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HEURISTIC METHOD FOR OPTIMUM SHIFT SCHEDULING DESIGN

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ABSTRACT. This paper describes a method to schedule shifts in the most optimum way desire for today's cost sensitive industries. The main problem for this domain is to make sure all shifts are assigned to cover all or maximum jobs available. The shifts also need to be schedule with the least manpower possible, avoid manpower idling during the shift and take into consideration employee's time adaptability. Our approach is to use the existing manpower prediction method to determine the minimum manpower require to complete all the jobs. Based on the minimum manpower number and shift criteria's, the shifts are then assigned to form schedules using our proposed algorithm. The potential schedules are then optimized. Our prototype running data from airline staff shows that the method used can solve the problem efficiently even for large problem instances in seconds.

Keywords: heuristic, minimum manpower, shift scheduling, jobs

INTRODUCTION

The demand for fast and reliable operation in any organization and industries has never been greater, especially in the manufacturing, call center, logistic, transportation industry, etc. With rising operations and maintenance cost, all the industries are fighting an uphill battle to keep the cost low. The biggest potential cost saving areas is in manpower where most organizations are looking for ways to reduce wastage and optimize manpower utilization. This solution is hardly new, Anbil et al. (1991) has presented an optimization software solution for crew rostering to a major airline resulting annual savings more than USD20 million. In most organization having the optimum number of manpower is very important as it's not only reduce cost it also improved efficiency and avoid bureaucratic. Therefore, it justifies the huge spending by organization to procure a good system for scheduling and rostering.

Real-life manpower scheduling problem mostly focus on assigning employees to shifts, determining working days and rest days or constructing flexible shifts and their starting times for each shift. Moreover, it usually includes a wide range of operational constraints. These problems are difficult to solve optimally due to its large size and pure integer nature, thus these problems are normally label as NP-hard and NP-complete (Lau 1996 and Kolisch et. al 2010). Methods and models commonly used for solving these problems have been surveyed in Jorne et. al (2012) and Ernst et al. (2004). Ernst et al. (2004) classified the solution methods for scheduling problem into: demand modelling (Lin et al. 2000) artificial intelligence approaches e.g. fuzzy set theory by Shahnazari et .al (2013), constraint programming (Di-Gaspero et al. 2010), metaheuristics (Ho et. al 2010) and mathematical model (Naudin et. al 2012). Most of the literatures are heavily skewed towards mathematical programming and metaheuristic for scheduling as opposed to constraint programming and other techniques. Ásgeirsson et al. (2011) classify the real-world manpower scheduling process into two main processes, namely the Workload Prediction and Shift Generation. Sze's (2012) presented Workload Prediction algorithm on "Multi-Trip Vehicle Routing and Scheduling Problems with time window with meal break considerations". Luca et al. (2010) propose a new hybrid Local Search-Constraint Programming method to solve the shift generation by automating the whole process of shift design and break assignment.

Heuristic have been known to be the method that have been employed often to solved scheduling problems which are either difficult or too complex to attain through exact solution approach. Heuristic method tends to be robust and able to produce reasonable "good" result, although not the best result. The reasonable "good" result normally is achieve in a very short period which cannot be achieve through exact solution approach where there is a possibility of not producing any result at all.

PROBLEM DESCRIPTION

Designing schedule with multiple shifts entails numerous challenges; it is governed by a set of rules or operation constraints that induce the complexity in generating an optimum schedule. In an ideal world, schedule will be created with shift with just the right amount of manpower required. The manpower will be fully utilized during the shift avoiding resource wastage such as idling due to no job.

However, in real world where it's less than ideal, designing schedule and scheduling shifts is not an easy task. Most of the organization till today still relies on human to schedule shifts, this include the company that we retrieve our data from which is an airline base in Malaysia. The schedule and shifts generated takes a lot of time to design and a waste of resource. Un-plan changes in the airliner daily operation causes chaos as schedule cannot be re-schedule in short time. This have resulted airliner to increased manpower for standby and to take up additional jobs resulting additional cost. One airliner in Malaysia currently on manual system wastes about USD267 per person a month just for overtime pay. This represents a waste of USD40,000 per month, or USD480,000 per year for just one department of 150 people.

The problem we addressed in this paper is generation of shift schedules or what we call shift scheduling design. The method that we proposed will predict the workload and use it to schedule shift with start time pattern that is consistent throughout the week which utilizes the resources smartly per work load distribution. The algorithm for workload prediction will be based on existing heuristic method and shift scheduling using heuristic. The objectives of the algorithm are to make sure all jobs are assigned with the minimum resource and avoid wastage or unutilized resource. Heuristic is the method of choice to deal with messy real world objectives and constraints that do not solve easily with a mathematical programming formulation.

PROPOSED ALGORITHM

To solve the problem described and formulated in the previous section, the Two-Stage scheduling heuristic (TSH) are adopted to find a good valid integer solutions for workload prediction, subsequently a simple local search heuristic procedure is implemented for optimum shift scheduling. The flow of the proposed algorithm is shown in Figure 1.

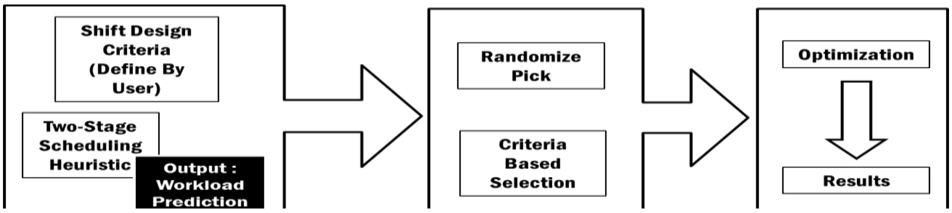

Figure 1. Proposed Algorithm.

Criteria Preparation

The initial step to the solution is to generate an optimum workload prediction using TSH. The optimum workload prediction is based on unlimited resources that can be utilized at any time. Shift cannot be implemented based on workload prediction; this is because the shift will have a different manpower at different period. However, the workload prediction can be used as a guide to generate an optimum schedule. User input of shift design criteria will be used to list out all possibilities of schedules with all the combination of start times and durations. The list of raw schedules together with the result of workload prediction (TSH) will form the input for shift scheduling algorithm to schedule shift.

Shift Design Criteria

In the shift scheduling, a shift is time intervals defined by a beginning time, an ending time and duration. Scheduling of shifts to carry out the respective tasks is depending on the work-load of that time slot. Shift time for a day is define as four shift a day which are morning, day, afternoon and night. For each of the shift time, the user will be able to choose the earliest start time, latest start time, minimum duration and maximum duration as illustrated in Figure 2.

	Earliest Start Time (EST)		Latest Start Time (LST)		Min Duration		Max Duration	
Morning	05	00	08	00	07	00	09	00
Day	09	00	11	00	07	00	08	00
Afternoon	13	00	15	00	07	00	10	00
Night	21	00	23	00	08	00	09	00

Figure 2. Defining Day Shift Time.

Shift Scheduling

A set of parameters defined by user will be used to generate all the possible shifts. The shifts will be assigned to form schedules. The list of schedules is then processed using two separate methods to try to pick the good schedules to increase the chances of getting the "best" solution within a short time frame. All the good schedules selected are then optimize as best as possible to cover all jobs with minimum manpower and reduce wastage.

Randomize Pick

This method is using simple randomize method hoping to pick good schedules from all the possible shifts available. Users can decide on the percentage of potential candidate schedules to be pick randomly. Recursive randomize is also implemented to reduce the potential candi-date schedules with the hope of maintaining the good schedules in the list of possible good candidate schedules.

Criteria Based Selection

The criteria based selection tried to pick schedules that fulfilled certain criteria requirement such as minimum manpower or minimum duration or earliest/latest start time of a shift.

$\alpha^{min/max}$=min/max({$f(x)$:x = 1, …, n}), α = resource

$\beta^{min/max}$=min/max({$f(y)$:y = 1, …, n}), β = duration

$\gamma^{earliest/latest}$=earliest/latest({$f(z)$:z = 1, …, n}), γ = start time

There are 48 combination of criteria used to select the candidate of "good" schedule for the next selection process. The lists of criteria combination are as follows:

$\alpha^{min/max} > \beta^{min/max} > \gamma^{earliest/latest}$

$\beta^{min/max} > \alpha^{min/max} > \gamma^{earliest/latest}$

$\gamma^{earliest/latest} > \alpha^{min/max} > \beta^{min/max}$

$\beta^{min/max} > \gamma^{earliest/latest} > \alpha^{min/max}$

$\gamma^{earliest/latest} > \beta^{min/max} > \alpha^{min/max}$

$\alpha^{min/max} > \gamma^{earliest/latest} > \beta^{min/max}$

From this criteria selection, the number of "good" schedules candidate picked will be 48. The intention for criteria based selection being used is to evaluate and find out criteria that most likely influence the best solution.

Optimization

Good schedule candidates picked or selected from both randomize and criteria based selection will be optimize to improve the quality of schedules. The objectives of the optimization are to reduce the resource/manpower used, overlapped in shift period and uncover jobs. First it tries to optimize the duration within the permitted time window restriction to cover more jobs while avoiding overlap of shifts. Next it tries to adjust the start time to reduced overlap of shifts while respecting the time window restriction. Last it tries to cover the jobs by pushing previous shifts start time even though the benefit is for the subsequent shifts. All the optimizations avoid overlapping with other shifts and stay within the range of parameters defined by user. The optimization steps are repeated till there are no changes in the schedule. Once there is no improvement, the candidate for good schedule is considered optimized and ready to be in the pool for the evaluation of the best schedule.

COMPUTATIONAL RESULTS

The results presented in this section relate to a real problem data collected from one of the international airport in Malaysia. The real problem datasets contain 1023 jobs; each job has the following attributes: a job number, release time, deadline and processing time. The datasets are collection of real number of jobs for the first four days of the week. Due to unforeseen circumstances, we're unable to get the complete datasets for the last three days of the week. Nevertheless, with only four days of datasets we still are able to simulate and produce the desire result. We're confident that even the additional three days added, the algorithm will still be able produce the same good result.

Table 1 shows another real problem data collected from an airline company based in Malaysia (KLIA). This data was used to evaluate the performance of proposed heuristic solution.

Table 1. Manually Assigned Shifts.

Day 1	Day 2	Day 3	Day 4
0700-	0700-	0700-	0700-
1500-	1500-	1600-	1600-
2200-	2200-	2200-	2200-

To study the sensitivity analysis of the proposed algorithm, the real problem datasets from Table 1 is used to generate shift scheduling with different start time range. We used two different range for the start time; 4 hours and 2 hours' range. The results generated by the proposed algorithm are as tabulated in Table 2.

Table 2. Shift Schedules from the Proposed Algorithm.

Parameters start time range = 2 & 4 hours							
• manpower = 310 • overlapped duration = 7:45 hours				• manpower = 316 • overlapped duration = 8 hours			
Randomize Pick				**Criteria Based Selection**			
0700-1300	0700-1300	0645-1245	0700-1300	0700-1300	0700-1300	0700-1300	0700-1300
1200-1800	1200-1800	1200-1800	1200-1800	1200-1800	1200-1800	1200-1800	1200-1800
1800-2400	1800-2400	1800-2400	1800-2400	1800-2400	1800-2400	1800-2400	1800-2400
2300-0700	2300-0645	2300-0700	2300-0900	2300-0700	2300-0700	2300-0700	2300-0900

Results obtained from the proposed algorithms with the TSH and manual shifts schedule are illustrated in Figure 3. From our test, start time range in this scenario does not impact the schedule selected. We will further explore this in a wider range start time with different datasets to validate this finding. Randomize pick perform slightly better that criteria based selection as later require more manpower (resource) and have more overlapped shift time. The highlighted cell indicate the difference between two schedule shift from different solutions. In summary, the manpower required by the proposed shift scheduling algorithm is lower than the manual assigned shifts. The reduction of manpower is up to 4.32%.

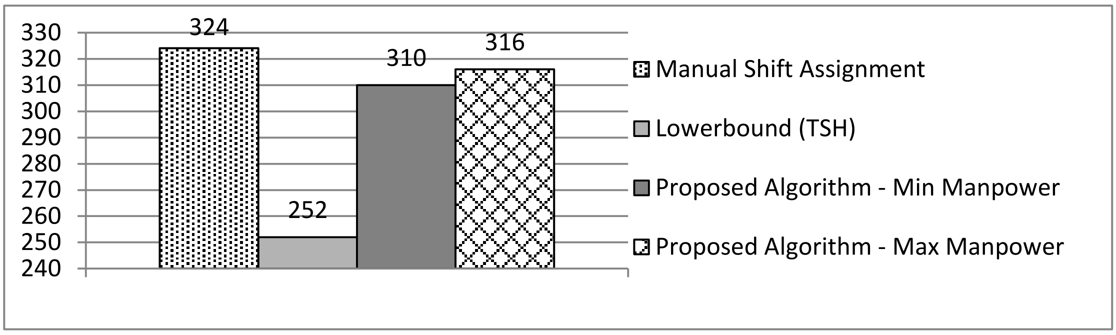

Figure 3. Comparison between Manual, Lower bound and Proposed Algorithms Manpower Requirements.

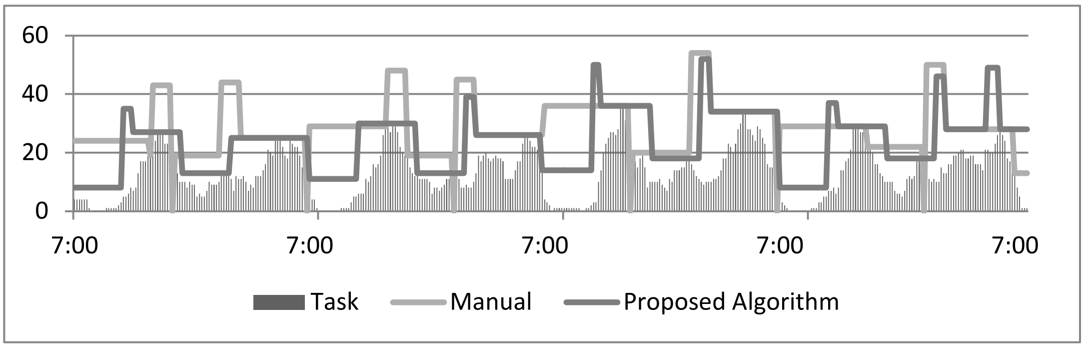

Figure 4. Comparison of the Manpower Assigned for Shifts between the Proposed Algorithm vs. Manual Assignment.

The chart from Figure 4 shows that the proposed algorithm displayed a more predictable manpower requirement throughout the week which helps employees adapt more easily to the schedule. The peak exhibited in the chart indicates overlapped of shift that points out wastage of resources. From the chart, the proposed algorithm produces fewer peaks as compared to the manual shift scheduling. This shows that proposed algorithm has less of overlapped between shifts which indicate less wastage of manpower. The manual scheduling generates 12 hours of overlapped shifts while the proposed algorithm only generates 7:45 to 8 hours.

CONCLUSION

In this paper, an algorithm to design shift schedules are presented, the shift scheduling was solved using heuristic algorithm which was successfully applied to real airline data. The results proved that the algorithm can solve real size problems. The algorithm managed to reduce up to 4.32% in resource and overlapped of shift duration up to 30%.

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