A SCIENTIFIC APPROACH FOR UNIVERSITY COURSE TIMETABLING

by

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DECLARATION

The work described in this thesis was carried out by me under the supervision of Dr.W.B.Daundasekera and a report on this has not been submitted in whole or in part to any university or any other institution for another Degree/Diploma.

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October, 2005.

We approve the thesis of Mr.P.Paramathevan for the Master degree in Industrial Mathematics.

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ABSTRACT

The main objective of this thesis is to search for a scientific method to prepare the university course timetable satisfying all the university requirements subject to the available resources in the university. In this report we propose an optimization method to achieve this objective. First, we develop an optimization model by interpreting the objective and the constraints of the existing problem mathematically.

This particular optimization model is known as a 0-1 Integer Linear Programming problem. We apply the Branch and Bound technique to solve this model with the help of the optimization software package known as LINGO. Finally, the solution to the optimization model is transformed to a regular university course timetable.

Chapter 1

INTRODUCTION

University course timetabling problems are combinatorial problems which consist of scheduling a set of courses within a given number of rooms and time slots. Solving a university timetabling problem manually, often requires a significant amount of time, sometimes several days or several weeks. Therefore, a lot of researches have been invested in order to provide automated support for human timetablers. Contributions come from the fields of Operations Research (graph coloring, network flow techniques) are much more than other techniques such as simulated annealing, tabu search, genetic algorithms, constraints satisfaction etc.

Many practical problems in Operational Research can be expressed as Linear Programming Problems and certain special cases of mathematical programming problems such as Mixed Integer Linear Programming, Integer Linear Programming, 0-1 Integer Linear Programming etc. They have been used to maximize profit and minimize cost on decisions involving production planning, transportation, finance, portfolio allocation, capital budgeting, blending, scheduling, inventory, resource allocation ect.

In 0 -1 Integer Linear Programming, the decision variables both in the objective function and the constraints are linear and they can take values either 0 or 1.

There are several computer software packages available to solve these types of mathematical programming problems such as Maple, Mathematica, Dora, Lingo etc. Out of these packages LINGO is used since it has the potential to solve 0-1 Integer Linear Programming Problems.

Also, there are several techniques such as, Branch and Bound enumeration method, cutting plane method, search enumeration method, graph theoretical approach to solve these types of programming problems. The nature of the model suggested us to use Branch and Bound enumerative method. The method is explained in Chapter 3.

In this report, a mechanism based on 0 -1 Integer Linear Programming is proposed to prepare the University course timetable. This proposed method not only avoid the overlapping among the teachers, classes (group of students attending exactly the same courses) or classrooms but also include some additional features which are not so easy to include when preparing a timetable manually, such as:

- if a course has to be assigned on a particular day more than one time slots, that should be scheduled in the adjacent time slots.
- all the lecture hours of a course on a particular day should be scheduled in the same lecture hall, etc.

The objective function of our optimization model is considered as a cost function, where cost is interpreted as penalty and penalty is defined based on the desirebility of a teacher to teach in a particular time slot. Therefore, our attempt is to minimize the penalty subject to the given constraints.
Penalty is calculated in 1 to 100 scale and it is decided according to the magnitude of the undesirability of a teacher to teach in a particular time slot. Here, undesirability of a teacher to teach a subject at a particular time slot is

obtained based on the following conditions:

- health condition.
- traveling time.
- personal matters.

A penalty is assigned to each teacher according to the method mentioned above and hence prepare the penalty matrix (shown in Table 7.6). Based on these penalties, optimal objective value returns minimum number of "undesired" time periods. These penalties will appear as coefficients in the objective function.

The following assumptions are made in this proposed method:

- length of each time slot is one hour.
- uncapacitated classrooms.
- upper limit of number of time slots per day is 7.
- upper limit of number of working days per week is 5.

Decision variables are represented as Xi_j_k, where i, j, k represent the course, room, time slot number, respectively. Details of the Courses offered in the university are listed in Table 7.2 of Appendix B. Lecture halls and their assigned numbers are shown in the Table 7.8 . Since each working day consists of seven time slots, there are total of 35 time slots per week. Teacher's name, and the number assigned to that teacher is given in Table 7.1.

The constraints of the model are given in Chapter 3. In this chapter we also discuss the method of interpreting the solution obtained by LINGO.

In this research project we develop a computer program, coded in C++, to generate the objective function as well as the constraints. Therefore, the user only has to input the data which are given in Appendix B according to the application. Since the model generated by this computer program suits the LINGO format, the user can simply feed the model to the package to solve the problem.

Chapter 2

LITERATURE REVIEW

In the recent past many scientists have developed different algorithms to solve a very common problem in an academic institution known as timetabling problem. By going through the research papers published on this subject, it is quite evidence that most of the attempts were made to solve this problem using optimization technique.

In this chapter we present some of the methods discussed on different research papers to solve the problem, which are related to our proposed method.

The research paper published by Slim Abdennadher and Michael Marte from Germany under the title "University Course Timetabling Using Constraint Handling Rules" in year 2000 has proposed a Constraint Logic programming approach. Here they categorized the constraints into hard and soft constraints. Initially the effort is given to satisfy the hard constraints relaxing soft constraints. Once this is achieved the some efforts are given to satisfy the soft constraints without violating the hard constraints. In this way the proposed method has made an effort to solve the problem on a reasonable computational time.

The research paper published in 2001 under the title "University Course Timetabling with Soft Constraints" by Hana Rudova and Keith Murray form USA is also an extension of Constraint Logic programming which is used by

Slim Abdennadher and Michael Marte. But in this approach it is suggested that to give a weight for each soft constraint rather than treating them equally as in Constraint Logic programming algorithm.

A genetic algorithm was also proposed in the same year under the title "A GA evolving instructions for a timetable builder" by Christian Blum, Sebastiao Correia, Marco Dorigo, BenPacchter, Olivia Rossi-Doria and Marko Snock to solve university course timetabling problem. This is generally known as a non-optimization technique.

After a couple of years later, in 2003 another research paper was published by Krzysztof Socha, Michael Sampels, and Max Manfrin from Belgium, under the title "Ant Algorithms for the University Course Timetabling Problem with Regard to the State-of-the-Art" to solve the university course timetabling problem. Here they proposed two algorithms known as Ant algorithms which are also optimization technique. The algorithms are named as "Ant Colony System" and "MAX-MIN Ant System". In the same year, there was another research paper titled "Efficient Timetabling Solution with Tabu Search" published by Jean-Franois Cordeau, Brigitte Jaumard, Rodrigo and Morales from Canada based on Tabu search algorithm. This is also an optimization technique which is similar to the approach used in the research paper "University Course Timetabling Using Constraint Handling Rules". Initially the objective is to satisfy the hard constraints and then try to satisfy the soft constraints.

In addition to these techniques, some local search algorithms have been proposed by Abramson[2], Colorni et al.[3], Corne et al.[4] and Schaerf & Gaspero [5], Burke et al.[6]. An extensive overview of other recent heuristic approaches is reported in [7,8,9,10,11]. A mathematical programming formulation for the School Timetabling problem has been introduced in Tripathy [12]. Birbas et al.[13] presented the formulation of a Timetabling problem for