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A Shift Sequence for Nurse Scheduling Using Linear Programming Problem

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Abstract: *The Nurse scheduling problem (NSP) of this paper is to study and analyze the scheduling process in practice, and propose models and heuristics to improve both the process and the quality of the resulting schedule. Nurses should benefit from this study by having higher quality schedules while the employees in charge of scheduling should enjoy the positive benefits of an optimization tool to solve problem related to healthcare, which should guide their work and is certainly superior to suit and fallacy. The objective is to maximize the fairness of the schedule. This paper illustrates how the linear programming solves the nurses scheduling problem and how it has been effectively used in hospitals. A numerical illustration example of nurse scheduling for 8 hour shift is presented and the optimum solution is solved by Excel solver*
Keywords: *Nurse scheduling (NSP), Linear Programming Problem (LPP), Constraints, Objective function.*

I. Introduction

Nurse scheduling, or rostering, is the series of action of constructing a single whole work timetables for its staff so that an activity can satisfy the requirement for its worships. The deed of transferring the working shifts to nurse over a period for many days is a hard for utilizing the task. It involves constructing a schedule for each employee within an organization in order for a set of tasks to be fulfilled. In the domain of healthcare, this is particularly challenging because of the presence of a range of different staff requirements on different days and shifts. The objective in this paper is to conduct a practical study on the process of nurse scheduling in hospitals, then introduce a heuristic that can be easily implemented in these hospitals at no extra cost, and finally, use software to generate scheduling problem to solve is the determination of day schedules for nurses.

Constraints are usually divided into two groups: hard and soft constraints, which vary significantly with respect to legal regulations and individual preferences, depending on individual institutions and countries. *Hard constraints* must be satisfied to obtain *feasible* solutions. *Soft constraints* are desirable but not obligatory, and thus can be violated. In real nurse rostering settings, we noticed that the problems are nearly always over-constrained. It is therefore quite common to express the quality of solutions in terms of soft constraint violations.

All the feasible weekly shift patterns were pre-defined and associated with costs concerning preferences, requests, the number of successive days, etc. These shift patterns were then used to construct nurse rosters by employing different heuristic decoders within a genetic algorithm to schedule both shifts and patterns for the best permutations of nurses. The idea of permuting the nurses to be scheduled is similar to the method presented in this paper.

The Mason and Smith introduced work stretch cost and work stretch transition in an Integer Programming model to define the cost of the *day-on* within and between the work stretches. Column generation was employed to decide on the content of the work stretch and to link them in constructing the schedules concerning other costs related to shifts. Where a concept called *stint* is introduced to define a feasible sequence of shifts on consecutive days. Schedules for nurses can then be constructed by using a series of *stints*. Millar and Kiragu , used the term *stint* to denote patterns, which were defined by a start date, a length, a cost and the shifts. Network programming was used where each node is a *stint* to construct either cyclic or non-cyclic rosters.

In this work, the purpose of this article is suitable method for linear programming to solve an instance of the nurse scheduling problem met in real modern hospital, while seeking for the schedule that guarantees a high level of fairness between the nurses

In Section 2, we present the problem formulation. The application area is described in Section 3 and literature review in Section 4. Section 5 shows the structures of LPP. Finally, we present nurse scheduling model and the conclusion in Section 6 &7 respectively.

II. Problem formulation

Nurse scheduling is a complex exercise with multiple and contradictory objectives: minimizing total costs while maximizing the nurses' preferences and requests, and equally distributing workload between nurses. Work constraints imposed by collective agreements and unions as well as contracts have to be respected. Constraints in nurse scheduling relate to; requirement for each shift, that can be assigned to each particular nurse, maximum number of consecutive days of work, minimum amount of rest time between two shifts and isolated days of work or days-off.

The objective in this paper is to create a rostering tool, which is practically applicable and which complies with the requirements of realistic settings in a hospital. Several literatures reviews have addressed the lack of broadly applicable approaches:

> *If this is our goal [to solve real nurse scheduling problems in real hospitals], then we must address the full range of requirements and demands that are presented by modern hospital workplaces. - Burke et al. (2004)*
>
> *It is hard to avoid the conclusion that, in the United States at least, practitioners do not accept academically produced management and computer science solutions to the nurse-scheduling problem. - Kellogg and Walczak (2007)*

From these we are describe general roster characteristics as; Fixed planning period, Fixed number of shifts, Time norm for each employee, Maximum number of days on in a week / on-stretch, Some combinations of on/off days prohibited, A minimum rest period after a shift is required, Specific shift transitions are not allowed, Single days-on / days-off are undesirable., Each nurse has individual preferences, May have shift assignments which are fixed in advance.

We, at the same time, find a number of individual rules and agreements which are very specific and only apply to few of the problems. We must be able to cater for these individual rules by several literatures as;

On all days: at least one of the nurses was also there the day before, A nurse cannot work two consecutive weekends , Minimize the number of different shifts in a stretch, One week with 60 hours allows only 16 hours the following week , If working night shifts, at least to consecutive night shifts must be scheduled , If a set of days on ends with a night shift, then the following on-stretch must not begin early, unless there is a 'long' off-stretch in-between , Some nurses have a weekly off day called a zero-day. For each nurse, it is preferred that zero-days are always on the same day of the week, A special shift type must be covered by the same employee for a whole week.

III. Application area

Health care systems

The foremost rostering focus in health systems has been in nurse scheduling, usually in acute care hospital wards. There are both clinical and cost imperatives associated with providing appropriate levels of staff in the different medical wards in a hospital. The rosters must provide suitably qualified nurses to cover the demand arising from the numbers of patients in the wards while observing work regulations, distinguishing between permanent and casual staff, ensuring that night and weekend shifts are distributed fairly, allowing for leave and days off, and accommodating a range of employee preferences. The resulting rostering problems are, in most cases, over-constrained. Approaches in the 1970s and 1980s addressed a number of problem formulations and solution techniques. A goal in many studies was to provide support tools to reduce the need for manual construction of nurse rosters. Some studies addressed the problem of determining staff levels and skills based on the numbers of patients and their medical needs. Others adopted mathematical programming, branch and bound techniques, or goal programming, approaches in which the objective contains weighted coverage and shift satisfaction terms and the constraints enforce hard rules such as the ratios of nurse grades that must be observed on shifts. Others used iterative algorithms to generate cyclic rosters in which fairness is achieved by having each nurse work the same sequence of shifts with individual shift sequences offset so as to provide the required coverage and skill mix within wards. In the 1990s a number of papers provided classifications of nurse rostering systems and reviews of methods for solving different classes of problems. Further advances were made in applying linear and/or mixed integer programming and network optimization techniques for developing nurse rosters. Constraint programming (CP) methods were also used to model the complicated rules associated with nurse rosters. The methods were applied to problems involving cyclic and non-cyclic rosters. Typically, the problems contained roster rules applicable to a particular hospital. As such, these approaches may require substantial reformulation for use in a different hospital.

A number of approaches have included a mix of heuristic and simulation techniques in an attempt to deal with more complex nurse rostering and clinical service problems. A simulation model augmented by AI methods is used to incorporate nurse training into rosters. A decision support system based on a shift pattern generating heuristic is used to provide an interactive system for developing weekly work schedules. A simulated annealing (SA) algorithm for solving a large set covering integer programming formulation is used to develop rosters for a mix of permanent and casual staff with demand specified in half hourly intervals over a 10 day period. Day to day nurse scheduling based on decisions arising from stochastic models of patient acuity, assessed via simulation modeling, is considered .An attempt to develop a knowledge based system for generating weekly nurse rosters and then adjusting the rosters so as to react to daily changes in demand and staff availability is discussed .More recently, a mix of tabu search (TS) and integer program sub problems is used to generate weekly ward rosters while satisfying a complex set of shift rules, cost restriction, nurse grade, and employee preference constraints. A hybrid TS algorithm is used to obtain solutions within a reasonable timeframe for a commercial nurse rostering system. The algorithms incorporate various tabu and hybrid TS procedures within a genetic algorithm (GA). These algorithms are designed to overcome one of the basic problems associated with using heuristics for complex nurse rostering problems, namely that, as indicated by the authors, ''the quality of a solution is not necessarily a sum or combination of the partial solutions''. A number of other aspects of health system rostering systems have been studied by different researchers. Models for developing rosters for nurses serving home care and regional clinics, in which travel between different locations is an important factor, have been developed. A queuing model is used to determine the staffing levels needed to handle call arrivals for inpatient, outpatient and other hospital generated appointments. Simulation modeling is used to consider operational management policies for providing maintenance staff in a large hospital. The use of a simple relational database system to manage work schedules for radiologists is discussed.

IV. Literature review

Literature on nurse rostering and scheduling is extensive. Several studies have employed optimization methods to solve the NSP, like linear, integer or mixed integer programming, goal programming or constraint programming. Many of more recent paper tackle the NSP with met heuristic methods such as genetic algorithms, tab search or simulation. We believe the resolution techniques involving the use of solvers are more easily transferable to hospital-services. Other approaches, like heuristics or meta- heuristics are less accessible, and could be time-consuming. Hence our contribution, related to existing approaches, is focused on the linear programming problem, which seeks to satisfy the demand coverage while minimizing the salary cost and maximizing the nurses' preferences as well as team balance.

Different objectives are studied in this literature are to decrease manual scheduling, to increase demand covering in terms of workforce size but also according to required skills, to obtain equity between the schedules.

V. Structure of Linear Programming model.

The general structure of the Linear Programming model essentially consists of three components.

- The activities (variables) and their relationships
- ii) The objective function and
- iii) The constraints

The activities are represented by $x_1, x_2, x_3 \ldots\ldots..x_n$.
These are known as Decision variables.

The objective function of an LPP (Linear Programming Problem) is a mathematical representation of the objective in terms a measurable quantity such as profit, cost, revenue, etc.

$$\text{Optimize (Maximize or Minimize) } Z = c_1x_1 + c_2x_2 + c_3x_3 + \cdots c_nx_n.$$

Where Z is the measure of performance variable?
$c_1x_1 + c_2x_2 + c_3x_3 + \cdots c_nx_n$ are the decision variables. And $c_1, c_2, c_3, \ldots, c_n$ are the parameters that give contribution to decision variables.

The constraints these are the set of linear inequalities and/or equalities which impose restriction of the limited resources

5.1 Assumptions of Linear Programming

Certainty.

In all LP models it is assumed that, all the model parameters such as availability of resources, profit (or cost) contribution of a unit of decision variable and consumption of resources by a unit of decision variable must be known and constant.

Divisibility (Continuity)

The solution values of decision variables and resources are assumed to have either whole numbers (integers) or mixed numbers (integer or fractional). However, if only integer variables are desired, then Integer programming method may be employed.

Additivity

The value of the objective function for the given value of decision variables and the total sum of resources used, must be equal to the sum of the contributions (Profit or Cost) earned from each decision variable and sum of the resources used by each decision variable respectively. /The objective function is the direct sum of the individual contributions of the different variables

Linearity

All relationships in the LP model (i.e. in both objective function and constraints) must be linear.

5.2 General Mathematical Model of an LPP

Optimize (Maximize or Minimize) $Z = C_1 X_1 + C_2 X_2 + \cdots \ldots + C_n X_n$

Subject to constraints,

$a_{11}x_1 + a_{12}x_2 + \cdots \ldots \ldots \ldots \ldots \ldots + a_{1n}x_n (<,=,>)\ b_1$
$a_{21}x_1 + a_{22}x_2 + \cdots \ldots \ldots \ldots \ldots \ldots + a_{2n}x_n (<,=,>)\ b_2$
$a_{31}x_1 + a_{32}x_2 + \cdots \ldots \ldots \ldots \ldots \ldots + a_{3n}x_n (<,=,>)\ b_3$
……………………………………
$a_{m1}x_1 + a_{m2}x_2 + \cdots \ldots \ldots \ldots \ldots \ldots + a_{mn}x_n (<,=,>)\ b_m$
$and\ x_1, x_2, \ldots .. x_n > 0$

5.3 Guidelines for formulating Linear Programming model

- Identify and define the decision variable of the problem
- Define the objective function
- State the constraints to which the objective function should be optimized (i.e. Maximization or Minimization)
- Add the non-negative constraints from the consideration that the negative values of the decision variables do not have any valid physical interpretation

VI. Nurse scheduling problems Modeling

Nurse scheduling is a known problem, Improving self-scheduling scheduling are of the familiar. Some of them will be describe in the technical way. The practical examples will be studied, modeled, and different ways of enlighten the present process will be published. In studied hospitals, the clerk goes through the pursuing steps to create a schedule:

- Gather preferences
- Block out the schedule
- Revise the schedule
- Display the schedule
- Accommodate the schedule

Nurse Scheduling aim is to minimize changes to be original schedule while minimizing costs, rebuilding the schedule with current staff is usually be simple way ,by changing the schedule will alter other nurse schedules as well. One of the Coimbatore city hospitals has the following minimal daily requirements for nurses.

Shift(Period)	Clock time (24hours day)	Minimum number of nurses required
1	6.00 a.m. – 10.00 a.m.	70
2	10.00 a.m. – 2.00 p.m	140
3	2.00 p.m. – 6.00 p.m.	200
4	6.00 p.m. – 10.00 p.m.	85
5	10.00 p.m. – 2.00 a.m.	25
6	2.00 a.m. – 6.00 a.m.	40

Nurses report at the hospital at the beginning of each period and work for 8 consecutive hours. The hospital wants to determine the minimal number of nurses to be employed so that there will be a sufficient number of nurses available for each period.

Formulate this as a linear programming problem by setting up appropriate constraints and objective function.

i) Identify and define the decision variable of the problem

Let $x_1, x_2, x_3, x_4, x_5\ and\ x_6$ be the number of nurses joining duty at the beginning of periods 1, 2, 3, 4, 5 and 6 respectively.

ii) Define the objective function

$$Minimize\ Z = x_1 + x_2 + x_3 + x_4 + x_5 + x_6$$

iii) State the constraints to which the objective function should be optimized. The above objective function is subjected to following constraints.

$$x_1 + x_2 \geq 70$$
$$x_2 + x_3 \geq 140$$
$$x_3 + x_4 \geq 200$$
$$x_4 + x_5 \geq 85$$
$$x_5 + x_6 \geq 25$$
$$x_6 + x_1 \geq 40$$
$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

Since the model has 6 variables by using the solver to solve LPP, the feasible solution is Minimize Z=295

The solution found by the linear programming algorithm (Excel-shown below) uses the minimum number of 295 nurses to meet the schedule.

VII. Conclusion

In this paper shows an overview of the planning and nurse scheduling problem, this seeks the minimum number of nurses can handle the hospital needs. Although we have describe the constraints satisfaction system in terms of shift and piece of works. The aim of this problem is to maximizing the fairness of the schedule, while respectively all the constraints .Nurse rostering is a complex scheduling problem that affects hospital personnel on a daily basis all over. In general it is efficiently utilize the time and effort, to balance the workload to lead more contented and effective.

Reference

[1]. Aickelin, U., K. Dowsland. 2004. An indirect genetic algorithm for a nurse-scheduling problem. Comput. Oper. Res. 31(5) 761–778.

[2]. Azaiez, M. N., S. S. Al Sharif. 2005. A 0-1 goal programming model for nurse scheduling. Comput. Oper. Res. 32(3) 491–507.

[3]. Bailey, R., K. Garner, M. Hobbs. 1997. Using simulated annealing and genetic algorithms to solve staff scheduling problems. Asia-Pacific J. Oper. Res. 14(2) 27–43.

[4]. Berrada, I., J. Ferland, P. Michelon. 1996. A multi-objective approach to nurse scheduling with both hard and soft constraints. Socio- Econom. Planning Sci. 30(3) 183–193.

[5]. De Grano, M.L, Medeiros, D.G and Eitel, D.(2009). Accommodating individual preferencesin nurse scheduling via auctions and optimization, Health Care Management Science,12: 228 – 242

[6]. Ernst, A.T., Jiang, H., Krishnamoorthy, M. and Sier, D. (2004). Staff scheduling and rostering: A review of applications, methods and models, European Journal of Operational Research, 153: 3 – 27

[7]. Jaumard, B., F. Semet, T. Vovor. 1998. A generalized linear programming model for nurse scheduling. European Journal of Operational Research 107(1) 1-18.

[8]. Moz, M. and Pato, M. V. (2007). A genetic algorithm approach to a nurse rerostering problem, Computers and Operations Research 34(3): 667–691.

[9]. Okada, M. 1992. An approach to the generalised nurse scheduling problem – generation of a declarative program to represent institution-specific knowledge. Computers and Biomedical Research 25.