Faculty of Computer Science and Information Technology

Rule Prioritisation Heuristic in Shift Design of Airline Ground Crew

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

In various industries, the exigency of workforce shift scheduling and rostering demands immediate, innovative solutions. Many off-the-shelf scheduling products lack the flexibility to adapt to varied organizational requirements, resulting in widespread reliance on manual interventions. This research, rooted in a case study of a local airline at Kuala Lumpur International Airport (KLIA), a major regional hub, endeavours to formulate an algorithm addressing workforce shift scheduling and rostering complexities. The proposed algorithm aims to ensure judicious allocation of operational tasks, emphasizing minimal workforce utilization, reduced idleness, and heightened adaptability in employee schedules. Utilizing an existing workforce prediction method and shift design criteria, the study determines the minimum workforce required for task completion. Shifts are assigned based on this minimum, employing heuristic and genetic algorithms. Subsequent optimization of potential schedules culminates in the identification of the most efficacious ones. Empirical tests reveal the proposed heuristic method's superiority over manual practices and genetic algorithms. It not only minimizes shift idle time and aligns with optimal shift starting times but also significantly reduces workforce requirements, streamlining the shift scheduling process, irrespective of data size. This research contributes valuable insights to the advancement of workforce management strategies, offering practical and innovative solutions within the specified context.

Keywords: Heuristic, genetic algorithm, minimum workforce, shift design, shift scheduling

Heuristik Penentuan Keutamaan Aturan dalam Rekabentuk Shif untuk Krew Syarikat Penerbangan

ABSTRAK

Dalam pelbagai industri, kemendasakan mengenai penjadualan shif tenaga kerja dan penjadualan tugasan menuntut penyelesaian segera dan inovatif. Kebanyakan produk penjadualan siap-pakai kurang fleksibel untuk menyesuaikan keperluan organisasi yang berbeza, menyebabkan bergantung kepada penyelesaian manual secara meluas. Kajian ini, berakar dalam kajian kes sebuah syarikat penerbangan di Lapangan Terbang Antarabangsa Kuala Lumpur (KLIA), sebuah pusat serantau utama, bertujuan merumuskan algoritma menangani kekompleksan jadual pergeseran tenaga kerja dan penjadualan tugasan. Algoritma yang dicadangkan bertujuan memastikan peruntukan tugas operasi yang bijak, menitikberatkan penggunaan tenaga kerja minimum, mengurangkan pembaziran masa, dan meningkatkan kebolehtelapan jadual pekerja. Dengan menggunakan kaedah ramalan tenaga kerja sedia ada dan kriteria reka bentuk shif, kajian menentukan jumlah minimum pekerjaan yang diperlukan untuk penyelesaian tugasan. Giliran diberikan berdasarkan jumlah minimum ini, dengan menggunakan kaedah heuristik dan algoritma genetik. Penyesuaian kemudian dilakukan untuk mengoptimumkan jadual berpotensi hingga pemilihan yang paling berkesan. Ujian empirik menunjukkan keunggulan kaedah heuristik dicadangkan berbanding amalan manual dan algoritma genetik. Ia tidak hanya mengurangkan masa menganggur giliran dan sejajar dengan waktu permulaan giliran yang optimum, malah mengurangkan secara ketara keperluan tenaga kerja, menyelaraskan proses penjadualan giliran, tanpa mengira saiz data. Kajian ini memberikan pandangan berharga untuk kemajuan strategi pengurusan tenaga kerja, menawarkan penyelesaian praktikal dan inovatif dalam konteks yang ditentukan.

Kata kunci: *Heuristik, algoritma genetik, tenaga kerja minimum, reka bentuk shif, penjadualan shif*

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LIST OF ABBREVIATIONS

CBS	Criteria based selection
CGS	Centre for Graduate Studies
FP	Flat peak
RP	Randomise pick
RPH	Rule prioritisation heuristic
RPH-CBS	Rule prioritisation heuristic – criteria-based selection
RPH-RP	Rule prioritisation heuristic – randomise pick
SP	Significant peak
TSH	Two-stage heuristic
UNIMAS	Universiti Malaysia Sarawak

CHAPTER 1

INTRODUCTION

1.1 Introduction

In various industries, workforce rostering and scheduling poses problems that require immediate solutions. The demand for fast and reliable operation in any organisation and businesses has never been higher, especially in manufacturing, logistics, transportation, and various other industries. With the rising cost face by operations and managing, all businesses are struggling to keep their expenditures low. The most significant potential area for cost saving is workforce administration through which most organisations pursue approaches that would lessen wastage and optimise workforce utilisation. This solution is hardly new; American Airlines adopted an optimisation software solution developed by (Anbil et al., 1991) for crew rostering which resulted in annual savings of millions. (Afifi & Aly, 2018) and (Odoni & Barnhart, 2003) discuss optimization models and techniques for crew scheduling and schedule planning, respectively, which can lead to increased efficiency and cost savings for airlines. While (Mallick & Mishra, 2018) focus on revenue management practices, their insights can indirectly impact scheduling by helping airlines optimize pricing and revenue streams. In most organisations, having the ideal number of workforces is critical, as it reduces not only cost but also enhances effectiveness and decreases bureaucracy. Therefore, the enormous spending by organisations to secure a viable system for scheduling and rostering is justified and even indispensable, as it provides a forecast of the optimal number of the workforce needed by the organisations.

In solving the rostering and scheduling, there have been various solutions proposed by researchers all over the world. The widely used approach is the heuristic-based solution,

where computational performance gain has higher priority than accuracy or precision. The heuristic method will generate the most probable solutions and pick the best solution instead of generating all the solutions. This approach can find an approximate solution in a reasonable timeframe or when in a situation where finding an optimal solution is not possible. There is also a possibility that an optimal solution would not be found. Researchers all over the world have discovered various heuristic approaches for rostering and scheduling solutions.

Another widely used approach in solving rostering and scheduling is by using an integer programming method which is based on mathematical optimisation. An integer programming method is a mathematical optimisation or feasibility program where it restricted in which some or all of the variables to integers. Integer programming is a powerful solution technique for obtaining an optimum or near-optimal solution. Regarding solution quality, integer programming has proven to produce a better solution when compared to the heuristic approach but is inferior with regards to computational speed. The literature review will elaborate and discuss the details on the approaches taken over the years and also current development to solve rostering and scheduling.

Rostering and scheduling algorithm aims to address the challenge of ensuring that it assigned all jobs using minimum resources while preventing wastage. Its secondary goal is to avoid unutilized resource such as idling workforce during the working hours. Aside from that, the algorithm will schedule a shift with a consistent start time pattern throughout the week. This consistency in the start time pattern will ensure workers' adaptability to the schedule and exercise fairness. The fundamental need to solve this problem is to ensure that it assigned all shifts to cover all or as many jobs as possible. It should additionally plan the

shifts with minimum workforce utilisation, least workforce idleness and enhanced adaptability of employees' time.

Our approach is to utilise the existing workforce prediction method to decide the minimum workforce required to complete all jobs. Based on the minimum workforce number and shift criteria, the shifts were assigned to form schedules using a random pick and criteria-based selection methods. The potential schedules were then optimised, and the best ones were selected. Based on several realistic test instances, the proposed heuristic approach appears to offer promising solutions for rostering and scheduling as it improves shift idle time, complies with better shift start time and significantly reduces the workforce needed and the time spent on creating schedules, regardless of the data.

1.2 Problem Statement

The scheduling or rostering problem is not new, and there will be a continual change to the requirements because of the dynamic and competitive nature of the airline industry. Schedule or roster is an organised structure of keeping track of staff working timetable to complete the tasks or services for a period defined. Shifts are created in order to split the day's work in schedule or roster so that the workforce or personnel can be assigned accordingly. The main problem involves determining the best possible schedule with shifts for at least 100 jobs per day within 12 hours or fewer. The schedule and shifts generated should cover at least one-week period or more and should be flexible in accepting parameters changes.

A set of rules which dictate the structure of the schedule or roster typically governs a schedule or roster. In this research, these rules are known as parameters from the programming perspective or operations constraints in the airline industry. The lists of

parameters or operational constraints that will be considered are discussed in the following section.

i. Shift start time

Shift start time for different tasks is generally interdependent since staff cannot cover more than one task at a time. This is true, especially at peak times, when tasks will overlap each other. In shift assignment, the shift schedule or roster will need to have minimum rest times between shifts and maximum offsets between start times on consecutive days. Each shift-type defines a valid starting and ending time for a shift duty and prescribes one or several meals or relief breaks. Usually, break time rules are based on state and federal laws, union agreements, company policies, or practical considerations. Shift start time is a parameter definable based on the requirement of the operations. Shift start time comprises two attributes that form the shift start time range, which allow flexibility of shifts to cover jobs as much as possible; the attributes are:

- Earliest start time (EST) refers to the earliest time the shift can start.
- Latest start time (LST) refers to the latest time the shift can start.

ii. Shift duration

Personnel then covered the base workload with typical shift lengths of between six and eleven hours and up to three meals and relief breaks. Planners often try to use full-time shifts, which cover at least two peak periods within the day. Similar to shift start time, the shift duration is definable parameters and comprises two attributes that form the shift duration range. The attributes are:

- Min duration refers to the shortest period of duration for a shift.

- Max duration refers to the longest period of duration for a shift.

1.3 Objectives

The goal of this research is to develop a computationally bounded heuristic algorithm that can solve rostering and scheduling problems in the case study within a short time frame. The research will satisfy the following objectives by achieving the goal:

i. To design and develop a computational bounded heuristic algorithm that ensures efficiency within defined constraints on time, space, and practicality.

ii. To formulate a simulated model of airline scheduling/rostering model by digitally replicating operations.

iii. To design and develop a hybrid meta-heuristic rostering algorithm.

The research will also subject to the following limitations:

a. Simulated models may involve simplifications.

b. Involve trade-offs between algorithmic efficiency and solution optimality.

c. Limited or inaccurate data may impact the realism.

Apart from the research objectives and limitation mentioned, it is also vital to evaluate the quality of current industries practices and the proposed algorithms. We take into consideration three types of cost savings under different operational constraints. The cost savings are given below:

- All jobs must be assigned/covered. All jobs must be assigned and completed by the personnel assigned to the job, no compromise on this constraint.

- To reduce the use of resource/workforce. In shift scheduling, to lower the operational cost, the shift schedule should utilise the most minimum resource.

- Avoid overlaps of shift period. Overlapping of shifts happened when two teams of workforce is on duty in the same period where one of the team will be assigned to jobs while the other will most likely be idling which is a waste of resource and cost.

In these studies, two algorithms are being proposed and developed. The heuristic approach will be the focus, as the genetic algorithm approach will be used as a control algorithm. An optimisation function would be developed and implemented on both algorithms. The optimisation function will try to tackle three types of cost savings under different operational constraints mentioned earlier.

1.4 Thesis Structure

An overview of current rostering and scheduling literature is given in Chapter 2. It gave a detailed review of various methods to solve the rostering and scheduling problem in the first subsection. The second subsection emphasis of the chapter looks at the previous implementation of the two heuristic approaches. Last, the chapter concludes with the pass studies on genetic algorithm approaches.

Chapter 3 looks at rostering and scheduling modelling; its constraints and objectives are explained. All operational constraints, decision variables and parameters are explained in detail with the goal is to minimise the number of resources and wastage.

Two rule-prioritisation heuristic algorithms are introduced in Chapter 4. The first heuristic-based algorithm is the randomise pick approach where all the possibilities of the shifts schedule are generated randomly and pre-processed and optimised before the proceeding with the process of the best schedule selection. An optimisation algorithm is developed and implemented so that the resource utilisation is more efficient throughout the schedule. The second heuristic-based algorithm is a criteria-based selection approach where the main goal is to pick schedules that fulfil specific required criteria, such as minimum workforce, minimum duration, or the earliest/latest start time of a shift. This chapter illustrates the computational effort of generating an optimal solution using the heuristic algorithm.

Chapter 5 presents the Genetic Algorithm method for rostering and scheduling. The algorithm is implemented with the various improvements, which include adaptive crossover, which tries to encourage a better shift schedule to be generated. Optimisation from Chapter 4 was integrated into the algorithm to improve the shift schedule. The chapter concludes with results from various parameter and strategy settings experimentation.

In Chapter 6, to validate the results obtained so far, all previous algorithms implementation applies to the same real-life data obtained from an airline in Malaysia. A numerical study of the heuristic and genetic algorithm solutions is performed with a range of data. The comparison of the different approaches and extensive sensitivity analysis are performed in order to show the effectiveness and robustness of the proposed algorithms. The numerical results and discussion are also reported at the end of the chapter.

Chapter 7 summarises the findings in this thesis and contains concluding remarks, contribution and ideas for future investigation are identified.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Research on scheduling and rostering is extensive and identified several problems involving real-life shift scheduling. The problems mostly involve assigning workers to shifts, determining working days and rest days, or constructing flexible shifts and their starting times for each shift. Furthermore, the problem includes a wide range of operational constraints. These constraints pose a challenge in addressing optimal scheduling because of integer's large size and pure nature; thus, these problems are typically labelled as NP-hard and NP-complete, as stated by both (Lau, 1996) and (Heimerl & Kolisch, 2010). Methods and models commonly used for solving these problems have been surveyed by (Ernst et al., 2004; Van den Bergh et al., 2013). In this paper by (Ernst et al., 2004), the authors categorise the solution methods for scheduling problems based on method and approaches such as artificial intelligence, fuzzy set theory, constraint programming, meta-heuristics, and mathematical model. Most literature reviews are intensely skewed towards mathematical programming and meta-heuristic for scheduling as opposed to constraint programming and other techniques.

Since the linear ordering problem is NP-hard, we cannot expect to solve practical problem instances of arbitrary size to optimality. Depending on the size of an instance or depending on the available CPU time, we will often have to be satisfied with approximate computing solutions. Also, under such circumstances, it might be impossible to assess the real quality of approximate solutions. In this chapter, we will attend to the question of how to find good enough solutions in a short or reasonable time by using heuristic algorithms.