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LINEAR PROGRAMMING APPROACH FOR SCHEDULING SPORTS LEAGUE PROBLEMS IN MALAYSIA

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LINEAR PROGRAMMING APPROACH FOR SCHEDULING SPORTS LEAGUE PROBLEMS IN MALAYSIA

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Sports league problems in Malaysia are usually made by manual method or so called ad-hoc method. This means that the construction of a particular schedule is based on the availability of the chosen venues (stadiums) and number of teams involved. Moreover, the popular style of scheduling team sport in Malaysia was Home-Away approach which has no mathematical formulation model and never consider important factors such as travelling cost. Thus, heuristic is used in the beginning to solve sports league problem in term of minimizing travelling distance.

In this thesis we propose to formulate a linear programming (LP) model to schedule sports league problems in Malaysia whereby the tournament style will be definitely different from Home-Away restriction. We consider an important factor such as travelling cost while scheduling and efficient strategy to replace tournament with Home-Away style. Besides, the venues (stadiums) involve are predefined before the construction of the schedule begin. To validate the formulated model, we compare results obtain by heuristic approach using the same data.

In order to solve the formulated LP model, we proposed several solution methods such as simplex and genetics algorithm. Besides, we also consider large problems in our formulated model as we introduced the cluster approach. In cluster approach, the large problems in scheduling sports league will be separated into few small clusters where all the small problems solve simultaneously and being linked back to the original problem in the end to achieve global optimal solution.

A sensitivity analysis is performed towards our formulated model. In our case, we focus on solely the predefined venues while performing sensitivity analysis to see how our model reacted. We get a greater number of total travelling distances when we select different predefined venues which are at remote places. This means that our formulated model is suitable for solving our problems.

Our numerical results show that the total travelling distance using our formulated model is lower than the conventional Home-Away style of tournament. The results shown is promising because the formulated model can lowered the cost associated with travelling distance.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENJADUALAN MASALAH LIGA SUKAN DI MALAYSIA MENGGUNAKAN PENDEKATAN PENGATURCARAAN LINEAR

Oleh

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Kebiasaannya, masalah penjadualan liga sukan di Malaysia menggunakan kaedah manual atau dipanggil sebagai kaedah segera (eg: tanpa perancangan rapi) dalam pembinaan jadual. Dalam erti kata lain, kaedah segera ini hanya mengambil kira kekosongan tempat dan bilangan pasukan yang terlibat. Tambahan, kaedah penjadualan liga sukan di Malaysia menggunakan peraturan tuan-rumah-pelawat yang mana ianya tidak mempunyai model matematik dan juga tidak mengambil kira faktor-faktor penting seperti kos perjalanan.

Dalam tesis ini, kami bercadang untuk membina satu model pengaturcaraan matematik linear di dalam tesis ini untuk membentuk jadual liga sukan di Malaysia sejurus peraturan yang diguna pakai sama sekali berbeza daripada peraturan tuan-rumah pelawat. Kami pertimbangkan faktor penting seperti kos perjalanan dalam pembinaan jadual liga sukan dan strategi yang lebih efisien untuk menggantikan kaedah penjadualan tuan-rumah-pelawat. Selain itu, stadium yang terlibat dalam jadual liga sukan ditetapkan sebelum proses pembuatan jadual bermula.

Bagi menyelesaikan masalah penjadualan menggunakan model pengaturcaraaan linear yang dibina, kami mencadangkan beberapa kaedah penyelesaian seperti simplex dan algoritma genetik. Selain itu, kami pertimbangkan penyelesaian bagi masalah yang besar dalam model yang telah diformulasi dengan mengenalkan kaedah kluster. Dalam pendekatan kluster, suatu masalah besar dalam penjadualan liga sukan dibahagikan kepada beberapa masalah kecil yang dipanggil sebagai

kluster. Masalah-masalah kecil tersebut akan diselesaikan secara serentak dan hasil dapatan daripada setiap kluster akan digabungkan kembali kepada masalah asal pada akhirnya menjadi hasil yang optimum.

Kami menjalankan analisis kesensitifan terhadap model yang telah diformulasi. Dalam kes kami, analsis kesensitifan yang dijalankan berfokus kepada stadium-stadium yang dipilih pada awalnya untuk melihat bagaimana model kami bertindak balas. Hasilnya, jumlah jarak perjalanan adalah lebih tinggi jika stadium-stadium yang dipilih terletak di tempat yang terpencil. Ini bermaksud bahawa model yang diformulasi adalah sesuai untuk digunakan untuk menyelesaikan masalah yang kami hadapi.

Keputusan numerik menunjukkan bahawa jumlah jarak perjalanan menggunakan model yang direka adalah lebih rendah daripada kaedah yang digunapakai iaitu kadeah tuan-rumah-pelawat. Hasil yang diperoleh adalah memberangsangkan kerana model yang diformulasi mampu untuk mengurangkan kos yang berkaitan dengan jarak perjalanan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

LP	Linear Programming
ILP	Integer Linear Programming
RRT	Round Robin Tournament
DRRT	Double Round Robin Tournament
TTP	Traveling Tournament Problem
GA	Genetics Algorithm

CHAPTER 1

INTRODUCTION

1.1 Operations Research

In 1940, London was in ruins. German bombers rained fire at will on virtually defenceless England. If future positions of approaching enemy planes could be anticipated, anti-aircraft guns could be mounted. In August of 1940 however, when the new technology of radar, on which rode the very hopes of British survival, was introduced into the field, the data were worse than what human spotters from rooftops were providing.Thus, to work out in a week or two the best method of using the radar data was the assignment for the first operational research (OR) group created to ensure the survival of a country; England.

Operations research or operational research in the U.K, is a discipline that deals with the application of advanced analytical methods to help make better decisions. The terms management science and analytics are sometimes used as synonyms for operations research. In operations research, problems are broken down into basic components and then solved in defined steps by mathematical analysis.

Operations research encompasses a wide range of problem-solving techniques and methods applied in the pursuit of improved decision-making and efficiency, such as simulation, mathematical optimization, queuing theory, Markov decision processes, economic methods, data analysis, statistics, neural networks, expert systems, and decision analysis. Nearly all of these techniques involve the construction of mathematical models that attempt to describe the system.

Because of the computational and statistical nature of most of these fields, OR also has strong ties to computer science. OR researchers faced with a new problem must determine which of these techniques are most appropriate given the nature of the system, the goals for improvement, and constraints on time and computing power. The process of analytical methods used in OR can be broadly broken down into three steps.

1. A set of potential solutions to a problem is developed. (This set may be large.)
2. The alternatives derived in the first step are analyzed and reduced to a small set of solutions most likely to prove workable.
3. The alternatives derived in the second step are subjected to simulated implementation and, if possible, tested out in real-world situations. In this final step, psychology and management science often play important roles.

Meanwhile, the major sub-disciplines in modern operations research are optimization, transportation, financial engineering, marketing science, computing & information technologies, policy modeling & public sector work, revenue management, simulation stochastic model, manufacturing, service science & supply chain and environment, energy, & natural resources.

Among all the eleven sub-disciplines listed before, our research will mainly relates on only two of them which are optimization and transportation. For a clearer picture, let see some of the theories and problem instances involved within the operations research.

1.1.1 Queuing Theory

The first queueing theory problem was considered by Erlang in 1908 as stated in Beasley (1990) who looked at how large a telephone exchange needed to be in order to keep to a reasonable value the number of telephone calls not connected because the exchange was busy (lost calls). Within ten years he developed a (complex) formula to solve the problem. In general, queuing theory deals with problems which involve queuing (or waiting). Typical examples might be:

- public transport - waiting for a train or a bus,
- banks/supermarkets - waiting for service,
- computers - waiting for a response,
- failure situations - waiting for a failure to occur (e.g. in a piece of machinery).

Wait time is affected by the design of the waiting line system. A waiting line system (or queuing system) is defined by two elements: the population source of its customers and the process or service system itself. When there is more customer demand for a service than what can be provided, a waiting line occurs. Customers can be either humans or inanimate objects. Examples of objects that must wait in lines include a machine waiting for repair, a customer order waiting to be processed, and subassemblies in a manufacturing plant (that is, work-in-progress inventory).

In a waiting line system, managers must decide what level of service to offer. A low level of service may be inexpensive, at least in the short run, but may incur high costs of customer dissatisfaction, such as lost future business and actual processing costs of complaints. A high level of service will cost more to provide and will result in lower dissatisfaction costs. Because of this trade-off, management must consider what is the optimal level of service to provide. In essence all queuing systems can be broken down into individual sub-systems consisting of entities queuing for some activity as shown below:

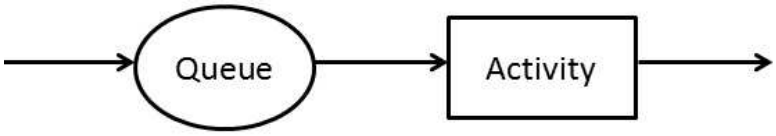

Figure 1.1: Queueing theory essence.

1.1.2 Transportation Problems

In 1781, a French Mathematician formulated the transportation theory which is name given to the study of optimal transportation and allocation of resources. Major advances were made during World War II by the Soviet/Russian mathematician and economist. In latter, the transportation theory is also known as the Monge-Kantorovich transportation problem and the linear programming formulation of the transportation problem is known as the Hitchcook-Koopmans transportation problem.

Transportation problems are best illustrated by an example. Suppose that we have a collection of n mines mining iron ore, and a collection of n factories which consume the iron ore that the mines produce. Suppose for the sake of argument that these mines and factories form two disjoint subsets M and F of the Euclidean plane $\mathbb{R}^2$. Suppose also that we have a cost function $c : \mathbb{R}^2 \times \mathbb{R}^2 \to [0, \infty)$. So that $c(x,y)$ is the cost of transporting one shipment of iron from x to y.

For simplicity, we ignore the time taken to do the transporting. We also assume that each mine can supply only one factory (no splitting of shipments) and that each factory requires precisely one shipment to be in operation (factories cannot work at half- or double-capacity). Having made the above assumptions, a transport plan is a bijection $T : M \to F$. In other words, each mine $m \in M$ supplies precisely one factory $T(m) \in F$ and each factory is supplied by precisely one mine. Thus, in transportation problems, the aim is to find the optimal transport plan, the plan T whose total cost is the least of all possible routes from M to F.

One of the famously known transportation problem is the assignment problem. For instance, say that five groups of computer users must be trained for five new types of software. Because the users have different computer skill levels, the total cost of trainings depends on the assignments.

A balanced assignment problem has the same number of people and tasks. For a balanced assignment problem, the relationships are all equal. Each person must do a task. For an unbalanced assignment problem with more people than tasks, some people don't have to do a task and the first class of constraints is of the type. In general, the simplex method does not guarantee that the optimal values of the

Table 1.1: Cost of trainings according to the groups of users

User Groups	Software Types				
	S1	S2	S3	S4	S5
A	5	4	6	4	1
B	2	5	4	10	5
C	10	12	10	6	8
D	1	3	4	2	6
E	2	5	8	11	7

decision variables are integers. Fortunately, for the assignment model, all of the corner point solutions have integer values for all of the variables. Therefore, when the simplex method determines the optimal corner point, all of the variable values are integers and the constraints require that the integers be either 1 or 0 (Boolean).

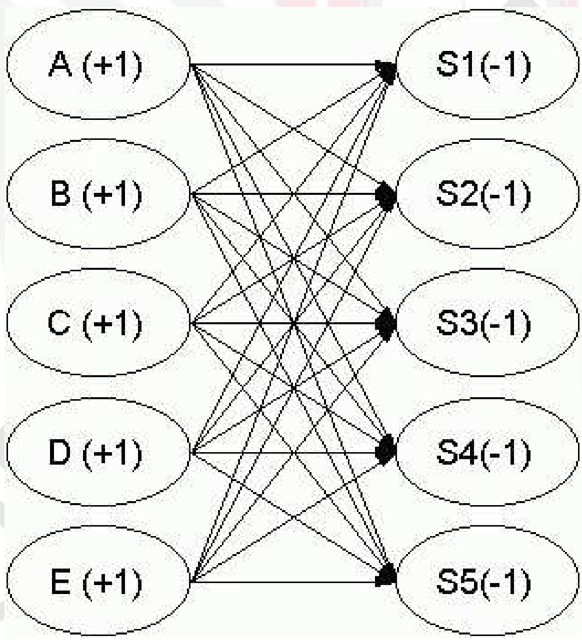

Figure 1.2: Network model for assignment problem

1.1.3 Scheduling Problems

A schedule or a timetable, as a basic time-management tool, consists of a list of times at which possible tasks, events, or actions are intended to take place, or of a sequence of events in the chronological order in which such things are intended to take place. The process of creating a schedule that is deciding how to order these tasks and how to commit resources between the variety of possible tasks is called scheduling. Meanwhile, a person responsible for making a particular schedule may be called as scheduler. It is believed that making and following schedules is an ancient human activity.

Schedules can usefully span both short periods, such as a daily or weekly schedule, and long-term planning with respect to periods of several months or years. They are often made using a calendar, where the person making the schedule can note the dates and times at which various events are planned to occur. Schedules that do not set forth specific times for events to occur may instead list algorithmically an expected order in which events either can or must take place.

In operations research, the scheduling of resources, usually subject to constraints, is the subject of several problems, in terms of finding an optimal solution or method for solving. For example, the nurse scheduling problem is concerned with scheduling a number of employees with typical constraints such as rotation of shifts and limits on overtime. The travelling salesman problem is concerned with scheduling a series of journeys to minimize time or distance. Some of these problems may be solved efficiently with linear programming, but many scheduling problems require integer variables. An example of the objective function of linear programming formulation for the nurse scheduling problem can be seen below.

$$\min \quad \lambda * (\sum_{i=1}^{T}\sum_{k=1}^{K}\sum_{s=1}^{S} D_{i,k,s}) + (1-\lambda) * G(\sum_{i=1}^{T}\sum_{k=1}^{K}\sum_{s=1}^{S} D_{i,k,s})$$

The objective function above was aimed to minimize shift of nurses in a day, D with a weightage that assigned by λ and then subject to several hard and soft constraints.

1.2 Sports Tournament

The history of sports by myth probably extends as far back as the military training existence, to prove themselves fit and useful for army requirements, the best been chosen to serve and fight for the power in command. Team sports had most probably been developed to train and prove the capability to fight and work together as a team (army). Later, sports has also been a useful way for people to increase their mastery of nature and the environment.

The history of sport can teach us a great deal about social changes and about the nature of sport itself. Sport seems to involve the development and exercise of basic human skills for their own sake, parallel with their being exercised for their usefulness. It also shows how society has changed its beliefs and therefore there are changes in rules. Of course, as one goes further back in history, dwindling evidence makes theories of the origins and purposes of sport more and more difficult to support.

An example of math formulation (linear programming) for sports tournament can be seen as in objective function below.

$$\min \sum_{i \in N} \sum_{j \in N \setminus \{i\}} \sum_{t=1}^{T} c_{ijt} x_{ijt}$$

The objective of linear programming formulation above is to minimize the total costs where the c_{ijt} is the cost of preferences in scheduling sports league and the x_{ijt} is a decision variable. Of course the objective will be subject to several constraints too as in linear programming shown for scheduling nurses shift.

1.3 Background and Scope of the Study

Today, the urge of finding solutions and best method to solve a problem are no more focuses on anticipating aircraft missiles; it is now about everything. Even public servants use the lowest distance route in order to save their own fuel consumption. Same goes to scheduling, as the problem grows bigger it becomes harder to do it manually. Scheduling nowadays is no longer simply about making a game fixture. There are a lot of constraints to think of and the best way to tackle such hardness is by using mathematical model. Therefore, we come out with an idea which is to solve the scheduling of sports league problems which uses one of the mathematics know-how or known as linear programming.

We believe that our work is very significant as most of schedulers here in Malaysia are using ad-hoc method to establish schedule for sports league. Plus, most of them never consider costs such as travelling cost as the main subject. Hence, we introduce some of mathematical tools such as heuristic approach and linear programming model to schedule sports league with minimum cost.

1.4 Objectives

This thesis focuses on scheduling a tournament by considering constraints which normally present in scheduling a basic tournament. We consider different types of tournaments, since we want to be as universal as possible, but yet not too generics as we will focus on team sports. The specified constraints for teams sports could for instance be the constraints on traveling distance or the order in which teams play against each other. The result will be a program which can be used and run in polynomial time based on data and requirement given from the tournament organiser.

The second part is actually where this thesis differs from the previous work. Most of previous work are on scheduling a Home-Away tournament and to be more specific, a lot of them are focusing on minimizing the number of breaks (the number of consecutive home or away games). On the other hand, this thesis aimed to formulate an alternative method for Home-Away tournament which at the same time reduce cost as much as possible. Therefore, to achieve such aims, our objective can be specified as follows:

(i) to construct LP model for scheduling sports league in Malaysia with predefined venues to replace the standard Home-Away approach;

(ii) to propose clustering technique in handling large problem arises in scheduling sports league with many teams;

(iii) to perform the sensitivity analysis on the proposed model in terms of traveling distance.

1.5 Outlines

Chapter 2 provides a literature review, sorted based on the type of approaches. This then lead to how the idea of our research pop out. Methods used for some previous works will also be mentioned as it will help to clarify the novelty of our proposed model. Chapter 3 presents details on heuristics approach and an example of heuristic algorithm. We also show how heuristic approach solve preliminary data as a matter of comparison in the next chapter.

Chapter 4 gives the general problem description and the formulation mathematical model that we propose. We input preliminary data into the formulated model to to validate our model. While aiming for the desired or expected result, we continue on establishing the sports schedule simultaneously.

Chapter 5 is the implementation of real data into our proposed model and the solving parts of the problem using polynomial algorithm. We also insert an alternative way towards large problem when the initial approach is no longer efficient or to be more specific, exceed software limitations. Lastly in Chapter 6 we provide the conclusion and some of possible future works.

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