ADVANCING INDUSTRIAL ENGINEERING IN NIGERIA THROUGH TEACHING, RESEARCH AND INNOVATION

A BOOK OF READING

Edited By
Ayodeji E. Oluleye
Victor O. Oladokun
Olusegun G. Akanbi

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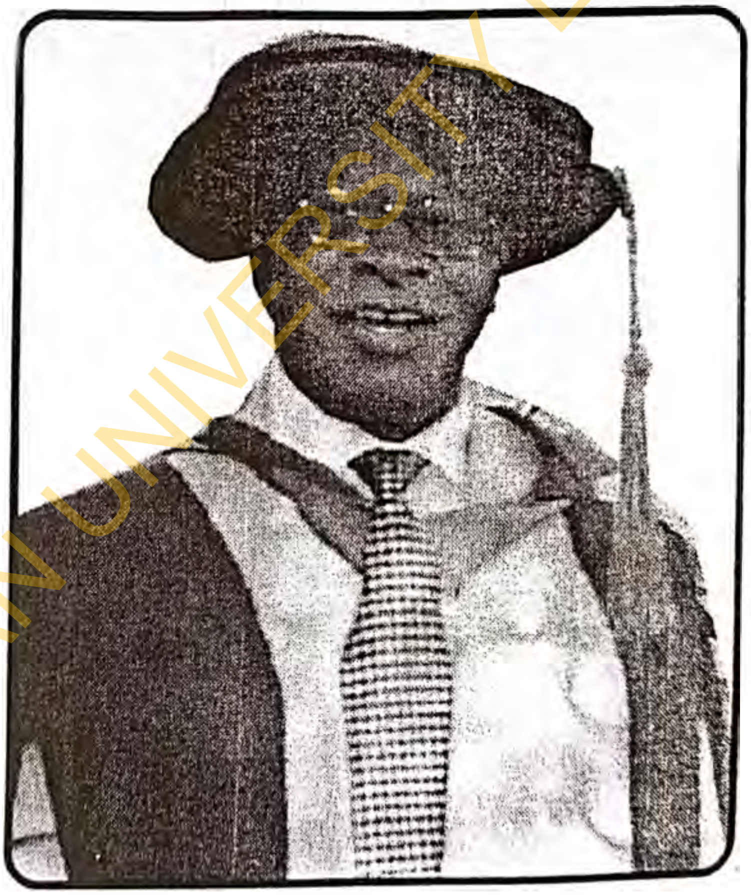
(A Festchrift in honour of Professor O. E Charles-Owaba)



Professor O. E. Charles-Owaba

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FOREWORD

It gives me great pleasure writing the foreword to this book. The book was written in recognition of the immense contributions of one of Nigeria's foremost industrial engineers, respected teacher, mentor, and lover of youth – Professor Oliver Charles-Owaba.

His commitment to the teaching and learning process, passionate pursuit of research and demonstration of excellence has prompted his colleagues and mentees to write this book titled – Advancing Industrial Engineering in Nigeria through Teaching, Research and Innovation (A Festschrift in honour of Professor O. E Charles-Owaba) as a mark of honour, respect and recognition for his personality and achievements.

Professor Charles-Owaba has written scores of articles and books while also consulting for a medley of organisations. He has served as external examiner to various programmes in the tertiary educational system. The topics presented in the book cover the areas of Production/Manufacturing Engineering, Ergonomics/Human Factors Engineering, Systems Engineering, Engineering Management, Operations Research and Policy. They present the review of the literature, extension of theories and real-life applications. These should find good use in the drive for national development.

Based on the above, and the collection of expertise in the various fields, the book is a fitting contribution to the corpus of knowledge in industrial engineering. It is indeed a befitting gift in honour of erudite Professor Charles-Owaba.

I strongly recommend this book to everyone who is interested in how work systems can be made more productive and profitable. It represents a resourceful compilation to honour a man who has spent the last forty years building up several generations of industrial engineers who are part of the process to put Nigeria in the rightful seat in the comity of nations. Congratulations to Professor Charles-Owaba, his colleagues and mentees for this festschrift.

Professor Godwin Ovuworie
Department of Production Engineering
University of Benin

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CHAPTER 6
An Integer Linear Programming Model of a University Soccer Timetabling Problem

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1. Introduction

Timetabling is an integral part of the human life. Schedules and timetables are made every day, although in an informal way. This ranges from deciding whether or not to go to the market, to deciding what time to go see that friend or go to the bank. Plans and schedules of activities are made every single day. Without timetabling, there would be low productivity and chaos in the arrangements of activities. Hence, it is important that there is an optimization method that provides some form of organization. The whole process of timetabling is aimed at finding suitable timeslots for defined tasks, all subject to certain constraints. Essentially, the allocation of resources to time is the sole purpose of timetabling. Timetabling can be applied in several sectors, such as schools, factories, sporting events and so on.

The application of timetabling in sporting events has grown to become perhaps the most popular use case amongst the various application areas mentioned. Many sporting events feature games or matches between teams. There is also a specified duration of the sporting event, along with other constraints like stadium and official availability. The teams also have to be taken into consideration, as they must not be put under duress by the tournament schedule.

Also, whether or not the teams will be put in groups have to be determined. There are several other essential factors that need to be studied and determined for a sporting event to be a success. This means that for any sporting event to be well organized, an optimization method to assign the teams to time slots subject to the many constraints has to be employed. The importance of timetabling in sports cannot be overemphasized as every single sport tournament employs timetabling methods to ensure seamless and smooth operations.

Resources will not be properly utilized if the schedule of a sporting event is not well planned. The quality of the schedule of sporting events impacts the fairness of competition, revenue generation from the event, and the satisfaction of the players, coaches and fans(Goldberg, 2003). Given the importance of the schedule of sporting events, it is very paramount to optimize the various resources of these events.

Timetabling in sports has been studied by several scholars over the years. Extensive studies have been done on various types of sporting events, particularly, National sports tournaments (Bartsch et al., 2006; Cocchi et al., 2018; Della Croce & Oliveri, 2006; Durán et al., 2007; Kostuk & Willoughby, 2012; Ribeiro & Urrutia, 2012). Studies on sport scheduling and soccer timetabling in particular have been focused more on professional and commercial sports. College basketball competition was scheduled for nine universities (Nemhauser & Trick, 1998) but information is sparse on scheduling of university soccer. Also, University course time tabling has been studied extensively(Chung & Kim, 2019; Gülcü & Akkan, 2020; Oladokun & Badmus, 2008; Thepphakorn & Pongcharoen, 2020) but there are no studies reported in the literature on university soccer timetabling to the best of our knowledge. This study aims at formulating a university soccer timetabling problem by identifying the variables, parameters and constraints of University soccer timetabling problem and defining and solving the University soccer timetabling problem.

2. **Literature review**

This section gives the general review of scheduling, the concept of timetabling and its application, overview of sport scheduling problem, soccer timetabling problem and its solution methods.

2.1 **General Review of scheduling**

Scheduling and timetabling is everyday activity of humans and it is a vital tool in decision making. Scheduling is a decision making process which has significant contribution to the operations of production and manufacturing systems, information processing environments, transportation, distribution and other service industries(Pinedo, 2008). It deals with the problem of allocating resources over time to perform a number of tasks (jobs) with the aim of maximizing profit or minimizing cost. Oluleye & Oyetunji, (1999) stated that the real problem of scheduling is determining schedules that best satisfies the set objectives.

Earlier work on scheduling was done by Henry Gantt who developed a chart which tracks the activity to be carried out and the time designated for each activity (Pinedo, 2008). This also provides tracking of activities to be done and the extent to which it has been executed. This has led to development of other tools used in scheduling such as loading, planning to mention a few. Development of computer based scheduling system has greatly helped in quick response to customer order, on-time delivery and also development of realistic schedules. Despite all that has been done, implementing effective scheduling system still remain a challenge to this present day.

Scheduling problems contain a set of tasks to be carried out with available set of resources with certain capacity to perform those tasks putting into consideration uncertainties with the sole aim of determining the timing of the tasks. Scheduling problem can be classified based on the scheduling environment, the characteristics of the job to be scheduled and objective function which could be single or multiple but real life situation always have multi objectives(Vieira *et. al.* , 2003).

Nagar et al., (1995) give detailed review on multiple and bi-criteria scheduling problem. The study also provides a broad classification of scheduling based on the nature of the problem, shop configuration, solution methods, performance measures, criteria and application. Oyetunji, (2011) considers solving multi-objective scheduling problem which has both minimisation and maximization type and a methodology is proposed to solve this mixed multi objective scheduling problem. A bi-criteria algorithm was developed by Oladokun et al., (2011) for single machine scheduling problem with sequence dependent set-up time. Oyetunji & Oluleye, (2010) proposed two heuristics to solved bi-criteria scheduling problem for single processor. Also, a generalized algorithm for solving multi-criteria scheduling problem was proposed by Oyetunji & Oluleye, (2012).

Scheduling has found application in real-life problems such as healthcare, production and manufacturing processes and maintenance. Scheduling in health care is different from that in other industries because the physiological state of a patient is dynamic and this introduces an inherent uncertainty into patient flow. Brandenburg et al., (2015) argue that this clinical variability or uncertainty has not been consistently addressed in scheduling system for elective appointment and this result in an impromptu method of triage. Huang,(2003) considers the limitations of the current patient scheduling system, and a model which meets the clinic policies and ancillary services was developed and implemented. Gupta & Denton, (2008) study the opportunities and challenges of appointment scheduling in healthcare.

Job and machine scheduling has been well studied in the literature for various class of problem and different shop configuration. Horn, (1974) presents scheduling algorithms for jobs that require only one operation on a single machine or one of a set of identical machines. Glazebrook, (1987) considers sensitivity analysis for stochastic single machine scheduling problem. Position-based learning effect in stochastic scheduling for single machines was analysed by Zhang et al., (2013). Skutella et al., (2014) give the combination of classical unrelated machine scheduling model with stochastic processing times of jobs. Dynamic stochastic scheduling of preemptive jobs on parallel machine was considered by Megow & Vredeveld, (2014) with processing times that follows independent discrete probability distribution.

(Lawler et al., 1993) review optimisation and approximation algorithm and results complexity for parallel machine, single machine, open shop, job shop and flow shop scheduling problems. The authors also consider stochastic machine scheduling and resource constrained project scheduling. Stephen & Sewell, (1997) consider job shop scheduling problem with uncertain processing times. The study compares dynamic and static application of exact and heuristics methods for the problem. The study by Pfund et al., (2006) give the review of dispatching techniques and overview of deterministic scheduling approach in semiconductor manufacturing. Stochastic job shop scheduling problem was modelled as non-linear mathematical programming and a hybrid method was proposed in solving the problem.(Tavakkoli-Moghaddam et al., 2005). Other applications are maintenance scheduling(Charles-Owaba et al., 2015; Charles-Owaba et al., 2008a, 2008b; Oke, 2004; Oke & Charles-Owaba, 2006)and resource constrained project scheduling(Lawler et al., 1993; Odedairo & Oladokun, 2011).

Wren, (1996) gives a relationship between scheduling and timetabling by giving the following definitions. The author defines scheduling as "the allocation subject to constraints, of resources to objects being placed in space –time in such a way as to minimise the total cost of some set of resources used" while timetabling is defined as "the allocation subject to constraints, of given resources to objects being placed in space time in such a way to satisfy as nearly as possible a set of desirable objectives". This can be simply put that timetabling is the process where by a schedule is derived from sequence while schedules contains timetabling as well as the sequencing information that is the order of processing activities through given resources. This study focuses on timetabling.

2.2 Timetabling

A large variety of problem in real life fits into timetabling problem and this among other reasons made timetabling problem attracted a lot of attention in the research community(de Werra, 1985). Timetabling problem involves the allocation of resources in time and space such that utilization and stakeholders' requirements is optimised. Leite et al.,

(2019) defined timetabling problem as “scheduling of a set of events (lectures, exams, surgeries, sport events, trips) to a set of resources (teachers, nurses and medical doctors, referees, vehicles) over space (classrooms, examination rooms, operating rooms, sport fields), in a prefixed period of time” The goals of timetabling is to achieve feasible timetable by satisfying all hard constraints and minimising the soft constraints costs.

Timetabling problem is an NP-hard problem which cannot be solved optimally in polynomial time. Approximation method (heuristic based) are employed to obtain satisfactory solution within a good computation times. Classes of timetabling problem as given by Burke et al.,(2004) includes school timetabling, university course timetabling, examination timetabling, sports timetabling, transport timetabling, employee timetabling and roster problem. The authors applied graph theory to solve these classes of timetabling problem and illustrated the graph theory application to timetabling for class-teacher timetabling, university course timetabling, university examination timetabling, and sport timetabling.

2.3 Application of timetabling

Timetabling has a wide range of application in university course and examination timetabling, transportation, healthcare, sports, entertainment, workers’ shift scheduling. Some of the applications are presented as follows:

2.3.1 Train Timetabling

Train timetabling problem considers models which are operations-centred and passenger-centred. Railway operations such as operation cost minimisation, maximisation of robustness of timetable to absorb disruption are the focus of operations-centred models. The passenger-centred models focuses on increasing the passengers’ satisfaction such as maximisation of the number of direct links between rail stations and minimisation of passengers waiting time. Operations –centred models have been widely studied(Fischetti et al., 2009; Liebchen & Stiller, 2009) while there is sparse literature on passenger-centred models(Espinosa-Aranda et al., 2015; García-Ródenas et al., 2020; Wong et al., 2008)

Some studies on train scheduling problems are as follows: Wang et al., (2019) establish two models for high speed railway train timetabling problem using space-time network method. Zhang et al., (2019) reformulate cyclic train timetabling problem and applies two dual composition approaches to solve it. Qi et al.,(2019)propose a new method for train timetabling problem which considers special passenger demands of women-only passenger cars. Caprara et al., (2002) apply graph theory to model and formulate train timetabling problem which uses a directed multigraph with its nodes corresponding to arrival/departure at any defined rail station at any given time. García-Ródenas et al., (2020) propose a mathematical model for passenger-centred train timetabling with the consideration of elasticity of demand against the supply's features. Improved variant of bundle method which uses disaggregate method was proposed for solving train timetabling problem. The proposed approach gives a reduced computation time when compared to the standard bundle method(Ait-Ali et al., 2020).

2.3.2 University Course and Examination timetabling

Exact and approximation methods are used in solving the university course and examination time tabling problem. (de Werra, 1985) describes class-teacher timetabling problem and its variations which was formulated and solved as graph theoretical models. (Oladokun & Badmus, 2008) models the university course timetabling as integer linear programming which assigns, courses, rooms and lecturers to timeslots that are fixed, usually a week. The model also, satisfies some problem-specific constraints. The study by (Chung & Kim, 2019) consider university course timetabling and examination timetabling problems. The problem was formulated as integer programming and a solution approach called NOGOOD was used to solve the problem.

Also, Leite et al., (2019) use a simulated annealing approach for solving examination timetabling. The author proposes two simulated annealing algorithm; the standard simulated annealing and fast simulated annealing. The result shows that fast simulated annealing is better in terms of solution cost when compared to standard simulated annealing. Gülcü & Akkan,(2020) formulate robust university course timetable as bi-criteria optimisation problem and Multi Objective Simulated Annealing was proposed for solving the single and multiple disruptions. Leng et al., (2020) apply a two-phase hybrid local search algorithm to solve post enrollment course timetabling problem. Cuckoo search algorithm was developed by Thepphakorn & Pongcharoen, (2020)for solving university course timetabling problem to minimise the total operating cost incurred by the university.

2.4 Sport scheduling problem

Sport scheduling problem is important because of its impact on the attendance, public interest as well as the profitability of sponsors, broadcasting and advertising organisations. Each of these stakeholders have their preferences which must be considered in ensuring good schedules. Sport scheduling problem helps in generating schedules that ensures requirements are met and fairness to all stakeholders. It can be difficult to generalize sports scheduling problem because the objectives and constraints of each league differs and these differences makes generation of schedule with respect to requirements and constraint difficult. Nurmi et al., (2010) argue that the development of an effective solution method for real-life scheduling problem is to understand relevant requirements and request of the league. This suggests that the knowledge about the requirements of each league is paramount in achieving a good schedule.

Sport scheduling has been widely studied for several sports and different tournament types(Cocchi et al., 2018; Froncek, 2010; Nemhauser & Trick, 1998; Nurmi et al., 2010; Urban & Russell, 2003). It has considered sports such as soccer(Alarcón et al., 2017; Bartsch et al., 2006; Recalde et al., 2013; Ribeiro & Urrutia, 2012), table tennis(Schonberger et al., 2004), basketball(Nemhauser & Trick, 1998; Wright, 2006; H. Zhang, 2002), handball(Larson & Johansson, 2014), ice hockey(Kyngäs & Nurmi, 2009; Nurmi et al., 2015), volleyball(Cocchi et al., 2018).

Sports timetabling and management of schedules has been attracting scholars across various disciplines and different optimization methods have been employed to solve sports scheduling problems. The optimization techniques employed for any sporting event depends on the complexity of the desired schedule and the constraints. The type of tournament is also another factor to consider in sports timetabling. A sports event is usually either a round robin tournament, a group tournament, an elimination tournament or a combination of any of the types. This has to be considered in selecting the type of optimization method to employ in solving it.

This study considers a tournament played by an even number of teams. A round robin tournament is defined by Ribeiro, (2012) as "one in which each team plays against every other a fixed number of times." Every team plays each other exactly once and twice in a single round robin (SRR) tournament and double round robin (DRR) tournament respectively and plays at most once in each round. Most tournaments and leagues across the world uses round robin sport schedules(Lewis & Thompson, 2011). Round robins are schedules that involve n teams and each team played each other m number of times in a fixed number of rounds. Single round robin and double round robin are the most common round robin types.

(Wright, 2009) reviews the application of operations research to sports for a period of 50 years. The study covers the analysis of tactics and strategy, scheduling and forecasting and other policy issues and the effect of sports on the society. Nurmi et al., (2010) give the major reason for the interest of academic in sports scheduling as the minimisation of distance travelled by teams during tournaments, the use of smart computers for computational tasks demand of sport scheduling, development of algorithms in tackling the intractable problem of sport scheduling and the organisation of sports in more professional manner requires a good schedules for the success of the league.

Also, Kyngäs et al., (2014) identify three major problem of sport scheduling as minimum number of breaks problem, travel tournament problem and constrained sport scheduling problem. The identified problem has been addressed in general and for specific sports. The study by Van Bulck et al., (2020) propose a three-field notation to describe a round robin sport scheduling in terms of tournament format, constraint in operation and the objective of sport timetabling. Froncek, (2010) presents several schedules for round robin tournament for alternate home and away games and some other features are consider in the construction of various schedules. (Larson & Johansson, 2014) give a methodology for scheduling general tournament that allows each division holds a round-robin tournament before a double round-robin tournament. The study gives tournament schedules that satisfy alternate venue requirement with consideration of necessary conditions for home-away patterns.

Nurmi et al., (2010) define the framework for scheduling professional sport leagues by introducing a set of artificial and real life instances and some of the best solutions of these examples were published. Lewis & Thompson, (2011) view sports timetabling problem as a graph coloring problem. Two algorithms for real-life sport scheduling was proposed based on the links between round robin sports scheduling and graph coloring. Briskorn & Drexl, (2009) consider the prominent requirements of round robin tournament in developing sport league schedule. These requirements are defined as integer programming model and solved by CPLEX.

Constraint programming was used by Carlsson et al., (2017) to schedule double round robin tournament with divisional single round robin tournament. Sport league scheduling problem was formulated as constraint satisfaction problem and was solved using repair-based linear time algorithm(Hamiez & Hao, 2004). Kyngäs & Nurmi, (2009) propose algorithm for constrained minimum break problem for scheduling Finnish major Ice Hockey league .The algorithm gives a feasible and acceptable schedule which was used for that season and the schedule was used for 2008-2009 season. Nurmi et al.,(2015) applied PEAST algorithm to scheduling of Finnish major ice Hockey league. The study shows that the algorithm generates a good quality schedules for 2013-2014 season.

The study develops suitable schedule for Atlantic Coast Conference basketball competition which involves 9 universities using a combination of integer programming and enumerative techniques. The solution approach gives a schedule which was accepted for play in 1997-1998 by Atlantic Coast Conference(Nemhauser & Trick, 1998). Wright,

(2006) considers the scheduling fixtures for Basket Ball league in New Zealand. This study gives detailed description of the problem and a general solution method was adopted. Zhang, (2002) develops a schedule for College Conference Basketball which was formulated as constraint satisfaction problem which was solved using 3-phase procedure of Nemhauser & Trick, (1998).

Mixed integer linear programming was developed by Cocchi et al., (2018) for regular season schedule for Italian Volleyball Leagues which has at least 12 teams. Non-professional indoor football league schedules was developed by Van Bulck et al., (2018) .The authors present integer programming formulations and Tabu Search based heuristics. Della Croce & Oliveri, (2006) adapt the solution procedure of Nemhauser & Trick, (1998) for scheduling of Italian football league which gives a feasible schedule that satisfies the cable television's requirements. Briskorn & Drexl, (2009) reiterate that integer programming approach in finding optimal schedule for sport scheduling outperforms the constraint programming in terms of run-time.

Wright, (2009) identifies the study of sports at amateur level and suggests that the focus of research should not only be on the professional level scheduling but it should consider amateur level which has a large proportion of the population as their audience. Schonberger et al., (2004) argue that timetabling of non-commercial sport leagues have received minor attention as compared to the commercial sport leagues. The authors propose a model for timetabling of non-commercial sport leagues that uses Memetic algorithm in solving the problem.

Non- professional sport scheduling is interesting because the games are not planned in rounds but each team considers time slots to play home games and timeslots they cannot play at all (Van Bulck et al., 2018).The study gives reviews on professional and non-professional sports scheduling problem. Table 1 gives the sport type, it states whether it is a professional or non-professional and the algorithm used in sport scheduling. Based on the article reviewed, the argument that professional sport scheduling has been given more attention more than the non-professional is further established.

Table 1: Professional and non- professional sport scheduling showing the sport type and solution method

Sport type	Author(s)	Professional	Non-professional	Solution method
Volleyball	Cocchi et al., 2018	√		Mixed integer linear programming
Soccer	Alarcón et al., 2017	√		Integer programming
Table tennis	Schonberger et al., 2004		√	Memetic algorithm
Ice hockey	Kyngäs & Nurmi, 2009	√		A blend of evolutionary and local search method
Handball	Larson & Johansson, 2014	√		
Ice Hockey	Nurmi et al., 2015	√		PEAST algorithm
Football	Van Bulck et al., 2018		√	Integer programming and Tabu search heuristics
Basket ball	Wright, 2006	√		

Football	Della Croce & Oliveri, 2006	√		
Basket ball	Nemhauser & Trick, 1998	√		Integer programming and enumeration techniques
Soccer	Rasmussen, 2008	√		Logic-based Benders decompositio n
Football	Ribeiro, 2012	√		Integer programming
Football	Recalde et al., 2013	√		Integer programming
Soccer	Bartsch et al., 2006	√		Graph coloring
Soccer	Fiallos et al., 2010	√		Integer Programming solved by CPLEX
Soccer	Ribeiro & Urrutia, 2012	√		IP with 3-phase decompositio n method
Soccer	Goossens & Spieksma, 2009	√		Integer programming
Football	Urban & Russell, 2003	√		Integer programming
Soccer	Durán et al., 2007	√		Integer Linear Programming

Soccer	Russell & Urban, 2006			Constraint programming
Football	Kyngäs et al., 2014	√		PEAST algorithm
Football	Roboredo et al., 2014	√		Improved decomposition method
Basketball	Zhang, 2002	√		3-phase approach using SAT solver
Volleyball	Bonomo et al., 2012	√		Integer programming and Tabu search heuristic
Baseball	Easton et al., 2001	√		Integer programming and constraint programming
Baseball	Easton et al., 2002	√		Hybrid method
Football	Kent & Keith, 2011; Kostuk & Willoughby, 2012	√		Decision based method

2.5 Soccer timetabling problem

Soccer is one of the most significant sports in terms of general acceptance and its activities involve several stakeholders whose contribution must be considered for efficient and feasible schedule.

Alarcón et al., (2017) apply operations research to soccer scheduling at the international level. The study shows that the application of operations research to soccer scheduling gives economic savings and its impact is significant on the sports fans, the media and the public institutions.

Goossens & Spieksma, (2009) argue that there is no single model that can be applied to all soccer timetabling problems because each tournament/ league is unique by its structure and requirements. Kyngäs et al., (2014) schedule Australian Football league using a three-phase procedure proposed by Nemhauser & Trick, (1998). PEAST algorithm was applied to generate schedules for 2013 season. Roboredo et al., (2014) schedule Brazilian football league as classical mirrored double round robin tournament which considers place constraints and even number of teams. This study proposed a scheduling problem that minimises the number of breaks and the total number of the extended carry-over effects. It also uses the procedure of Nemhauser & Trick, (1998)

Study by Urban & Russell, (2003) addresses the problem of sport scheduling and balancing of sport competitions over multiples venues. The problem was defined and solved as integer goal programming. Also, Russell & Urban, (2006) use constraints programming for the same problem and the study shows that constraint programming gives optimal schedules for problem of about 16 teams and near optimal for teams up to 30.

2.6 Solution Methods for soccer timetabling problem

Karger et al., (1996) argue that the choice of solution methods for scheduling problem depends on the application of the problem, the decision maker and size of problem. Different exact and approximate methods such as integer programming, constraint programming, metaheuristics and hybrid methods have been applied to solving soccer timetabling problem.

2.6.1 Integer programming

Integer programming is a mathematical optimization method which maximises and minimises the objective function(s) while satisfying a set of constraints. Integer programming is used to model and solve sport scheduling problem. Nemhauser & Trick, (1998) apply integer programming to phases one and two and enumeration for phase three in scheduling of a major college basketball conference. Goossens & Spieksma, (2009) modelled the Belgium football league as a mixed integer programming and was solved as a two-phase approach. Heuristic approach and branch and bound method was used by Bartsch et al., (2006) in scheduling of Austrian and German football leagues.

Della Croce & Oliveri, (2006) apply a heuristic solution procedure to the Italian football league which solves a series of integer programming models and generates double round robin timetables which meets the league' s various requirements. A logic-based Benders decomposition was applied by Rasmussen, (2008)and found home-away pattern sets was found as well as the timetables from the sub problems. Recalde et al., (2013) formulate the Ecuadorian football league scheduling problem as an integer programming formulation which was solved for optimality and ca feasible sports schedule was created. The authors apply a heuristic approach based on three phases. Integer programming was applied by (Durán et al., (2007) to develop the schedule for the Chilean football league. Ribeiro & Urrutia,(2012) formulate the Brazilian football league scheduling as an integer programming and a three-phase solution approach was developed. (Fiallos et al., 2010) develop a mathematical integer programming model for the Honduran football league. It can be seen that heuristics is used in solving the integer programming models to generate round robin timetables that considers several constraints. This combination of methods can be referred to as hybrid method.

2.6.2 Constraint programming method

Constraint programming method is seen to be appropriate for tournament scheduling because acceptable schedules must satisfy many constraints. Constraint programming (CP) has been applied to schedule sports leagues particularly soccer. Russell & Urban, (2006) use constraints programming for soccer timetabling problem which considers multiple venues. Constraint programming has been applied to travelling tournament problem by Easton et al., (2002) 2.6.3 Heuristics

Heuristics are approximation methods that gives satisfactory solutions in good time. It is used for large and NP-hard problems and also for problems that are intractable by enumeration methods. Della Croce & Oliveri, (2006) apply a heuristic solution procedure to the Italian football league scheduling problem. Recalde et al., (2013) apply heuristics to solve the Ecuadorian football league scheduling problem which was formulated as integer programming.

2.6.4 Meta heuristics

It is a master strategy that guides and modifies other heuristics to produce solutions beyond those that are normally generated in a quest for local optimality.it provides a means for approximately solving the complex optimization problems and it is designed to search for global optimum. Three well known heuristics are Tabu search, scatter search and genetic algorithms. Ant based hyper-heuristics algorithm was applied by Chen et al., (2007) to determine double round robin tournament schedule which minimises the travel distance. Lim et al.,(2006) applied simulated annealing and hill climbing to travelling tournament problem while Anagnostopoulos et al., (2006) applied simulation annealing to the same problem.

2.6.5 Decision based method

Decision based methods have been used by scholars in solving timetabling problems. This approach helps the users in answering certain questions that determine what resources will be allocated to what timeslots in timetabling problems. Decision-based models have several advantages. some of these are simplicity, ease of comprehension, ease of application, and so on. It also has some drawbacks in that it is very sensitive to changes in parameters, very limited and have to be specifically designed for their application cases. This study employs the decision based method in solving the university timetabling problem. Decision based model was applied to scheduling of Canadian football league(Kent & Keith, 2011; Kostuk & Willoughby, 2012)

2.6.6 Graph-based method

Graph-based methods are based on graph-colouring heuristic approaches. Graph-colouring heuristics are often also called sequential heuristics. Generally, sequential heuristics have been found to be quite effective and yet simple methods for determining a feasible timetabling solution. However, its major limitation is that it cannot be able to produce a very high quality and accurate solution with respect to the satisfaction of the timetabling problem's soft constraints. Bartsch et al., (2006) applied graph coloring to solve soccer timetabling problem.

Integer programming has been applied extensively to solve soccer timetabling problem and some studies also combine several other methods in solving this problem and such approaches that combine a number of methods is referred to as hybrid method. Most of the methods have strengths and limitations but this study will consider decision based method in solving the university soccer timetabling because of its advantages.

3. Methodology

3.1 Variables, Parameters and Constraints of soccer timetabling problem

The general timetabling problem is concerned with assigning resources to a fixed time period while satisfying some set of constraints. Soccer timetabling is the process of assigning matches, fields, teams and officials to a fixed time period subject to a given number of constraints. The variable of soccer timetabling problem is a binary variable which gives match scheduled at a particular period on a particular field.

The parameters required for modelling soccer timetabling are the Number of officials, Number of matches, Number of soccer fields available, Number of soccer teams, Number of soccer team groups, Duration of soccer matches, and so on. The soccer timetabling constraints are divided into two categories – hard constraints and soft constraints. Hard constraints are requirements that must be fulfilled to have a feasible timetable while soft constraints are secondary constraints which are desirable for timetabling but not necessary to satisfy.

Hard constraint

1. A field must not be assigned for more than one match at a timeslot.
2. A team in a group cannot take more than one match at a time slot, z
3. Not more than h matches can be played in a day for the group stage.
4. The total number of matches is expressed as
5. There must be more than one-day break between consecutive games of a unique team in any match that is there must be a break between i^{th} match and the next i^{th} +1 match.
6. There must be at least a day's break between the last game of all football group games and the first game of the semi-finals.
7. There must be at least a day's break between the last semi-final game and the final match

Soft constraints

1. There should be days off between the last game of a football group and the first game of the next football group
2. There should be days off between the last game of all football group games and the first game of the semi-finals
3. There should be days off between the last semi-final game and the final match

3.2 Model formulation, defining and solving the University soccer timetabling problem

3. 2.1 Notations

The following notations used in the model formulation, defining and solving the problem are described below:

x = Match index (where x=1, 2,3,…,r) , $1 \leq x \leq n$ for group stage, $n < x \leq m$ for knock out stage, $m < x \leq q$ is for quarter final, $q < x \leq w$ for semifinal and r is the final match.

y = Field index (where y=1, 2,3,…,s)

z = Time slot index (where z=1,2, 3, …, t)

h = Number of available time slots per day

H = Number of available time slots

A = Set of team groups($a_1, a_{2,} \dots, a_{v,}$)

v = Number of team groups

J = Number of teams in a group, a

F =Total number of teams in all groups

K =Number of matches (set of two unique teams) to be played in a group (K ϵ U)

U = Total number of matches to be played all through the competition (group stage and knockout stages)

CG_a =Set of matches to be taken by team group, a

CT = Set of timeslot available for match per day

d = number of days off between two consecutive games

Decision variable, $P_{xyz} = \begin{cases} 1, if\ match\ x\ is\ played\ on\ field\ y\ at\ timeslot\ z \\ 0,\ If\ otherwise \end{cases}$

3.2.2 Mathematical Model Formulation

The soccer timetabling problem which assigns matches, fields and officials to fixed timeslots considering a number of problem-specific constraints is modelled as integer linear programming.

Assumptions

The underlying assumptions for the University Soccer timetabling problem are highlighted below:

1. The soccer teams in each soccer group are predetermined
2. The set of two unique soccer teams in every soccer match in the group stage is predetermined
3. Every soccer group has a set of available timeslots during which only soccer games in such groups can be scheduled
4. Every team in a soccer group is available on all available timeslots assigned to the group
5. Set of Officials (referee, linesmen and third official) for each soccer game are predetermined
6. No set of officials can officiate two soccer matches at the same time
7. For every given timeslot, the soccer game will be played at a predetermined time and all teams are available at that time
8. Every soccer match must have a total allocated time which is equivalent to its time pocket and is contiguous
9. The actual time used for a soccer match must be greater than or equal to the total time allotted to that soccer match.
10. No field preferences are given to any soccer team
11. All fields are available on all available days in the time table duration
12. All games must be within the defined tournament schedule (timetable duration), and the number of available days must be specified
13.

Development of Constraints and Objective Functions

The hard constraints of the soccer timetabling problem are shown mathematically as follows:
A field must not be assigned for more than one match at a timeslot.

$$\sum_{x=1}^{r} P_{xyz} = 1 \, , \forall \, \mathrm{y} = 1, 2, \dots, \mathrm{s} \ \forall \, \mathrm{z} = 1, 2, \dots, t \qquad (1)$$

A team in a group cannot take more than one match at a time slot, z

$$\sum_{x \epsilon CG_a} \sum_{y=1}^{s} P_{xyz} \leq 1 \quad \forall \, \mathrm{x} = 1,2, \dots, \mathrm{r} \ \forall \, \mathrm{a} = 1,2, \dots, \mathrm{v} \qquad (2)$$

Not more than h matches can be played in a day for the group stage.

$$\sum_{y}\sum_{z\,\epsilon\,CT_H} P_{xyz} \leq h \; for \; 1 \leq x \leq n \tag{3}$$

The total number of matches is expressed as

$$\sum_{x=1}^{r}\sum_{y=1}^{s}\sum_{z=1}^{t} P_{xyz} = U \tag{4}$$

There must be more than one-day break between consecutive games of a unique team in any match that is there must be a break between i^{th} match and the next i^{th} +1 match. The last match x_i of two unique teams played at z_i and the next matchx_{i+1} of those same teams must be scheduled at time$z_{i+(h+1)}$, where h is the number of timeslot in a day.

$$z_{i+(h+1)} - z_i > h \tag{5}$$

There must be at least a day's break between the last game of all football group games and the first game of the semi-finals.

$$|x_w - x_n| \geq 1 \tag{6}$$

There must be at least a day's break between the last semi-final game and the final match

$$|x_r - x_w| \geq 1 \tag{7}$$

The soft constraints of the soccer timetabling problem are shown mathematically as follows:

There should be days off between the last game of a football group and the first game of the next football group

$$|x_n - x_1| \geq d \tag{8}$$

There should be days off between the last game of all football group games and the first game of the semi-finals

$$|x_w - x_n| \geq d \qquad (9)$$

There should be days off between the last semi-final game and the final match

$$|x_r - x_w| \geq d \qquad (10)$$

Objective Function

The combination of the soft constraints gives the objective function:

Let f1(t) represent equation (8). Let α1 be the weight assigned to this constraint. Hence, we aim to maximize: $\alpha 1 f1(t)$

Let f2(t) represent equation (9). Let α2 be the negative weight assigned to this constraint. Hence, we aim to maximize: $\alpha 2 f2(t)$

Let f3(t) represent equation (10). Let α3 be the negative weight assigned to this constraint. Hence, we aim to maximize: $\alpha 3 f3(t)$

Combining the above three soft constraints, gives the objective function of the model**:**

$$F(t) = \alpha 1 f1(t) + \alpha 2 f2(t) + \alpha 3 f3(t) \qquad (11)$$

The University soccer timetabling model is given as

$$Maximize\ F(t) = \alpha 1 f1(t) + \alpha 2 f2(t) + \alpha 3 f3(t)$$

Subject to:

$$\sum_{x=1}^{r} P_{xyz} = 1$$

$$\sum_{x \epsilon CG_a} \sum_{y=1}^{s} P_{xyz} \leq 1$$

$$\sum_{y} \sum_{z\, \epsilon\, CT_H} P_{xyz} \leq h$$

$$\sum_{x=1}^{r}\sum_{y=1}^{s}\sum_{z=1}^{t} P_{xyz} = U$$

$$z_{i+(h+1)} - z_i > h$$

$$|x_w - x_n| \geq 1$$

$$|x_r - x_w| \geq 1$$

3.2.3 Method of Solving the Soccer Timetabling Problem

A decision-based algorithm is applied to solve the soccer timetabling problem. Figure 1 gives a flowchart representation of the algorithm. Given a pool of unassigned match indices and a specific time slot to assign matches to, the algorithm is given as follows:

STEP 0 Check if there exist unassigned match indices. If yes, proceed to step 1. If no, stop algorithm.

STEP 1 Randomly select the maximum number of match indices that can fit into the current time slot.

STEP 2 For each unique soccer teams in the match indices selected, do:

2-A Check if the same soccer team appears in multiple match indices selected

2-B If the soccer team appears in more than one of the match indices selected, select only one such match index and discard the other selected match indices the team appears in

2-C Proceed to randomly select another *n* match indices from the unassigned pool to replace the *n* discarded index / indices above. This selection will be done such that the soccer teams in the selected index in step a. above are not present in any of the newly selected match index / indices.

STEP 3 For each match index in the selected match indices, do:

3-A Check if any of the soccer teams in the match index have had any immediate previous games

3-B If no, proceed to step 4. If yes, proceed to 3-C.

3-C Check if the difference between the current timeslot and the timeslot of the immediate previous game is greater than one.

3-D If yes, proceed to step 4. If no, discard the match index

3-E If this is the last match index amongst selected match indices, proceed to step 0.

STEP 4 Insert match index in this timeslot

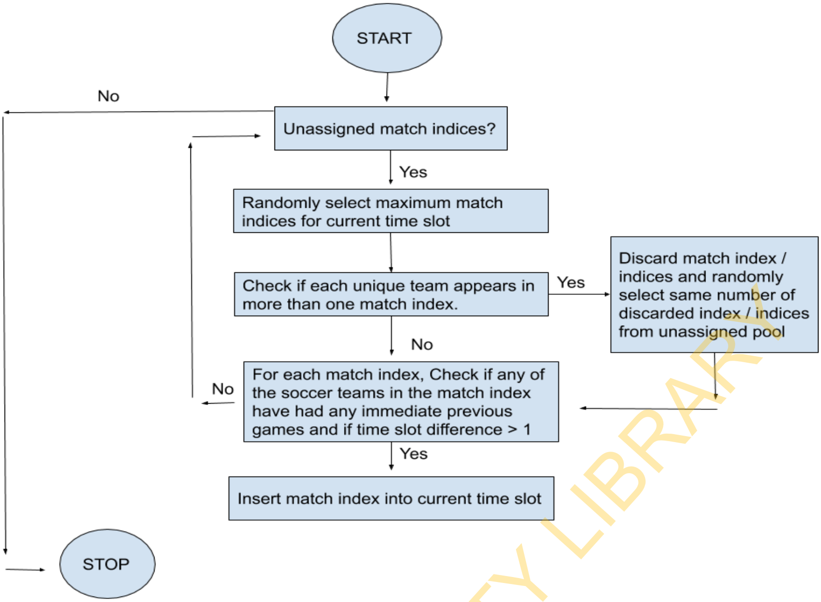

Fig. 1: Flowchart for decision-based algorithm

4. Model Application and Discussion of Results

This section gives the description of the case study, collection of data, defining and solving the University of Ibadan inter-faculty soccer timetabling problem, presentation and discussion of results.

4.1 Brief description of the case study

The interfaculty soccer competition in the University of Ibadan is an annual competition. This competition is held between faculties in the University of Ibadan. The competition has two phases - a single-round robin group stage and a knockout stage. The competition usually consists of 12 teams split into two groups. Each team in a group plays every other team in the same group once. Two teams then qualify from each group based on a point-based system (win – 3 points, Draw – 1 point, Loss - 0 point). The two top two teams which qualify from each group (making four teams in total) then proceed to the semi-final stages. Two teams are knocked out in this stage and then the two teams which qualify then proceed to the final. The winning team at the final wins the competition. The duration of this tournament is usually five weeks.

4.2 Data Collection

The data and information about the university of Ibadan inter-faculty soccer competition was gotten from the organizing sports council. The organizing sport council provided the various rules of the competition, as well as information about facilities, officials, groups, teams, fields, and so on. The values of the parameters for the competition obtained are shown in Table 2. Also, the faculty teams that will play in the University of Ibadan inter-faculty competition and their respective groups are shown in Table 3. The predefined teams that will play in soccer matches in the competitions were obtained and match indices were assigned to them as shown in Table 4.

Table 2: List of Parameters and their respective values for the University of Ibadan Inter-faculty soccer timetabling problem

Name of Parameter	Value
Number of football fields	2
Timetable Duration	5 weeks (Available days – Mondays to Saturdays)
Number of available days	30

Number of football teams	12
Number of football groups	2
Number of football teams per group	6
Number of soccer matches to be played per group	15
Total Number of Soccer matches in the group stage	30
Number of soccer matches in knockout stages	3
Total Number of soccer matches in the inter-faculty competition	33

Table 3: Groupings of teams in the University of Ibadan Inter-faculty soccer competition

Group A	Group B
Science	Law

Social Science	Basic Medical Sciences
Pharmacy	Public Health
Agriculture and Forestry	Clinical Sciences
Technology	Education
Arts	Veterinary Medicine

Table 4: List of Soccer matches and their corresponding match indices in the University of Ibadan Inter-faculty soccer competition

Match	**Corresponding Match Indices**
Science vs Social Science	1
Science vs Pharmacy	2
Science vs Agriculture and Forestry	3
Science vs Technology	4

Clinical Sciences vs Veterinary Medicine	29
Education vs Veterinary Medicine	30
First semi-final game	31
Second Semi-final game	32
Final game	33

Other rules concerning the tournament were stated thus:

- Four teams will be eliminated from each group, leaving two teams from each group to qualify for the knockout phase
- Timeslot is defined as the continuous length of time during which the match takes place. For the university soccer timetabling, since matches can only be played early in the morning or in the evening before or after lectures respectively. 2 timeslots are available per day. The number of available timeslot per day is equal to 2 timeslots per day multiply by the number of football pitch available. Timetable must span a maximum of 5 weeks, and the only available timeslots are from Mondays to Saturdays. This means there are 30 available days, available timeslot in 5 weeks is 2 x 2 x 30 = 120

4.3 Defining and Solving the University of Ibadan Inter-Faculty Soccer Timetabling Problem

Problem parameters are estimated and weights are selected for the objective function and a decision based model is applied to solve the

University timetabling problem for inter-faculty soccer competition.

Defining the University of Ibadan Inter-Faculty Soccer Timetabling Problem

The soccer timetabling problem is defined as the University of Ibadan inter-faculty soccer competition. The problem parameters are listed as follows:

Number of football fields (s) - 2

Timetable Duration - 5 weeks

Number of available timeslots in days -30

Number of available timeslots (H) – 120

Number of football teams (F) - 12

Number of football groups (v) -2

Number of football teams per group (J) - 6

Number of soccer matches to be played per group (K) - 15

Total Number of soccer matches in the inter-faculty competition (U) – 33

The mathematical model for University of Ibadan inter-faculty soccer timetabling is given as

$$Maximize\ F(t) = 3\,(f1(t)) + 1.5\,(f2(t)) + 2\,(f3(t)))$$

Subject to

$$\sum_{x=1}^{r} P_{xyz} = 1\ ,\ \forall\ \mathrm{y} = 1, 2.\ \forall\ \mathrm{z} = 1, 2, \dots, 120$$

$$\sum_{x \epsilon CG_a} \sum_{y=1}^{s} P_{xyz} \leq 1 \quad \forall \ \mathrm{x} = 1,2, \dots, 33 \ \forall \ \mathrm{a} = 1,2.$$

$$\sum_{y} \sum_{\mathrm{z} \, \epsilon \, CT_H} P_{xyz} \leq h \ for \ 1 \leq x \leq 30$$

$$\sum_{x=1}^{r} \sum_{y=1}^{2} \sum_{z=1}^{120} P_{xyz} = 33$$

$$z_{i+(h+1)} - z_i > 4$$

$$|x_w - x_n| \geq 1$$

$$|x_r - x_w| \geq 1$$

Solving the University of Ibadan Inter-Faculty Soccer Timetabling Problem

The decision algorithm was used to solve the University of Ibadan Inter-faculty soccer timetabling problem and the result is shown in Table 5. There is 4-timeslot per day which makes a total of 120 timeslots for the available days for the match which is 30 days. For constraint of space, the result only shows the timeslot for each match and the field at which the match will take place. The results in Table 5 is presented as follows; On Day 1, Match 2 takes place on field 1 at timeslot 1 while match 7 takes place on field 2 at timeslot 4.

Table 5: Timetable obtained for the University of Ibadan Inter-faculty soccer competition

Available days for match	Available Time Slots	Match Indices	Field indices
1	1, 4	2,7	1,2
2	6	15	1
3	11	1	2
4	14,15	11,14	1,2
5			
6	21,24	9,10	1,2
7	26	4	1
8	31	6	2
9	33,36	5,13	1,2

10			
11	42,43	3,8	1,2
12	45	12	1
13			
14			
15	58,59	17,28	1,2
16	61	30	1
17	68	16	2
18	69,72	26,29	1,2
19			
20	78, 79	24,25	1,2
21	81	19	1
22	87	21	2

23	89,92	20,28	1,2
24			
25	98,99	18,23	1,2
26	101	27	1
27			
28	110,111	31,32	1,2
29			
30	117	33	1

4.4 Discussion of Results

A feasible timetable obtained for the University of Ibadan inter-faculty competition with the use of the decision algorithm indicates that an optimal timetable was obtained. The timetable obtained satisfies all hard constraints and all soft constraints of the University soccer timetabling problem. 33 soccer matches were assigned to 33 timeslots out of the available total of 120 timeslots, Matches were played on 22 days out available 30 days. This means that there were eight seven timeslots during which no soccer match held. The field assignment shows that field 1 was used more than field 2. Out of the 33 games to be played in the University of Ibadan inter-faculty soccer competition, 18 are to be played on field 1. The remaining 15 soccer matches were assigned to field 2. The timetable obtained shows that the soccer matches begin on the first timeslot and the last soccer match, which signifies the end of the competition is assigned to the last available timeslot. The results show that the group stage matches is completed by day 26 and necessary breaks are observed in the timetable. Also, there would be a day rest before the semi-final games as well as a day rest before the final game. The results show that the decision algorithm gives a feasible timetable that satisfies all hard and soft constraints.

5 Conclusion and Recommendation

This study focuses on the development of the University soccer timetabling problem. The parameters, decision variables, hard constraints and soft constraints were identified for the university soccer timetabling problem. A mathematical model was developed for the university soccer timetabling problem. The model developed was applied to University of Ibadan inter-faculty soccer competition. The competition featured 12 teams split into 2 groups, with 6 teams in each group. The competition featured a single-round robin group stage from which two teams qualified into the knockout stage.

The timetable for this competition was obtained with the use of a decision algorithm. The algorithm was developed to adequately cater for the hierarchical weighted soft constraints. The algorithm was applied until an optimal solution was obtained. 33 soccer games were scheduled over 120 available timeslots within 30 available days without violating any hard or soft constraint. The result shows that the soccer timetabling problem is feasible as demonstrated in its application to the inter-faculty soccer competition in the University of Ibadan.

Based on the results of the study, it is recommended that the decision algorithm developed for this study be further studied to improve its computational efforts as it took several trials for an optimal timetable to be obtained.

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