting to constraints (2) and goal equations (3). Since all the objective, constraints, and goal equations are in the linear form, M1 belongs to the linear programming type. Besides, all decision and deviation variables are continuous. In some occasions, decision variables (e.g., number of academic staff employed in resource allocation) are integer-valued, and thus M1 belongs to the mixed integer linear programming type (Williams, 1999).

take in Figure 2

3.2. Multiple attribute decision making

The analytic hierarchy process (AHP), developed by Satty (1980), was found to be the most prevalent MADM technique for dealing with the decision problems in higher education from 1972 to 1995 (Mustafa and Goh, 1996). Basically, the AHP consists of 3 main operations including hierarchy construction, priority analysis, and consistency verification. First of all, the decision makers need to break down complex multiple criteria decision problems into its component parts of which every possible attributes are arranged into multiple hierarchical levels. For example, overall goal, criteria, attributes of each criterion are in the first, the second, and the third levels, respectively. After that, the decision makers have to compare each cluster in the same level in a pairwise fashion based on their own experience and knowledge. For instance, every two criteria in the second level are compared at each time while every two attributes of the same criteria in the third level are compared at a time. Since the comparisons are carried out through personal or subjective judgments, some degree of inconsistency may be occurred. To guarantee the judgments are consistent, the final operation called consistency verification, which is regarded as one of the most advantages of the AHP, is incorporated in order to measure the degree of consistency among the pairwise comparisons by computing the consistency ratio (Anderson et al., 2005). If it is found that the consistency ratio exceeds the limit, the decision makers should review

and revise the pairwise comparisons. Once all pairwise comparisons are carried out at every level, and are proved to be consistent, the judgments can then be synthesized to find out the priority ranking of each criterion and its attributes. The overall procedure of the AHP is shown in Figure 3.

take in Figure 3

There is actually a similarity among the GP and the AHP. The decision makers are responsible for determining the priority level of goals during the formulation of the GP models, while the decision makers are committed to assign the priority values to every criteria and attributes in the AHP.

The major reason why both techniques are most widely adopted compared with other MCDM techniques is that they possess unique advantages. Badri and Abdulla (2004) pointed out that "good decisions are most often based on consistent judgments". To prevent inconsistency, the consistency verification operation of the AHP contributes greatly as it acts as a feedback mechanism for the decision makers to review and revise their judgments. Consequently, the judgments made are guaranteed to be consistent, which is the basic ingredient for making good decisions. Nevertheless, the output of the AHP is the priority ranking of the criteria and the attributes merely. In some multiple criteria decision problems like resource allocation in higher education, the decision makers would like to know how much should be allocated to which area (e.g., number of administrative staff employed). For this reason, the GP can compensate with the AHP because the decision variables are used to determine the amount of allocation. It can definitely provide more and useful information for the decision makers. Based on the above analysis, it is believed that it must be beneficial to the decision making process if the AHP and the GP are integrated together.

4. Result Analysis

In this paper, 25 journal articles, which appeared in the period from 1996 to 2005, studying the resource allocation, performance measurement, budgeting, and scheduling in higher education were collected. The classification of these articles and the techniques used in each of four major decision problems are summarized in Table I. In the following sub-sections, three issues related to the relevant articles are examined including: (i) What kind of decision problems was paid most attention to? (ii) Were the MCDM techniques prevalently adopted? (iii) What are the inadequacies of these approaches?

take in Table I

4.1. Higher education decision problems

Regarding the decision problems, performance measurement is the most commonly studied as shown in Table II. Among 11 (44%) articles, the subjects measured were generally the performance of universities (Johnes, 1996; Sarrico et al., 1997; Adcroft and Willis, 2005; Emrouznejad and Thanassoulis, 2005), departments (Sarrico and Dyson, 2000; Al-Turki and Duffuaa; 2003), and faculty members or students (Badri and Abdulla, 2004; Stinebrickner and Stinebrickner, 2004). Besides, some researchers incorporated quality into the performance measurement (Kwan and Ng, 1999; Pounder, 1999; Cullen et al., 2003).

take in Table II

The numbers of articles studying resource allocation and budgeting are both six (24%). For the resource allocation, the focus of the articles was diverse. Watts (1996) examined the changes and challenges in the methods of internal allocation of funds in Australian universities. Clarke (1997) re-assessed the resource allocation strategies in higher education. Gillie (1999) compared the outcome of some traditional and resource-based learning at the Open University, United Kingdom. Alho and Salo (2000) studied the formula-based resource allocation with random variation in the measures. Caballero et al. (2001) allocated financial resources at the University of Malaga, Spain. Ntshoe (2003) suggested the equitable allocation of resources to higher education in developing countries.

Surprisingly, five out of six articles investigating budgeting are from United States. This may be due to the fact that a large proportion of income of the United States universities is based on private funding. Good budgeting decision is, therefore, utmost important to them. Borgia and Coyner (1996) surveyed the budgeting systems in higher education of United States. McClatchey (1998) reviewed the tuition fees at the University of Nebraska-Lincoln, United States. Schmidtlein (1999) argued that the assumptions underlying performance-related budgeting are unrealistic. DePillis and DePillis (2001) studied the long-term impact of reducing, maintaining, and increasing government funding at the United States universities. Menash and Werner (2003) proved that there is a positive relationship between the degree of financial flexibility and cost inefficiency for all types of private United States higher education institutions. Besides, Hübner and Rau (2002) studied the acceptability of performance-related budgeting at the Freie Universität Berlin, Germany.

Comparatively, the scheduling problem has attracted less attention. Only two (8%) articles investigated the problem in the past decade. Johnson (2001) applied the capacity planning elements from the manufacturing industry to the higher education. Traditional manufacturing scheduling rules are applied to student scheduling, space availability, and faculty assignment. Thompson (2005) collected information on student demand for building the course schedule so that the time conflicts between required courses are avoided as well as the time conflicts between designated groups of courses are minimized.

Unlike the findings of Mustafa and Goh (1996), performance measurement was paid most attention, rather than resource allocation. Once again, this is because the funding to the most higher education institutions is performance related. It is essential for the decision makers to measure their university's performance, including teaching and research, so that they can review and improve their processes based on the benchmarking results. Nevertheless, the performance of all individual members, departments, and universities is highly dependent on how much resource is allocated to them. It is, therefore, worth studying this crucial issue in the immediate future.

4.2. Techniques used

One of the objectives of this paper is to discover the application of MCDM techniques to the higher education management process, and this forms the second question. According to Table III, techniques used to deal with the resource allocation, performance measurement, budgeting, and scheduling can be classified into three groups: qualitative, quantitative, and MCDM. Firstly, the quantitative approach was the most widely adopted as there are 11 articles (44%) applying this approach, which is slightly more than the application of qualitative approach, that is 10 articles (40%). The quantitative techniques include the statistical models (Alho and Salo, 2000; Hübner and Rau, 2002; Mensah and Werner, 2003; Stinebrickner and Stinebrickner, 2004), data envelopment analysis (DEA) (Sarrico et al., 1997; Sarrico and Dyson, 2000; Emrouznejad and Thanassoulis, 2005), multiple regression analysis (Johnes, 1996; Gillie, 1999), stepwise regression analysis (Kwan and Ng, 1999), and differential equations (DePillis and DePillis, 2001). It is noticed that the DEA is a prevalent quantitative approach to carry out the performance measurement. Actually, DEA adopts the linear programming to measure the relative efficiency of homogenous operating units, for instance, banks, hospitals, schools, and so on. The goal is to find out the best practitioner as a model for the others to benchmark, identify inefficiency, and improve their performance (Thanassoulis, 2001).

take in Table III

Secondly, and most importantly, it is found that MCDM techniques can be applied to the resource allocation (Caballero et al., 2001), performance measurement (Badri and Abdulla, 2004), budgeting (McClatchey, 1998), and scheduling (Thomson, 2005). Unlike the DEA, which is just suitable for the performance measurement, the MCDM techniques are more practical and applicable. Besides, the techniques coincide with real-world situations because the decision problems normally consist of multiple criteria rather than a single objective. However, the MCDM techniques have attracted less attention than both qualitative and quantitative techniques, 16% vs. 40% and 44%. It is, therefore, worth investigating the application of MCDM techniques to higher education decision problems in the immediate future.

4.3. Scope of the MCDM techniques

Finally, the scope of four articles applying MCDM techniques, which are summarized in Table IV, is discussed in detail to discover the inadequacies of their approaches. Based on their limitations, we suggest possible improvements and some future work in the next section. McClatchey (1998) observed that the tuition structure at the University of Nebraska-Lincoln in United States must be optimized because of increasing educational costs and reduced government's support. The author formulated a GP model to optimize this budgeting problem in which six decision variables or different types of students are defined, which are classified as resident or non-resident, as well as undergraduate, graduate, or professional. Four goals with artificially assigned priority levels are established in the model. The goals are conflicting, for example, one is to ensure that the amount of revenue raised from tuition fees must cover operating expenses, while the other is to limit percentage increase in tuition fees. Obviously, this study may not be suitable for other universities whose tuition fees are not determined by themselves.

take in Table IV

Caballero et al. (2001) pointed out that the decision makers of a university always optimize their choices with regard to multiple and conflicting objectives. The authors constructed a GP model to allocate financial resources at the University of Malaga, Spain. There are five goals in the model. Since all goals are related to teaching, there are only

three decision variables including the amount of money assigned to employ assistant teachers, to employ associate teachers, and to improve the current staff either by stabilizing their jobs or promoting them. It is believed that teaching is not only contributed by assistant and associate teachers, but also research assistants and administrative staff. These faculty members do not participate in teaching directly, but they assist the teachers in doing research and administrative works so that the burden of teachers can be reduced. As a consequence, they can concentrate on their teaching. The decision variables should, therefore, also include the amount of money assigned to employ research assistant and administrative staff.

Since Badri and Abdulla (2004) found that there was a lack of explicit award/reward system in academia, they proposed a model that identifies relevant and essential criteria in measuring the performance of individual departmental staff for rewarding purpose. After identification, the authors adopted AHP to prioritize the criteria. The criteria include research and publication, teaching, and community and university services. In each criterion, there are multiple attributes. The higher score a member of departmental staff possesses, the higher possibility he/she can win awards for excellence. Undoubtedly, their approach can be well applied to performance measurement. This may not, however, be suitable for other decision problems, particularly resource allocation. In such types of decision problems, the amount of financial resources assigned to employ, promoting, and motivating universities' members should be determined. In this circumstance, the approach adopted in Badri and Abdulla (2004) loses its advantage.

Thompson (2005) constructed a GP model to build the schedule for elective courses in which there are five goals and two binary decision variables. The variables include the assignment of courses to faculty members, and the assignment of faculty members to teaching days. Following that, a binary integer programming model was formulated to assign students to courses. A heuristic method based on simulated annealing was adopted to solve the model. In the study, the author used the information on unconstrained student demand to make decisions on scheduling so that the schedules better suited the needs of students. The information was collected from student polling via internet. Actually, the quality of the course schedule is mainly affected by two issues. Firstly, the students may change their course preferences, and not register the courses as they stated. Varied preferences can be regarded as inconsistent information, and will affect the schedule's quality. Secondly, the schedule's quality is affected by the amount of students who specify course preferences. The strategies for increasing the number of responses as well as avoiding inconsistent information are not considered.

5. Discussions

After the detailed description of the approaches in the previous section, two major possible future research areas can be recommended. Firstly, it is noticed that nearly half of the journal articles studied performance measurement. Only a few journal articles, however, investigated resource allocation. Resource allocation is definitely a dominant attribute of performance. A system's performance can be enhanced provided that sufficient resource is allocated to it. Because of gradual cuts in higher education budgeting, resource allocation should be optimized so that the performance of a university can be at least maintained or even superior to its competitors. To accomplish this goal, a resource allocation model in the hierarchical form as illustrated in Figure 4 is proposed. The resource is mainly divided into three groups: manpower, "hardware", and "software". They can be regarded as criteria in each of which there are multiple attributes. Manpower includes all university members who can directly or indirectly contribute to teaching and research including academic, research, and administrative staff. "Hardware" refers to the university's infrastructures. For example, an industrial centre is established for students especially studying the subjects of engineering and hotel management in order to acquire knowledge and experience through extensive hands-on training. "Software" refers to the intangible effects that can be beneficial to the university, its members, and its students. For instance, increasing the subsidy for university's members to attend national or international conferences can motivate them to participate actively in those knowledge intensive events. These events provide opportunities for university members to acquire new knowledge, share their own knowledge, and generate new knowledge through integration or collaboration with other researchers at the conferences. Based on the resource allocation model, the decision makers not only can determine the priority level of these three criteria and their attributes, but also how much amount of money should be assigned to them while satisfying multiple and conflicting goals of the university.

take in Figure 4

Secondly, GP is found to be the most prevalent technique in dealing with the decision problems with multiple criteria. It can be applied to all four major decision problems. Nevertheless, it is noticed that there is a drawback of GP technique. Since the judgment is determined subjectively by the decision makers, there may be some inconsistencies. To avoid such problems and to improve the performance of GP further, it is desirable to

incorporate both priority analysis and consistency verification operations of AHP into the GP development process as shown in Figure 5. In determining the priority level of the goals, the decision makers are required to compare the criteria and the attributes of each unique criterion in a pairwise manner. Following that, the consistency test is carried out in order to examine whether the judgments made by the decision makers are consistent. Once the consistency test is satisfied, the goal equations and objective function of the GP model can then be formulated. Since some knowledge-based agents are hybridized in the original GP technique, we call this as knowledge-based goal programming (KBGP) technique. In the immediate future, KBGP can be used to tackle the resource allocation problem or model, as shown in Figure 4.

take in Figure 5

6. Conclusions

This paper mainly reviewed the application of the multiple criteria decision making techniques to four major higher education decision problems, namely resource allocation, performance measurement, budgeting, and scheduling. Since many universities, particularly in United Kingdom and United States have changed to a market-oriented system, in which the funding is heavily dependent on the performance, it was found that 11 out of 25 international journal articles collected in the past decade (1996 to 2005) studied performance measurement. The previous researchers preferred measuring performance of universities, departments, or faculty members using the data envelopment analysis. However, this quantitative technique is not suitable for other decision problems with multiple criteria or objectives like resource allocation.

Facing gradual decreases in higher education funding, resource allocation plays a crucial role in maintaining or even improving the performance of a university. Generally, this issue involves multiple and conflicting objectives. For instance, the decision makers of the university plan to employ more qualified scholars to improve the performance in terms of both quality and quantity in teaching and research, while at the same time, aim at minimizing expenditure. In order to aid the decision makers, a resource allocation model was introduced in this paper. The model in the form of hierarchy consists of a couple of levels. The first level is the criteria of resource allocation including manpower, “hardware” (university’s infrastructure), and “software” (intangible factors that are beneficial to university, its members, and its students), whereas the second level refers to multiple

attributes of each criterion. Besides formulating a comprehensive resource allocation model, a new knowledge-based goal programming (KBGP) technique was also suggested to tackle the model intelligently. The KBGP technique is very similar to GP, except that some operations of AHP are hybridized so as to guarantee that the determination or judgment on priority level of the goals is consistent. This hybridization is absolutely a significant contribution because consistency is an important ingredient of good decision making.

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Figure 1 The market-oriented higher education system

Figure 2 The procedure of the goal programming model development

Figure 3 The flowchart of the analytic hierarchy process

Figure 4 The resource allocation model

Figure 5 The flowchart of the knowledge-based goal programming

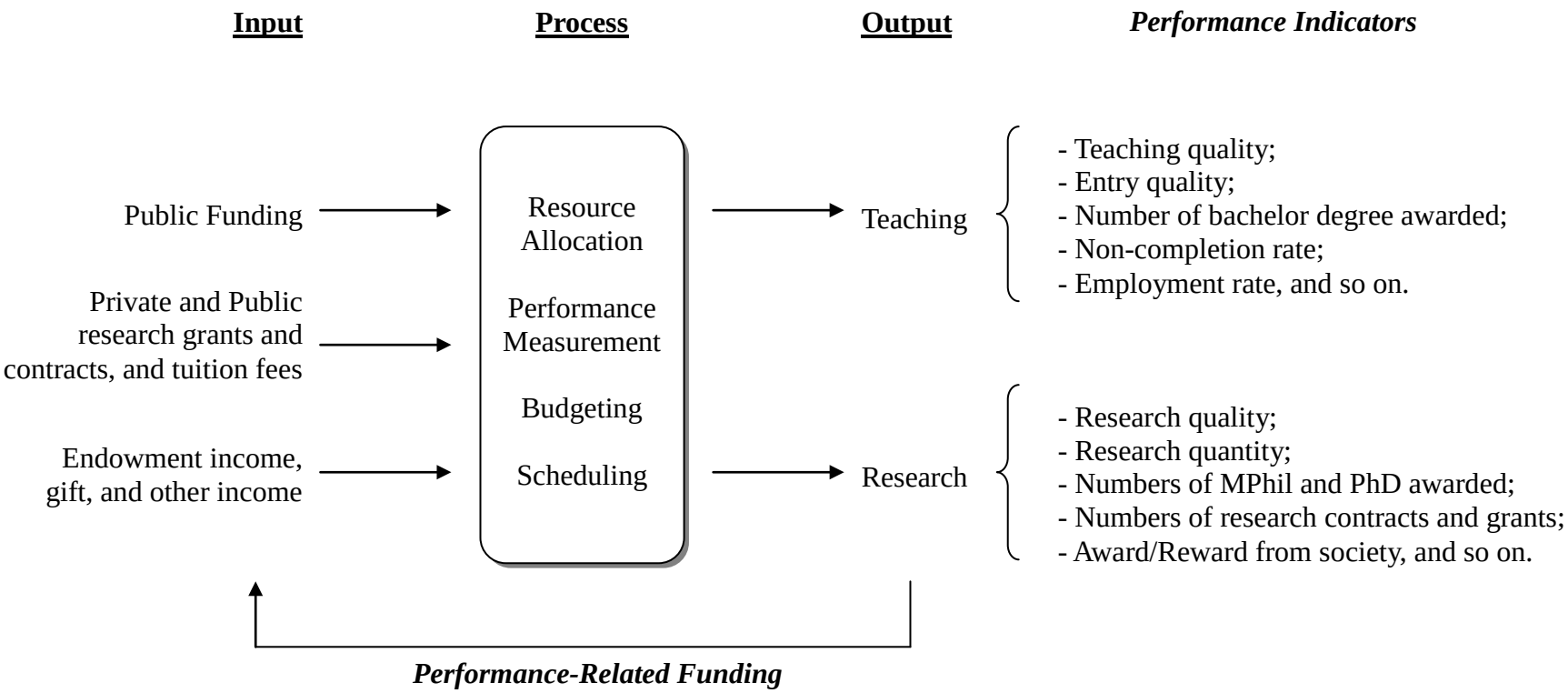

Figure 1 The market-oriented higher education system

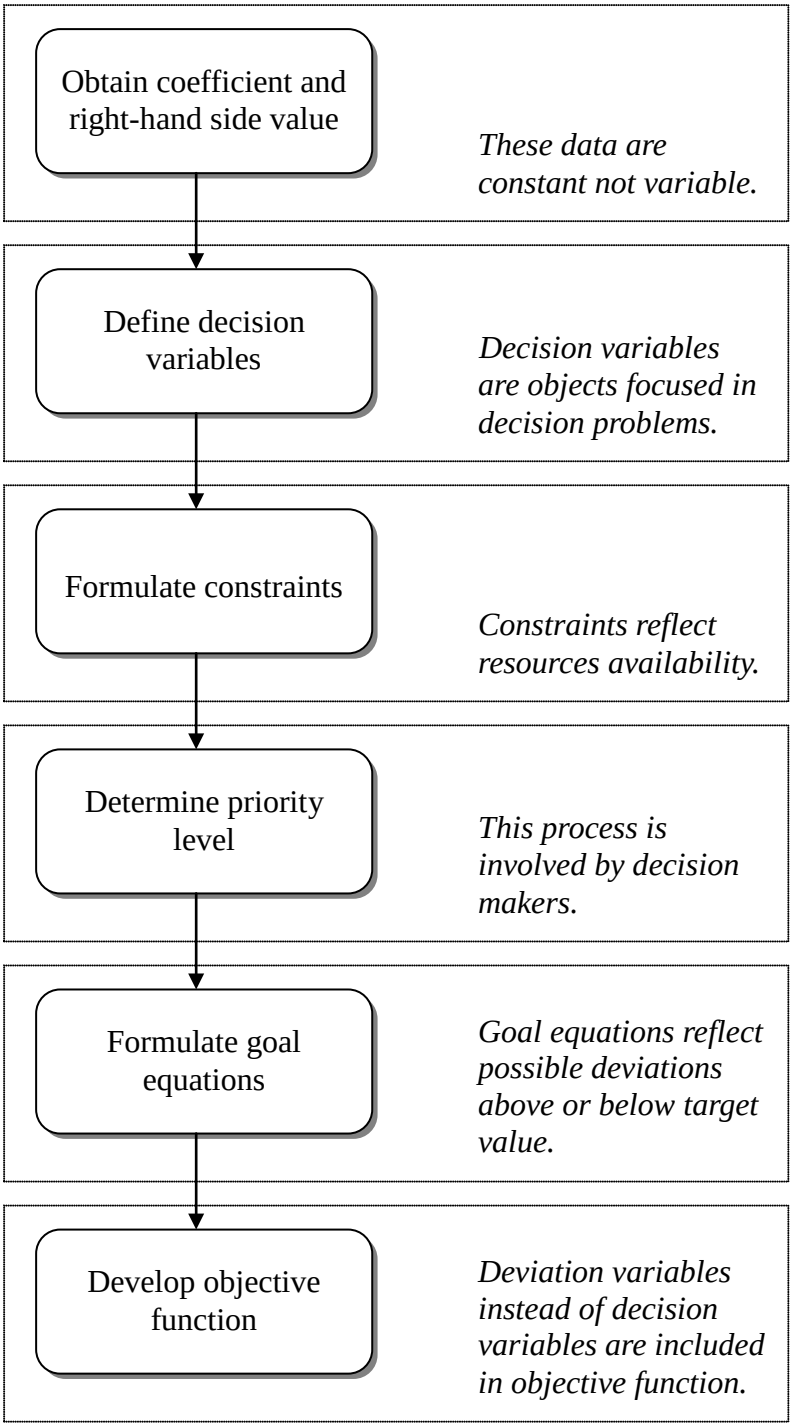

Figure 2 The procedure of the goal programming model development

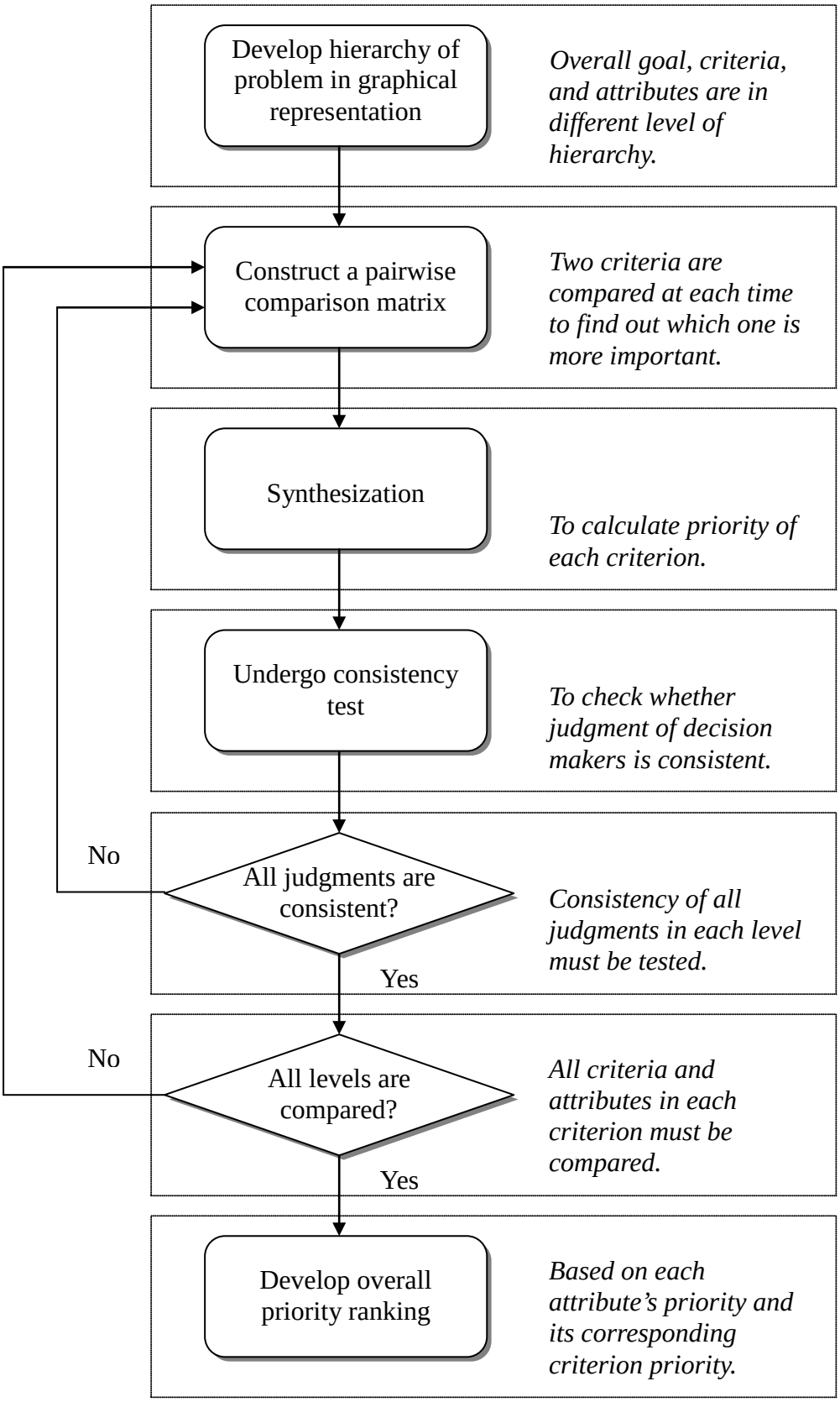

Figure 3 The flowchart of the analytic hierarchy process

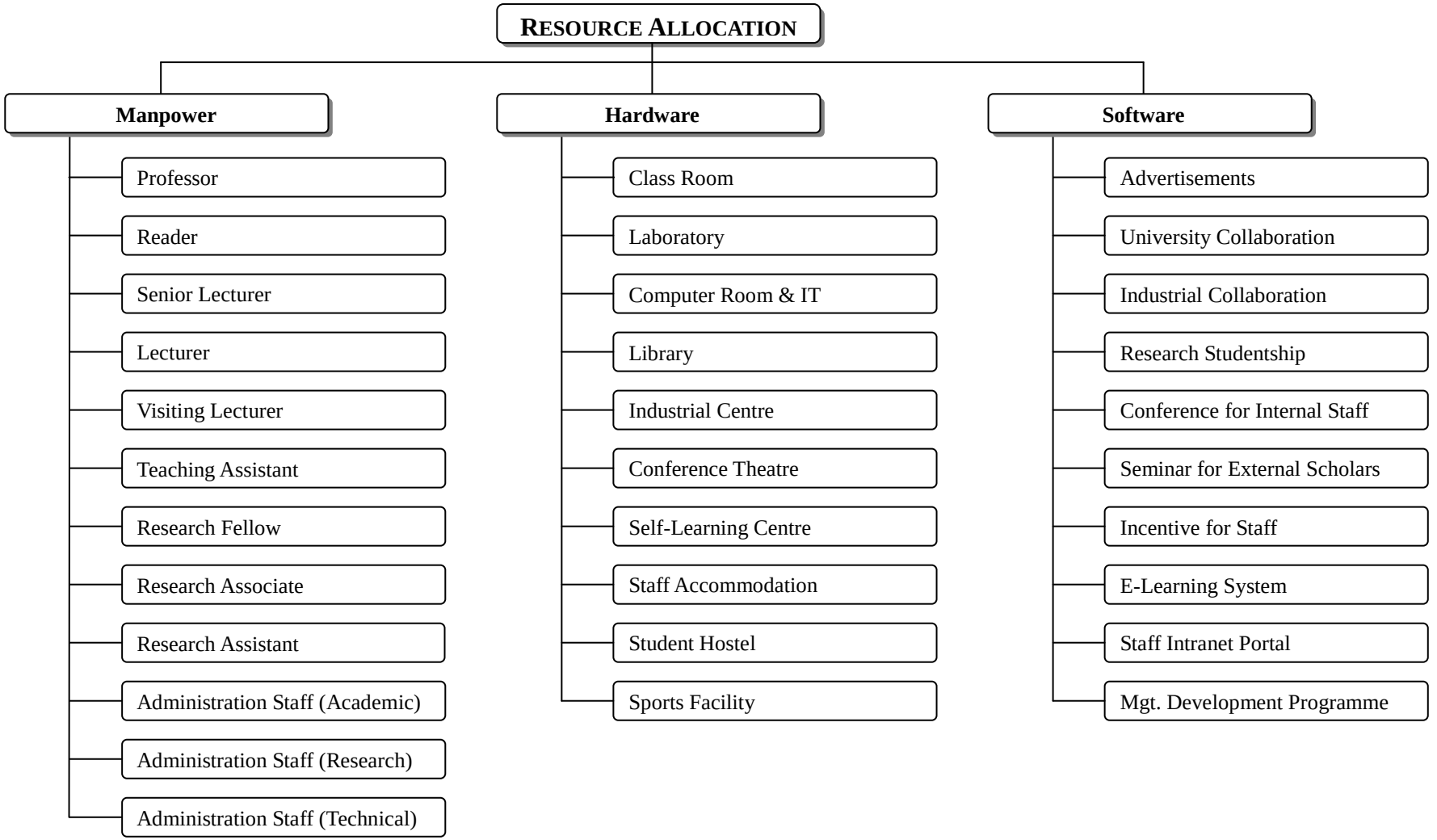

Figure 4 The resource allocation model

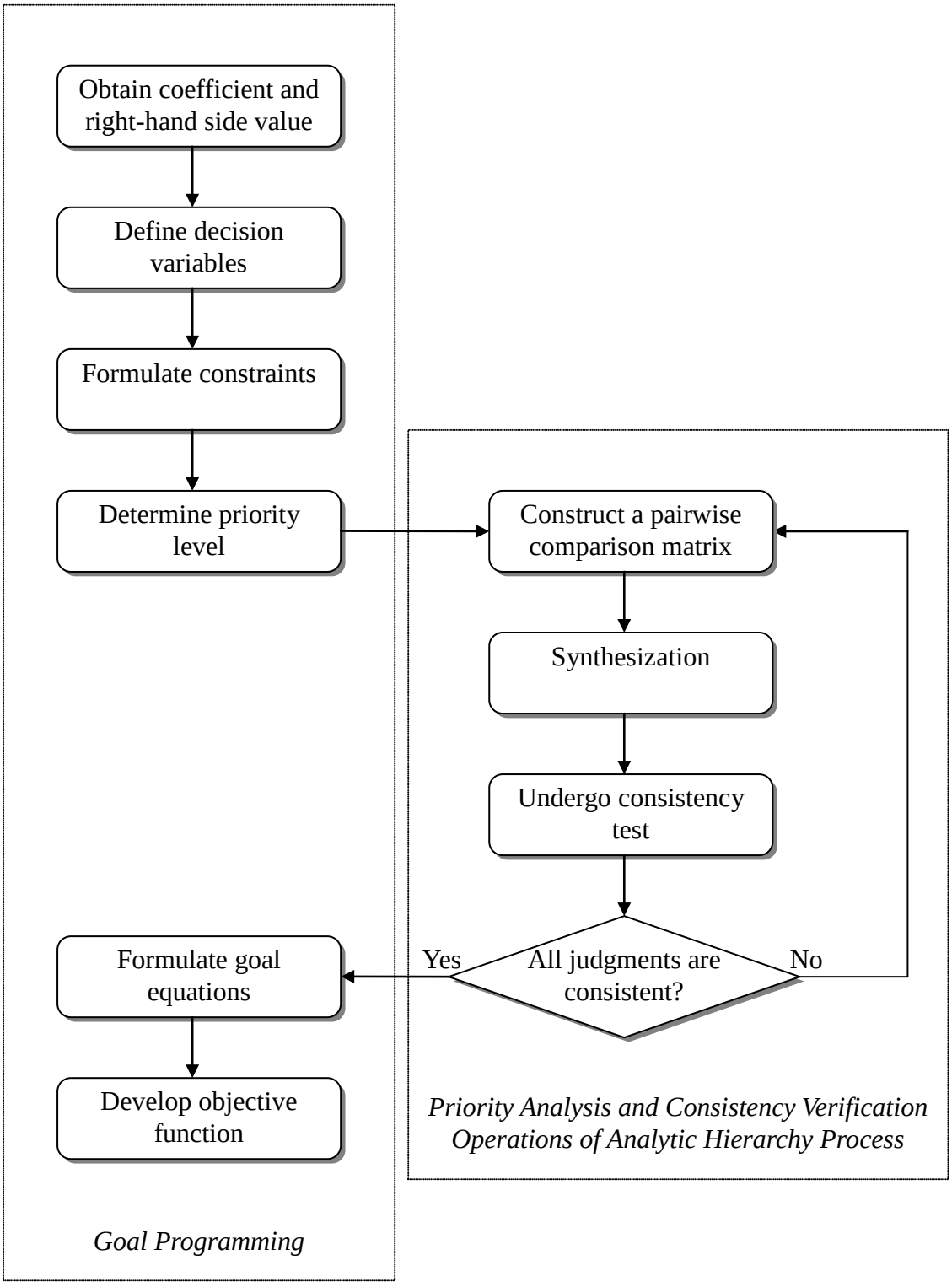

Figure 5 The flowchart of the knowledge-based goal programming

Table I Summary of techniques used in four major higher education decision problems

Table II Number of articles in each higher education decision problem

Table III Number of articles in each technique

Table IV Summary of MCDM techniques used in higher education decision problems

Table I

Summary of techniques used in four major higher education decision problems

Decision Problems	Articles	Approaches
Resource Allocation	1. Watts (1996)	Qualitative
	2. Clarke (1997)	Qualitative
	3. Gillie (1999)	Quantitative
	4. Alho and Salo (2000)	Quantitative
	5. Caballero et al. (2001)	MCDM
	6. Ntshoe (2003)	Qualitative
Performance Measurement	1. Johnes (1996)	Quantitative
	2. Sarrico et al. (1997)	Quantitative
	3. Kwan and Ng (1999)	Quantitative
	4. Pounder (1999)	Qualitative
	5. Sarrico and Dyson (2000)	Quantitative
	6. Al-Turki and Duffuaa (2003)	Qualitative
	7. Cullen et al. (2003)	Qualitative
	8. Badri and Abdulla (2004)	MCDM
	9. Stinebrickner and Stinebrickner (2004)	Quantitative
	10. Adcroft and Willis (2005)	Qualitative
	11. Emrouznejad and Thanassoulis (2005)	Quantitative
Budgeting	1. Borgia and Coyner (1996)	Qualitative
	2. McClatchey (1998)	MCDM
	3. Schmidtlein (1999)	Qualitative
	4. DePillis and DePillis (2001)	Quantitative
	5. Hübner and Rau (2002)	Quantitative
	6. Mensah and Werner (2003)	Quantitative
Scheduling	1. Johnson (2001)	Qualitative
	2. Thomson (2005)	MCDM

Table II

Number of articles in each higher education decision problem

Decision Problems	Number of Articles	Percentage
Resource Allocation	6	24%
Performance Measurement	11	44%
Budgeting	6	24%
Scheduling	2	8%

Table III

Number of articles in each technique

Decision Problems	Number of Articles	Percentage
Qualitative	10	40%
Quantitative	11	44%
MCDM	4	16%

Table IV

Summary of MCDM techniques used in higher education decision problems

Articles	Decision Problems	Techniques Used	Scope
McClatchey (1998)	Budgeting	GP	● Reviews the tuition fees of students at the University of Nebraska-Lincoln; ● Decision variables or students are classified as resident or non-resident, as well as undergraduate, graduate, or professional.
Caballero et al. (2001)	Resource Allocation	GP	● Allocates financial resources at the University of Malaga; ● Decision variables are the amount of money assigned to employ assistant teachers, associate teachers, and to improve the current staff either by stabilizing their jobs or promoting them.
Badri and Abdulla (2004)	Performance Measurement	AHP	● Measures performance of individual departmental staff for rewarding purpose; ● The criteria include research and publication, teaching, and community and university services. In each criterion, there are multiple attributes.
Thompson (2005)	Scheduling	GP	● Develops university course schedules that best fit the needs of students; ● Binary decision variables are the assignment of courses to faculty members, and the assignment of faculty members to teaching days.

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