A CASE STUDY ON THE APPLICATION OF 0-1 GOAL PROGRAMMING : NURSE SCHEDULING

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To my beloved

ayah, Hj. Rosdy Hj. Dalhani

ibu, Hjh. Siti Aminah Hj. Ibrahim

akak, Shantini Hj. Rosdy

abang, Hj. Ahmad Yasir Hj. Rosdy

&

little niece, Auni Dalili

Hold fast to dreams
For if dreams die
Life is a broken-winged bird
That cannot fly.

Hold fast to dreams
For when dreams go
Life is a barren field
Frozen with snow.

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ABSTRACT

The continuous pattern of working 24 hours a day, 7 days a week, needs a working shift environment that could affect the working conditions of the nurses. This involves social life and nurses' level of health. Therefore the development of a nurse scheduling model that can be accepted well by all parties is necessary to enable it to be applied in the nurse scheduling system. This nurse scheduling considers policy imposed by the hospital and demand from the nurses so that there is more balance, quality and fairness in the production of the nurse scheduling model. Hence, in this research, 0-1 goal programming approach is applied in the development of nurse scheduling model because of its ability to produce a model with multiple objectives. Approach to the problem was illustrated on the Maternity Ward 2, Hospital Tawau, Sabah involving U29 and U19 nurses. The result obtained by LINGO software version 10.0 shows that the developed model of nurse scheduling using 0-1 goal programming approach performs better than the manual method. This is because it was successful in meeting the hospital policy and nurses' preferences.

ABSTRAK

Corak bekerja yang berterusan iaitu selama 24 jam sehari 7 hari seminggu, memerlukan waktu kerja mengikut syif yang boleh memberi kesan yang mendalam ke atas keadaan kerja jururawat. Ini melibatkan kehidupan sosial dan tahap penjagaan kesihatan jururawat. Oleh itu pembangunan sebuah model penjadualan jururawat yang dapat diterima baik oleh semua pihak adalah perlu bagi membolehkan ia digunapakai dalam sistem penjadualan jururawat. Penjadualan jururawat ini mempertimbangkan polisi yang dikenakan oleh pihak hospital dan permintaan daripada jururawat agar model penjadualan jururawat yang dihasilkan lebih adil, berkualiti dan seimbang. Justeru, dalam kajian ini, pendekatan pengaturcaraan gol 0-1 diaplikasikan di dalam pembangunan model penjadualan jururawat ini kerana keupayaannya menghasilkan sebuah model dengan pelbagai matlamat. Pendekatan ke atas masalah ini diilustrasikan ke atas jururawat di Maternity Ward 2, Hospital Tawau, Sabah yang melibatkan jururawat terlatih U29 dan jururawat masyarakat U19. Daripada hasil penyelesaian menggunakan perisian LINGO versi 10.0, didapati model penjadualan jururawat secara pengaturcaraan gol 0-1 adalah lebih baik berbanding kaedah secara manual. Ini kerana ia berjaya memenuhi polisi pihak hospital dan permintaan jururawat.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Operational Research involves the application of scientific principles to decision making. Its development as a formal discipline can be traced to World War II when these techniques were used by the British military in order to determine how best to use radar devices (Cohen, 1984). The name “Operational Research” was introduced because scientists were used to study operational problems. The allied forces also used operational research for strategic bombing, anti submarine and mining operations.

The growth of operational research since World War II has been due primarily to the development of the digital computer. Many of the techniques that were developed during the war also could be applied to industry problems after the war. Production, inventory, maintenance and scheduling techniques were readily transferable. New models eventually were developed for applications in budgeting, capital, marketing and other areas. Today, operational research is being used in almost every field where complex decisions must be made. It is used not only by industries, but also by local and federal governments for public health, regional planning, transportation, education, meteorology and countless other areas.

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LIST OF ABBREVIATIONS

MCDA	-	Multi-criteria decision analysis
MCDM	-	Multi-criteria decision making
MIGP	-	Mix Integer Goal Programming
ME	-	Marketing executive
GP	-	Goal programming
LGP	-	Linear goal programming
NP	-	Non-deterministic polynomial-time

LIST OF SYMBOLS

G_i	-	*ith* goal
w_i	-	*ith* weight
ρ_i	-	*ith* priority
G	-	general objective function

LIST OF APPENDICES

The analysis of a problem involves many steps. The formulation phase is the most crucial, because if the problem is not set up correctly, the solution found may be the correct answer to the wrong problem. An operational research model usually consists of a system of mathematical equations that contains all information that is relevant to the decision. Computational algorithms have been developed that will solve the system equations and find the satisfying solution.

The environment in which decision makers operate has become increasingly complex. To deal with the vast amount of data that needs to be assimilated and many objectives that must be considered, managers have called upon mathematical modeling to help them make the best decisions. In many instances the use of these models is the only way that a person can hope to attain the best solution.

The decision maker is further limited by a lack of information, limited resources, and an inability to analyze the decision environment accurately. When a decision is reached, it may not be the absolute optimum, the point where all goals have been achieved. Usually, only a "satisfying" solution can be attained, not every goal has been completely achieved, but the firm has come as close as possible. Modern decision analysis introduces a scientific approach that aids the decision maker in achieving the best non optimum, satisfying value.

Decisions are limited by many constraints that are placed upon them. There are two types of constraints which limit the options of decision makers. System constraints are imposed by the decision environment. These include limits on time, manpower, the production capacity of equipment, government regulations, and collective bargaining agreements. Decision constraints are imposed by the organizational goal structure and can change as new policies are adopted. If these goals are ranked and weights are placed upon each one according to its importance, the decision analysis will indicate the best decision. Possible goals include sales goals, profit goals, pollution control,

labor stabilization and goals external growth. A good model will take all of these factors into consideration.

One of the discipline in operational research is multi-criteria decision analysis (MCDA), which sometimes called as multi-criteria decision making (MCDM). It is a discipline aimed at supporting decision makers who are faced with making numerous and conflicting evaluations. MCDA aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process. Unlike methods that assume the availability of measurements, measurements in MCDA are derived or interpreted subjectively as indicators of the strength of various preferences. Preferences differ from decision maker to decision maker, so the outcome depends on who is making the decision and what their goals and preferences are. (Andrew, *et al.* , 2008). Since MCDA involves a certain element of subjectiveness, the morals and ethics of the researcher implementing MCDA play a significant part in the accuracy and fairness of MCDA's conclusions. The ethical point is very important when one is making a decision that seriously impacts on other people, as opposed to a personal decision. Some of the MCDA methods are analytic hierarchy process, analytic network process, inner product of vectors, multi-attributte value theory, data envelopment analysis, dominance-based rough set approach, aggregated indices randomnization method and goal programming. The choice of which model is most appropriate depends on the problem at hand and may be to some extent dependent on which model the decision maker is most comfortable with.

1.2 Background of the problem

Linear programming (LP) is a mathematical method for determining a way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model for some list of requirements represented as linear equations.

More formally, linear programming is a technique for the optimization of a linear objective function, subject to linear equality and linear inequality constraints. Given a polyhedron a real-valued affine function defined on this polyhedron, a linear programming method will find a point on the polyhedron where this function has the smallest (or largest) value if such point exists, by searching through the polyhedron vertices.

Linear programs are problems that can be expressed in canonical form :

Maximize $\boldsymbol{c^T x}$
Subject to $\boldsymbol{Ax \leq b}$

where $\boldsymbol{x}$ represents the vector of variables (to be determined), $\boldsymbol{c}$ and $\boldsymbol{b}$ are vectors of (known) coefficients and **A** is a (known) matrix of coefficients. The expression to be maximized or minimized is called the objective function ($\boldsymbol{c^T x}$ in this case). The equations $\boldsymbol{Ax \leq b}$ are the constraints which specify a convex polytope over which the objective function is to be optimized.

Linear programming can be applied to various fields of study. It is used most extensively in business and economics, but can also be utilized for some engineering problems. Industries that use linear programming models include transportation, energy, telecommunications, and manufacturing. It has proved useful in modeling diverse types of problems in planning, routing, scheduling, assignment, and design.

In linear programming problems there is a single objective function to be maximized or minimized (subject to constraints). In some problems there may be more than one competing objective (or goal) and we need to trade-off objectives against each other.

One way of handling problems with multiple objectives is to choose one of the goals as the supreme goal and to treat the others as constraints to ensure that some minimal ‘satisficing’ level of the other goals is achieved. However, goal programming provides a more satisfactory treatment where in many cases problems can still be solved using standard linear programming algorithms.

In a linear programming problem, there is a single objective and constraints are absolutely binding. While in a goal programming problem, there are multiple objectives (with trade-offs) and deviations from constraints are penalized.

Goal programming is a form of linear programming that considers multiple goals that are often in conflict with each other. With multiple goals, all goals usually cannot be realized exactly. For example, the twin goals of an investor who desires investments with maximum return and with minimum risk are generally incompatible and therefore unachievable. Other examples of multiple conflicting objectives can be found in organizations that want to: (1) maximize profits and increase wages; (2) upgrade product quality and reduce product cost; (3) pay larger dividends to stockholders and retain earnings for growth; and (4) reduce credit losses and increase sales. Goal programming does not attempt to maximize or minimize a single objective function as does the linear programming model. Rather, it seeks to minimize the deviations among the desired goals and the actual results according to the priorities assigned. The objective function of a goal programming model is expressed in terms of the deviations from the target goals.

As goal programming is a branch of multi-criteria decision analysis (MCDA), also known as multiple-criteria decision making (MCDM), which in turn it is known as a branch of multi objective optimization. This is an optimization program. It is an extension or generalization of linear programming to handle multiple, normally conflicting objective measures. Each of these measures is given a goal or target value to be achieved. Unwanted deviations from this set of target values are then minimized in

an achievement function. This can be a vector or a weighted sum dependent on the goal programming variant used.

Goal programming has been applied to multi objective decision problems in nonprofit organizations, business firms, and government agencies. The most popular application areas of goal programming have been functional management problems, policy analysis, scheduling, resource allocation, and planning. Applications of goal programming include financial planning, resource allocation for environmental problem, municipal economic planning, transportation logistics, advertising media planning, manpower planning, aggregate production planning, capital budgeting, portfolio selection, marketing planning, academic resource planning, and hospital administration.

Goal programming problems can be categorized according to the types of mathematical programming models such as linear programming and nonlinear programming. In this dissertation, the application of goal programming that will be explored is scheduling using the linear goal programming model. This is goal programming problems that fit linear programming where each objective function is linear.

Scheduling is the process by which we plan our use of time. By scheduling effectively, we can reduce stress and maximize our effectiveness. This makes it one of the most important time management skills we can use. It is also a form of planning selects and sequences activities such that they achieve one or more goals. Nurse scheduling is part of a general scheduling problem, which deals with the satisfactory allocation of resources over time to achieve an organization’s tasks. A hospital in general unavoidably will have many scheduling problems in its operations. They need to minimize unnecessary conflicts in the proper and efficient use of its limited resources.

Nursing costs account for 50 percent of total hospital costs (Kiranmai *et al*., 2000), in other words, the manner on which nurses are deployed has a significant impact on a hospital's operating budget and quality of work life for employees. Moreover, scheduling is a key to effectiveness and efficiency. An effective scheduling of nursing personal is directly affects the quality of patient care. Hence, in this research, we will focus on scheduling problems which dealing with the nurse shifting activity of Maternity Ward 2, Hospital Tawau, Sabah.

Nurse scheduling has been addressed by operations researchers and computer scientists for more than 40 years (Burke *et al.*, 2004). The scheduling of hospital personnel is particularly challenging because of different staffing needs on different days and shifts. Unlike many other organizations, healthcare institutions work around the clock. Irregular shift work has an effect on the nurses' well being and job satisfaction (Muelle *et al.*, 1990). The extent to which the staff roster satisfies the staff can impact upon the working environment.

The nurse rerostering problem occurs when one or more nurses cannot work in shifts that were previously assigned to her or them. If no pool of reserve nurses exists to replace those absent, then the current roster must be rebuilt. This new roster must comply with the labour rules and institutional constraints. Moreover, it must be as similar as possible to the current one.

The problem is further complicated by such factors as, variation in patient demand, nurse qualification and specialization, acuity of patient illnesses, organizational characteristics (e.g minimum required coverage and days off policies), unpredictable absenteeism, and personal requests for vacations, work stretch, and work pattern. Moreover, some of these considerations may conflict with others, such as employee requests versus the need to balance workload.

Nursing skills are in short supply and retaining qualified people is important (Ozkaharan,1989). Job satisfaction, turnover and absenteeism have all been related to personnel scheduling flexibility. Some individuals might prefer longer but fewer days while others might prefer shorter days. Some nurses would choose part time work if available. Some people, irrespective of shift, would like to start earlier while others would opt for a later start time. No fixed personnel scheduling policy can satisfy all interests and flexible alternatives are needed to increase satisfaction and retention. Besides, the demand for care varies more on the morning and evening shift than on night shift.

One major disadvantage of these various alternative flexible scheduling patterns was the increased complexity of management control. As long as a nursing shortage exists, nursing administrators must either accept the added complexity of work schedules or find themselves paying more for nursing and accepting reduced quality of nursing care.

Oldenkamp and Simons (1995) have suggested five factors for assessing a schedule quality. These factors are given below :

1. Optimality : represents the degree in which nursing expertise is distributed over the different shifts.

2. Completeness : represents the degree in which the quantitative demands for occupation per shift are met.

3. Proportionality : represents the degree in which each nurse has been given about the same amount of working days (morning, evening and night shifts).

4. Healthiness : represents the degree in which it has been taken care of the welfare and health of the nurses.

5. Continuity factor : represents the degree in which there is continuity in the nursing crew during the different shifts.

1.3 Statement of the problem

In order to develop a model of scheduling, this study will embark on the application of 0-1 linear goal programming particularly in nurse scheduling based on identified constraints.

Nurse scheduling is a difficult and time consuming task. The schedule should determine the day to day shift assignments of each nurse for a specified horizon of time in a way that satisfies the given requirements. The schedule should also be fair enough to everyone and not disruptive to nurses' health, families or social lives.

The problems in nurse scheduling are including developing a systematic procedure for allocating nurses to work shifts and workdays in a way to ensure a continuous and appropriate service of patient care and satisfying organizational scheduling policies, such as specific work requirements while using minimum staffing to avoid wasted manpower.

There are few research questions to be answered throughout this research which are:

1. What is the importance of linear goal programming in multi objectives problem?

2. How can 0-1 linear goal programming be applied in nurse scheduling problem?

3. How effective is the linear goal programming approach in solving scheduling problem?

1.4 Objectives of the study

The goal of this research is to apply 0-1 linear goal programming in nurse scheduling for Maternity Ward 2, Hospital Tawau, Sabah.

The objectives of this study are:

- To highlight the importance of linear goal programming in multi objectives problem
- To apply 0-1 linear goal programming approach in nurse scheduling system
- To investigate the effectiveness of linear goal programming approach and its contribution in improving scheduling system

1.5 Scope of the study

The scope of this study is to apply 0-1 linear goal programming approach in nurse scheduling with the aid of LINGO software. Data is gathered from Maternity Ward 2, Hospital Tawau, Sabah which consists of nurses' preferences and nurses' roster. Respondents involve are U29 nurses and U19 nurses from Maternity Ward 2.

1.6 Significance of the study

The need for quick, reliable and manageable scheduling system is often encountered in any organization. This study is an introduction of scientific approach in making decision. The result from this study is practical for other organizations as a guide in scheduling especially that involves in working shift time. Scheduling nursing personnel in hospitals is very complex because of the variety of conflicting interests and objectives. Also, demand varies 24-hours a day 7-days a week, needs specific skills to build up the schedule. In the face of this complexity, the needed of a good approach is important in order to satisfy all the constraints and requirements in nurse scheduling models. Thus, application of 0-1 linear goal programming using LINGO software is the main purpose of this study to see whether this approach is good enough for helping to improve the scheduling problems in the hospital.

1.7 Dissertation Organization

The contents of this dissertation have been arranged to be read chapter by chapter. The contents of each chapter are as follows:

Chapter 1 : This chapter outline a general introduction, background of the problem, statement of the problem, objectives of the study, scope of the study and significance of the study.

Chapter 2 : This chapter looks at the literature review involving scheduling, nurse scheduling and goal programming.

Chapter 3 : This chapter describes the methodology for using linear goal programming to solve nurse scheduling problem.

Chapter 4 : This chapter presents the implementation of 0-1 linear goal programming in nurse scheduling problem.

Chapter 5 : This chapter highlights the result from the implementation of 0-1 linear goal programming in nurse scheduling using LINGO version 10.0 and the discussion as well as the analysis is done and presented using appropriate graphs by the help of Microsoft Office Excel 2007.

Chapter 6 : This chapter summarizes and concludes the study. Some conclusions are drawn and finally, some thoughts on possible directions in which future study in this area might be pursued are offered.

1.8 Summary

This chapter, generally discusses on background of the problem, problem statement, research objective, scope and significance of the study. In other word, this chapter gives a general idea of overall situation and the flow of research.