BUDGET ALLOCATION FOR OPTIMAL PERFORMANCE OF A UNIVERSITY THROUGH ADJUSTED-PROGRAM-BUDGET MARGINAL-ANALYSIS

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Abstrak

Sesuatu perancangan strategik yang dibangunkan oleh universiti-universiti di serata dunia, termasuk di Malaysia, digunakan sebagai indikator utama kemajuan menggunakan petunjuk-petunjuk prestasi utama (KPIs) dalam mencapai dan memperlengkap universiti dengan cabaran keperluan pendidikan di alaf ini. Malangnya sesetengah universiti merangka strategi khusus bagi mencapai KPIs mereka tanpa mengambil kira kekangan sumber-sumber yang ada. Secara khususnya, kos dan kos marginal ke arah pencapaian KPIs kurang diberi tumpuan. Justeru, kajian ini mencadangkan pelaksanaan program analisis marginal bajet terlaras (PBMA terlaras), satu pendekatan yang digunapakai dengan sedikit pengubahsuaian pada PBMA yang sedia ada, untuk mengimbangi keduadua output kewangan dan kualiti secara telus ke arah peruntukan bajet sedia ada yang lebih baik bagi mencapai KPIs. Pertamanya, persamaan di antara langkah-langkah di bawah PBMA dan langkah-langkah yang telibat dalam merangka pelan strategik bagi sesebuah universiti dikenalpasti. Kemudian, beberapa pengubahsuaian dilakukan dengan mencadangkan penggunaan kos marginal dan analisis kos akibat bagi menggantikan pendekatan kualitatif sedia ada dalam menentukan keutamaan strategi, serta penggunaan model pengaturcaraan integer (Model IP) untuk proses pengagihan bajet. Hasilnya adalah satu cadangan model yang baharu iaitu PBMA terlaras. Untuk mengilustrasi kebolehgunaan model PBMA terlaras ini, satu kajian kes berkaitan agenda pembangunan pelajar di Universiti Utara Malaysia bagi mencapai tahap enam bintang dalam penarafan SETARA telah dilaksanakan. Enam model IP yang sesuai telah dibentuk. Keputusan optimum telah diperoleh, dibincang, dan dibuat perbandingan. PBMA terlaras ini adalah bermanfaat dan sesuai untuk organisasi-organisasi berorientasikan program yang berKPIs dan mempunyai bajet yang terhad.

Katakunci: PBMA terlaras, Peruntukan bajet universiti, Model pengaturcaraan integer, Pelan strategik universiti.

Abstract

A strategic plan designed by universities globally, as well as in Malaysia, is used asa key indicator of progress using key performance indicators (KPIs) in assessing and equipping the universities with challenges of the educational needs in this millennium. Unfortunately, some universities set up their specific strategies to achieve their KPIs without much consideration to the limited available resources. Particularly, less attention is given to the cost and marginal cost of achieving the KPIs. This research therefore proposes the implementation of adjusted-program-budgetingmarginal-analysis (adjusted-PBMA), an approach used to accommodate both financial and quality output with transparency to allocate the available budget on KPIs, through minor-adjustments on the existing PBMA. Firstly, the similarities between the steps under PBMA and the steps involved in constructing the strategicplan for a university were identified. Next, adjustments were made by suggesting the application of marginal cost and cost-consequence analysis to replace the existing qualitative approach in prioritizing the strategies, and the application of integer programming models (IP-Models) for the budget allocation process. The outcome was the new proposed adjusted-PBMA. To illustrate the applicability of the proposed adjusted-PBMA, a case study on Universiti Utara Malaysia for its student development agenda to achieve a six-star SETARA rating was conducted. Six possible IP-Model were developed. The optimal results were obtained, discussed, and compared. This adjusted-PBMA is useful and suitable for other organisations with KPI-oriented programs having limited budget allocation.

Keywords: Adjusted-PBMA, University budget allocation, Integer programming model, University strategic plan.

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Table of Contents

List of Tables

List of Figures

List of Appendixes

List of Abbreviation

ARWU Academic Ranking of World Universities

BSC Balanced Score Card.

CBA Cost-Benefit Analysis.

CCA Cost-Consequences Analysis

CEA Cost-Effectiveness Analysis.

CF Collaborative filtering.

CMM Cost-Minimization Analysis

CPC Child Parent Center.

CUA Cost-Utilization Analysis.

DEA Data Envelopment Analysis

GP Goal Programming

HTA Health Technology Agency.

ICER Incremental Cost-Effective Ratio

IP Integer Programming

KPI Key performance indicators

LP Linear programming

LGP Lexicographic Goal Programming

MYRA Malaysia Research Assessment System

NTNU Norwegian University of Technology and Science

PBMA Program-Budget Marginal Analysis

RS Recommmended System.

SETARA Rating System for Malaysia Higher Education

STAFF Number of academic staff

THE Times Higher Education World University Rankings

UK United Kingdom

US United States of America

UPM Universiti Putra Malaysia

USM Universiti Sains Malaysia

UTeM Universiti Teknikal Malaysia Melaka

UTHM UniversitiTeknologiTun Hussein Onn Malaysia

UTM UniversitiTeknologi Malaysia

UUM Universiti Utara Malaysia

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

The program budget is a system of budgeting which describes a program or a set of activities by giving details of the cost of carrying out the given program (Mitton & Donaldson, 2001). Program-budget marginal-analysis (PBMA) on the other hand, is a decision-making tool for maximization of benefit and minimization of cost through resource allocation to individual programs, with the aim of tracking future allocation of resources in the same organizational programs with the added benefit (Ruta, 2005;Holmes, 2018). PBMA originated in the 1950s in the USA Rand Cooperation, with significant applications in the defence department in the 1960s. At the time, it was used as a cost-accounting tool to display overtime, deployment of resources for different military objectives, and in allocating additional missiles to destroy military targets (Brambleby & Fordham, 2003a). Later, Bramblebyand Fordham (2003b) bridged the gap in the application of PBMA between military and healthcare applications in the USA to maximize health gain by deploying available resources for the more significant benefit.

Since then, PBMA has become more prominent in healthcare applications, evidenced by various studies such as by Peacock (2007), KapiririandRazavi, (2017), Kapiriri (2017), Holmes, Steele, Exley, Vernazza, and Donaldson, C. (2018). Nowadays, PBMA is also being applied for decision making in government funded research, guidelines for clinicians, as well as pricing decisions by manufacturers and government (Polisena et al.

2013). The primary goal of applying PBMA is to answer the question of whether more needs can be included within existing resources, through the process of prioritizationof cost.

1.2 PBMA Steps

PBMA is a single point tool used for decision making for organizations to make decisions on programs as to whether to fund or not to fund, articulating high-performance success regarding value for money. Decision makers need to look at the availability of resources to fund available programs to produce adequate benefit. It is not an easy task since some programs with high funding may have to be forfeited for existing lower value program producing high benefit services with minimal cost. Essentially, PBMA is an economic tool used through Multi-criteria Decision Analysis (MCDA) to make legitimate and fair choices (Smith, Mitton, Dowling, Hiltz, Campbell, & Gujar,2016). Mitton, Dionne, and Donaldson (2014) outlined seven steps for PBMA:

i. Determining the goal, aim and scope of setting the program.
ii. Identifying the available resources for funding a particular program, that is the program budget.
iii. Conducting marginal analysis by taking the viewpoints of stakeholders, managers, service providers, consumers, and head of organizations in setting priorities.
iv. Determining the decision-making criteria to be used to maximize benefits or profits as well as to minimize cost.

v. Identifying the options in the program for which choices are to be made. These can be achieved through the process of MCDA.

vi. Evaluating the potential impact of investment and disinvestment regarding benefit and cost.

vii. Validating the outcome and the decision made in the process of allocation and re-allocation of funds according to the ratio of cost-benefit.

Summarily, PBMA can also be regarded as an economic evaluator, through other approaches, that is a combination of some marginal analytical approaches and multi-criteria decision-making (MCDM) techniques in setting priorities for making decisions. It is mainly initiated with the aim of applying an economic framework, recommendations for allocation and re-allocation made in organizations to improve the overall benefit and help the decision maker to maximize the needs for services with limited available resources. Generally, it aids in decision making on what project to fund and what not to fund, with a tangible process in addressing scarcity (Mitton, Dionne, & Donaldson, 2014). Based on the steps described for PBMA, it seems that the steps can be suited, with some adjustments to help the budget management process for a university strategic planning. The flow chart for the PBMA is presented in Figure 1.1.

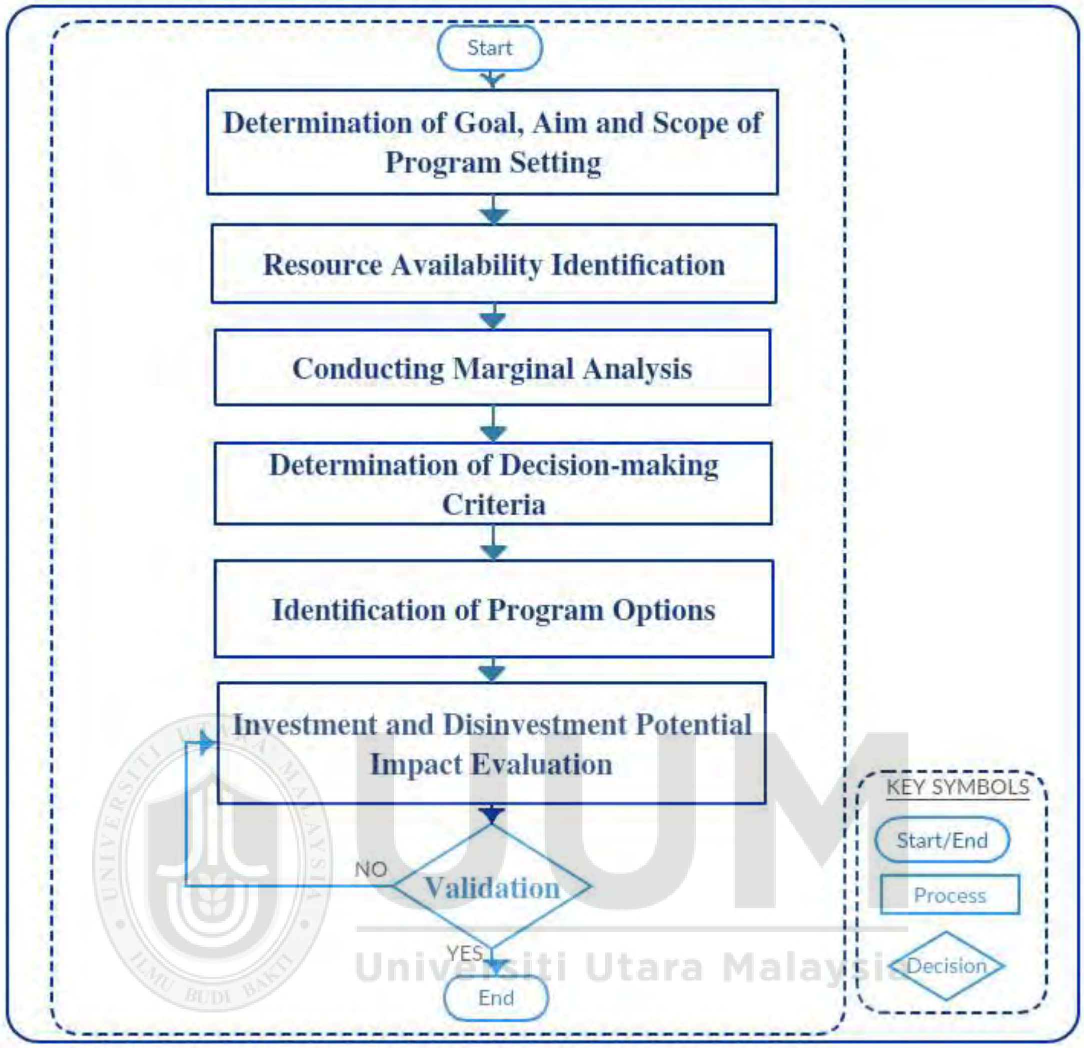

Figure 1.1*PBMA Flowchart*

1.3 Strategic Plan for Universities

In this new millennium, one way to guide and equip the university with challenges and realities of education aimed at making a significant impact on higher education is through the strategic plan. A strategic plan is a goal or target needs of an organization to be identified and assessed as a key indicator of progress made in that particular organization in line with the plans made. In the context of the higher institution of learning, it is regarded as a comprehensive university success indicator giving more emphasis on teaching and learning through improvement of staff and students with the aim of becoming the best-intensified institution (Hall, 2013; Al-Khalek, 2014).

Broader studies on assessment of universities, such as to determine how the university performs and is ranked compared to other leading university institutions have consistently been conducted. For instance, in the 1960s, the American Council conducted a large-scale reputation assessment on educational institutions. The obtained report from the U.S World, which included the undergraduate programs and the ranking of universities was made accessible to prospective students and the public as there was a higher demand for such information (Ballard, 2013; Brooks, 2005). Such assessment of higher academic institutions in the form of ranking and rating helps the general public and hence prospective students to get a best-fit university.

To ensure that the university is ranked highly the strategic plan is tied up with the key performance index (KPI) for all the strategies listed in the strategic plan (Arora & Kaur, 2015; Carey, 2007; Ishak, 2009). KPI is a measure focusing on aspects of performance of an organization that is most critical for current and future organizational success. In educational organizations, KPI is used to communicate measures that matter, aid in providing result and help in university prioritization of resources to achieve the more significant outcome (Ballard 2013; Burke & Minassians, 2002b).

KPIs are also deployed to track the performance of the university through other institutional KPIs to deploy, learn, and integrate the strategic plan through areas leading to academic excellence (Ishak&Sahak, 2011). Such KPIs support variety of purposes in organizational analysis, review of the overall performance, operational improvement, change management, and comparing performances with best practice in comparable organizations. These measurements are focused on getting results which will be used to balance and create value for students and the organization at large (Arora & Kaur, 2015; Carey, 2007; Ishak, Suhaida & Yuzainee, 2009). Most KPIs in educational institutes involve management of quality assurance and improvement, facilities and equipment, financial planning, management staff employment, learning resources, consultancy and service, innovation and research, and finally, teaching and supervision. However, to improve the quality of the universities, there are different strategies used.

Various universities in the world have different strategies used to improve the quality of their institutions (Asmar, 2002). For instance, at The University of Oxford, its strategic plans are focused on research, education, widening engagement, personal finance capital, and value for money in sharing knowledge, encouraging interactions between departments, colleges and the university, as well as reducing financial barriers. These can be made poosible through scholarships, applicability of quality education, enhancing culture, social and economy in the university and the university region, as well as recruitment and maintenance of the best staff, with the aim of becoming the leading university in research (University, 2013-2018). Table 1.1 shows the summary of the vision/mission and strategic plans of some selected international universities.

Table 1.1
Vision/Mission and Strategic Plans in Some U.K Universities

UNIVERSITY	VISION/MISSION	STRATEGIC PLAN
University of Worcester (2013-2018)	Transforming contributions and positive impact on the staff, students, and the community.	• Learning, teaching, and assessment. • Knowledge transfer and research. • Student's development. • Environmental strategy. • Financial strategies. • Human resources strategy.
Cornell University (2010-2015)	To be recognised as the top research university in the world and a model for excellent knowledge with significant impact on education, community, society, and the world.	• Faculty. • Education. • Entrepreneurship. • Staff. • Research.
California Coast University (2015)	Moving the university to the next stage of development through leadership team improved research goal, and plans to increase enrolment within the next decade	• Improving teaching and learning. • Improving graduate outcomes. • Access to university experiences. • Build significant output of research productivity. • Developing a sustainable future for the university.
University of Essex (2013)	To contribute to the society through excellence in education	• Education. • Research. • Support for education and research.
University of Oxford (2013-2018)	To be the leading university in research	• Education. • Widening engagement personal finance capital. • Reducing financial barriers through scholarships. • Applicability of quality education, enhancing culture. Social and economy in the university and the university region.

The same scenario can be found in universities in Malaysia as illustrated in Table 1.2.

Table 1. 2
Vision/Mission and Strategic Plans of Some Universities in Malaysia

UNIVERSITY	VISION/MISSION	STRATEGIC PLAN
Universiti Utara Malaysia UUM (2016-2020)	Making the university an outstanding eminent management university and ranked among the top 5 in Malaysia, top 50 in Asia and top 200 in the world	• Enhancing scholarship and • Internationalization. • Developing management and human capital. • Students' development. • Wealth creation.
Universiti Putra Malaysia UPM (2014-2020)	To be the leading institution in Malaysia with high international standard through the best program and providing a conducive learning environment for its student and staff	• Increase the value of the university with supervision. • High research output, thesis publications, postgraduate research publications. • Support for students and staff.
Universiti Sains Malaysia USM (2015-2020)	Aimed at transforming higher education for sustaining, availability, affordability and improved quality of education as an optimal endpoint.	• Research and innovation, external activities and services. • Resources supportive governance, concentration of talent. • Post graduate studies and alumni services.
Universiti Keba ngsaan Malaysia UKM (2017)	To be the leading institution in Malaysia with high international standard through the best program and providing a conducive learning environment for its student and staff.	• Teaching and learning, enhancing access. • Quality of education, research and innovation. Internationalization • Lifelong learning and reinforcing ministry's delivery system.
International Islamic University Malaysia IIUM (2015-2020)	To be the best Islamic international university.	• Consultancy and entrepreneurship. • Research and development, postgraduate, science, technology and innovation. • Internationalization. Islamizing and integration. • Students and staff development.

Table 1.2 cont.

Universiti Tekn ologi Malaysia UTM (2013-2017)	To be a world-class academic and technological excellence through creativity and management.	• Education, research innovation and graduate education. • Professional and distance learning • International standards. • Strengthening community outreach. • Quality management and effective risk management.

Many studies have been conducted on the performance of educational institutions. Various rating /ranking bodies are used to assess the quality of the university system whereby such ranking and ratings can be achieved through the strategic plans and the achievements of the university (White, 2015; Deering, 2015).

1.3.1 The Ranking/Rating Bodies

There are various university rankings or ratings used globally. Among them are, the Times Higher Education World University Ranking (THE) and the Academic Ranking of World Universities (ARWU). In Malaysia, the SETARA Rating is used to gauge the performance of local universities, focusing on the delivery and management of the undergraduate studies.

1.3.2 Times Higher Education World Universities Ranking

Times Higher Education World Universities Ranking (THE), formally known as the *Times Higher Education Supplement (THE-Q*S) was first initiated by Quacquarelli Symonds (QS), an international career and educational network in London with specialities in the reviewing of higher education and related activities. The annual rating was founded and produced based on the information obtained from institutions participating and conducting elaborate worldwide academic reputation survey and referring it to a well-established database such as SCOPUS, the world scientific journals, and so on. THE is one of the first rating systems which has gone through several revisions with the latest revision in 2010 and is claimed to be better than the previous version of 2004-2009. The 2004-2009 version assessed universities based on broader range of university activities in association with the university teaching, research, and transfer of knowledge in expressing preferences on the concept of the rating using "scaled data and research productivity relative to size" giving advantage to smaller and new universities (Willetts, 2010; Wan Husain, 2012).

The ranking of the universities is based on five (5) categories namely, (1) teaching (30%), (2) research (30%), (3) citations (32.5%), (4) industrial income (5%), and (5) internationalization (2.5%) indicators, with different weightings on the level of importance depending on the applicability of elements as represented in Figure 1.1 (http://www.timeshighereducation.co.uk/world-university-rankings/2011-2012/analysisrankings-methodology.html).

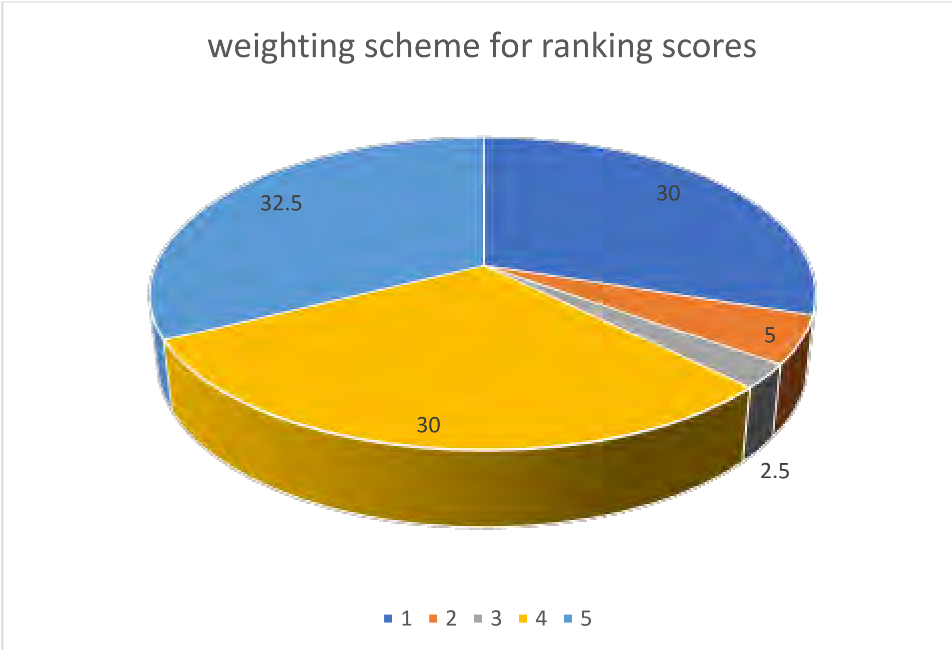

Figure 1. 2*Assessment Criteria Employed by Times Higher Education World University Ranking.*

1.3.3 Academic Ranking of World Universities

Academic Ranking of World Universities (ARWU) was first established in June 2003 and registered with the name *Shanghai Jiao Tong World University Ranking.* It is used to evaluate the university performance, restricted to research and innovations, and publications, with less value given to contributions to the community and the country as a whole (Wan Husain, 2012). To determine the quality of the universities, the evaluation is grouped into four (4) components as represented in Table1.3(http://www.shanghairanking.com/ARWU-Methodology-2011).

Table 1. 3
Indicators Employed by ARWU

GROUP	CRITERIA	INDICATORS	WEIGHT
1	Quality of Education	Number of first-class graduates.	10%
2	Quality of Faculty	The staff of an institution winning excellent prize and medals. Highly-cited researchers in 21 broad subject categories.	40%
3	Research output	Paper published in a high impact journal. Paper index-expanded and social sciences citation index.	40%
4	Per capital performance	Cost of maintaining the performance of an institution.	10%

The content of ARWU as expressed in the Table 1.3 above is a transparent and robust approach in generating ranking with a specified aim at improving the university research excellence. In 2009 ARWU-FIELD, a rating procedure adopting the process of THE and ARWU according to broad subject fields as well as ARWU-SUBJECT about subject fields wereintroduced (Grapragasem, 2014).

1.3.4 SETARA Rating

The Malaysian government uses a form of rating called the SETARA rating in rating the quality of the university system in the country. First introduced in 2007, SETARA rating aims at improving the quality of education in Malaysia through the appraisals on the input, process, and output that are directly/indirectly related to the institutional service delivery at the undergraduate level. The SETARA rating is categorized into six

(6) ratings based on the number of stars givenas shown in Table 1.4 (MoHE - Rating of SETARA 2009 – KPI).

Table 1. 4
Malaysian SETARA Rating

STARS GIVEN	STATUS
1	Weak
2	Satisfactory
3	Good
4	Very good
5	Excellent
6	Outstanding

The Malaysian Qualification Framework (MQF) is used for measurement of the SETARA ranking. The assessment includes not only government-funded universities, but it is also extended to private universities as well. SETARA rating from the operational view measures the effectiveness of undergraduate teaching and learning activities as a process of transforming learning resources into the valuable outcome. The rating system consists of three significant components which are input (governance, physical and financial resources, and talent), output (quality of graduates), and process (curriculum), with a certain percentage allocated to each of the components.

1.4 Problem Statement

As mentioned previously, a strategic plan designed by different universities is used as a guide and key indicator of progress in assessing the universities and equipping the universities with challenges and realities of the educational needs in this millennium. Unfortunately, some universities set up their specific strategies without consideration of the limited available resources, which is of great benefit to the university system and the country. Less attention is given to the cost in achieving the best performance, which may lead to mismanagement of funds allocated in such universities.

Resource allocation and re-allocation of activities are two very critical parts of budget planning whereby most of the budgetary allocations are based on past implementations that can be either inefficient or suitable for another round of budgetary allocation (Ruther, 2014; Karlsson, 2016). In addition, expectations on high-ranked university or education are very high and increase at a faster rate in this millennium. However, the goals set by the university to achieve a highstandardmust be based on the available resources (Alcock, 2016). Unfortunately, with limited available resources, it is tough to decide how the resources should be allocated.

The review of existing strategies in the strategic plan is crucial to know which of the strategies are cost-effective and give maximum benefit towards the achievement of the KPIs set. This in turn will decide whether to maintain the existing strategies or to re-allocate resources and allocation of resources to new strategies for the next cycle of the strategic plan. In this situation, PBMA seems to be one possible way of improving the allocation of budget by reviewing the effectiveness or the efficiency of the existing strategies and the new suggested strategies.

However, to implement PBMA for the university budget problem, some adjustments on the current PBMA must be made. To recall, thesteps for PBMA as stated by Mitton (2013)are as follows:

i. Determine the goal, aim and scope of setting the program.

ii. Identify the available resources for funding a particular program, that is the program budget.

iii. Conduct marginal analysis by taking the viewpoints of stakeholders, managers, service providers, consumers, and head of organizations in setting priorities.

iv. Determine the decision-making criteria to be used to maximize benefits or profits as well as minimization of cost.

v. Identify the options in the program for which choices are to be made. These can be achieved through the process of MCDA.

vi. Evaluate the potential impact of investment and disinvestment regarding benefit and cost.

vii. Validate the outcome and the decision made in the process of allocation and re-allocation of funds according to the ratio of cost-benefit.

There are two major steps from the existing PBMA-steps that can be improved. The first concern is on the steps on conducting the marginal analysis by taking the viewpoints of stakeholders, managers, service providers, consumers, and head of organizations in setting priorities. The existing implementation is solely based on perceptions and preferences of those parties involved. This, to a certain extent can certainly lead to biased and inaccurate preferences and evaluations. As such, the marginal analysis should be conducted and formulated using some deterministic, evidence-based approaches to reduce the biasness.

The second concern is on the identification of the options in the program for which choices are to be made which currently is achieved through the application of a certain

MCDAapproach. In other words, the allocation of budget to strategies and activities is based on subjective evaluation by the decision makers based on the decision makers' preference weight and ranking or based on expert opinion. This once again may lead to biased budget allocation. In addition, it will be difficult to prove that the allocation is just and accurate without showing a concrete evidence. Thus, it is suggested that some form of deterministic mathematical model to be utilized for this budget allocation process.

Unfortunately, not many studies have been able to identify any systematic concept into applying the PBMA on other organizations. This is evidently so, since the application of PBMA as employed in most of the studies have focused mainly within health organizations. Thus, presenting the need for the adaptation of the method to make it suitable for other organizations whose focus is towards KPI and service-delivery is seen to be very timely. This is essentially required considering the financial constraints faced by so many organizations and the corresponding need to enhance performance of these organizations.

1.5 Research Questions

This research aimed at answering these following research questions:

i. How can PBMA be adjusted to better-suit the need for a more deterministic or quantitative decision-making process particularly for the budget-planning purposes for universities?

ii. What is the most suitable marginal-analysis formula to be used for a university budget-planning purpose?

iii. Which mathematical models can be used for the final budget allocation for the university?

iv. How are the evaluation and validation of the results produced by the proposed mathematical model done?

1.6 Research Objectives

The underpinning objective of this study is therefore, to propose an adjusted-PBMA that can be applied by many universities to solve their budgetary problem in the allocation of funds to strategic activities aimed at achieving the optimal performance as stated by the KPIs in their university strategic plan.The specific objectives of this research are to:

i. Identify the specific aspects of the PBMA-stepsthat should be adjusted to better-suit the need for a more deterministic or quantitative decision-making process particularly for the budget-planning purposes for universities.

ii. Calculate the marginal cost contribution for each strategy to achieve the respective KPIs using the most suitable marginal-analysis formula to be used for a university budget-planning purpose.

iii. Apply the most suitable mathematical model for the final budget allocation for the university.

iv. Evaluate the proposed mathematical model and validatethe result produced by the mathematical model.

1.7 Scope of the Study

In most universities, the strategic plan will focus on the achievement with regards to the quality of the service delivery, the quality of research, publication and consultation, the amount of income generated, and the quality of students produced. In this research, the focus was only on the students' achievement agenda that universities in Malaysia should be implementing in order to fulfil the requirements set by the 2009 SETARA rating instrument. To illustrate how adjusted-PBMA can be implemented, a case study at Universiti Utara Malaysia (UUM) was conducted. The required data involving the strategies and the KPIs that relate to students' achievement agenda were extracted from the 2016 UUM's strategic plan. UUM was selected due to the availability of the data. Furthermore, the management of UUM is similar to those of other public universities in Malaysia.

Secondly, in achieving the final "optimal solution" in terms of the activities or strategies to be adopted and executed by the universities, the term "optimal solution" here refers to the activities or strategies to be adopted and executed by the universities as well as the total budget required in order to obtain at least 85 percent of the full SETARA rating points, which is the requirement set by the SETARA rating if the universities are to achieve a 6-Star rating.

Thirdly, only the output element in the SETARA rating was considered. The input and process were not considered in this study.

1.7 Significance of Study

This research showshow the use of PBMA which is currently prominent in the health industry, can be extended to be applicable, with slight modifications, in other industries as well, particularly in other KPI-based service-oriented institutions such as the tourism and hospitality-based organizations, security-enforcement institutions, and universities. Firstly, this research will practically demonstrate the adjusted-PBMA as a potential approach to prioritize strategic activities in any KPI-based and service-oriented organization to achieve a successful and sustainable standard. The adjusted-PBMA will encourage transparency in the decision-making process and ensure quality by achieving the required standard and can easily be modified to cater for changes. Since universities can be considered as KPI-based service organizations, this adjusted-PBMA can be used on strategic activities in the university aimed at achieving a higher university rating.

Secondly, the present PBMA proposed the use of MCDA, which can be very subjective, as the determining factor. However, under the adjusted-PBMA approach, we proposed the use of any objectively and quantitatively suitable marginal cost (in our case, cost consequences analysis (CCA) was used) as one of the determining factors.

Thirdly, the present PBMA approach distributes the allocated budget based on subjective evaluation involving decision makers' preference weight and ranking or expert opinion. For the adjusted-PBMA we proposed the use of IP-model for the budget distribution. IP-model can not only distribute the budget allocated among strategies if the budget allocation is already determined ahead of time and is fixed, but the IP-model can also determine the proper budget to be reserved if a certain target or KPIs need to be attained.

1.8 Summary and Organization of Report

In this chapter, we provide the introduction to PBMA framework, strategic planning in the university system, university ratings, strategies used by universities to achieve the targets set and the KPIs used by universities to measure the achievements. The chapter presents further the research problem, aim, objectives and also the research questions. The scope and significance of the study and study limitations are also included in this chapter. The remaining chapters are organized as follows.

Chapter Two reviews the literature on PBMA, SETARA ratings in Malaysian universities, economic evaluators such as the cost-consequences analysis (CCA), cost-benefit analysis (CBA), cost-effectiveness analysis (CEA), cost-minimization analysis (CMA), cost-utility analysis (CUA). Thisis followed with the review on multi-criteria decision-analysis (MCDA) and the techniques in MCDA and finally, integer programming as well as goal programming for budgetary allocations, and finally similar studies related to university budgeting and ranking problems.

Chapter Threepresents the method to be used for the research which is presented in six significant steps:

i. Identifying strategies.
ii. Comparing actual achievement with the given KPIs

iii. Calculating marginal contribution of each strategy.

iv. Introducing new strategies.

v. Identifying suitable strategies for the next cycle of the strategic plan.

vi. Allocating budget using linear programming for proposed Model A, B, and C,for existing strategies and models D, E, and F for both existing and new introduced strategies.

Next, Chapter Four presents the procedural approaches through which objectives of the study were achieved. Evaluation of the proposed models for achieving the research aims and objectives hence answering the research questions is also given. The validation of the proposed models using data from 2016 strategic thrust forUUM, presentation of results and also the interpretation of the results are given immediately after.

Finally,Chapter Fivepresents the research summary, conclusions, research contributions, limitation of studyas well as the recommendations for future studies.

Operational Definition of Terms in Outcome Components of SETARA Rating

To facilitate the understanding on some of the terms used throughout this thesis, we give the full definition of some of the important terms.

Optimal performance: the combination of strategies/activities that should be executed by any university in Malaysia to achieve a six- star SETARA rating.

Generic Attribute: This is the collection of skills attributes and knowledge regarding how to develop the university system to efficiently achieve a great outcome with concepts of teaching and learning practices.

Employer Satisfaction: This is regarded as the employer's perception of graduate employability which shows the level at which the employer is satisfied with the skills of a new university graduate as an employee.

Student Marketability: This refers to the expertise of a university student in a particular field of study with an added benefit of broad exposure and experience such as communication and interaction, hence making marketability a lifestyle necessity.

Students Satisfaction: This is strengthening the quality of student experience in a comprehensive and satisfactory process with services given to students over time as a powerful tool to improve the quality of students.

International students: Foreign nationals studying in a country other than their country of origin that is visitors who come to other countries to study.

Student quality: The ability of the university to impact rigorous academic training to expose the students to what is obtainable outside the university. That is in quality of work life such as entrepreneurship and quality of management.

Faculty experience: The faculty members with knowledge of active learning techniques that are both practical and theoretical, for the compelling mission of developing critical learning skills.

Faculty capacity: The strength in evidence-based teaching through the opportunity to test and apply knowledge, coaching support and emerging of knowledge of how people learn by the university instructors.

Faculty adequacy: The method used to meet the standard for accreditation of the university to support mission and vision of the university, the institutional responses framed within the faculty with workload policies and student-faculty ratios.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, the techniques within the application of PBMA, particularly in answering the research questions and achieving the research objectives put forward for this research were reviewed. It started with a section on the SETARA-rating which is the ranking procedure used by the Malaysian universities to rate the quality of the university concerning the standards set by the Malaysian government. This is followed with a review on the cost-effectiveness approaches and several multi-criteria decision analysis (MCDA) techniques used to decide which current strategies should be maintained and which new strategies should be introduced into the next cycle of the strategic plan. Finally, a brief review on integer programming and pre-emptive integer programming model to be used for the budget allocation as well as to determine the strategies to be adoptedwere given.

2.2 SETARA Rating

SETARA is viewed as a comprehensive level of performance evaluator for the university system in Malaysia with an assessment scope of learning and teaching. The rating system was first introduced in Malaysia in 2007 (Easyuni.My, 2015) as an official rating system for all public universities in Malaysia about the evaluation of the KPIs, and was later revised in 2009 (Services, 2013). The assessment includes not only government-funded universities, but it is also extended to private universities as well.

SETARA rating from the operational view measures the effectiveness of undergraduate teaching and learning activities as a process of transforming learning resources into the valuable outcome. The rating system consists of three significant components which are input (governance, physical and financial resources, and talent), output (quality of graduates), and process (curriculum), with a certain percentage allocated to each of the components as shown in Table 2.1 (MoHE - Rating of SETARA 2009 – KPI).

Table 2. 1
Assessment Criteria for SETARA 2009

DIMENSION	**DOMAIN**	**CRITERIA**
Input (20%)	Governance (12%)	Governing Body (Board of Directors, Governors, Council, etc.) Academic Governance Leadership and Staff Strategic Planning Academic Autonomy Defined Lines of Responsibility & Decision-Making Students' Representation Organizational Climate
	Physical & Financial Resources (3%)	Infrastructure (Physical) Financial Support services
	Talent (5%)	Faculty: Adequacy Faculty: Capability Faculty: Experience Student Quality International Student
Process (40%)	Curriculum (40%)	Curriculum Content Quality Delivery / Pedagogy Quality Assessment

		Monitoring Ancillary Activities
Output (40%)	Quality of graduates (40%)	Student Marketability Students' Satisfaction Employers' Satisfaction Generic Student Attributes

Meanwhile, the information about each aspect being evaluatedare collected from each university yearly, but the assessment is conducted every three years. The points accumulated by each university will be translated into star ratings as shown in Table 2.2 (MoHE - Rating of SETARA 2009 – KPT).

Table 2. 2
SETARA Ratings Distribution in Percentage

STAR RATINGS	STATUS	PERCENTAGE
1	Weak	0-39.99
2	Satisfactory	40-49.99
3	Good	50-59.99
4	Very good	60-69.99
5	Excellent	70-79.99
6	Outstanding	80-100

2.3 Evaluation of the Benefit of Cost of Expansions

When allocating and re-allocating funds, organizations require evidence of the effectiveness of interventions with reasonable value for money (Ganzeret al., 2013). As such, economic evaluators are needed for publicly funded services to perform a comparative analysis or alternative of actions particularly with regards to consequences and cost in executing or implementing specific options. Increase emphasis on economic evaluators to interventions for improving organizational strategies in institutions as well as other organizations in an environment that is the process of being cost-effective requires assessment of different interventions about its economic implication. Failure to evaluate the cost-effectiveness may lead to over expenditure or reduced services. On the other hand, improvements are possible with fewer expenses through the process of cost-effectiveness.

Depending on the type of the analysis of the consequences, there are mainly five economic evaluators used for PBMA, namely cost-effectiveness analysis (CEA), cost-benefit analysis (CBA), cost-utility analysis (CUA), cost-minimization analysis (CMA), and cost-consequence analysis (CCA) (Smith et al., 2016).

2.3.1 Cost-Effectiveness Analysis

Cost-effectiveness analysia (CEA)is used as a method of assessing services that are less cost-effective with maximum benefit and, as priority settings by authorities such asprovince, state, and local government, aimed at benefiting public services, making decision for both private and government-owned organizations (Miller, 2012; Polisena et al. 2013; Sekar&Randhir, 2016). CEA is referred to in most literature as an economic evaluator in general. CEA is calculated as the amount of cost per unit effect. The essential requirement of CEA is a fixed budget constraint and used when there is a single objective for an intervention (Drugs & Health, 2014).

In the healthcare application, for instance, most researchers make use of Markov decision model for the CEA with the cost-effective incremental ratio (ICER) using Markov model to provide additional benefit with less cost to determine the cheapest option for treatment for bladder failing optimal therapy (Jenks et al., 2013). In another healthcare application, Peersman et al. (2014) used state-transition Markov model for comparing cost-effectiveness with minimal cost and increased benefit in the treatment of knee arthroplasty. This same procedure used in healthcareorganizations can also be used in other organization to improve productivity.

The significant advantage of CEA is that the result or outcome can be compared with results of other technologies that are expressed using the same outcome measures (Smith et al. 2013). It is straightforward to conduct than most of its competitors like CUA or CBA. Nevertheless, it is not suitable for comparing technologies and allocation of resources across different conditions because of its reliance on one common measure.

2.3.2 Cost-Benefit Analysis

Cost-benefit analysis (CBA) is a direct economic evaluation to address allocation efficiency and value the cost and results of economic evaluation in monetary terms

(Mak, 2005). The most widely CBA values used by economic evaluators are monetary values, determined for the intervention of input and output. It has a single unit measurement for various outcomes and allows for comparison between multiple different outcomes such as comparison of social and financial CBA. CBA primarily is used to evaluate the consequence of an intervention using performance of a particular measure when the attribute of an intervention on performance of that measure and the outcome process is considered an important factor in analyzing the various responses.

In medical application for example, CBA has been applied by Pyenson, Sander, Jiang, Kahn, and Mulshine (2012) to estimate the cost-benefit of lung cancer screening about prolonging life with minimum cost, determine the cost of treatment immediately after early detection through cancer screening, and determine cost of treatment towards the end of observed late cancer stage annually. In the same vein, Thompson and Kempton (2015) determined the cost-benefit of fuel for generation of electricity such as coal, natural gas and wind, and to determine the social cost-benefit and private cost-benefit fuel generation, while Reynolds, Temple, White, Ou, and Robertson (2011) determined the CBA of child-parent center (CPC) early intervention of child, to list a few.

Even though all the alternatives can be quantified and estimated using monetary measures, nonetheless, the primary disadvantage of CBA is with regards to the uncertainty in assigning and quantifying of monetary value to alternatives which can be a significant cause of inaccuracy in the analysis of cost-benefit. Adversely, the inaccuracy in the calculation of the present value as evaluations made on the past period, with a decision on the present and future will undoubtedly be unrealistic. It requires the benefit and cost to be identified and qualified appropriately. The imperfection in human gives rise to omission and errors when performing the CBA (Goldstein &Sapra, 2015; Mishan, 2015).

2.3.3 Cost-Utility Analysis

Cost-utility analysis (CUA), regarded as a particular case of CEA, estimates the ratio between cost and benefit of intervention to an individual. It is used by policy makers to determine priorities when choosing alternatives (Kind &Raisch, 2009). As a special case of CEA, CUA deals with individuals and not group and allows comparison between alternatives with a complete analysis of total benefit compared to other economic evaluators. However, one of the disadvantages of CUA is the social benefits and cost are not considered. Instead, individual benefits are mostly considered. Examples of applications include some studies in the health organization measuring quality years gained by an individual suffering from a specific illness concerning the cost of that treatment (Borisenko et al. 2015),measuring quality of life gained per patient treated of lungs cancer and incorporating smoking cessation interventions for different individuals (Villanti, Jiang, Abrams, & Pyenson, 2013), and estimating the cost and quality of life gained in years per patient for treatment of five years and above with cost of maintenance of stroke for every individual in the study (Morris et al. 2016).

2.3.4 Cost-Minimization Analysis

Cost-minimization analysis (CMA) regards factors that are relevant to the decision, considering equivalent and the lowest cost options selected. Generally applied as an extension of CEA, outcomes will be demonstrated as equivalent to CEA, which is comparing benefits yielded by different methods/processes on the same treatment only by cost (Smith et al., 2016). Most applications are on cost-minimization on healthcare (Graham et al. 2015; Graham et al., 2013; Petren et al. 2013) such as cost evaluation on cost associated with treatment of a specific disease, and the evaluation of cost at each stage of cancer treatment with regards to the benefit of the treatment for a lower cost alternative.

2.3.5 Cost-Consequence Analysis

Cost-consequence analysis (CCA) is used to assess the impact of interventions, the cost and outcomes of alternative interventions listed separately, in a disaggregated format. The outcome disaggregated to show the trends, insight, and patterns that cannot be applied in an aggregated data set. The transparency of CEA, CBA, CMA, is improved with CCA as an intermediate step in reporting the analysis showing outcome and cost presented in disaggregation before it is combined for other economic evaluations (Mitton et al. 2014; Smith et al., 2016).

CCA compares interventions across different sectors and reports in different, disaggregated format. According to Golan, Hansen, Kaplan, and Tal (2011), the process of economic evaluation accepts the fact that different types of benefit cannot be compared using the same unit. Hence CCA is an instrumental technique with multiple outcomes, with different perspectives and units.

Similar to the other four economic evaluators, applications of CCA are mostly in the health sector. Dale, Madtes, Fan, Gorden, and Veenstra (2012) for example, applied CCA on different strategies with the help of a decision tree to evaluate the social cost and consequences of the differential diagnosis process for the solitary pulmonary nodule and concluded with a strategy with less cost and less complication. On the other hand,Desborough, Sach, Bhattacharya, Hollad, and Wright (2012) applied CCA by evaluating the mean cost of before and after intervention for medication in reducing emergency hospital admission which saved medical cost, providing a transparent process for allocating resources to decision making.

Finally, Van Vugt et al. (2014) utilized CCA to evaluate three different methods of diagnosis of patients with high energy trauma where the cost of the diagnosis was put into consideration as an alternative with the aim of choosing the best beneficial alternative with minimum cost. Although, most examples given surround the applications in a healthcare environment, all the analyses above can be applied in various fields or organizations, with some modification, if required, to weigh alternatives and to make decisions based on the best alternatives surrounding cost-minimization and benefit-maximization.

To conclude, the use of economic evaluators, coupled with other economic tool such as CCA is beneficial in assisting decision makers to make evaluations in the process of decision makingbecause resources are finite (Mak, 2005). It relates to opportunity cost which is the cost of an alternative that must be forgone to pursue a specific action in the set of alternatives. In other words, allocating resources to an option instead of another better option may lead to the loss of potential benefits (McCullough, Zimmerman, Fielding, &Teutsch, 2012).

Once the evaluation of the strategies is completed, the process of allocating and re-allocating of funds or budget for those existing strategies and perhaps some new ones can be executed by analyzing various factors and criteria. Hence, this activity belongs to the group of multi-criteria decision analysis (MCDA) problem.

2.4 Multi-criteria Decision Analysis

Choice making and priority settings are realities for most publicly funded programs in most organizations, for many years to come due to the limited resources. Rationing requirement when resources are limited can be achieved through economic evaluators and implementation methods as well as approaches for prioritization and decision making through multi-criteria decision-analysis (MCDA) (Golan, Hansen, Kaplan, & Tal, 2011). Lack of effective approach will lead to poor decision making about value for money and hence reflect inaccurate decision making.

Standard process in priority setting constitutes the desired impact or success of managing resources and activities in organizations're-allocation of resources through the effect of individual, group, and system (Cornelissen et al. 2014). The approach normally uses fundamental economic principles such as opportunity cost and marginal analysis for priority settings (Eckermann, 2015). Technology or strategy assessment can be appliedto the improvement of performance on a practical level and how management practices should be applied regarding future funding (Mitton et al. 2014). Priority settings aim to minimize cost and maximize benefit given a set of resources that is the foregone benefit of the best alternative use of a given resource.

Deciding who or what receives priority when allocating resources in an organization is difficult and challenging (Sullivan, 2012). In this situation, the basic decision making cannot be applied, else uncorrected mistakes might be made, and such situations might be irreversible with substantial consequences. In complex situations, decision aids such as MCDA is required for decision mainly when a variety of choices are being considered (N. Smith et al. 2016).

MCDA is a valuable tool used in broad fields for complex decision making among alternatives, applicable in a range of disciplines such as science (medical, mathematics, statistics, psychology) (Ramirez-Garcia et al. 2015) and administration (economics, political science, business administration) (Blanco et al. 2014) in focusing logical, importance, as well as consistent decisions. It is an essential branch of operational research dealing with diverse decision-making. MCDA approach comprises of a range of procedures and techniques developed in many areas of decision making through making decisions on complex problems with an explicit, transparent, and consistent way used mostly to compliment priority settings such as the PBMA (Smith et al. 2016; Sullivan, 2012). It involves identifying programs that need priority, deciding who should be given priority and determining the importance of the criteria, while ensuring consistency and transparency in the process (Sullivan, 2012). Golan et al. (2011) for example, in their review on application of health technology involving the selection of appropriate technology to be applied in different countries, the criteria used for prioritization are as given in Table 2.4 (Source: Golan et al. (2011) health technology prioritizationHTP).

Table 2. 3
Criteria for Prioritization

• Need for appropriateness and benefits.
• Efficiency.
• Solidarity, social equality and ethical values.
• Consistent with allocative justice principles.

In addressing multi-criteria problems, the concept of the optimal solution is not the goal. Instead, the goal is helping the decision maker to bring a clear solution to the problem through advancing towards a solution which is mostly a compromise. This process depends on not only different factors such as organizational and decision makers but also on circumstances that are prevailing and hence the different methods used for MCDA also address the problem with conflicting, multiple incommensurable criteria. Resolving these problems does not mean finding the final truth rather it helps the decision maker to address the complex situation through handling the data to make advancement towards getting a solution (Omann, 2004).

Multi-Criteria Decision-Analysis (MCDA) investigates methods that are discrete and has relations that are outranking, that is comparing options through evaluation to decide on which option is better than the other based on the criteria employed. It involves a process to promote transparency with the goal of arriving at a satisfactory solution.

2.4.1 A Typical MCDA Procedure Phases

Typically, the MCDA procedure involves the following phases (Saaty& Vargas, 2013; N. Smith et al. 2016).

i. Organizing the decision context
ii. Defining the objectives and the evaluation criteria
iii. Generating and defining the options
iv. Developing the evaluation matrix
v. Identifying the preference of the decision makers and stakeholders
vi. Selecting and applying the aggregation method
vii. Interpreting the result and applying the sensitivity and robustness analyses.

2.4.2 MCDA Methods for Estimating Criteria Weights

MCDA's implementation in any decision-making process is mainly to determine the criteria weight whereby the criteria weight can be determined either directly (this is when alternatives are ranked between the highest/best alternative and lowest/worst alternatives or indirectly (this is used when there is uncertainty or incomplete information associated with decision making). One of the direct methods used is Simple Multi-Attribute Rating Technique (SMART/SWING) while the indirect methods are among others, Discrete Choice Experiments (DCEs), best-worst scaling, and Analytic Hierarchy Process (AHP), Potentially All Pairwise Ranking of All Possible Alternatives (PAPRIKA), and Technique for Order Preference by Similarity and Ideal Solution (TOPSIS) (Sullivan, 2012; Van Til, 2014). Four of the techniques are discussed here.

2.4.2.1Simple Multi-Attribute Rating Technique (SMART / SWING)

SMART/SWING method uses interval through acknowledging every alternative without special consideration to the most or the least alternative. Decisions can be made using the interval to weight ratio in accounting for uncertainties in judgment, thatismaking a judgment on interval estimation, not on point estimation. Also, it has the possibility for allowing interval estimation for the referenceattribute, for example, whenweare facedwith a situation ranging from very good to verybad (Danielson, Ekenberg, Larsson, &Riabacke, 2014;Musajoki, Hamalainen, & Salo, 2005).

SMART works in two stages. Firstly, the criteria are ranked according to importance, from the most important to the criteria that are least important. SMART givesten points to the least essential alternative, then more points are assigned to the other alternatives according to their importance. The weight of the alternatives should reflect the range and importance of an alternative. Edwards and Barron (1994) originally developed SMART to include SWING and extended it to reducing the required input by the decision maker. SWING considers the level of criteria when evaluating the weight of the criteria in a hypothetical alternative where all the criteria are at their worst level, and the decision maker is asked to identify the most important to be moved from worst to the best level. Higher points, say one hundred are given to the most important alternatives with fewer points given to other alternatives, and the process continues until the last criteria are assigned and ranked accordingly to their weight scores to other alternatives.

2.4.2.2 Discrete Choice Experiments (DCEs)

This technique is used when the decision maker is to choose between two or more choices (Ryan, Gerard, & Amaya-Amaya, 2007). The weights here are estimated using statistical tools. The choice sets made by the decision maker depends on the total number of attributes, levels and experimental designs. With the increase in the number of attribute combination, the number of potential profiles increases exponentially. A factorial design is mostly used where a subset of all possible selected attributes is combined to reduce the number of choices presented to reduce the overload of information.

Other statistical estimation tools such as probit, logit, and also the multinomial logit are also used to produce set of weights (Clark et al. 2014). Respondents' group characteristics regarding interaction can also be included in the statistical model by taking the average weights of all the responses.

2.4.2.3 Technique for Order Preference by Similarity and Ideal Solution (TOPSIS)

TOPSIS, first developed and introduced by Hwang and Yoon (1987), is one of the most classical Multiple Criteria Decision Making (MCDM) methods (Chakraborty &Yeh, 2009; Jahanshahloo, Lotfi, &Izadikhah, 2006; Lai, Liu, & Hwang, 1994). It is based on the idea that the chosen alternative should have the shortest distance from the positive ideal solution and on the other side the farthest distance of the negative ideal solution. It is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalizing scores for each criterion, and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion.

TOPSIS has been used extensively to solve various practical MCDM problems for the following reasons: (a) Comprehensive mathematical concept, (b) Easy usability and simplicity, (c) Computational efficiency, and (d) Ability to measure alternative performances in simple mathematical form. (Behzadian, Otaghsara, Yazdani& Ignatius, 2012).

2.4.2.4 Potentially All Pairwise Ranking of All Possible Alternatives (PAPRIKA)

The PAPRIKA method is based on users expressing their preferences with respect to the relative importance of the criteria or attributes of interest for the decision or choice at hand by pairwise comparing (ranking) alternatives. In MCDM applications, PAPRIKA is used by decision-makers to determine weights on the criteria for the decision being made, representing their relative importance. Depending on the application, these weights are used to rank, prioritize or choose between alternatives. It can be applied when a decision maker is faced with a series of hypothetical choices, and a decision choice is required to trade-off one characteristic for another. An ordinal preference is made by the decision makerby choosing which of the alternatives should be considered first. Then several trade-off questions are posed to each decision maker, by changing the order of the questions so that each decision maker will answer the questions in a different order. The changing the order of the question can eliminate or reduce potential order bias on the average (Sullivan, 2012). Various levels of criteria can be included in a study, but with an increase in the number of criteria and levels, the number of combinations will also increase exponentially.

2.4.2.5 Analytic Hierarchy Process (AHP)

AHP is a decision-making method for prioritizing alternatives when multiple criteria must be considered. It has been applied to a wide variety of decision areas, including economics and management (selection of alternatives in purchase and supply) (Nydick& Hill, 1992; Podvezko, 2009), in health for deciding on alternative treatment available (Jain & Rao, 2013), and in computer and engineering (Kumar, 2014). This method allows the decision maker to structure complex problems in the form of a hierarchy, or a set of integrated levels. Generally, the hierarchy has at least three levels: the goal, the criteria, and the alternatives. For instance, within issues related with the organization strategy in selection, the goal is to rank the strategies from best overall to the least overall strategy. Examples of the criteria that might be used are quality, the budget allocated, efficiency, and delivery. The alternatives are the different strategies employed by the organization.

AHP offers a methodology to rank alternative courses of action based on the decision maker's judgments concerning the importance of the criteria and the extent to which each alternative meets them. The problem hierarchy lends itself to an analysis based on the impact of a given level on the next higher level (Mukherjee, 2014). The process begins by determining the relative importance of the criteria in meeting the goals. Next, the focus shifts to measuring the extent to which the alternatives achieve each of the criteria. Finally, the results of the two analyses are synthesized to compute the relative importance of the alternatives in meeting the goal.

The comparison of elements at each level of the hierarchyis done in a pairwise manner which then provides the estimation of the criteria weights or alternatives about the overall goal of the decision-making process. The hierarchies as demonstrated in Figure 2.1 below (Sullivan, 2012):

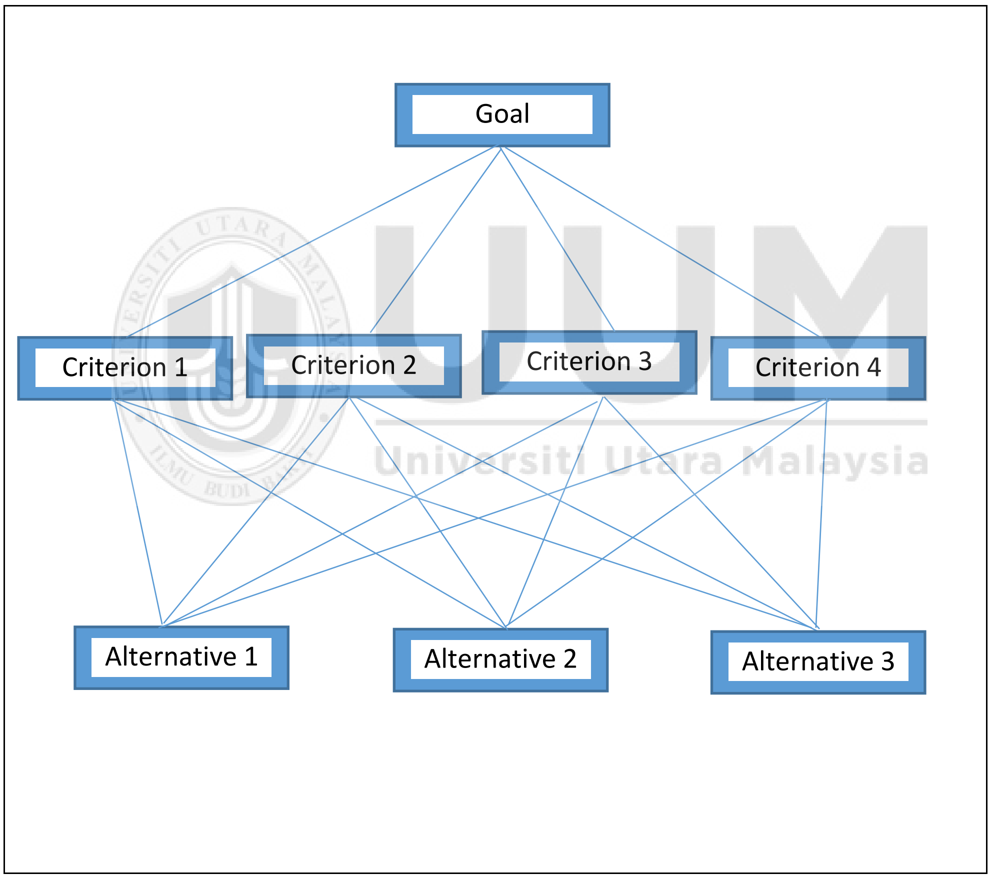

Figure 2. 1*A simple AHP hierarchical process*

From the diagram above the estimation of the weight of an alternative will be determined by the decision maker to show the importance of an alternative to another regarding criteria represented with lines from a criterion to each alternative. Two pairwise comparison exercises will be done. The first one will be the pairwise comparisons among the criteria. The second one will be the pairwise comparisons between alternatives concerning each criterion. The pairwise comparisons will be based on the scales as demonstrated in Table 2.5(Sullivan, 2012):

Table 2. 4
AHP Nine-Point Intensity Scale

INTENSITY OF IMPORTANCE	DEFINITION
1	Equal importance.
3	Moderate importance.
5	Strong importance.
7	Very strong importance.
9	Extreme importance.
2,4,6,8	Compromises between the levels.
Reciprocals of above	In comparing criteria *i* and *j*, if *i* is moderately more important than *j* (i.e. intensity of 3), then *j* is moderately less important than *i*(i.e. intensity of 1/3).

A comparison matrix is then constructed as the next step using preferences for each of the alternatives to determine a set of relative priority amongst the *n* different alternatives and a total of $n(n-1)/2$ judgments are required. The estimation of the principle Eigenvector determines the weights of the alternatives. For accuracy of judgment, a consistency ratio is also calculated. The alternative weights and consistency ratio can be estimated automatically through AHP software such as Expert Choice or Super Decisions (Huang, Zhang, Lee, Chew, & Chen, 2016).

The significantdisadvantage of AHP is a rank reversal, which occurs when adding or removing a new alternative. However, through the use of ideal mode AHP, ranks are preserved or kept constant when an alternative is being added or removed (Saaty, 2008). The other major problem with the AHP process is the consistency of the pairwise comparison matrices. To address this problem a proposed revised-AHP approach by (Baihuwaisl, 2013) managed to solve the issue.

2.4.2.6 Balhuwaisl's Revised-AHP Approach

Balhuwaisl (2013) introduced a new approach of utilizing Saaty's Likert Scale ranging from 1 to 9 and combined that with the existing pairwise comparisons in AHP. In his approach, instead of asking decision makers to directly perform pairwise comparisons among the attributes, the decision makers will be asked to only rank the level of importance of each attribute in determining the final selection of the decision alternatives using Saaty's Likert scale ranging from 1 (least significant) to 9 (extremely important). Later, the evaluations from the Likert Scale are converted into Saaty's pairwise comparison tables. By doing so, Balhuwaisl managed to show that the pairwise comparisons will always be consistent regardless of the number of attributes being analyzed.

Specifically, Balhuwaisl's approach is as follows: Suppose we have *N* criteria. Each evaluator must then rate the level of importance of each criterion in determining the weight of that criterion towards the final goal. Suppose that the evaluator rates criterion

i as $w_i$and criterion j as w_j. Then c_{ij}which are the pairwise comparison value between criterion $i$and criterion j will be determined as follows:

Let $b = w_i - w_j$

If $b > 0$ then $c_{ij} = b+1$

If $b = 0$ then $c_{ij} = 1$(2.1)

If $b < 0$ then $c_{ij} = 1/(1-b)$

Once the pairwise matrix is obtained, the weight for each criterion will be calculated using the existing AHP technique. The process, of course, includes the consistency test.

In situations where decisions need to be made with alternatives whether to fund or not to fund specific activities or strategies when dealing with complex situations, one of the suitable and convenient methods to use is linear or integer programming. It is suitable for problems with multiple constraints such as project selection and resource allocation problem (Karande, 2013).

2.5 Integer Programming (IP)

Integer Programming (IP) is a mathematical technique applied in mathematical and computer modelling as well as simulations to find the best possible solution in planning, routing, scheduling, assigning, designing, and allocation of limited resources to achieve maximum benefit with minimum cost. In the case of planning and resource allocation, IP is used for priority setting to determine which set of activities, projects or strategies to be implemented based on the budget allocated tomaximize or minimize the intended objective (Uctug&Yukseltan, 2012). It is a subset of linear programming (LP). The general IP model for planning and resource allocation may appear as follows:

Maximize/Minimize $\sum_{j=1}^{n} c_j x_j$

Subject to:

$$\sum_{j=1}^{n} a_{ij} x_j = \text{or } \leq \text{or } \geq \ b_i \ (i = 1,2, \ldots, m) \quad (2.2)$$

$$x_j \geq 0 \text{ and integer } (j = 1,2, \ldots, n)$$

This is called the (linear) integer-programming problem. It is said to be a mixed integer program when some variables are restricted to be integer but not all. Pure integer program is when all decision variables are integers(Solow, 2007).

In another scenario, the IP-model may have more than one objective function. These set of problems are called the multi-objective integer programming (MOIP) problems. The objectives may involve some conflicting objectives. In such situations, it is difficult to find a single solution that can optimize these conflicting objectives simultaneously. Two common techniques to solve MOIP are the preemptive method and the weights method (Taha, 2007).

2.5.1 Preemptive Method for MOIP

The preemptive method optimizes the objective functions one at a time starting with the highest-priority objective and ending with the lowest-priority objective, never degrading the quality of a higher-priority objective (Gass, 1987). Specifically, in this method, the decision maker must rank the objectives in order of importance or preference. For instance, given a p-objective situation, the objectives of the problem can be written as (Taha, 2007):

Maximize/Minimize $f_{i1}(x)$ (Highest priority)

Maximize/Minimize $f_{i2}(x)$ (2nd highest priority

…

Maximize/Minimize $f_{ip}(x)$ (Lowest priority)

Next, solve IP_{i1} to optimality. If the optimal solution for IP_{i1} is obtained (say the optimal solution is *fopt1*) then continue to solve for IP_{i2}. To ensure that the solution for IP*i2* will not degrade the optimal solution for IP*i1*, the constraint IP*i1* $\leq$ *fopt1* must be added to the model for IP*i2*. As long as the model is still feasible, repeat the process until all the objectives are covered. Otherwise, if the model at the current priority is infeasible, stop the process.

2.5.2 Weights Method for MOIP

The weights method forms a single objective function consisting of the sum of weights of variables of the goals (Winston & Goldberg, 2004). Suppose that the MOIP model has p objectives and that the ith objective is given as

Maximize/Minimize $f_i(x)$, $i = 1, 2, \ldots, p$

The combined objective function used in the weights method is then defined as

Maximize/Minimize $z = w_1 f_1(x) + w_2 f_2(x) + \ldots + w_p f_p(x)$

The parametersw_i, $i = 1, 2, \ldots, p$ are positive weights that reflect the decision maker's preference regarding the relative importance of each objective and the determination of the specific values of these weights is subjective (Taha, 2007).When an IP-model or an

MOIP-model can produce any solution at all or in this case is infeasible, the problem can be solved using goal programming.

2.5.3 Goal Programming

Goal Programming (GP) is a branch of multi-objective technique, and it is also a multi-criteria decision-making (MCDA) tool. It can be regarded as a generalization or an extension of LP or IP that deals with multiple objective measures. In this type of programming, each of the measures is given a target or goal aimed to be achieved. Goal programming is used to achieve the following type of problems (Adhikari, 2009):

i. To determine the required source used to achieve the desired set of objectives
ii. To determine the degree of attainment of the specified goal with available resources.
iii. To provide the best solution under varying amount of resources and priority of the set goal.

The general model for GP is presented as

$$\text{Min } Z = \sum d_i^+ + d_i^-$$

Subject to the goal constrains

$$a_{ij}x_j - d_i^+ + d_i^- = b_i \quad for\ i = 1, 2, \dots, m \qquad (2.3)$$

With $d_i^+,\ d_i^-,\ x_j \geq 0\ for\ i = 1, 2, \dots, m\ and\ j = 1, 2, \dots n.$

Where

Z = objective function

a_{ij}= coefficient associated with variable j^{th} in the i^{th} goal

x_j= j^{th} decision variable

b_i= right hand side value for constraint i

d_i^+= overachieved goal (positive deviational variable)

di^-= underachieved goal (negative deviational variable)

Table 2. 5
Procedure for Achieving a Goal

MINIMIZED	GOAL	ACHIEVED
d_i^+	Minimize overachievement	$d_i^+ =0$
d_i^-	Minimize underachievement.	$d_i^- = 0$
$d_i^+ + di^-$	Minimize both underachieved and overachieved	$d_i^+ = 0, d_i^- = 0$

2.5.4 Lexicographic Goal Programming

Lexicographic programming is a programming technique used to solve a series of integer programs, with the priority order, visibly clear among goals or target to be achieved. Decisions are made through direct comparison of objectives to be measured priority indicating the degree of importance, and is regarded as a single form to achieve the required objective (Chang, 2007; Ignizio, 1983).

Assuming no two goals have the same priority, the goals are given or assigned ranks, and the ranks are regarded as preemptive priority factor. In this case, the P_1 goal represents the most important priority, andP_2has the next important priority, and so on such that,

$$P_i > P_{i+1}$$

The model is represented as,

$$Z = \sum_{i=1}^{m} P_i d_i^+ d_i^-$$

Subject to, goal constraint

$$a_{ij}x_j - d_i^+ + d_i^- = b_i \quad for\ i = 1, 2, \dots, m \qquad (2.4)$$

With $d_i^+,\ d_i^-,\ x_j\ \geq 0\ for\ i = 1, 2, \dots, m\ and\ j = 1, 2, \dots n.$

2.5.5 Weighted Goal Programming

When a decision maker considers a direct comparison of the objective, the weighted goal programming is used. The deviant variables are attached or given weight at the same priority level to show the relative importance of each deviation. The general model is given as

$$Min\ Z = \sum_{i=1}^{m} w_i^+ d_i^+ + w_i^- d_i^-$$

Subject to the linear goal constraint,

$$\textstyle\sum_{i=1}^{m} a_{ij}\, x_j - d_i^+ + d_i^- = b_i \quad for\ i = 1, 2, \dots, m \qquad (2.5)$$

With $d_i^+,\ d_i^-,\ x_j\ \geq 0\ for\ i = 1, 2, \dots, m\ and\ j = 1, 2, \dots n.$

Wherew_i^+andw_i^- are non-negative constants representing the weight assigned to the respective positive and negative deviational variable. The weight assigned maybe real numbers, and the greater the weight, the greater is its importance (Chang, 2007; Ignizio, 1983).

In some instances, we may be faced with a combination of both the preemptive priority and weighting problem. The general model to use for such problems is,

$$\sum_{i=1}^{m}\sum_{k=1}^{n} P_i(w_{ik}^{+}d_i^{+} + w_{ik}^{-}d_i^{-})$$

Subject to the linear goal constraint,

$$\sum_{i=1}^{m} a_{ij}\, x_j - d_i^{+} + d_i^{-} = b_i \quad for\ i = 1, 2, \dots, m \tag{2.6}$$

With $d_i^{+},\ d_i^{-},\ x_j\ \geq 0\ for\ i = 1, 2, \dots, m\ and\ j = 1, 2, \dots n$.

Where $w_{ik}^{+}w_{ik}^{-}\ \geq 0$representing the relative weight to be assigned to each *k= 1, 2,…, n* that is, different classes within the *i^th^* category.

2.6 Similar Previous Studies on Budget Allocation on Programs for Universities

There are some research works done on budget allocation activities to improve the performance of university. Some of the researches are on the budget allocation while some are on improving the university rating. Wan (2012) for example, proposed a Data Envelopment Analysis (DEA) framework as a complementary technique to measure performance in Malaysian universities based on the Malaysia Research Assessment System (MYRA) and SETARA rating. The proposed frameworks looked at both research activities and undergraduate teaching activities as they relate to MYRA and SETARA rating, respectively. The proposed technique along with the existing MYRA and SETARA rating will provide a more integrated procedure to improve the university performance. However, this research ignores the budgetary aspect of improving the university system.Other studies are on the budgetary allocation based on the performance of a university (Tahar 2013; Larsen, 2013), and the university budget allocation based on the university's history of past performances (Hilburg, 2010; Pedersen 2017; Johnston, 2002; Aziz, 2015; Reome, 2017; Chatfield, 2017).

Tahar (2013**)** used a performance-based budget allocation. The study called for universities to improve its productivity by suggesting the evaluation from the public to control the quality of teaching and research in the university. Considering the fact that the university is not established for profit making, the traditional economics techniques such as productivity, regarding the ratio of inputs to output in an organization was not used to measure the efficiency. Hence, the use of budget and resource allocation based on the evaluation from the public was used as an instrument to improve the quality and productivity of the university.However, the major disadvantage of performance-based budget allocation is, it is used when faced with a single output (performance such as the number of graduates with first class, number of citations, number of research publications), thus not applicable when we have multiple outputs. It can only be used in a multiple output analysis when we sum the total benefits generated through various costs (inputs).

On the other hand, Hilburg's (2010) budgetary allocation in the university was based on budget allocation by considering the programs for three previous years at the university. The programs were classified as effective, adequate, or adequately effective, and assessed based on the university management perspective of effective, adequate and adequately effective. Ultimately, the budget allocation was based on the program that has a higher rating from the university management team whereby the higher budget is being allocated to programs rated high inadequacy and effectiveness. The study conducted for three years was compared to identify the discrepancy in performance about the total budget allocated for the three years and adjustment was made accordingly.

Prior to that Johnston (2002) researched on Strategic University Resource Allocation Model considering the past procedure for budget allocation in the university (history based), almost similar to Hilburg's study as cost to be challenged. This study described the development and implementation of budget allocation within a university going through significant changes on strategic directions. In this case, history-based budget allocation was considered as a robust tool used to support changes in strategies. This budget allocation procedure is regarded as performance-based budget allocation.

Meanwhile, Pedersen (2017)suggested a procedure known as student-based funding model giving priority strategies. The student funding model based on consultation with senior management staff of the university on funding strategies used to improve performance as well as to generate funds, improve academic quality and efficiency. The model formulation varies between faculties as it relates to their research, fee income generation, and high-demand student programs.

Reome (2017) studied on university budget models, whereby the process used for this budget allocation is regarded as strategic-based budgeting. The budget allocation evolved from a response to government policies, changes in students demands, administrative demands, institutional priorities based on strategic plans aimed at achieving high student quality, increasing the graduation rate and retention of the best students as new staff (https://www.ipb.uwo.ca). The major strength of this budgetary process has demonstrated the ability to change as the government policies changes accommodating various components that come with increment in the funding; it uses the performance-based model as a process of the needs between the academic priorities and available resources while the major weakness is communication challenges for the management staff. Due to limitation in allocation of funds from the government, there will be need for transparency in budget planning, to balance between limited budget allocation and budget allocation decision making. This budget allocation was carried out, giving little or no regards to management staff, thus limiting the possibility of getting fresh ideas regarding new strategies to be executed from the management.

Last, but not least, Chatfield (2017) researched on budget allocation based on three different funding strategies. The first funding wasbased on the total budget allocated to the university in the contract between university and ministry of education, the second funding, performance funding, wasbased on the performance in both research and teaching, while the third model was the strategic funding where by the component can differ based on the university whereby the two first models were combined into one model.

The study that is closely related to our present research is the study conducted by Aziz (2015). It focuses the development of a mathematical model for faculty budget planning aimed at optimizing the faculty utilization of budget allocation. The strategies proposed was based on the analysis of past quarterly budget allocation (history-based budget allocations), used to maximize the efficiency of each faculty budget allocation. In this case, the quarterly allocation was referred to as the percentage allocation for each quarter, with two different formulations. Firstly, to determine the proportion of available budget and secondly, to determine the proportion from quarterly budget to be allocated to each project. The mathematical programming model used was based on the history of budget allocation. The models proposed by Aziz (2015) are:

Proposed Model 1: The horizontal line approach. This model considered equally likely proportion allocations for all quarters.

Proposed Model 2: The staircase method. This model followed a certain decreasing pattern with the first quarter having the highest budget allocation and the fourth having the least allocation.

Proposed Model 3: The zigzag strategy. This model described budget proportion allocation that decreases and increases according to the quarter. A linear model was used to determine the total amount used for faculty's budget that should be allocated for each quarter. The model formulation is stated below.

$$T_i = \sum_{j=1}^{4} A_{ij} = \sum_{j=1}^{4} P_{ij} \, T_i$$

Where i=1,2,..., n and j=1,2,3,4

$$P_{ij} = \frac{A_{ij}}{T_i} * 100\%$$

$P_{ij} \in [0,1]$ where $\sum_{j=1}^{4} P_{ij} = 1$ (2.7)

and

$P_{ij}$is the budget proportion allocation (in per cent) for faculty i in quarter j allocated.

A_{ij} is the proposed quarterly budget allocation.

T_i is total amount of the faculty budget allocated for each quarter.

P_{ij} is to be determined based on the proposed models. The budget proportion allocation (in per cent) for faculty i in quarter j allocated for project (vote) k,C_{ijk} is determined as the following:

$$\sum_{k=1}^{m} V_{ijk} = G_{ij} \quad (2.8)$$

Where i=1,2,…,n and j=1,2,3,4 k=1,2,…,m

G_{ij} = adding previous balance from previous quarterly allocation and the proposed quarterly allocation for the next quarter $(B_{i-1,j}+A_{ij})$.

V_{ijk} =project vote k in faculty i and quarter j.

Therefore

$$\sum_{K=1}^{m} G_{ij}C_{ijk} = \sum_{k=1}^{m} V_{ijk} = G_{ij} \quad (2.9)$$

Where i=1,2,…n, j=1,2,3,4. and k=1,2,…m

Determine quarterly history proportion given vote allocation C_{ijk}(previous quarterly proportion of a given project k) by

$$C_{ijk} = \frac{V_{ijk}}{\sum_{k=1}^{m} V_{ijk}} = \frac{V_{ijk}}{G_{ij}} \quad (2.10)$$

Where i=1,2,…, n, j=1,2,3,4. and k=1,2,…m

C_{ijk} = previous quarterly proportion of a given project k

CalculateG_{ij}(G_{ij} = adding previous balance from previous quarterly allocation and the proposed quarterly allocation for the next quarter $(B_{i-1,j}+A_{ij})$) whereby

$$G_{ij} = \begin{cases} A_{ij} & i = 1,2,\dots n, \quad j = 1 \\ A_{ij} + B_{ij-1} & i = 1,2,\dots n, \quad j = 2,3,4. \end{cases}$$

$$G_{ij} = \begin{cases} P_{ij}T_i & i = 1,2,..n, j = 1 \\ P_{ij}T_i + B_{ij} & i = 1,2,\dots n, \ j = 2,3,4 \end{cases} \qquad (2.11)$$

Where the quarterly balance of faculty i in quarter j, B_{ij} is equal to total balance after utilization of faculty i in quarter j for vote k,b_{ijk}:

$$B_{ij} = \sum_{k=1}^{m} b_{ijk}$$

Where i=1,2,…, n, j=1,2,3,4.

$$X_{ij} = \sum_{k=1}^{m} Y_{ijk} \qquad (2.12)$$

Hence

$$B_{ij} = G_{ij} - X_{ij}$$

Where i=1,2,…n, j=1,2,3,4.

X_{ij} the proportion used in quarter j for faculty i.

Y_{ijk} yearly (sum of all the quarterly allocation)

Thus, the objective function of the model is to optimize the variation between allocation and minimizing the cost. The second step is determining the allocation proportion in percentage for faculty i in j quarter for voted project k.

The study by Aziz (2015) which was conducted on a quarterly basis is the closest to the process adopted for this present research whereby all the decision variables to be determined all are based on previous budget allocation, performance and also strategic based funding. The first difference in Aziz's approach was it was done on a quarterly basis having four different budget allocations on faculty strategies based on opinion of the management staff while in this thesis the budget allocation model is proposed based on a yearly basis.

Secondly, the model proposed by Aziz is to optimize the variation between allocation and minimizing the value while this thesis employed all the university strategies that are involved in budget allocation towards improving the university SETARA rating. The model formulation for this thesis is first to determine the actual cost needed to achieve full SETARA rating by the university, secondly, a model to minimize the limited available resources on the existing strategies aimed at achieving the required points set by SETARA. Finally,a third model was developed to minimize the limited available resources on both new and existing strategies aimed at achieving the required points set by SETARA.

Despite numerous literature on improving the performance of higher education, the study on performance monitoring, and tie the performance with the budget allocation involving available resources has not really been put into consideration.

2.7 Summary

Budget management is an essential aspect of a university system. Budgets are essentially used to control the efficiency of operations in university organizations effectively. To achieve the university KPIs, the process of allocating funds to achieve the targeted KPIs, and consequently the strategies to be executed, must be given high priority. Identification of the most effective strategies to achieve the KPIs, the allocation and re-allocation of priorities concerning the strategies, and the proper monetary funding in the form of objective budget allocation may improve the strategic outcome significantly.

The budgetary allocation on the KPIs and strategies to be executed to achieve the KPIs should be able to answer these following questions:

i. Have we succeeded in improving the performance of the university through the strategies set?
ii. Is the cost allocation for all the strategies effective?
iii. Should we allocate or relocate funds to other existing or new strategies/activities?

The implementation of PBMA (later be enhanced in this thesis to suit our problem, and hence will be referred to as adjusted-PBMA) will help in the identification, evaluation, measurement, and prioritization of a specific strategy to achieve a specific KPI with transparency and cost-effective. The adjusted-PBMA technique, through the allocation and re-allocation of the budget for strategies to achieve the stated goal and objective of improving the performance of university, is result oriented, with optimization of the university performance becoming the main aim. The identification of the most important strategies to achieve the stated objective form the foundation of the overall evaluation process. It also has the strength to focus on result and accomplishment and is a straightforward approach of measurement and evaluations which in the end helps to promote prioritization of resources to meet the performance criteria.

A major consideration for improvement in performance involves selection and use of indicators or measures of performance. Such measures are representatives of factors that improve the performance of the university, the university's operational management, and the university's financial performance (Arora & Kaur, 2015). This can be done through CCA. In this case, CCA will provide information on the cost of prioritizing interventions to the existing strategies, thus helping to make priorities to potential cost saving alternatives associated with the future strategies to achieve the KPIs. CCA is chosen since the results are represented in a disaggregated format with the estimation of the cost of each intervention or strategy done separately. Furthermore, it has no restriction regarding units of measurement since the interventions are evaluated separately. Therefore, CCA can include measurement of objects or items as well as human.

Due to finite resources, important choices are made through the use of economic evaluators. An economic evaluator is an analytical tool used in assessing the social desirability of a particular program about other alternatives (Drugs & Health, 2014; Mak, 2005) and helps in assisting a decision maker on the decision-making process. The outputs are usually expressed in monetary terms, and the effects of the output are said to be the benefits. Next, the prioritization of the strategies based on specific objectives will be conducted using the CCA method to optimize the achievement of the KPIs and the objectives giving priority to the strategies one at a time, starting with the strategy with the highest priority and ending with the strategy with the lowest point. Finally, having prioritized the strategies, IP-model will be used to for budget allocation decision.

Having reviewed all the necessary theories, models, and previous studies, the development of the new adjusted-PBMA is explained in Chapter Three.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

In this Chapter, the methodology employed throughout this research is elaborated. The Chapter starts with the research framework, which is then followed bb the description of the proposed adjusted-PBMA and ends with the flowchart for adjusted-PBMA.

3.2 The Research Framework

The research framework for this study involved these following activities:

i. Activity 1: Reviewing relevant literature to help understand and solve the problem in this study. The literature on PBMA, university strategic plan, SETARA rating instrument, MCDA, marginal analysis formulation, suitable mathematical models, and related previous studies were done and elaborated in Chapter 2.

ii. Activity 2: Identifying the research gap which involves the aspects of the existing PBMA that can be improved.

iii. Activity 3:Developing the adjusted-PBMA framework.

iv. Activity 4: Conducting a case study on UUM to test the feasibility of the proposed adjusted-PBMA. The 2016 UUM Strategic Plan and the officer in charge of the SETARA rating agendum were referred for the data collection activities.

v. Activity 5: Writing the final report.

The research framework is summarized in Figure 3.1.

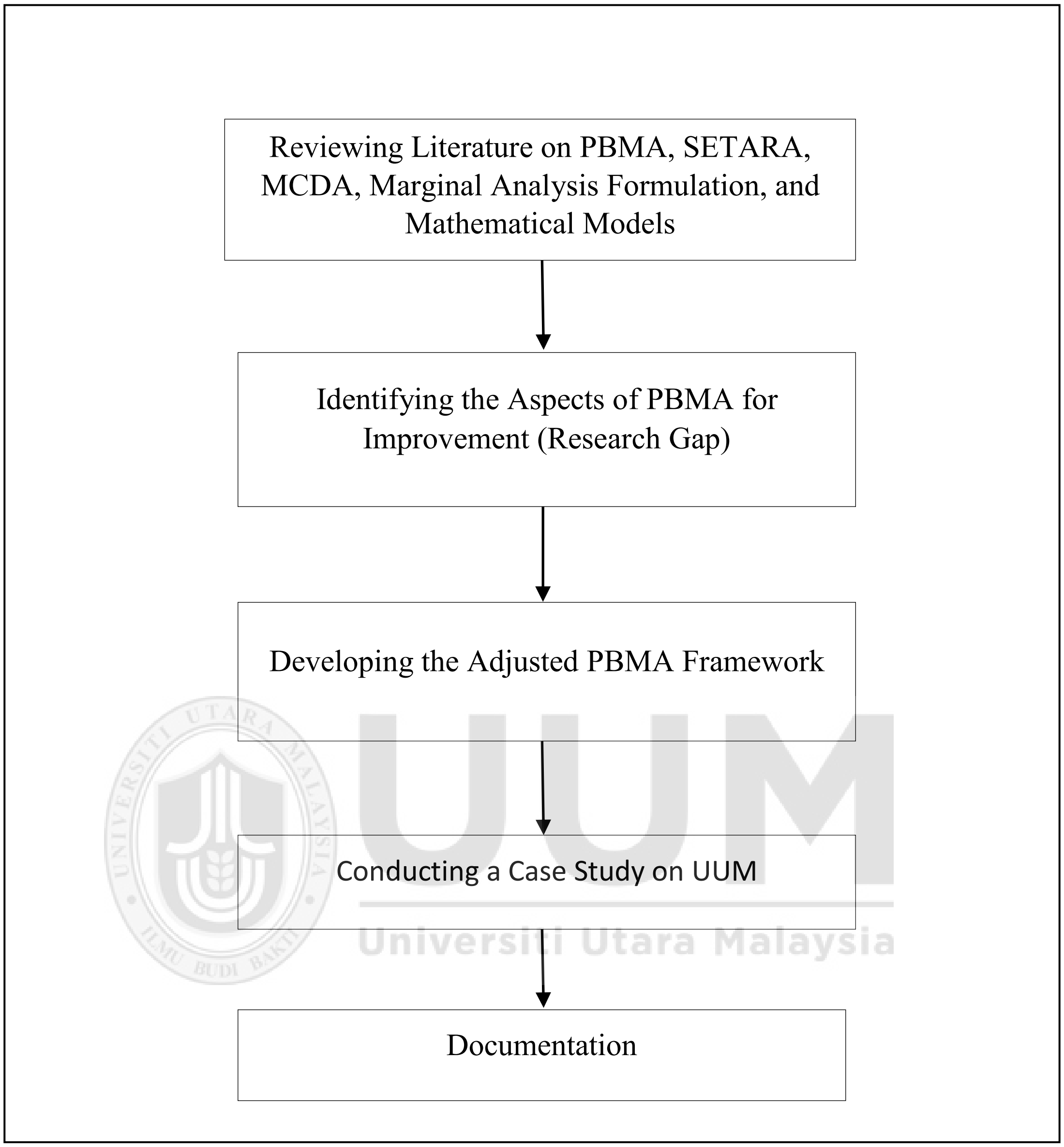

Figure 3.1 *Flow Chart for Research Framework*

3.3 The Existing PBMA and Changes to be Made Under Adjusted-PBMA

To develop the adjusted-PBMA the first two steps under PBMA were maintained. Step 3 and step 4 under PBMA were combined into one step. The other three steps, step 5, step 6, and step 7 were modified slightly. The modifications made are as listed in Table 3.1.

Table 3.1
PBMA and Proposed-Changes Under Adjusted-PBMA Steps.

	PBMA Steps		Adjusted-PBMA Steps
1	Determining the goal, aim and scope of setting the program.	**1**	Maintain
2	Identifying the available resources for funding a particular program, that is the program budget.	**2**	Maintain
3	Conducting marginal analysis by taking the viewpoints of stakeholders, managers, service providers, consumers, and head of organizations in setting priorities.	**3**	Calculating the marginal analysis for the strategies/activities using a quantitative formula as the measure of marginal contribution of each strategy/activity towards the final goal. In this thesis, the marginal cost of running/executing an activity/strategy and CCA to calculate the contribution of each activity's achievement with respect to the SETARA point were applied.
4	Determining the decision-making criteria to be used to maximize benefits or profits as well as minimization of cost.		
5	Identifying the options in the program for which choices are to be made. These can be achieved through the process of MCDA.	**4**	Determining the decision-making criteria to be used to maximize benefits or profits as well as minimization of cost and introducing new strategies. In this thesis, the decision-making criterion used was the SETARA points.
6	Evaluating the potential impact of investment and disinvestment regarding benefit and cost.	**5**	Evaluating the potential impact of investment and disinvestment regarding benefits and cost. This can be achieved by developing suitable mathematical model to identify which set of old strategies/activities that should remain and which set of the newly proposed strategies/activities that should be implemented.
7	Validating the outcome and the decision made in the process of allocation and re-allocation of funds according to the ratio of cost-benefit.	**6**	Validating of the proposed models with suitable validation techniques and conducting what-if analysis.

3.4 The Adjusted-PBMA Framework

As previously mentioned in the literature review section, Mitton et al. (2014) outlined seven steps for PBMA:

i. Determine the goal, aim and scope of setting the program
ii. Identify the available resources for funding a particular program that is the program budget.
iii. Conduct marginal analysis by taking the viewpoints of stakeholders, managers, service providers, consumers, and head of organizations in setting priorities.
iv. Determine the decision-making criteria to be used to maximize benefits or profits as well as minimization of cost.
v. Identify the options in the program for which choices are to be made. That is through the process of MCDA.
vi. Evaluate the potential impact of investment and disinvestment regarding benefit and cost.
vii. Validate the outcome and the decision made in the process of allocation and re-allocation of funds according to the ratio of cost-benefit.

The adjusted-PBMA to suit our problem in this thesis involves six main steps as shown in Table 3.1. The steps for the adjusted-PBMA will be elaborated in this section step by step,

3.4.1 Step 1: Determining the Goal, Aim and Scope of Setting the Program

The goal of the adjusted-PBMA for the university budget allocation problem is to propose a framework, considering the limited availability of resources for managing the university strategic plans with much attention on the cost of achieving the best performance with the little availability of resources. This could be achieved by

i. Considering different strategic activities used in the university starting with the review of existing strategies for cost-effectiveness with maximum benefit towards achieving the points as set by SETARA and
ii. Making decisions on whether to maintain existing strategies or allocating resources to new introduced strategies for the next cycle of the strategic plan.

3.4.2 Step 2: Identifying the Strategies Used for the Strategic Activities at Any University for the Purpose of SETARA Rating.

SETARA was first introduced in 2007 as an official rating system for Malaysian universities (SETARA, 2007) as a ranking/rating procedure in all public universities. The components of SETARA are grouped into three (3), with every indicator having a specified percentage which is then further grouped into domains as follows:

i. INPUT (40%) - Governance (12%), physical and financial resources (3%), and talent (5%).
ii. PROCESS (40%) - curriculum (40%).
iii. OUTPUT (40%) -quality of graduates (40 %).

The strategic activities used by the university in the year before the intended budget-planning year in achieving the specific assessment criteria set by SETARA rating must be listed and mapped according to the SETARA domain listed above. For example, if the budget-planning exercise if for 2017, then the strategic activities for 2016 must be listed.

3.4.3 Step 3: Calculating the Marginal Cost of Each Strategy

Before the marginal cost could be calculated, firstly, the actual cost of conducting each activity/strategy for the year before the intended budget-planning year must be identified. At the same time, the actual achievement with respect to each activity/strategy for that year must also be identified as well. These two informationsare crucial to guide us concerning the estimated cost for the same activities to be conducted for the budget-planning year as well as in calculating the marginal cost for each activity/strategy.

3.4.4 Step 4: Determining the Decision-Making Criteria to be used to Maximize Benefits or Profits as well as Minimization of Cost and Introducing New Strategies.

We proposed that the CCA-value criterion to be used for this decision-making model. Since the CCA-values can be determined using deterministic values instead of subjective preference values, we would not have to apply any of the MCDA techniques discussed in the literature review section. The CCA-value can be calculated as follows:

CCA-value for strategy/activity i = (Expected SETARA point/Expected SETARA output). (3.1)

3.4.5 Step 5: Evaluating the Potential Impact of Investment and Disinvestment Regarding Benefits and Cost

This can be achieved through the application of suitable IP models. However, before the models can be applied, the university management must first identify new potential strategies/activities that have not been included and implemented in the previous years, but have the potential to be included in the current strategic-plan year, and estimate the CCA-values for these new suggested strategies/activities. The IP-models can now be formulated using these following decision variables:

X_i= the number of existing strategies that should be implemented, $i = 1, 2, 3, \ldots, I$

X_{iNEW}= the number of new activities that should be implemented, $i = 1, 2, 3, \ldots, I$

At least six different IP-models can be developed based on six different objectives. These different IP-models are very useful to the university management for the purpose of doing further analysis on the effect on changes in some of the variables and parameters in the models on the final output, i.e. the number of strategies/activities to be implemented and the total budget needed. The six suggested IP-models are given in the next six sub-sections.

3.4.5.1 Model A: To Determine the Total Budget That a University Must Set Aside to achieve 80 percent SETARA Marks for All the Existing Strategies Involved.

Objective function:

Minimize Total Budget Required = $\sum_{i=1}^{I} c_i X_i$

Subject to

Constraint 1: Total points to be accumulated for each activity or person

$P_i X_i \leq Point_i$ For each i = 1, 2, 3, …,I (3.2)

Constraint 2: Total SETARA points needed for all the activities

$$\sum_{i=1}^{I} P_i X_i \geq 80\% \ SETARA\ Point$$

Xi ≥ 0 and integer.

Where

c_i = marginal cost for strategy/activity *i*

P_i = expected points that can be accumulated by each strategy/activity *i*

$Point_i$= total SETARA points to be accumulated for each strategy/activity *i*

3.4.5.2 Model B: To Determine the Total Budget that a University Must Set Aside to Achieve 90 percent SETARA Marks for all the Existing Strategies Involved.

Objective function:

Minimize Total Budget Required = $\sum_{i=1}^{I} c_i X_i$

Subject to

Constraint 1: Total points to be accumulated for each activity or person

$P_i X_i \leq Point_i$ For each i = 1, 2, 3, …, I (3.3)

Constraint 2: Total SETARA points needed for all the activities

$$\sum_{i=1}^{I} P_i X_i \geq 95\ \%\ SETARA\ Point$$

Xi ≥ 0 and integer.

Where

c_i = marginal cost for strategy/activity *i*

P_i = expected points that can be accumulated by each strategy/activity *i*

$Point_i$= total SETARA points to be accumulated for each strategy/activity *i*

3.4.5.3 Model C: To Maximize Total SETARA Points That can be Obtained Given the Amount of Budget Allocated by the University Management, for the Existing Strategies.

Objective function:

Maximize total SETARA points that can be accumulated = $\sum_{i=1}^{I} P_i X_i$

Subject to

Constraint 1: Total points to be accumulated for each activity/strategy

$P_i X_i \leq Point_i$ for each i = 1, 2, 3, …,I

Constraint 2: Total budget allocated by the university management

$$\sum_{i=1}^{I} c_i X_i \leq Total\ budget\ allocated \qquad (3.4)$$

$X_i \geq 0$ and integer

Where

c_i = marginal cost for strategy/activity *i*

P_i = expected points that can be accumulated by each strategy/activity *i*

$Point_i$= total SETARA points to be accumulated for each strategy/activity *i*

3.4.5.4 Model D: To Determine the Total Budget That a University Must Set Aside to Achieve 80Percent SETARA Marks for All the New-Introduced and Existing Strategies Involved.

Objective function:

Minimize Total Budget Required = $\sum_{i=1}^{I} c_i (X_i + X_{iNEW})$

Subject to

Constraint 1: Total points to be accumulated for each activity or person

$P_i(X_i + X_{iNEW}) \leq \ Point_i$ For each i = 1, 2, 3, …, I

Constraint 2: Total SETARA points needed for all the activities

$$\sum_{i=1}^{I} P_i(X_i + X_{iNEW}) \leq 80\%\ SETARA\ Point$$

X_i, $X_{iNEW} \geq 0$ and integer.

Where

c_i = marginal cost for strategy/activity i

P_i = expected points that can be accumulated by each strategy/activity i

$Point_i$ = total SETARA points to be accumulated for each strategy/activity i

3.4.5.5 Model E: To Determine the Total Budget That a University Must Set Aside to Achieve 90 Percent SETARA Marks for All the New-Introduced and the Existing Strategies Involved.

Objective function:

Minimize Total Budget Required = $\sum_{i=1}^{I} c_i(X_i + X_{iNEW})$

Subject to

Constraint 1: Total points to be accumulated for each activity or person

$P_i(X_i + X_{iNEW}) \leq \; Point_i$ For each i = 1, 2, 3, …, I (3.6)

Constraint 2: Total SETARA points needed for all the activities

$$\sum_{i=1}^{I} P_i(X_i + X_{iNEW}) \geq 90\% \; SETARA \; Point$$

X_i, $X_{iNEW} \geq 0$ and integer.

Where

c_i = marginal cost for strategy/activity i

P_i = expected points that can be accumulated by each strategy/activity i

$Point_i$= total SETARA points to be accumulated for each strategy/activity i

3.4.5.6 Model F: To Maximize Total SETARA Points That Can be Obtained Given the Amount of Budget Allocated by the University Management, for Existing and New-Introduced Strategies.

Objective function:

Maximize total SETARA points that can be accumulated = $\sum_{i=1}^{I} P_i \; (X_i + X_{iNEW})$

Subject to

Constraint 1: Total points to be accumulated for each activity/strategy

$P_i(X_i + X_{iNEW}) \leq Point_i$ for each i = 1, 2, 3, … ,I(3.7)

Constraint 2: Total budget allocated by the university management

$$\sum_{i=1}^{I} c_i(X_i + X_{iNEW}) \leq Total\ budget\ allocated$$

X_i, $X_{iNEW} \geq 0$ and integer

Where

c_i = marginal cost for strategy/activity i

P_i = expected points that can be accumulated by each strategy/activity i

$Point_i$= total SETARA points to be accumulated for each strategy/activity i

3.4.6 Step 6: Model Validation and What-if Analysis

The IP models are considered to be valid if the models can produce results that satisfy all the models' constraints. However, in order to show that the proposed models can actually help the university management to better manage their strategic plan in terms of the strategies/activities to be planned along with the total budget to be allocated ,the proposed model A, B and C for budget allocation on existing strategic activities and model D, E, and F for both existing and new introduced strategies will be further validated by comparing the achievements of the previous years, strategies/activities along with the total budget spent, with the results obtained from the proposed models for the new budget and strategic planning year.

Several what-if analyses could also be performed to see the effect of changes in some of the model parameters on the final solutions. Some of the possible what-if analyses include:

i. Changing the total budget allocated by the university management.

ii. Varying the percentage of SETARA points to be achieved.

iii. Changing the marginal cost for the activities/strategies.

3.5 Conclusion

The concept of PBMA mostly applied in the health sector was proposed in this research with slight adjustments, and the proposed adjusted-PBMA framework was presented in Section 3.2 to show its applicability in other organizations as well as in the university system by introducing some modifications to suit the organizations problem.

The proposed adjusted-PBMA framework is represented in six (6) steps as explained here and summarized here and in Figure 3.2:

i. Determine the goal, aim and scope of setting the program - The goal of the adjusted-PBMA is to propose a budgetary process in the allocation of funds to strategic activities in a university aimed at achieving the required point set by SETARA or any ranking or rating instruments.

ii. Identify the strategies used for the strategic activities in the university for the current strategic-planning year and the next strategic-planning year.

iii. Calculate the marginal cost of each strategy/activity.

~~iv.~~ Determine the decision-making criteria to be used to maximize benefits or profits. In this case, the SETARA points was chosen as the determining factor.

v. Evaluate the potential impact of investment and disinvestment regarding benefit and cost. Six different possible IP-models are proposed.

vi. Validate all the proposed models and once the models are validated, perform various suitable what-if analyses.

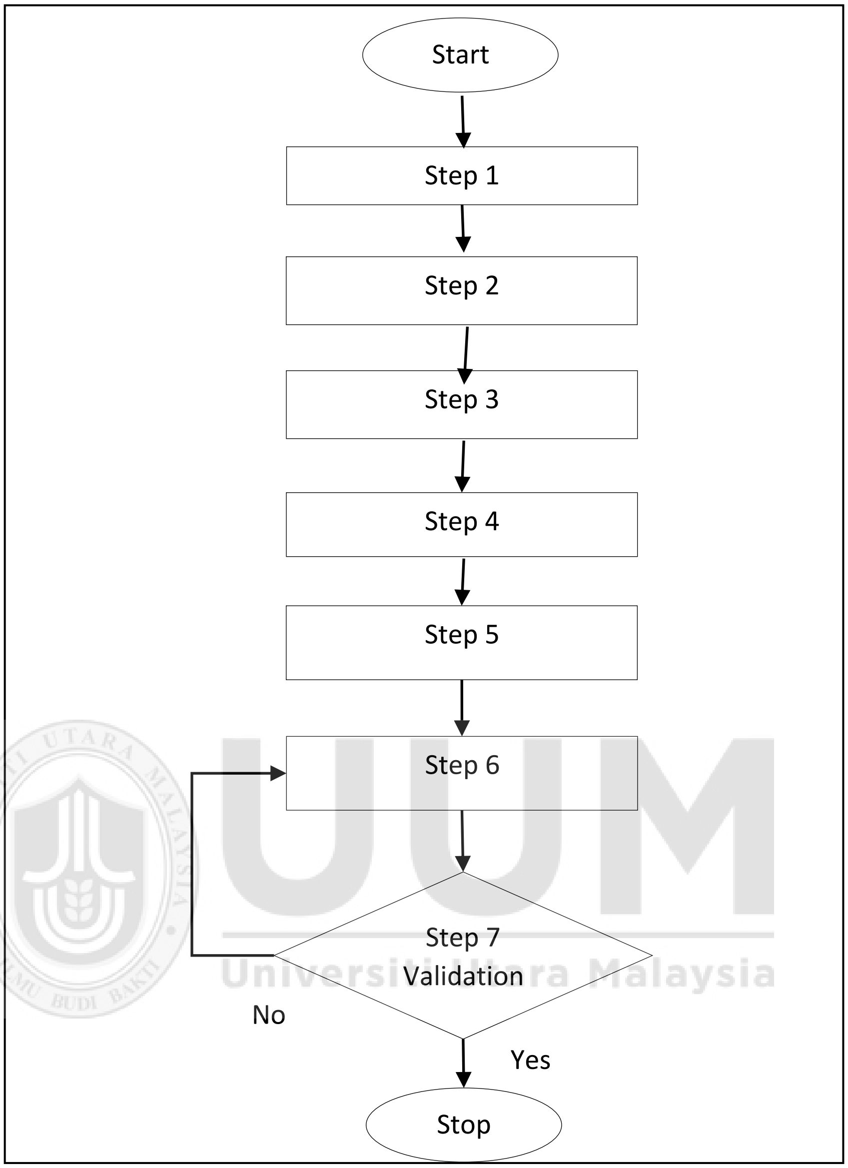

Figure 3.2*Flow Chart for the Process to Develop the Adjusted-PBMA Model*

Key:

Step 1: Determining the goal, aim, and scope of setting the program.
Step 2: Identifying the strategies used for the strategic activities at a universiti.
Step 3: Conducting the marginal analysis via marginal cost and CCA-value for each strategy/activity.
Step 4: Determining the decision-making criteria. In this case, the SETARA rating was used.
Step 5: Identifying of program options through IP-models.
Step 6: Evaluating the results produced by the models. A case study at UUM was used to illustrate the application of the IP-models and how the results could be interpreted.
Step 7: Validating the IP-models and conducting what-if analyses.

CHAPTER FOUR

CASE STUDY AT UNIVERSITI UTARA MALAYSIA, RESULTS AND ANALYSIS

4.1 Introduction

To illustrate how the adjusted-PBMA can be implemented, a case study involving the budget allocation for student development agenda for the 2017 strategic plan at Universiti Utara Malaysia (UUM) was conducted. The chapter begins with the illustration of each adjusted-PBMA steps, followed by the presentation of the results and the analysis of the results.

4.2 The Application of Adjusted-PBMA: A Case Study at UUM

As mentioned in Chapter Three, the adjusted-PBMA process involved six steps. Each step is explicitly illustrated here, starting with Step 1.

4.2.1 STEP 1: Determining the Goal, Aim and Scope of Setting the Program

The objective of this case study is to determine the strategies/activities that UUM should include in the 2017 UUM-Strategic Plan and to determine the total budget required for those strategies/activities to be implemented.

4.2.2 STEP 2: Identifying the Strategies Used for the Strategic Activities at UUM for the purpose of SETARA Rating.

For the purpose of identifying the strategies/activities to be implemented for the year 2017, the strategies/activities implemented in the year 2016 should be examined. The list of these 2016 activities to achieve the student development agenda was obtained from the UUM's 2016 Strategic Plan Report (please refer to Appendix A on page 137). The strategies/activities are as listed in Table 4.1.

Table 4.1
Strategies/Activities Implemented by UUM in 2016 to Achieve the SETARA Agenda.

KPI	STRATEGY/ACTIVITY IN THE FORM OF KPIs
1	Total Student's development Outreach Programs.
2	Percentage of full- time undergraduate (UG) students who receive scholarship yearly.
3	Percentage of outbound UG students to local universities with the transfer of credit.
4	Percentage of outbound UG students to international universities with the transfer of credit.
5	Ratio of total UG international students to total UG students.
6	Percentage of academic staff with industrial experience.
7	Percentage of academic staff with teaching experience abroad.
8	Percentage of academic staff with PhD.
9	Ratio of total academic staff to total staff.
10	Percentage of staff sent for training yearly.

Meanwhile, there are some other strategies/activities that were implemented by UUM and are relevant for the student development agenda. However, these strategies/activities were not included in our final model because these strategies/activities would not give any financial implication on UUM. The list of the strategies/activities and the reasons for their exclusion are given in Table 4.2.

Table 4. 2
Strategies/Activities Not Included in the Final Model with Reasons

STRATEGIES/ACTIVITIES IN THE FORM OF KPIs THAT ARE EXCLUDED	REASON
Percentage of working graduates with salaries exceeding RM1500 within six months of graduation.	The employers finance the salaries, and hence no allocation of the budget is required by UUM.
Percentage of students who receive scholarships from private organizations.	The scholarships are financed by the private organizations. Hence no budget allocation is needed by UUM.
Percentage of internet coverage throughout the campus.	Already achieved, and hence no budget allocation is needed by UUM.
Number of alumni who sit on the committee of the university.	No financial implication.
Number of local students involved in inbound transfer with credit.	Cost is taken care of by their respective universities.
Some international students involved in inbound with credit transfer.	Cost is taken care of by their respective universities.
Percentage of undergraduate students with entry points above 3.0.	Determined by their achievement in pre-university education, hence no budget allocation is needed by UUM.
Size of the area of teaching and learning per student.	Already achieved hence no budgetary allocation needed by UUM.
Percentage of actively used technology.	No budget required. The technology is already available.
Percentage of courses with 3.0 and above score.	The process is done online using the existing system. Thus, no budget allocation is required by UUM
The ratio of licensed counsellors to full-time undergraduate students.	Budget is already included in the salary component.
The ratio of medical officers to full-time undergraduate students.	Already achieved, hence no budget allocation is needed by UUM.
Ratio of full-time undergraduate students to the number of academic staff.	Already achieved, hence no budget allocation is needed by UUM.

4.2.3 STEP 3: Calculating the Marginal Cost of Each Strategy

As stated in Chapter 3, before the marginal cost could be calculated, firstly, the actual cost of conducting each activity/strategy for the year 2016 must be identified. At the same time, the actual achievement with respect to each activity/strategy for 2016 must also be identified as well. The specific activities/strategies to achieve each KPI are as listed in Table 4.1, while the actual cost of implementing each strategy/activity, and the actual achievement for 2016 by each activity are as given in Table 4.3. The data for the actual cost to implement each strategy/activity and the actual achievement for 2016 were given by the UUM officer at the UUM's Research and Innovation Management Center(RIMC) in-charge of the SETARA rating.

Table 4.3
Activities for Each KPI, Cost Involved (Marginal Cost) and Achievement of Each Strategy/Activity in 2016.

KPI	Activities Implemented	Cost per Activity (RM)	Achievement
1	Total student's development outreach programs.	300/program	653 programs
2	Percentage of full- time undergraduate (UG) students who receive scholarship yearly (Reported in the form of total number of UG students receiving scholarship)	6,000/student	234 students
3	Percentage of outbound UG students to local universities with the transfer of credit (Reported in the form of total number of UG students involved)	1,000/student	124 students
4	Percentage of outbound UG students to international universities with the transfer of credit (Reported in the form of total number of UG students involved)	3,000/student	256 students
5	Ratio of total UG international students to total UG students (Reported in terms of total promotional programs conducted to attract UG international programs)	20,000/program	33 promotional programs

6	Percentage of academic staff with industrial experience (Reported in the form of total number of academic staff with industrial training)	96,000/staff	147 staff
7	Percentage of academic staff with teaching experience abroad (Reported in the form of total number of academic staff with teaching experience abroad)	96,000/staff	87 staff
8	Percentage of academic staff with PhD (Reported in the form of total number of academic staff involved)	125,000/staff	756 staff
9	Ratio of total academic staff to total staff (Reported in the form of total number of academic staff available)	96,000/staff	1200 staff
10	Percentage of staff sent for training yearly (Reported in the form of total number of staff involved)	500/staff	1580 staff

4.2.4 Step 4: Determining the Decision-Making Criteria to be used to Maximize Benefits or Profits as Well as Minimization of Cost and Introducing New strategies.

The criteria used in our decision-making model was based on CCA-value as calculated in Table 4.4whereby

CCA-value for strategy/activity *i* = (Expected SETARA point for strategy/activity *i*/Expected SETARA output for strategy/activity *i*). (4.1)

Once again, the expected SETARA points and the expected outputs were obtained through the officer at RIMC. Since the CCA-values were determined using deterministic values instead of subjective preference values, we did not have to apply any of the MCDA techniques discussed in the literature review section (Chapter 2, Section 2.4).

Table 4.4
The CCA-value for Each Strategy/Activity in 2016.

KPI	Activities Implemented	Expected SETARA Point	Expected SETARA Output	CCA-Value
1	Total student's development 0utreach programs.	0.6	150 programs (one program involves 30 students)	0.6/150 = 0.004
2	Percentage of full- time undergraduate (UG) students who receive scholarship yearly (Reported in the form of total number of UG students receiving scholarship)	0.2625	5% of 18,000 students = 900 students	0.2625/900 = 0.00029
3	Percentage of outbound UG students to local universities with the transfer of credit (Reported in the form of total number of UG students involved)	0.3	2.5% of 18,000 students = 450 students	0.3/450 = 0.0007

4	Percentage of outbound UG students to international universities with the transfer of credit (Reported in the form of total number of UG students involved)	0.3	2.5% of 18,000 students = 450 students	0.3/450 = 0.0007
5	Ratio of total UG international students to total UG students (Reported in terms of total promotional programs conducted to attract UG international programs)	0.25	1,800 international UG students. One promotional activity will get 20 students on the average. Thus 90promotional programs will be needed.	CCA per program = 0.25/90 = 0.0028
6	Percentage of academic staff with industrial experience (Reported in the form of total number of academic staff with industrial training)	0.4	10% of the academic staff is required. 10/100 x 1200 = 120 staff	0.4/120 = 0.0033
7	Percentage of academic staff with teaching experience abroad (Reported in the form of total number of academic staff with teaching experience abroad)	0.3	10% of the academic staff is required. 10/100 x 1200 = 120 staff	0.3/120=0.0025
8	Percentage of academic staff with PhD (Reported in the form of total number of academic staff with PhD)	0.6	70 % of academic staff = 70/100 x 1200 = 840	0.6/840=0.0007
9	Ratio of total academic staff to total staff (Reported in the form of total number of academic staff involved)	4	In 2016 UUM has 1200 academic staff and 1300 non-academic staff. To get 4 points, the ratio of the academic staff over the total number of staff should be 0.5. Thus, total academic staff should be 1300.	4/1300 = 0.003
10	Percentage of staff sent	0.2	20% out of total	0.2/500=0.0004

for training yearly (Reported in the form of total number of staff involved)	UUM staff will be required. 20/100 x 2500 = 500

As for the year 2017, three new strategies are to be introduced into the already existing strategies implemented in 2016. The new strategies/activities are the outbound double degree programs for UUM students to other universities involving:

i. Double degree programs to local universities in Malaysia.
ii. Double degree programs to international universities in Indonesia.
iii. Double degree programs to international universities in Thailand.

These three strategies had not been implemented before 2017. They were proposed because the cost of implementing the programs is lesser than the existing outbound programs for these two reasons:

i. For the outbound programs, the students are required to pay the tuition fee, whereas for the double degree programs, the tuition fee will be waived by the host university.
ii. The outbound programs do not include Indonesia and Thailand. Thus, for the double degree programs, Indonesia and Thailand were suggested due to lesser financial incentive provided by UUM to students.

These three new strategies/activities are later to be denoted as these following decision variables:

i. X_{3new}= number of students sent for thedouble degree program to local universities in Malaysia.

ii. X_{4newI}=number of students sent for the double degree to international universities in Indonesia.

iii. X_{4newT}=number of students sent for the double degree to international universities in Thailand.

4.2.5 Step 5: Evaluating the Potential Impact of Investment and Disinvestment Regarding Benefits and Cost.

To evaluate the effect of introducing CCA and marginal cost in the decision-making process on the activities/strategies that should be undertaken by UUM in 2017, six IP models were constructed for the 2017 UUM strategic plan. Three models involved only the existing activities/strategies implemented in 2016 while three other models involved the existing activities/strategies implemented in 2016 as well as the new suggested activities/strategies to be added in 2017. Here, we assumed that the cost of running each activity/strategy (marginal cost) and the CCA-values for 2016 remained the same for 2017. The six models developed based on six different objectives are as follows:

i. Model A: To minimize the total budget that UUM must set aside to achieve 80 percent SETARA marks for all the existing strategies involved.

ii. Model B: To minimize the total budget that UUM must set aside to achieve 90 percent SETARA marks for all the existing strategies involved.

iii. Model C: To maximize total SETARA points that can be accumulated by UUM given the amount of budget allocated by the university management, for the existing strategies.

iv. Model D: To minimize the total budget that UUM must set aside to achieve 80 percent SETARA marks for all the new-introduced and existing strategies involved.

v. Model E: To minimize the total budget that UUM must set aside to achieve 90 percent SETARA marks for all the new-introduced and existing strategies involved.

i. Model F: To maximize total SETARA points that can be accumulated by UUM given the amount of budget allocated by the university management, for existing and new-introduced strategies.

Meanwhile, the decision variables used in the models are:

X_1 = total students development Outreach Programs.

X_2 = number of full-time students to be given UUM scholarship yearly.

X_3 = number students involved in outbound programs in local universities with transfer of credit.

X_4 = number of students involved in outbound programs in international universities with credit transfer.

X_5 = number of promotional activities to attract international students.

X_6 = number of new academic staff with industrial experience to be hired.

X_7= number of new academic staff with teaching experience abroad to be hired.

X_8 = number of academic staff to be sent for PhD or are currently doing their PhD.

X_9= number of new academic staff to be hired.

X_{10} = number of staff sent for training.

X_{3new} = number of students sent for thedouble degree program to local universities in Malaysia.

X_{4newI} =number of students sent for the double degree to international universities in Indonesia.

X_{4newT} =number of students sent for the double degree to international universities in Thailand.

Before the six models are presented, the SETARA-point requirements that need to be fulfilled by UUM for 2017 are as given in Table 4.5.

Table 4.5
SETARA-point Requirements for UUM to Fulfill in 2017.

KPI	Activities Implemented	Expected SETARA Point	Expected SETARA Output (As Explained in Table 4.3)	SETARA Point to be fulfilled by UUM
1	Total Student's development Outreach Programs.	0.6	150 programs	0.6
2	Percentage of full- time undergraduate (UG) students who receive scholarship yearly.(Reported in the form of total number of	0.2625	900 students	0.2625

	UG students receiving scholarship)			
3	Percentage of outbound UG students to local universities with the transfer of credit. (Reported in the form of total number of UG students involved)	0.3	450 students	0.3
4	Percentage of outbound UG students to international universities with the transfer of credit (Reported in the form of total number of UG students involved)	0.3	450 students	0.3
5	Ratio of total UG international students to total UG students (Reported in terms of total promotional programs conducted to attract UG international programs)	0.25	One promotional activity will get 20 students on the average. UUM needs 1,800 international UG students to fulfil the KPI in 2017. Thus, 1800/20 = 90 promotional programs will be needed. However, 1,000 students from 2016 will still be around for the next academic year (2017) since they are not yet in their fourth year. Therefore, UUM only needs to get 800 students. Assume that 30% of these 800 will come on their own, and the remaining will come through promotional programs by UUM. Thus, UUM only needs to get 70/100(800) = 560 students through promotional activity. Thus 560/20 = 28 promotional programs will be needed.	28/90 x 0.25 = 0.078
6	Percentage of academic	0.4	10% of the academic staff	0

	staff with industrial experience (Reported in the form of total number of academic staff with industrial training)		is required. 10/100 x 1200 = 120 staff In 2016, UUM has 147 academic staff with industrial experience. Thus, for 2017, this KPI is already fulfilled.	
7	Percentage of academic staff with teaching experience abroad (Reported in the form of total number of academic staff with teaching experience abroad)	0.3	10% of the academic staff is required. 10/100 x 1200 = 120 staff In 2016, UUM has 87 academic staff with teaching experience abroad. Thus, for 2017, another 33 staff will be needed.	33/120 x 0.3 = 0.0825
8	Percentage of academic staff with PhD (Reported in the form of total number of academic staff with PhD)	0.6	In 2016, UUM has 1200 academic staff, and63% with PhDs has been achieved. In 2017, 70% or 840 staff are required. Thus and extra 7% will be needed by UUM. 7/100 x 1200 = 84	84/840 x 0.6 = 0.06
9	Ratio of total academic staff to total staff (Reported in the form of total number of academic staff involved)	4	In 2016 UUM has 1200 academic staff and 1300 non-academic staff. To get 4 points, the ratio of the academic staff over the total number of staff should be 0.5. Therefore another 100 academic staff should be hired.	100/1300 x 4 = 0.308
10	Percentage of staff sent for training yearly (Reported in the form of total number of staff involved)	0.2	500 staff	0.2

Combining Table 4.4 and Table 4.5, we have these following parameters as shown in Table 4.6 to be used in all the six IP-models.

Table 4.6

The Parameters to be Used in the Six IP-Models.

KPI	1	2	3	4	5	6	7	8	9	10
Variable	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
Marginal Cost	300	6,000	1,000	3,000	20,000	96,000	96,000	125,000	96,000	500
CCA-Value	0.004	0.00029	0.0007	0.0007	0.0028	0.0033	0.0025	0.0007	0.003	0.0004
Required SETARA points	0.6	0.2625	0.3	0.3	0.078	0	0.0825	0.06	0.308	0.2

In the following six subsections, all the six models were formulated, and the optimal result obtained for each model is given immediately after each model.

4.2.5.1 Model A.

Objective function: To minimize the total budget that UUM must set aside to achieve 80 percent SETARA marks for all the existing strategies involved.

Min $f(X) = 300X_1 + 6{,}000X_2 + 1{,}000X_3 + 3{,}000X_4 + 20{,}000X_5 + 96{,}000X_6 + 96{,}000X_7 + 125{,}000X_8 + 96{,}000X_9 + 500X_{10}$

Subject to these constraints:

i. Total SETARA points that can be garnered through student's development outreach programs.

$$0.004X_1 \leq 0.600$$

ii. Total SETARA points that can be garnered through full- time UG students who receive scholarship yearly.

$0.0003X_2 \leq 0.263$

iii. Total SETARA points that can be garnered through out bound UG students to local universities with the transfer of credit.

$0.0007X_3 \leq 0.300$

iv. Total SETARA points that can be garnered through out bound UG students to international universities with the transfer of credit.

$0.0007X_4 \leq 0.300$

v. Total SETARA points that can be garnered through UG international students.

$0.0029X_5 \leq 0.0078$

vi. Total SETARA points that can be garnered through academic staff with industrial training.

$0.0033X_6 = 0$

vii. Total SETARA points that can be garnered through academic staff with teaching experience abroad.

$0.0025X_7 \leq 0.0825$

ix. Total SETARA points that can be garnered through academic staff with PhD.

$0.0007X_8 \leq 0.06$

x. Total SETARA points that can be garnered through academic staff.

$0.003X_9 \leq 0.308$

xi. Total SETARA points that can be garnered through staff sent for training.

$$0.0004X_{10} \leq 0.2$$

xii. 80 percent of the total SETARA points to be garnered through the combination of all the strategies/activities [i.e. 0.8(0.6 + 0.263 + 0.3 + 0.3 + 0.013 + 0 + 0.275 + 0.06 + 0.308 + 0.2) = 0.8(2.319) = 1.8552].

$$0.004X_2+0.00029X_2+0.0007X_3+ 0.0007X_4+ 0.0028X_5+ 0.0033X_6+ 0.0025X_7+ 0.0007X_8+ 0.003X_9+ 0.0004X_{10} \geq 1.8552$$

$X_i \geq 0$ and integer, i= 1,2,3,…, 10.

The optimal result obtained via *Lingo 12.0*(please refer to Appendix B on page 141) is as in Table 4.7.

Table 4.7
Optimal result for Model A.

Variable	Solution
X_1	150 student's development outreach programs.
X_2	873full- time UG students to be given scholarship yearly.
X_3	428UG students to b*e* sent to local universities for out bound program with the transfer of credit.
X_4	428UG students to b*e* sent to international universities for out bound program with the transfer of credit.
X_5	27 promotional programs.
X_6	0 academic staff with industrial training to be hired.
X_7	33academic staff with teaching experience abroad to be hired or to be sent for teaching assignment abroad.
X_8	0 academic staff with PhD to be hired or existing staff to be sent for PhD.
X_9	15new academic staff to be hired.
X_{10}	500 staff sent for training.
Total Budget	RM12,393,000

4.2.5.2 Model B.

Objective function: To minimize the total budget that UUM must set aside to achieve 90 percent SETARA marks for all the existing strategies involved.

Min $f(X) = 300X_1 + 6{,}000X_2 + 1{,}000X_3 + 3{,}000X_4 + 20{,}000X_5 + 96{,}000X_6 + 96{,}000X_7 + 125{,}000X_8 + 96{,}000X_9 + 500X_{10}$

Subject to these constraints:

i. Total SETARA points that can be garnered through student's development outreach programs.

$$0.004X_1 \leq 0.600$$

ii. Total SETARA points that can be garnered through full- time UG students who receive scholarship yearly.

$$0.00029X_2 \leq 0.2625$$

iii. Total SETARA points that can be garnered through outbound UG students to local universities with the transfer of credit.

$$0.0007X_3 \leq 0.300$$

iv. Total SETARA points that can be garnered through outbound UG students to international universities with the transfer of credit.

$$0.0007X_4 \leq 0.300$$

v. Total SETARA points that can be garnered through UG international students.

$$0.0028X_5 \leq 0.078$$

vi. Total SETARA points that can be garnered through academic staff with industrial training.

$0.0033X_6 \leq 0$

vii. Total SETARA points that can be garnered through academic staff with teaching experience abroad.

$0.0025X_7 \leq 0.0825$

ix. Total SETARA points that can be garnered through academic staff with PhD.

$0.0007X_8 \leq 0.06$

x. Total SETARA points that can be garnered through academic staff.

$0.003X_9 \leq 0.308$

xi. Total SETARA points that can be garnered through staff sent for training.

$0.0004X_{10} \leq 0.2$

xii. 90 percent of the total SETARA points to be garnered through the combination of all the strategies/activities [i.e. 0.90(0.6 + 0.263 + 0.3 + 0.3 + 0.013 + 0 + 0.275 + 0.06 + 0.308 + 0.2) = 0.90(2.319) = 2.087].

$$0.004X_2 + 0.00029X_2 + 0.0007X_3 + 0.0007X_4 + 0.0028X_5 + 0.0033X_6 + 0.0025X_7 + 0.0007X_8 + 0.003X_9 + 0.0004X_{10} \geq 2.087$$

$X_i \geq 0$ and integer, $i = 1,2,3,\ldots, 10$.

Table 4.8 gives the optimal result for Model B (please refer to Appendix C on page 144).

Table 4.8

Optimal result for Model B.

Variable	Solution
X_1	150 student's development outreach programs.
X_2	875 full- time UG students to be given scholarship yearly.
X_3	428UG students to b*e* sent to local universities for out bound program with the transfer of credit.
X_4	428UG students to b*e* sent to international universities for out bound program with the transfer of credit.
X_5	27 promotional programs.
X_6	0 academic staff with industrial training to be hired.
X_7	21 academic staff with teaching experience abroad to be hired or to be sent for teaching assignment abroad.
X_8	0 academic staff with PhD to be hired or existing staff to be sent for PhD.
X_9	102 new academic staff to be hired.
X_{10}	500 staff sent for training.
Total Budget	RM 19,605,200

4.2.5.3 Model C.

Objective function: To maximize total SETARA points that can be accumulated by UUM given the amount of budget allocated by the university management, for the existing strategies. For this purpose, we assumed that the total budget allocated by UUM is RM RM25,000,000.

$$Max f(X) = 0.004X_2 + 0.00029X_2 + 0.0007X_3 + 0.0007X_4 + 0.0028X_5 + 0.0033X_6 + 0.0025X_7 + 0.0007X_8 + 0.003X_9 + 0.0004X_{10}$$

Subject to these constraints:

i. Total SETARA points that can be garnered through student's development outreach programs.

$$0.004X_1 \leq 0.600$$

ii. Total SETARA points that can be garnered through full- time UG students who receive scholarship yearly.

$0.00029X_2 \leq 0.263$

iii. Total SETARA points that can be garnered through outbound UG students to local universities with the transfer of credit.

$0.0007X_3 \leq 0.300$

iv. Total SETARA points that can be garnered through outbound UG students to international universities with the transfer of credit.

$0.0007X_4 \leq 0.300$

v. Total SETARA points that can be garnered through UG international students.

$0.0028X_5 \leq 0.013$

vi. Total SETARA points that can be garnered through academic staff with industrial training.

$0.0033X_6 \leq 0$

vii. Total SETARA points that can be garnered through academic staff with teaching experience abroad.

$0.0025X_7 \leq 0.0825$

ix. Total SETARA points that can be garnered through academic staff with PhD.

$0.0007X_8 \leq 0.06$

x. Total SETARA points that can be garnered through academic staff.

$0.003X_9 \leq 0.308$

xi. Total SETARA points that can be garnered through staff sent for training.

$$0.0004X_{10} \leq 0.2$$

xii. Total budget allocated by UUM.

$$300X_1 + 6{,}000X_2 + 1{,}000X_3 + 3{,}000X_4 + 20{,}000X_5 + 96{,}000X_6 + 96{,}000X_7 + 125{,}000X_8 + 96{,}000X_9 + 500X_{10} \leq 25{,}000{,}000$$

$$X_i \geq 0 \text{ and integer, } i = 1,2,3,\ldots, 10.$$

The optimal result is as shown in Table 4.9. Please refer to Appendix D on page 147 for the *Lingo 12.0* output.

Table 4.9
Optimal result for Model C.

Variable	Solution
X_1	150 student's development outreach programs.
X_2	876 full- time UG students to be given scholarship yearly.
X_3	428UG students to b*e* sent to local universities for out bound program with the transfer of credit.
X_4	428UG students to b*e* sent to international universities for out bound program with the transfer of credit.
X_5	27 promotional programs.
X_6	0 academic staff with industrial training to be hired.
X_7	33 academic staff with teaching experience abroad to be hired or to be sent for teaching assignment abroad.
X_8	33 academic staff with PhD to be hired or existing staff to be sent for PhD.
X_9	102 new academic staff to be hired.
X_{10}	500 staff sent for training.
Total SETARA points obtained	2.14 (92.28 percent)

4.2.5.4 Model D.

Objective function: To minimize the total budget that UUM must set aside to achieve 80 percent SETARA marks for all the existing and new strategies involved.

Min $f(X) = 300X_1 + 6{,}000X_2 + 1{,}000X_3 + 500X_{3NEW} + 3{,}000X_4 + 1{,}000X_{4NEWI} + 1{,}000X_{4NEWT} + 20{,}000X_5 + 96{,}000X_6 + 96{,}000X_7 + 125{,}000X_8 + 96{,}000X_9 + 500X_{10}$

Subject to these constraints:

i. Total SETARA points that can be garnered through student's development outreach programs.

$$0.004X_1 \leq 0.600$$

ii. Total SETARA points that can be garnered through full- time UG students who receive scholarship yearly.

$$0.00029X_2 \leq 0.263$$

iii. Total SETARA points that can be garnered through UG double-degree UG students with the transfer of credit and double-degree program to local universities.

$$0.0007X_3 + 0.0007X_{3NEW} \leq 0.300$$

iv. Total SETARA points that can be garnered through UG outbound students to international universities with the transfer of credit and double-degree programs at universities in Indonesia and Thailand.

$$0.0007X_4 + 0.0007X_{4NEWI} + 0.0007X_{4NEWT} \leq 0.300$$

v. Total SETARA points that can be garnered through UG international students.

$$0.0028X_5 \leq 0.0078$$

vi. Total SETARA points that can be garnered through academic staff with industrial training.

$0.0033X_6 = 0$

vii. Total SETARA points that can be garnered through academic staff with teaching experience abroad.

$0.0025X_7 \leq 0.0825$

ix. Total SETARA points that can be garnered through academic staff with PhD.

$0.0007X_8 \leq 0.06$

x. Total SETARA points that can be garnered through academic staff.

$0.003X_9 \leq 0.308$

xi. Total SETARA points that can be garnered through staff sent for training.

$0.0004X_{10} \leq 0.2$

xii. 80 percent of the total SETARA points to be garnered through the combination of all the strategies/activities

$$0.004X_2 + 0.00029X_2 + 0.0007X_3 + 0.0007X_{3NEW} + 0.0007X_4 + 0.0007X_{4NEWI} + 0.0007X_{4NEWT} + 0.0028X_5 + 0.0033X_6 + 0.0025X_7 + 0.0007X_8 + 0.003X_9 + 0.0004X_{10} \geq 1.8552$$

$X_i \geq 0$ and integer, $i = 1,2,3,\ldots, 10$.

$X_{3NEW}, X_{4NEWI}, X_{4NEWT} \geq 0$ and integer.

Table 4.10 gives the optimal result for Model D (please refer to Appendix E on page 150)

Table 4.10
Optimal Result for Model D.

Variable	Solution
X_1	150 student's development outreach programs.
X_2	868 full- time UG students to be given scholarship yearly.
X_3	0UG students to b*e* sent to local universities for out bound program with the transfer of credit.
X_{3new}	428 UG students to be sent for double degree program to local universities.
X_4	0UG students to b*e* sent to international universities for outbound program with the transfer of credit.
X_{4newI}	0 UG students to be sent for double degree program to universities in Indonesia.
X_{4newT}	428 UG students to be sent for double degree program to universities in Thailand.
X_5	27 promotional programs.
X_6	0 academic staff with industrial training to be hired.
X_7	0 academic staff with teaching experience abroad to be hired or to be sent for teaching assignment abroad.
X_8	0 academic staff with PhD to be hired or existing staff to be sent for PhD.
X_9	40 new academic staff to be hired.
X_{10}	500 staff sent for training.
Total Budget	RM10,525,000

4.2.5.5 Model E.

Objective function: To minimize the total budget that UUM must set aside to achieve 90 percent SETARA marks for all the existing and new strategies involved.

Min $f(X) = 300X_1 + 6{,}000X_2 + 1{,}000X_3 + 500X_{3NEW} + 3{,}000X_4 + 1{,}000X_{4NEWI} + 1{,}000X_4 + 20{,}000X_5 + 96{,}000X_6 + 96{,}000X_7 + 125{,}000X_8 + 96{,}000X_9 + 500X_{10}$

Subject to these constraints:

i. Total SETARA points that can be garnered through student's development outreach programs.

$$0.004X_1 \leq 0.600$$

ii. Total SETARA points that can be garnered through full- time UG students who receive scholarship yearly.

$$0.00029X_2 \leq 0.263$$

iii. Total SETARA points that can be garnered through UG double-degree UG students with the transfer of credit and double-degree program to local universities.

$$0.0007X_3 + 0.0007X_{3NEW} \leq 0.300$$

iv. Total SETARA points that can be garnered through UG outbound students to international universities with the transfer of credit and double-degree programs at universities in Indonesia and Thailand.

$$0.0007X_4 + 0.0007X_{4NEWI} + 0.0007X_{4NEWT} \leq 0.300$$

v. Total SETARA points that can be garnered through UG international students.

$$0.0028X_5 \leq 0.0078$$

vi. Total SETARA points that can be garnered through academic staff with industrial training.

$$0.0033X_6 \leq 0$$

vii. Total SETARA points that can be garnered through academic staff with teaching experience abroad.

$0.0025X_7 \leq 0.0825$

ix. Total SETARA points that can be garnered through academic staff with PhD.

$0.0007X_8 \leq 0.06$

x. Total SETARA points that can be garnered through academic staff.

$0.003X_9 \leq 0.308$

xi. Total SETARA points that can be garnered through staff sent for training.

$0.0004X_{10} \leq 0.2$

xii. 90 percent of the total SETARA points to be garnered through the combination of all the strategies/activities [i.e. 0.90(0.6 + 0.263 + 0.3 + 0.3 + 0.013 + 0 + 0.275 + 0.06 + 0.308 + 0.2) = 0.90(2.319) = 2.087].

$$0.004X_2 + 0.00029X_2 + 0.0007X_3 + 0.0007X_4 + 0.0028X_5 + 0.0033X_6 + 0.0025X_7 + 0.0007X_8 + 0.003X_9 + 0.0004X_{10} \geq 2.087$$

$X_i \geq 0$ and integer, i= 1,2,3, …, 10.

$X_{3NEW}, X_{4NEWI}, X_{4NEWT} \geq 0$ and integer.

The optimal result for Model E is summarized in Table 4.11 (please refer to Appendix F on page 154)

Table 4.11
Optimal result for Model E.

Variable	Solution
X_1	150 student's development outreach programs.
X_2	871 full- time UG students to be given scholarship yearly.
X_3	0UG students to be sent to local universities for outbound program with the transfer of credit.
X_{3new}	428 UG students to be sent for double degree program to local universities.
X_4	0UG students to be sent to international universities for out bound program with the transfer of credit.
X_{4newI}	288 UG students to be sent for double degree program to universities in Indonesia.
X_{4newT}	140 UG students to be sent for double degree program to universities in Thailand.
X_5	27 promotional programs.
X_6	0 academic staff with industrial training to be hired.
X_7	18 academic staff with teaching experience abroad to be hired or to be sent for teaching assignment abroad.
X_8	0 academic staff with PhD to be hired or existing staff to be sent for PhD.
X_9	102 new academic staff to be hired.
X_{10}	500 staff sent for training.
Total Budget	RM18,223,000

4.2.5.6 Model F.

Objective function: To maximize total SETARA points that can be accumulated by UUM given the amount of budget allocated by the university management, for the existing and new strategies. For this purpose, we assumed that the total budget allocated by UUM is RM25,000,000.

Max $f(X) = 0.004X_2 + 0.00029X_2 + 0.0007X_3 + 0.0007X_{3NEW} + 0.0007X_4 + 0.0007X_{4NEWI} + 0.0007X_{4NEWT} + 0.0028X_5 + 0.0033X_6 + 0.0025X_7 + 0.0007X_8 + 0.003X_9 + 0.0004X_{10}$

Subject to these constraints:

i. Total SETARA points that can be garnered through student's development outreach programs.

$$0.004X_1 \leq 0.600$$

ii. Total SETARA points that can be garnered through full- time UG students who receive scholarship yearly.

$$0.00029X_2 \leq 0.263$$

iii. Total SETARA points that can be garnered through outbound UG students to local universities with the transfer of credit.

$$0.0007X_3 + 0.0007X_{3NEW} \leq 0.300$$

iv. Total SETARA points that can be garnered through outbound UG students to international universities with the transfer of credit.

$$0.0007X_4 + 0.0007X_{4NEWI} + 0.0007X_{4NEWT} \leq 0.300$$

v. Total SETARA points that can be garnered through UG international students.

$$0.0028X_5 \leq 0.013$$

vi. Total SETARA points that can be garnered through academic staff with industrial training.

$$0.0033X_6 \leq 0$$

vii. Total SETARA points that can be garnered through academic staff with teaching experience abroad.

$$0.0025X_7 \leq 0.0825$$

ix. Total SETARA points that can be garnered through academic staff with PhD.

$$0.0007X_8 \leq 0.06$$

x. Total SETARA points that can be garnered through academic staff.

$$0.003X_9 \leq 0.308$$

xi. Total SETARA points that can be garnered through staff sent for training.

$$0.0004X_{10} \leq 0.2$$

xii. Total budget allocated by UUM.

$$300X_1 + 6{,}000X_2 + 1{,}000X_3 + 500X_{3NEW} + 3{,}000X_4 + 1{,}000X_{4NEWI} + 1{,}000X_{4NEWT} + 3{,}000X_4$$
$$+ 20{,}000X_5 + 96{,}000X_6 + 96{,}000X_7 + 125{,}000X_8 + 96{,}000X_9 + 500X_{10} \leq 25{,}000{,}000$$

$X_i \geq 0$ and integer, i= 1,2,3, …, 10.

X_{3NEW}, X_{4NEWI}, $X_{4NEWT} \geq 0$ and integer.

The optimal result obtained for Model F is as given in Table 4.12. (Please refer to Appendix G on page 157)

Table 4.12
Optimal Result for Model F.

Variable	Solution
X_1	150 student's development outreach programs.
X_2	876 full- time UG students to be given scholarship yearly.
X_3	0UG students to b*e* sent to local universities for outbound program with the transfer of credit.
X_{3new}	428 UG students to be sent for double degree program to local universities.
X_4	0UG students to b*e* sent to international universities for

	outbound program with the transfer of credit.
$X_{4\text{newI}}$	0 UG students to be sent for double degree program to universities in Indonesia.
$X_{4\text{newT}}$	428 UG students to be sent for double degree program to universities in Thailand.
X_5	27 promotional programs.
X_6	0 academic staff with industrial training to be hired.
X_7	33 academic staff with teaching experience abroad to be hired or to be sent for teaching assignment abroad.
X_8	42 academic staff with PhD to be hired or existing staff to be sent for PhD.
X_9	102 new academic staff to be hired.
X_{10}	500 staff sent for training.
Total SETARA point	2.155 (92.928 percent)

4.2.6. Step 6: Model validation.

To validate all the models, two aspects must be checked:

i. The optimal output is produced or in other words, all the model constraints have been satisfied or adhered to.

ii. The proposed solution makes a logical sense. This is to ensure that the model has been formulated correctly.

All the six models in this study produced an optimal solution meaning that the model constraints have been satisfied for all the six IP models. Thus, the only aspect left to be checked is the logical sense of the solution. We illustrate here the process that was done for Model A, which is by comparing the maximum output that should be achieved by UUM for each strategy/activity as expected by SETARA to obtain the full (100 percent) SETARA points and the proposed solution given by the output of Model A to achieve 80 percent SETARA points. The detail is as given in Table 4.13.

Table 4.13
Model Validation for Model A.

Variable	Maximum Output That Should be Produced by UUM to Achieve 100 Percent SETARA points	Proposed Output to be Produced by UUM to achieve 80 Percent SETARA points
X_1	150	150
X_2	900	873
X_3	450	428
X_4	450	428
X_5	28	27
X_6	0	0
X_7	33	33
X_8	84	0
X_9	100	15
X_{10}	500	500

From Table 4.13 the proposed outputs for all the variables are all within the allowable maximum outputs or in other words, all the model constraints are satisfied, and the outputs produced by the mathematical model are logical. Therefore, the mathematical IP model A has been validated.

The output comparisons for the other five 1P models are given in Table 4.14 and Table 4.15.

Table 4.14
Model Validation for Model B and Model C.

Variable	Maximum Output That Should be Produced by UUM to Achieve 100 Percent SETARA points	Optimal Output for Model B	Optimal Output for Model C
X_1	150	150	150
X_2	900	875	876
X_3	450	428	428
X_4	450	428	428
X_5	28	27	27
X_6	0	0	0
X_7	33	21	33
X_8	84	0	33
X_9	100	102*	102*
X_{10}	500	500	500

Once again, the values for each strategy/activity in proposed in Model B and Model C satisfy the constraints. Please note that the value for X_9 (*)for both Model B and Model C should have been 100 instead of 102. This happens due to the rounding down of its CCA-value in the model. The same can be concluded for Model D, Model E, and Model F as shown in Table 15.

Table 4.15
Model Validation for Model D, Model E, and Model F.

Variable	Maximum Output That Should be Produced by UUM to Achieve 100 Percent SETARA points	Optimal Output for Model D	Optimal Output for Model E	Optimal Output for Model F
X_1	150	150	150	150
X_2	900	868	871	876
$X_3 + X_{3new}$	450	428	428	428
$X_4 + X_{4newI} + X_{4newT}$	450	428	428	428
X_5	28	27	27	27
X_6	0	0	0	0
X_7	33	0	18	33
X_8	84	0	0	42
X_9	100	40	102	102
X_{10}	500	500	500	500

4.3Analyses of Results and Interpretations

The analyses of the results are be done in two ways:

i. To compare and analyze the results for the models involving the existing strategies (Model A, Model B, and Model C). This is done to see the impact of varying the objective functions and the model constraints on the solutions.

ii. To compare and analyze the results for Model A (involving the existing strategies and Model D (involving the existing and new strategies). This is done to see the effect of the inclusion of the three new strategies on the solutions.

The results for Model A, Model B, and Model C, put side by side are as in Table 4.16.

Table 4.16

Summary of Results for Model A, Model B, and Model C.

Variable	Model A	Model B	Model C
X_1	150	150	150
X_2	873	875	876
X_3	428	428	428
X_4	428	428	428
X_5	27	27	27
X_6	0	0	0
X_7	33	21	33
X_8	0	0	33
X_9	15	102	102
X_{10}	500	500	500
SETARA Points	(1.8552) 80%	(2.087) 90%	(2.140) 92.28%
Total Budget (RM)	12,393,000	19,605,000	25,000,000

As given in Table 4.16, by varying the required SETARA points to be achieved, there are only some minor adjustments on the total number of activities to be executed. The most notable one is for variable X_9 which is the total number of new academic staff to be hired and variable X_8 which is the total number of academic staff to be sent for PhD. To achieve 80 percent SETARA points, only 15 new academic staff should be recruited. However, if 90 or more percent SETARA points are required, a total of 100 (or 102 from the model output due to the rounding down of the CCA-value as explained earlier) new academic staff should be hired. On the other hand, to achieve 80 or 90 percent SETARA points, no academic staff is required to be sent for PhD. However, if 93 percent SETARA points are required, a total of 33 academic staff needs to be sent for PhD. This will increase the total budget that should be allocated by the UUM management by RM4,125,000 (RM125,000.00 x 33 staff).

Meanwhile, the results for Model A and Model D put side by side are as in Table 4.17.

Table 4.17
Summary of Results for Model A and Model D.

Variable	Model A	Model D
X_1	150	150
X_2	873	868
X_3	428	0
X_{3NEW}	-NA-	428
X	428	0
X_{4NEWI}	-NA-	0
X_{4NEWT}	-NA-	428
X_5	27	27
X_6	0	0
X_7	33	0
X_8	0	0
X_9	15	40
X_{10}	500	500
SETARA Points	80%	80%
Total Budget	12,393,000	10,525,000

Based on the values in Table 4.17, the introduction of the three new activities are significant in reducing the total budget that should be allocated by the UUM management. In this case, the total budget is reduced by 15.073 percent or RM1,868,00. For the strategic implementation, UUM should shift its strategy from sending its students for outbound programs to sending its students for the double degree programs to local universities and to either universities in Indonesia or Thailand due to the cheaper costs. However, there are also some other strategic adjustments that need to be done. For example, with the inclusion of the new suggested activities to be executed, no new academic staff with international teaching experience (X_7) should be hired. Without the new suggested activities, 33 academic staff should be hired. However, there is an increase by 25 new academic staff (X_9) to be hired (from 15 to 40 staff).

4.4 What-If Analyses

Once the models have been validated, several what-if analyses can be further performed to see the effect of changing some of the parameters on the decision variables. To illustrate, we performed these following parameter changes:

i. A decrease by 10 percent in total budget allocated by the university, implemented on Model F, which is a reduction of RM2,500,000, making the total budget allocated to be RM22,500,000.

ii. An increase in one of the strategies' cost, implemented on Model D. Here we experimented on an increase in X_1 by 10 percent or RM30 per program, making the marginal cost to be RM330.

iii. A decrease of 10 percent in SETARA points, implemented on Model A, making the SETARA points to be achieved at 70 percent.

Table 4.18
Result for What-if Analysis.

Variable	Model F	Model F (What if)
X_1	150	150
X_2	876	876
X_3	0	0
X_{3NEW}	428	428
X_4	0	0
X_{4NEWI}	0	0
X_{4NEWT}	428	428
X_5	27	27
X_6	0	0
X_7	33	33
X_8	42	22
X_9	102	102
X_{10}	500	500
SETARA Points	2.155 (92.93%)	2.141 (92.32%)
Total Budget	25,000,000	22,500,000

From Table 4.18, it can be seen that by reducing the allocated budget by 10 percent, the total SETARA points that can be achieved is 92.32%, which is a reduction of only 0.61 percent. For the specific solution, only solution for $X_8$is affected whereby with the reduction of the allocated only 22 instead of 42 academic staff should be sent for PhD.

Table 4.19
Result for What-if Analysis ii.

Variable	Model D	Model D (What if)
X_1	150	150
X_2	868	868
X_3	0	0
X_{3NEW}	428	428
X_4	0	0
X_{4NEWI}	0	0
X_{4NEWT}	428	428
X_5	27	27
X_6	0	0
X_7	0	0
X_8	0	0
X_9	40	40
X_{10}	500	500
SETARA Points	80%	80%
Total Budget	10,525,000	10,529,500

From Table 4.19, it can be concluded that by increasing the cost of conducting each students' program by 10 percent, the suggested specific solution for each activity/strategy remain unchanged. However, the total budget to be allocated has been increased to RM10,529,500, which is an increment of 0.043 percent.

Table 4.20
Result for What-if Analysis iii.

Variable	Model A	Model A (What if)
X_1	150	150
X_2	873	228
X_3	428	428
X_4	428	428
X_5	27	27
X_6	0	0
X_7	33	33
X_8	0	0
X_9	15	0
X_{10}	500	500
SETARA Points	80%	70%
Total Budget	12,393,000	7,083,000

It can be concluded that by reducing the expected SETARA points to be achieved by 10 percent (from 80 percent to 70 percent), the solutions for X2 and X9 have changed whereby only 228 students instead of 873 students should be given scholarship, and no new academic staff need to be hired. The total budget to be allocated by UUM can be reduced by 42.85 percent (a reduction of RM5,310,000).

4.4Summary

This chapter illustrated how Adjusted-PBMA was implemented to solve the budget allocation for UUM to achieve the expected SETARA points for the student development agenda. Six different IP models were proposed, and all the models produced optimal results. The budget allocation was based on the expected SETARA points to be achieved under each KPI, the marginal cost to implement each strategy/activity, the CCA-values for the strategies/activities. Since the CCA-values and the marginal costs were based on the explicit evidence from the previous achievements for all the existing strategies/activities, and some quantitative estimations by the experts for the new strategies, the subjective MCDA techniques were not needed. Lastly, what-if analyses were conducted to see the effect of varying the model parameters on the strategies/activities, total SETARA points, and the budget to be allocated by the UUM management.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 Introduction

This research focused on the efficient budget allocation for optimal performance of a university through adjusted-PBMA aimed at optimizing the choice of strategies/activities to improve SETARA rating for Malaysian universities. All the four specific research objectives were achieved.

Firstly, the first objective, which is to adjust the existing PBMA was achieved by introducing the use of a suitable quantitative approach instead of using a qualitative approach to calculate the marginal cost for the activities/strategies, and by introducing the implementation of a suitable mathematical programming model for the final budget allocation process. The summary of the amendments made on the PBMA is given in Table 5.1.

Table 5.1
PBMA and Adjusted-PBMA Steps.

PBMA Steps		Adjusted-PBMA Steps	
1	Determining the goal, aim and scope of setting the program.	**1**	Determining the goal, aim and scope of setting the program.
2	Identifying the available resources for funding a particular program, that is the program budget.	**2**	Identifying the strategies/activities currently used to achieve the optimal performance.
3	Conducting marginal analysis by taking the viewpoints of stakeholders, managers, service providers, consumers, and head of	**3**	Calculating the marginal analysis for the strategies/activities using a quantitative formula as the measure of marginal contribution of each strategy/activity towards the final goal. In this thesis, the marginal cost of running/executing an

	organizations in setting priorities.		activity/strategy and CCA to calculate the contribution of each activity's achievement with respect to the SETARA point were applied.
4	Determining the decision-making criteria to be used to maximize benefits or profits as well as minimization of cost.		
5	Identifying the options in the program for which choices are to be made. These can be achieved through the process of MCDA.	**4**	Determining the decision-making criteria to be used to maximize benefits or profits as well as minimization of cost and introducing new strategies. In this thesis, the decision-making criterion used was the SETARA points.
6	Evaluating the potential impact of investment and disinvestment regarding benefit and cost.	**5**	Evaluating the potential impact of investment and disinvestment regarding benefits and cost. This can be achieved by developing suitable mathematical model to identify which set of old strategies/activities that should remain and which set of the newly proposed strategies/activities that should be implemented.
7	Validating the outcome and the decision made in the process of allocation and re-allocation of funds according to the ratio of cost-benefit.	**6**	Validating of the proposed models with suitable validation techniques and conducting what-if analysis.

The second objective, which is to calculate the marginal cost contribution for each strategy/activity to achieve the respective KPIs using the most suitable marginal-analysis formula to be used for a university budget-planning purpose was achieved through (i) identifying the actual cost to run or execute each strategy/activity based on the cost of running the same strategy/activity from the previous strategic planning year for the existing strategies and by getting the cost estimation for the new strategies from the experts, and (ii) CCA-value which is the total SETARA point that is contributed by each strategy/activity.

The third objective, which is to apply the most suitable mathematical model for the final budget allocation for the university was achieved via the implementation of integer programming models. Six possible models were illustrated.

Finally, the final objective which is to evaluate the proposed mathematical model and validate the result produced by the mathematical model was achieved by checking the results obtained by the models to see whether the results satisfy all the constraints and are executable. In addition, several what-if analyses were also conducted to see the impact of varying the model parameters on the strategies/activities, total SETARA points that can be accumulated, as well as total budget that should be allocated.

5.2 Implications for Theory

The implications of the proposed adjusted-PBMA for the theory in Decision Science are three-folds. Firstly, the present PBMA proposed the use of MCDA, which can be very subjective, as the determining factor in the budget-planning decision problem. However, under the adjusted-PBMA approach, we proposed the use of any objectively and quantitatively suitable marginal cost formula (in our case, CCA was used) as the determining factor.

Secondly, the present PBMA approach distributes the allocated budget for the strategies/activities based on subjective evaluation which is either through decision makers' preference weight and ranking or expert opinion. For the adjusted-PBMA we proposed the use of IP-model for the budget distribution. IP-model can not only distribute the budget allocated among strategies/activities if the budget allocation is already determined ahead of time and is fixed, but the IP-model can also determine the proper budget to be reserved if certain targets or KPIs need to be attained.

Thirdly, employing the IP-model and the quantitative-based marginal analysis formula enables the decision maker to perform various what-if analyses which as a result can better prepare any organization on the implications of changes in the model parameters on the strategies/activities as well as on the financial requirements.

5.3 Implications for Practice

We have shown in this research how PBMA framework that is currently being used by healthcare institutions for the budget-planning exercise could also be used in other KPI-based service-oriented institutions with slight modifications. In our case, we applied it on the higher education institutions. The adjusted-PBMA framework has been successfully implemented in this thesis using the budget allocation problem at UUM as an example. From the optimal results obtained, UUM can better strategize on the strategies/activities to be executed by using the results as its guide. For example, comparing the result obtained by Model A with the strategies/activities, it is obvious that UUM should shift some of its budget from some strategies/activities to support other strategies/activities as shown in Table 5.2.

Table 5.2
Comparisons of Strategies/activities in 2016 With the Proposed-optimum Result from Model A

Variable	Result from Model A for 2017	What Was Implemented in 2016
X_1	150	653
X_2	873	234
X_3	428	124
X_4	428	256
X_{10}	500	1580
SETARA STARS	Six	Five

As illustrated in Table 5.2, UUM organized a total of 653 student activities which is five times more than what was required by SETARA. Similarly, UUM sent 1580 staff for training in 2016 when SETARA only set 500 staff as the requirement. On the other hand, UUM only managed to give scholarship to 234 students and 124 students for outbound programs with credit transfer. Thus, for 2017, UUM should shift the money spent on student activities and staff training to increase the number of students receiving scholarships and to subsidize more students for outbound programs.

This study has also practically demonstrated the adjusted-PBMA as a potential approach to prioritize strategies to achieve the required points set by the SETARArating agency and of course can be extended to cover the requirements by any other rating agencies to ensure successful and sustainable university rating. In addition, the adjusted-PBMA encourages transparency in the decision-making process and can easily be modified to cater the needs of other KPI-based organizationssuch as the tourism-based organizations and security enforcement-based organizations. In such cases, the output to be considered for the calculation of CCA can be the total tourists' total arrival or total spending and the total reduction in crime, respectively.

5.4 Limitations of the Study and Suggestions for Future Research

In general,adjusted-PBMA is a flexible framework that can be used in other organizations not just in the health sector where it originated, but also in other organizations especially the KPI-based service organizations as mentioned earlierand as shown in this study to be workable in the university system.

However, this adjusted-PBMA by no means is perfect. Firstly, the calculation for the marginal cost contribution may not be clear cut. The output must be able to be identified explicitly. Else, the CCA-values may be far from being accurate. Secondly, the IP-model proposed may not work if the relationship among variables are not linear. Furthermore, the IP-model may not be able to generate an optimal solution, in which some other techniques such as goal programming need to be utilized.

Based on the results of this research, a few recommendations are proposed. Firstly, it is recommended that the model should not be conducted by examining each agendum separately. All the strategic agenda should be included in the entire model because some of the activities can fulfil more than one agendum. An example of such activity is promotional programs to increase the number of international students. This activity can also be used to increase the number of international academicians, cultural exchange programs, student outbound or inbound to international universities, and so on.

The second recommendation will be on the selection and determination of strategies and activities. In reality, when selecting and determining the strategies and activities, other factors such as the preference or perhaps the capability of the university management staff in executing the strategies and activities should also be taken into consideration. Thus, for future work, this research suggests for this preference and capability factors to be included in the model.

The model used in this research was set at 80 percent and 90 percent to achieve six (6) stars SETARA rating. However, in reality, some of the plans or strategic activities may fail to be achieved or implemented. Therefore, our third recommendation is, instead of aiming at 80 percent, the university perhaps should aim at a higher percentage (greater than 80 percent) such as 100 percent so that when some of the activities are not achieved, those that are over achieved can cover for the unachieved activities hence, achieving the required points set by SETARA.

Fourthly, since the IP-model applied is very flexible, the model can be adjusted to cater for some special cases. One such example is the students exchange program. Normally, universities will have some Memorandum of Agreement (MOA) signed with some other universities, on the mandatory annual students exchange program involving a fixed number of students. This requirement should and can be easily embedded in the IP-model.

Lastly, the strategic activities in the university, the rating system, as well as the total budget available can change with time. Thus, the budget allocation model, i.e. adjusted-PBMA model should be revised every year or every two years.

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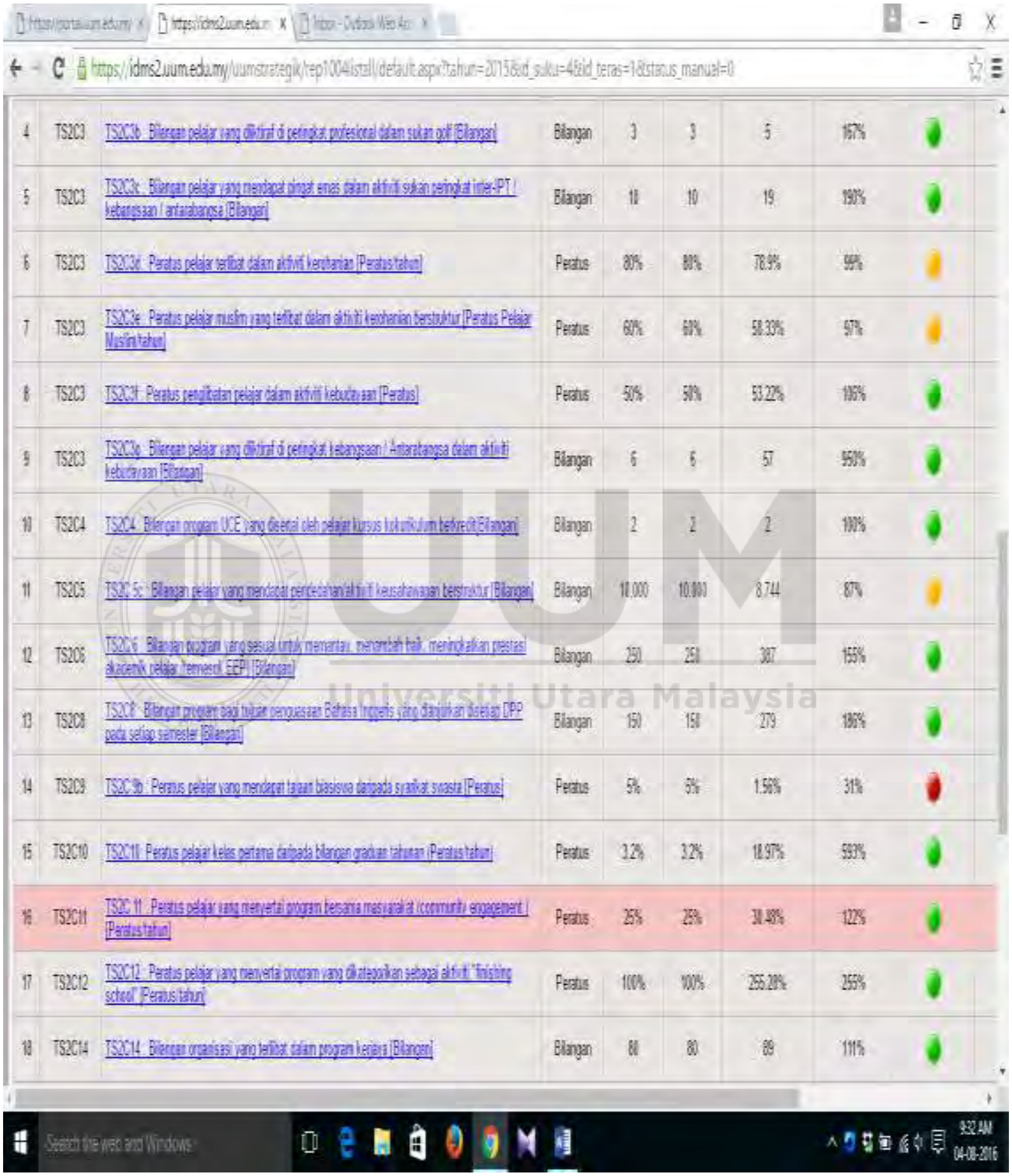
Appendix A

UUM 2016 Strategic Thrustson Student Achievement for SETARA Rating

(Due to the confidentiality of the document, only some of the pages are shown here)



4	TS2C3	TS2C3b : Bilangan pelajar yang diiktiraf di peringkat profesional dalam sukan golf [Bilangan]	Bilangan	3	3	5	167%	
5	TS2C3	TS2C3c : Bilangan pelajar yang mendapat pingat emas dalam aktiviti sukan peringkat inter-IPT / kebangsaan / antarabangsa [Bilangan]	Bilangan	10	10	19	190%	
6	TS2C3	TS2C3d : Peratus pelajar terlibat dalam aktiviti kerohanian [Peratus/tahun]	Peratus	80%	80%	78.9%	99%	
7	TS2C3	TS2C3e : Peratus pelajar muslim yang terlibat dalam aktiviti kerohanian berstruktur [Peratus Pelajar Muslim/tahun]	Peratus	60%	60%	58.33%	97%	
8	TS2C3	TS2C3f : Peratus penglibatan pelajar dalam aktiviti kebudayaan [Peratus]	Peratus	50%	50%	53.22%	106%	
9	TS2C3	TS2C3g : Bilangan pelajar yang diiktiraf di peringkat kebangsaan / Antarabangsa dalam aktiviti kebudayaan [Bilangan]	Bilangan	6	6	57	950%	
10	TS2C4	TS2C4 : Bilangan program UCE yang disertai oleh pelajar kursus kokurikulum berkredit[Bilangan]	Bilangan	2	2	2	100%	
11	TS2C5	TS2C 5c : Bilangan pelajar yang mendapat pendedahan/aktiviti keusahawanan berstruktur [Bilangan]	Bilangan	10,000	10,000	8,744	87%	
12	TS2C6	TS2C6 : Bilangan program yang sesuai untuk memantau, menambah baik, meningkatkan prestasi akademik pelajar (termasuk EEP) [Bilangan]	Bilangan	250	250	387	155%	
13	TS2C8	TS2C8 : Bilangan program bagi tujuan penguasaan Bahasa Inggeris yang dianjurkan disetiap DPP pada setiap semester [Bilangan]	Bilangan	150	150	279	186%	
14	TS2C9	TS2C 9b : Peratus pelajar yang mendapat tajaan biasiswa daripada syarikat swasta [Peratus]	Peratus	5%	5%	1.56%	31%	
15	TS2C10	TS2C10 : Peratus pelajar kelas pertama daripada bilangan graduan tahunan [Peratus/tahun]	Peratus	3.2%	3.2%	18.97%	593%	
16	TS2C11	TS2C 11 : Peratus pelajar yang menyertai program bersama masyarakat (community engagement) [Peratus/tahun]	Peratus	25%	25%	30.48%	122%	
17	TS2C12	TS2C12 : Peratus pelajar yang menyertai program yang dikategorikan sebagai aktiviti "finishing school" [Peratus/tahun]	Peratus	100%	100%	255.28%	255%	
18	TS2C14	TS2C14 : Bilangan organisasi yang terlibat dalam program kerjaya [Bilangan]	Bilangan	80	80	89	111%	

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15	TS2C10	TS2C10: Peratus pelajar kelas pertama daripada bilangan graduan tahunan [Peratus/tahun]	Peratus	3.2%	3.2%	18.97%	593%
16	TS2C11	TS2C 11 : Peratus pelajar yang menyertai program bersama masyarakat (community engagement) [Peratus/tahun]	Peratus	25%	25%	30.48%	122%
17	TS2C12	TS2C12 : Peratus pelajar yang menyertai program yang dikategorikan sebagai aktiviti "finishing school" [Peratus/tahun]	Peratus	100%	100%	255.28%	255%
18	TS2C14	TS2C14 : Bilangan organisasi yang terlibat dalam program kerjaya [Bilangan]	Bilangan	80	80	89	111%
19	TS2F1	TS2F1 : Peratus hasil terimaan luar untuk aktiviti pelajar [Peratus/tahun]	Peratus	60%	60%	99.06%	165%
20	TS2F2	TS2F2 : Bajet tahunan penyelidikan [RM/tahun]	RM	RM 160,000.00	RM 160,000.00	RM 141,626.00	89%
21	TS2P3	TS2P3 : Bilangan aktiviti yang melibatkan alumni [Bilangan]	Bilangan	35	35	57	163%
22	TS2P4	TS2P4a : Bilangan pelajar tempatan yang terlibat dengan mobiliti pelajar (Inbound) melibatkan transfer kredit [Bilangan]	Bilangan	45	45	267	593%
23	TS2P4	TS2P4b : Bilangan pelajar luar negara yang terlibat dengan mobiliti pelajar (Inbound) melibatkan transfer kredit [Bilangan]	Bilangan	43	43	291	677%
24	TS2P4	TS2P4c : Bilangan pelajar UUM yang terlibat dengan mobiliti pelajar (Outbound) di institusi tempatan melibatkan transfer kredit [Bilangan]	Bilangan	71	71	41	58%
25	TS2P4	TS2P4d : Bilangan pelajar UUM yang terlibat dengan mobiliti di institusi luar negara (Outbound) melibatkan transfer kredit [Bilangan]	Bilangan	71	71	96	135%
26	TS2P4	TS2P4e : Bilangan pelajar tempatan yang terlibat dengan mobiliti pelajar (Inbound) tidak melibatkan transfer kredit [Bilangan]	Bilangan	430	430	581	135%
27	TS2P4	TS2P4f : Bilangan pelajar luar negara yang terlibat dengan mobiliti pelajar (Inbound) tidak melibatkan transfer kredit [Bilangan]	Bilangan	430	430	743	173%
28	TS2P4	TS2P4g : Bilangan pelajar UUM yang terlibat dengan mobiliti pelajar (Outbound) tidak melibatkan transfer kredit [Bilangan]	Bilangan	404	404	427	106%
29	TS2P4	TS2P4h : Bilangan pelajar UUM yang terlibat dengan mobiliti di institusi luar negara (Outbound) tidak melibatkan transfer kredit [Bilangan]	Bilangan	404	404	325	80%

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9	TERAS 2	TS2P4b : Bilangan pelajar luar negara yang terlibat dengan mobiliti pelajar (Inbound) melibatkan transfer kredit [Bilangan]	43	43	291	677%	
10	TERAS 2	TS2P4c : Bilangan pelajar UUM yang terlibat dengan mobiliti pelajar (Outbound) di institusi tempatan melibatkan transfer kredit [Bilangan]	71	71	41	58%	
11	TERAS 2	TS2P4d : Bilangan pelajar UUM yang terlibat dengan mobiliti di institusi luar negara (Outbound) melibatkan transfer kredit [Bilangan]	71	71	96	135%	
12	TERAS 3	TS3C2f : Peratus enrolmen pelajar antarabangsa ijazah sarjana muda berbanding jumlah pelajar ijazah sarjana muda [Peratus]	10%	10%	6.05%	60%	
13	TERAS 3	TS3C5a : Peratus pelajar sarjana muda sepenuh masa yang mempunyai kelayakan masuk 3.0 dan ke atas [Peratus]	30%	30%	67.25%	224%	
14	TERAS 3	TS3L1a : Peratus staf akademik dengan pengalaman industri/ profesional [Peratus]	10%	10%	12.24%	122%	
15	TERAS 3	TS3L1b : Peratus staf akademik dengan pengalaman mengajar di luar negara [Peratus]	10%	10%	7.25%	73%	
16	TERAS 3	TS3L2a : Saiz ruang pengajaran dan pembelajaran per pelajar [per kaki perseg]	12	12	13	108%	
17	TERAS 3	TS3L2b : Peratus penggunaan teknologi terkini secara aktif [Peratus]	100%	100%	93.2%	93%	
18	TERAS 3	TS3L3 : Peratus kursus yang mendapat skor 3.0 dan ke atas [Peratus]	100%	100%	96.84%	97%	
19	TERAS 5	TS5C2 : Peratus jumlah staf akademik yang berkelayakan PhD daripada jumlah keseluruhan staf akademik [Peratus]	70%	70%	68.36%	98%	
20	TERAS 5	TS5L2 : Nisbah kaunselor berlesen kepada bilangan pelajar Sarjana Muda sepenuh masa [Nisbah]	1,000.00	1,000.00	761.00	131%	
21	TERAS 5	TS5L3 : Nisbah pegawai perubatan kepada pelajar Ijazah Sarjana Muda sepenuh masa [Nisbah]	1,000.00	1,000.00	845.56	118%	
22	TERAS 5	TS5L4a : Peratus staf akademik dari bilangan keseluruhan staf [Peratus]	50%	50%	32.86%	66%	
23	TERAS 5	TS5L4c : Nisbah pelajar sarjana muda sepenuh masa kepada jumlah staf akademik [Nisbah]	14	14	13.8	101%	

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11	TERAS 2	TS2P4d : Bilangan pelajar UUM yang terlibat dengan mobiliti di institusi luar negara (Outbound) melibatkan transfer kredit [Bilangan]	71	71	96	135%
12	TERAS 3	TS3C2f : Peratus enrolmen pelajar antarabangsa ijazah sarjana muda berbanding jumlah pelajar ijazah sarjana muda [Peratus]	10%	10%	6.05%	60%
13	TERAS 3	TS3C5a : Peratus pelajar sarjana muda sepenuh masa yang mempunyai kelayakan masuk 3.0 dan ke atas [Peratus]	30%	30%	67.29%	224%
14	TERAS 3	TS3L1a : Peratus staf akademik dengan pengalaman industri/ profesional [Peratus]	10%	10%	12.24%	122%
15	TERAS 3	TS3L1b : Peratus staf akademik dengan pengalaman mengajar di luar negara [Peratus]	10%	10%	7.25%	73%
16	TERAS 3	TS3L2a : Saiz ruang pengajaran dan pembelajaran per pelajar [per kaki persegi]	12	12	13	108%
17	TERAS 3	TS3L2b : Peratus penggunaan teknologi terkini secara aktif [Peratus]	100%	100%	93.2%	93%
18	TERAS 3	TS3L3 : Peratus kursus yang mendapat skor 3.0 dan ke atas [Peratus]	100%	100%	96.84%	97%
19	TERAS 5	TS5C2 : Peratus jumlah staf akademik yang berkelayakan PhD daripada jumlah keseluruhan staf akademik [Peratus]	70%	70%	68.36%	98%
20	TERAS 5	TS5L2 : Nisbah kaunselor berlesen kepada bilangan pelajar Sarjana Muda sepenuh masa [Nisbah]	1,000.00	1,000.00	761.00	131%
21	TERAS 5	TS5L3 : Nisbah pegawai perubatan kepada pelajar Ijazah Sarjana Muda sepenuh masa [Nisbah]	1,000.00	1,000.00	845.56	118%
22	TERAS 5	TS5L4a : Peratus staf akademik dari bilangan keseluruhan staf [Peratus]	50%	50%	32.86%	66%
23	TERAS 5	TS5L4c : Nisbah pelajar sarjana muda sepenuh masa kepada jumlah staf akademik [Nisbah]	14	14	13.8	101%
24	TERAS 5	TS5L8 : Perbelanjaan latihan staf [Peratus/tahun]	5%	5%	2.38%	48%

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APPENDIX B

MODEL A IN LINGO 12.0

```
MIN = 300*x1 + 6000*x2 + 1000*x3 + 500*x3new + 3000*x4 + 1000*x4newI +
1000*x4newT +20000*x5 + 96000*x6 + 96000*x7 + 125000*x8 + 96000*x9 +
500*x10;

0.004*x1 <= 0.600;

0.00029*x2 <= 0.2625;

0.0007*x3 <= 0.300;

0.0007*x4 <= 0.300;

0.0028*x5 <= 0.078;

0.0033*x6 <= 0;

0.0025*x7 = 0.275;

0.0007*x8 <= 0.06;

0.003*x9 <= 0.308;

0.0004*x10 <= 0.2;

0.004*x1 +0.00029*x2 + 0.0007*x3 +0.0007*x4 + 0.0028*x5 + 0.0033*x6 + 0.0025*x7
+ 0.0007*x8 + 0.003*x9 + 0.0004*x10 >= 1.8552;

@GIN (x1);

@GIN (x2);

@GIN (x3);

@GIN (x4);

@GIN (x5);

@GIN (x6);

@GIN (x7);

@GIN (x8);

@GIN (x9);

@GIN (x10);
```

MODEL A'S OPTIMAL SOLUTION

Global optimal solution found.

Objective value:	0.1529100E+08
Objective bound:	0.1529100E+08
Infeasibilities:	0.000000
Extended solver steps:	0
Total solver iterations:	0

Model Class:	MILP

Total variables:	12
Nonlinear variables:	0
Integer variables:	9

Total constraints:	11
Nonlinear constraints:	0

Total nonzeros:	30
Nonlinear nonzeros:	0

Variable	Value	Reduced Cost
X1	150.0000	300.0000
X2	364.0000	6000.000
X3	428.0000	1000.000
X3NEW	0.000000	500.0000
X4	428.0000	3000.000
X4NEWI	0.000000	1000.000

X4NEWT	0.000000	1000.000
X5	27.00000	20000.00
X6	0.000000	96000.00
X7	110.0000	0.000000
X8	0.000000	125000.0
X9	0.000000	96000.00
X10	500.0000	500.0000

Row	Slack or Surplus	Dual Price
1	0.1529100E+08	-1.000000
2	0.000000	0.000000
3	0.1569400	0.000000
4	0.4000000E-03	0.000000
5	0.4000000E-03	0.000000
6	0.2400000E-02	0.000000
7	0.000000	0.000000
8	0.000000	-0.3840000E+08
9	0.6000000E-01	0.000000
10	0.3080000	0.000000
11	0.000000	0.000000
12	0.1600000E-03	0.000000

APPENDIX C

MODEL B IN LINGO 12.0

```
MIN = 300*x1 + 6000*x2 + 1000*x3 + 3000*x4 +20000*x5 + 96000*x6 + 96000*x7 +
125000*x8 + 96000*x9 + 500*x10;
0.004*x1 <= 0.600;
0.0003*x2 <= 0.2625;
0.0007*x3 <= 0.300;
0.0007*x4 <= 0.300;
0.0028*x5 <= 0.078;
0.0033*x6 <= 0;
0.0025*x7 <= 0.0825;
0.0007*x8 <= 0.06;
0.003*x9 <= 0.308;
0.0004*x10 <= 0.2;
0.004*x1 +0.00029*x2 + 0.0007*x3 +0.0007*x4 + 0.0028*x5 + 0.0033*x6 + 0.0025*x7
+ 0.0007*x8 + 0.003*x9 + 0.0004*x10 >= 2.087;
@GIN (x1);
@GIN (x2);
@GIN (x3);
@GIN (x4);
@GIN (x5);
@GIN (x6);
@GIN (x7);
@GIN (x8);
@GIN (x9);
@GIN (x10);
```

MODEL B'S OPTIMAL SOLUTION

Global optimal solution found.

Objective value:	0.1960500E+08
Objective bound:	0.1960500E+08
Infeasibilities:	0.000000
Extended solver steps:	0
Total solver iterations:	0
Model Class:	PILP
Total variables:	10
Nonlinear variables:	0
Integer variables:	10
Total constraints:	12
Nonlinear constraints:	0
Total nonzeros:	30
Nonlinear nonzeros:	0

Variable	Value	Reduced Cost
X1	150.0000	300.0000
X2	875.0000	6000.000
X3	428.0000	1000.000
X4	428.0000	3000.000
X5	27.00000	20000.00
X6	0.000000	96000.00
X7	21.00000	96000.00
X8	0.000000	125000.0
X9	102.0000	96000.00
X10	500.0000	500.0000

Row	Slack or Surplus	Dual Price
1	0.1960500E+08	-1.000000
2	0.000000	0.000000
3	0.000000	0.000000
4	0.4000000E-03	0.000000
5	0.4000000E-03	0.000000
6	0.2400000E-02	0.000000
7	0.000000	0.000000
8	0.3000000E-01	0.000000
9	0.6000000E-01	0.000000

10	0.2000000E-02	0.000000
11	0.000000	0.000000
12	0.5000000E-04	0.000000

APPENDIX D

MODEL C

MAX = 0.004*x1 + 0.00029*x2 + 0.0007*x3 + 0.0007*x4 + 0.0028*x5 + 0.0033*x6 + 0.0025*x7 + 0.0007*x8 + 0.003*x9 + 0.0004*x10;

0.004*x1 <= 0.6;

0.00029*x2 <= 0.263;

0.0007*x3 <= 0.300;

0.0007*x4 <= 0.300;

0.0028*x5 <= 0.078;

0.0033*x6 <= 0;

0.0025*x7 <= 0.275;

0.0007*x8 <= 0.06;

0.003*x9 <= 0.308;

0.0004*x10 <= 0.2;

300*x1 + 6000*x2 + 1000*x3 + 3000*x4 +20000*x5 + 96000*x6 + 96000*x7 + 125000*x8 + 96000*x9 + 500*x10 <= 25000000;

@GIN (x1);

@GIN (x2);

@GIN (x3);

@GIN (x4);

@GIN (x5);

@GIN (x6);

@GIN (x7);

@GIN (x8);

@GIN (x9);

@GIN (x10);

MODEL C'S OPTIMAL SOLUTION

Global optimal solution found.

Objective value:	2.231040
Objective bound:	2.231040
Infeasibilities:	0.000000
Extended solver steps:	0
Total solver iterations:	0

Model Class:	PILP

Total variables:	10
Nonlinear variables:	0
Integer variables:	10

Total constraints:	12
Nonlinear constraints:	0

Total nonzeros:	30
Nonlinear nonzeros:	0

Variable	Value	Reduced Cost
X1	150.0000	-0.4000000E-02
X2	906.0000	-0.2900000E-03
X3	428.0000	-0.7000000E-03
X4	428.0000	-0.7000000E-03
X5	27.00000	-0.2800000E-02
X6	0.000000	-0.3300000E-02
X7	75.00000	-0.2500000E-02
X8	0.000000	-0.7000000E-03
X9	102.0000	-0.3000000E-02

X10	500.0000	-0.4000000E-03

Row	Slack or Surplus	Dual Price
1	2.231040	1.000000
2	0.000000	0.000000
3	0.2600000E-03	0.000000
4	0.4000000E-03	0.000000
5	0.4000000E-03	0.000000
6	0.2400000E-02	0.000000
7	0.000000	0.000000
8	0.8750000E-01	0.000000
9	0.6000000E-01	0.000000
10	0.2000000E-02	0.000000
11	0.000000	0.000000
12	25000.00	0.000000

APPENDIX E

MODEL D

MIN = 300*x1 + 6000*x2 + 1000*x3 + 500*x3new + 3000*x4 + 1000*x4newI + 1000*x4newT +20000*x5 + 96000*x6 + 96000*x7 + 125000*x8 + 96000*x9 + 500*x10;

```
0.004*x1 <= 0.600;

0.00029*x2 <= 0.2625;

0.0007*x3 + 0.0007*x3new <= 0.300;

0.0007*x4 + 0.0007*x4newI + 0.0007*x4newT  <= 0.300;

0.0028*x5 <= 0.078;

0.0033*x6 <= 0;

0.0025*x7 <= 0.275;

0.0007*x8 <= 0.06;

0.003*x9 <= 0.308;

0.0004*x10 <= 0.2;

0.004*x1 +0.00029*x2 + 0.0007*x3 + 0.0007*x3new + 0.0007*x4 +  0.0007*x4newI +
0.0007*x4newT  + 0.0028*x5 + 0.0033*x6 + 0.0025*x7 + 0.0007*x8 + 0.003*x9 +
0.0004*x10 >= 1.8552;

@GIN (x1);

@GIN (x2);

@GIN (x3);

@GIN (x4);

@GIN (x5);

@GIN (x6);

@GIN (x7);

@GIN (x8);

@GIN (x9);

@GIN (x10);

@GIN (x3new);

@GIN (x4newI);

@GIN (x4newT);
```

MODEL D'S OPTIMAL SOLUTION

Global optimal solution found.

Objective value: 0.1070500E+08

Objective bound: 0.1070500E+08

Infeasibilities: 0.000000

Extended solver steps: 0

Total solver iterations: 0

Model Class: PILP

Total variables: 13

Nonlinear variables: 0

Integer variables: 13

Total constraints: 12

Nonlinear constraints: 0

Total nonzeros: 39

Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	150.0000	300.0000
X2	898.0000	6000.000
X3	0.000000	1000.000
X3NEW	428.0000	500.0000
X4	0.000000	3000.000
X4NEWI	0.000000	1000.000
X4NEWT	428.0000	1000.000
X5	27.00000	20000.00
X6	0.000000	96000.00
X7	0.000000	96000.00

X8	0.000000	125000.0
X9	40.00000	96000.00
X10	500.0000	500.0000

Row	Slack or Surplus	Dual Price
1	0.1070500E+08	-1.000000
2	0.000000	0.000000
3	0.2080000E-02	0.000000
4	0.4000000E-03	0.000000
5	0.4000000E-03	0.000000
6	0.2400000E-02	0.000000
7	0.000000	0.000000
8	0.2750000	0.000000
9	0.6000000E-01	0.000000
10	0.1880000	0.000000
11	0.000000	0.000000
12	0.2000000E-04	0.000000

APPENDIX F

MODEL E

```
MIN = 300*x1 + 6000*x2 + 1000*x3 + 500*x3new + 3000*x4 + 1000*x4newI +
1000*x4newT +20000*x5 + 96000*x6 + 96000*x7 + 125000*x8 + 96000*x9 +
500*x10;
0.004*x1 <= 0.600;
0.0003*x2 <= 0.2625;
0.0007*x3 + 0.0007*x3new <= 0.300;
0.0007*x4 + 0.0007*x4newI + 0.0007*x4newT  <= 0.300;
0.0028*x5 <= 0.078;
0.0033*x6 <= 0;
0.0025*x7 <= 0.0825;
0.0007*x8 <= 0.06;
0.003*x9 <= 0.308;
0.0004*x10 <= 0.2;
0.004*x1 +0.0003*x2 + 0.0007*x3 + 0.0007*x3new + 0.0007*x4 + 0.0007*x4newI +
0.0007*x4newT  + 0.0028*x5 + 0.0033*x6 + 0.0025*x7 + 0.0007*x8 + 0.003*x9 +
0.0004*x10 >= 2.087;
@GIN (x1);
@GIN (x2);
@GIN (x3);
@GIN (x4);
@GIN (x5);
@GIN (x6);
@GIN (x7);
@GIN (x8);
@GIN (x9);
@GIN (x10);
@GIN (x3new);
@GIN (x4newI);
@GIN (x4newT);
```

MODEL E'S OPTIMAL SOLUTION

Global optimal solution found.

Objective value:	0.1822300E+08
Objective bound:	0.1822300E+08
Infeasibilities:	0.000000
Extended solver steps:	0
Total solver iterations:	25
Model Class:	PILP
Total variables:	13
Nonlinear variables:	0
Integer variables:	13
Total constraints:	12
Nonlinear constraints:	0
Total nonzeros:	39
Nonlinear nonzeros:	0

Variable	Value	Reduced Cost
X1	150.0000	300.0000
X2	871.0000	6000.000
X3	0.000000	1000.000
X3NEW	428.0000	500.0000
X4	0.000000	3000.000
X4NEWI	288.0000	1000.000
X4NEWT	140.0000	1000.000
X5	27.00000	20000.00
X6	0.000000	96000.00
X7	18.00000	96000.00
X8	0.000000	125000.0
X9	102.0000	96000.00
X10	500.0000	500.0000

Row	Slack or Surplus	Dual Price
1	0.1822300E+08	-1.000000
2	0.000000	0.000000
3	0.1200000E-02	0.000000
4	0.4000000E-03	0.000000
5	0.4000000E-03	0.000000
6	0.2400000E-02	0.000000
7	0.000000	0.000000
8	0.3750000E-01	0.000000
9	0.6000000E-01	0.000000
10	0.2000000E-02	0.000000
11	0.000000	0.000000

12	0.1000000E-03	0.000000

APPENDIX G

MODEL F

MAX = 0.004*x1 + 0.00029*x2 + 0.0007*x3 + 0.0007*x3new + 0.0007*x4 + 0.0007*x4newI + 0.0007*x4newT + 0.0028*x5 + 0.0033*x6 + 0.0025*x7 + 0.0007*x8 + 0.003*x9 + 0.0004*x10;

0.004*x1 <= 0.6;

0.00029*x2 <= 0.263;

0.0007*x3 + 0.0007*x3new <= 0.300;

0.0007*x4 + 0.0007*x4newI + 0.0007*x4newT <= 0.300;

0.0028*x5 <= 0.078;

0.0033*x6 <= 0;

0.0025*x7 <= 0.275;

0.0007*x8 <= 0.06;

0.003*x9 <= 0.308;

0.0004*x10 <= 0.2;

300*x1 + 6000*x2 + 1000*x3 + 500*x3new + 3000*x4 + 1000*x4newI + 1000*x4newT + 20000*x5 + 96000*x6 + 96000*x7 + 125000*x8 + 96000*x9 + 500*x10 <= 25000000;

@GIN (x1);

@GIN (x2);

@GIN (x3);

@GIN (x4);

@GIN (x5);

@GIN (x6);

@GIN (x7);

@GIN (x8);

@GIN (x9);

@GIN (x10);

@GIN (x3new);

@GIN (x4newI);

@GIN (x4newT);

MODEL F'S OPTIMAL SOLUTION

Objective bound:	2.258540
Infeasibilities:	0.000000
Extended solver steps:	0
Total solver iterations:	0
Model Class:	PILP

Total variables:	13
Nonlinear variables:	0
Integer variables:	13
Total constraints:	12
Nonlinear constraints:	0
Total nonzeros:	39
Nonlinear nonzeros:	0

Variable	Value	Reduced Cost
X1	150.0000	-0.4000000E-02
X2	906.0000	-0.2900000E-03
X3	0.000000	-0.7000000E-03
X3NEW	428.0000	-0.7000000E-03
X4	0.000000	-0.7000000E-03
X4NEWI	0.000000	-0.7000000E-03
X4NEWT	428.0000	-0.7000000E-03
X5	27.00000	-0.2800000E-02
X6	0.000000	-0.3300000E-02
X7	86.00000	-0.2500000E-02
X8	0.000000	-0.7000000E-03
X9	102.0000	-0.3000000E-02
X10	500.0000	-0.4000000E-03

Row	Slack or Surplus	Dual Price
1	2.258540	1.000000
2	0.000000	0.000000

3	0.2600000E-03	0.000000
4	0.4000000E-03	0.000000
5	0.4000000E-03	0.000000
6	0.2400000E-02	0.000000
7	0.000000	0.000000
8	0.6000000E-01	0.000000
9	0.6000000E-01	0.000000
10	0.2000000E-02	0.000000
11	0.000000	0.000000
12	39000.00	0.000000

APPENDIX H

WHAT-IF ANALYSIS I

MAX = 0.004*x1 + 0.0003*x2 + 0.0007*x3 + 0.0007*x3new + 0.0007*x4 + 0.0007*x4newI + 0.0007*x4newT + 0.0028*x5 + 0.0033*x6 + 0.0025*x7 + 0.0007*x8 + 0.003*x9 + 0.0004*x10;

0.004*x1 <= 0.6;

0.0003*x2 <= 0.263;

```
0.0007*x3 + 0.0007*x3new <= 0.300;

0.0007*x4 +  0.0007*x4newI +  0.0007*x4newT <= 0.300;

0.0028*x5 <= 0.078;

0.0033*x6 <= 0;

0.0025*x7 <= 0.0825;

0.0007*x8 <= 0.06;

0.003*x9 <= 0.308;

0.0004*x10 <= 0.2;

300*x1 + 6000*x2 + 1000*x3 + 500*x3new + 3000*x4 + 1000*x4newI +
1000*x4newT + 20000*x5 + 96000*x6 + 96000*x7 + 125000*x8 + 96000*x9 +
500*x10 <= 22500000;

@GIN (x1);
@GIN (x2);
@GIN (x3);
@GIN (x4);
@GIN (x5);
@GIN (x6);
@GIN (x7);
@GIN (x8);
@GIN (x9);
@GIN (x10);
@GIN (x3new);
@GIN (x4newI);
@GIN (x4newT);
```



```
Global optimal solution found.
Objective value:                 2.141500
Objective bound:                 2.141500
Infeasibilities:                 0.000000
Extended solver steps:                  0
Total solver iterations:                0

Model Class:                         PILP
```

Total variables:	13
Nonlinear variables:	0
Integer variables:	13
Total constraints:	12
Nonlinear constraints:	0
Total nonzeros:	39
Nonlinear nonzeros:	0

Variable	Value	Reduced Cost
X1	150.0000	-0.4000000E-02
X2	876.0000	-0.3000000E-03
X3	0.000000	-0.7000000E-03
X3NEW	428.0000	-0.7000000E-03
X4	0.000000	-0.7000000E-03
X4NEWI	0.000000	-0.7000000E-03
X4NEWT	428.0000	-0.7000000E-03
X5	27.00000	-0.2800000E-02
X6	0.000000	-0.3300000E-02
X7	33.00000	-0.2500000E-02
X8	22.00000	-0.7000000E-03
X9	102.0000	-0.3000000E-02
X10	500.0000	-0.4000000E-03

Row	Slack or Surplus	Dual Price
1	2.141500	1.000000
2	0.000000	0.000000
3	0.2000000E-03	0.000000
4	0.4000000E-03	0.000000
5	0.4000000E-03	0.000000
6	0.2400000E-02	0.000000
7	0.000000	0.000000
8	0.000000	0.000000
9	0.4460000E-01	0.000000
10	0.2000000E-02	0.000000
11	0.000000	0.000000
12	57000.00	0.000000

APPENDIX I

WHAT-IF ANALYSIS II

MIN = 330*x1 + 6000*x2 + 1000*x3 + 500*x3new + 3000*x4 + 1000*x4newI + 1000*x4newT +20000*x5 + 96000*x6 + 96000*x7 + 125000*x8 + 96000*x9 + 500*x10;

0.004*x1 <= 0.600;

0.0003*x2 <= 0.2625;

0.0007*x3 + 0.0007*x3new <= 0.300;

0.0007*x4 + 0.0007*x4newI + 0.0007*x4newT <= 0.300;

0.0028*x5 <= 0.078;

0.0033*x6 <= 0;

0.0025*x7 <= 0.0825;

0.0007*x8 <= 0.06;

0.003*x9 <= 0.308;

0.0004*x10 <= 0.2;

0.004*x1 +0.0003*x2 + 0.0007*x3 + 0.0007*x3new + 0.0007*x4 + 0.0007*x4newI + 0.0007*x4newT + 0.0028*x5 + 0.0033*x6 + 0.0025*x7 + 0.0007*x8 + 0.003*x9 + 0.0004*x10 >= 1.8552;

```
@GIN (x1);
@GIN (x2);
@GIN (x3);
@GIN (x4);
@GIN (x5);
@GIN (x6);
@GIN (x7);
@GIN (x8);
@GIN (x9);
@GIN (x10);
@GIN (x3new);
@GIN (x4newI);
@GIN (x4newT);
```

```
Global optimal solution found.
Objective value:                0.1052950E+08
Objective bound:                0.1052950E+08
Infeasibilities:                0.000000
Extended solver steps:                 0
Total solver iterations:              47

Model Class:                        PILP

Total variables:             13
Nonlinear variables:          0
Integer variables:           13

Total constraints:           12
Nonlinear constraints:        0

Total nonzeros:              39
```

Nonlinear nonzeros: 0

Variable	Value	Reduced Cost
X1	150.0000	330.0000
X2	868.0000	6000.000
X3	0.000000	1000.000
X3NEW	428.0000	500.0000
X4	0.000000	3000.000
X4NEWI	0.000000	1000.000
X4NEWT	428.0000	1000.000
X5	27.00000	20000.00
X6	0.000000	96000.00
X7	0.000000	96000.00
X8	0.000000	125000.0
X9	40.00000	96000.00
X10	500.0000	500.0000

Row	Slack or Surplus	Dual Price
1	0.1052950E+08	-1.000000
2	0.000000	0.000000
3	0.2100000E-02	0.000000
4	0.4000000E-03	0.000000
5	0.4000000E-03	0.000000
6	0.2400000E-02	0.000000
7	0.000000	0.000000
8	0.8250000E-01	0.000000
9	0.6000000E-01	0.000000
10	0.1880000	0.000000
11	0.000000	0.000000
12	0.000000	0.000000

APPENDIX J

WHAT-IF ANALYSIS III

```
MIN = 300*x1 + 6000*x2 + 1000*x3 + 3000*x4 +20000*x5 + 96000*x6 + 96000*x7 +
125000*x8 + 96000*x9 + 500*x10;
0.004*x1 <= 0.600;
0.0003*x2 <= 0.2625;
0.0007*x3 <= 0.300;
0.0007*x4 <= 0.300;
0.0028*x5 <= 0.078;
0.0033*x6 <= 0;
0.0025*x7 = 0.0825;
0.0007*x8 <= 0.06;
0.003*x9 <= 0.308;
0.0004*x10 <= 0.2;
0.004*x1 +0.00029*x2 + 0.0007*x3 +0.0007*x4 + 0.0028*x5 + 0.0033*x6 + 0.0025*x7
+ 0.0007*x8 + 0.003*x9 + 0.0004*x10 >= 1.6233;
```

```
@GIN (x1);
@GIN (x2);
@GIN (x3);
@GIN (x4);
@GIN (x5);
@GIN (x6);
@GIN (x7);
@GIN (x8);
@GIN (x9);
@GIN (x10);
```

```
Global optimal solution found.
Objective value:                    7083000.
Objective bound:                    7083000.
Infeasibilities:                    0.000000
Extended solver steps:                     0
Total solver iterations:                   0

Model Class:                            PILP

Total variables:                  9
Nonlinear variables:              0
Integer variables:                9

Total constraints:               11
Nonlinear constraints:            0

Total nonzeros:                  27
Nonlinear nonzeros:               0
```

Variable	Value	Reduced Cost
X1	150.0000	300.0000
X2	228.0000	6000.000
X3	428.0000	1000.000
X4	428.0000	3000.000
X5	27.00000	20000.00
X6	0.000000	96000.00
X7	33.00000	0.000000
X8	0.000000	125000.0
X9	0.000000	96000.00
X10	500.0000	500.0000

Row	Slack or Surplus	Dual Price
1	7083000.	-1.000000
2	0.000000	0.000000

3	0.1941000	0.000000
4	0.4000000E-03	0.000000
5	0.4000000E-03	0.000000
6	0.2400000E-02	0.000000
7	0.000000	0.000000
8	0.000000	-0.3840000E+08
9	0.6000000E-01	0.000000
10	0.3080000	0.000000
11	0.000000	0.000000
12	0.1200000E-03	0.000000