A Framework for a Practical Nurse Scheduling Approach: A Case of Operating Room of a Hospital in Thailand

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Abstract. Nurse Schedule Problem (NSP) is the assignment of nurses to fulfill hospitals operational goal and regulations. The major aim of NSP is to minimize the total cost, maximizing nurse's satisfaction, or maintain balanced distribution among preferable assignments and workloads. This paper is the preliminary research in development of NSP for a case of an operating room at a private hospital in Pathumthani, Thailand. An interview with the head nurse was conducted to capture insights and emerging issues that the head nurse wants to resolve. Then, a framework is proposed as a guideline for the development stochastic optimization model to tackle uncertainties in patients' arrival and surgery duration which are the main concerns. This paper aims to serve as a fundamental stage for a further case based NSP development research.

Keywords: Job satisfaction · Nurse scheduling problem · Healthcare management · Scheduling

1 Introduction

Nurse and medical staff are usually required to perform their duties over excessively long and irregular work hours. Certain shift assignment criteria are normally in place to ensure their workplace well-being and good work-life balance. However, in practice, nurses are still at high risk of receiving the cumulative effects of sleep disorders [1] and carrying excessive fatigue [2]. Working under shift work conditions, nurses are constantly subjected to work time alteration. Many find it difficult to maintain a proper work-life balance under a shift rotation scheme [3]. A robust and agreeable shift-scheduling for nurses is required to obtain smooth and optimized operations while providing nursing staffs with favorable working conditions. In the research field of the

nurse scheduling problem (NSP), previous studies have addressed potentially important nurse scheduling parameters and developed optimization-based decision-making tools. A number of nurse scheduling techniques and mathematical problem-solving approaches have been proposed. However, there is still a lack of empirical evidence about the effectiveness and the practicality of the pro-posed techniques. Based on our literature review, case study research is still underemphasized in nurse scheduling literature. This present study is the first step of wider research aimed to conduct a case study research to bridge the gap between theory and practice in nurse scheduling. The data regarding the current nurse scheduling of an operating room in a hospital located in Pathum Thani, Thailand, are collected and summarized in the following sections. A research framework that identifies the important scheduling parameters of the operating room case study and the main components of future scheduling approach is provided.

2   Literature Review

The research on NSP has been well-documented in both operational research and health-care system management literature. NSP is different from other scheduling problems due to its highly constrained nature. In hospitals, numerous requirements and regulations need to be considered for human resource planning and scheduling of staff. NSP is classified as NP-hard problem [4], due to the potentially large number of decision variables and constraints. Optimization, heuristics and hybrid problem-solving approaches have been used by previous NSP studies. The problem can be formulated as single- or multiple- operational objectives that involve the minimization of nurse staffing cost [5] and [6] or the maximization of nurse satisfaction [7] and [8]. Optimization-based NSP can be formulated as goal programming by minimizing the undesirable deviation from target value such as workload [9], targeted nurse-patient ratio, favorable and unfavorable shifts, and rest days [10]. In the case with a large number of constraints, NSP can be formulated as a constraint satisfaction problem as in [11] and [12], which aims to satisfy all hard constraints and minimize violation of soft constraints. All of the hard constraints are related to regulations and coverage requirements which cannot be violated. Soft constraints are related to preferences and balanced distribution. These soft constraints can be violated with penalties. The use of optimization techniques can help reach optimality. However, due to the complex nature of NSP, optimization potentially requires tremendous computation efforts, while a feasible solution is not guaranteed. Therefore, the application of problem-specific heuristics [13], and metaheuristics such as genetic algorithm [14] and simulated annealing [15] approaches in solving NSP has become more favored for its capability of generating good solutions with less solving time.

In order to develop a nurse scheduling approach with improved practicality, issues in real case studies such as uncertainties should be taken into account, given the dynamic nature of hospital settings. However, the NSP with uncertain parameters has not been receiving much attention in the literature. In [16] the fuzzy integer programming approach is applied to address the fuzzy environment of nurse coverage and preferences. Similarly, [17] developed a stochastic optimization technique to deal with uncertainties regarding demand and preferences. [18] consider uncertainties in patients'

arrival and their duration of stay using a stochastic optimization technique. [19] developed stochastic programming coupled with genetic algorithm for NSP with uncertain patient census and nurse absenteeism. To this end, there are still remaining research gaps. First, the way operation uncertainties are identified and managed can be improved. Second, the implementation of conceptual scheduling models can be validated by case study analysis. The details of our nurse scheduling case study are given in the next section.

3   A Case Study and Proposed Framework

The case study of this research is a hospital in Pathumthani, Thailand. The hospital is the main private hospital in the area that receives patients with national standard medical rights including universal coverage and social security. The designated department is the surgery department, where nurses are employed 24 h. An interview survey with the head nurse who is in charge of nurse scheduling was conducted to gain insights into problems emerging in the department.

The hospital has 3 working shifts, morning from 8 AM to 4 PM, Evening from 4 PM to 12 AM, and nightshift from 12 AM to 8 AM. The morning shift is the most crowded, and three teams of medical staff are scheduled, while the other shifts are assigned with only one team. In each medical team, there is a medical doctor, a nurse, an anesthetist nurse, and two nursing staff, where the head nurse ensures that there is a mix between experienced and non-experienced staff in each team. The total regular work hours of nurses are regulated at a maximum of 48 h per week or 6 shifts per week. Whereas overtime hours are counted when the working shifts exceed 22 shifts per month, and the overtime hours cannot exceed 36 h per week, which accounts for 18 shifts per month.

The current scheduling method is manually handled by the head nurse for at least one month in advance. One of the major problems they have currently encountered is the shortage of full-time nurses, in order to supply for demand coverage, they need to hire part-time nurses. The uncertainties in patient arrival and variation in the duration of surgery, which sometimes can be unexpectedly extended affect nurses' work hours and their satisfaction. Additionally, although the head nurse claimed she did her best in trying to distribute the shifts and weekend day-offs, manually handling these would be challenging to obtain a satisfactory outcome for all nurses, also, there is still no consideration of nurses' preference in the current schedule. The following framework for nurse scheduling has been proposed to provide better visualization in the plan to develop nurse schedules for managerial and the head nurse, the illustration is shown in Fig. 1.

The input of the model includes hospital regulations on the allowable number of shifts and workhours in a certain period of time. In order to cope with uncertainties more efficiently, the analysis of historical data of patients' arrival rate, and the estimated surgery time required for similar cases can be done through the prediction of patterns. Last, the nurse database should be electronically stored, the data should include years of experiences, preferences, and requested vacation, and automatically feed into the model as inputs. Since there is only a limited number of nurses in the case

study, optimization can be applied for obtaining optimal schedules. The stochastic optimization model provides an estimated monthly schedule for nurses based on historical data. However, once the emergency occurs, part-time nurses are still available on-call. The robustness of the model is verified based on the feasibility in not violating any of the hard constraints regulated by the hospital. At the same time, the model should be able to satisfy soft constraints, which are related to preferences and fairness, as much as possible.
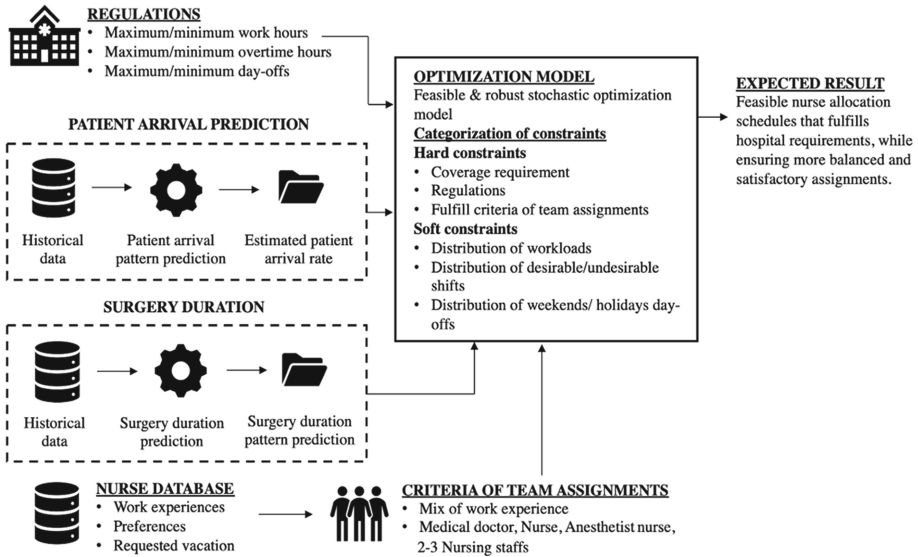

Fig. 1. The proposed framework of the nurse scheduling model.

4   Conclusion

The problem of nurse shortage and the requirements for nurses to work during unusual hours is the cause of fatigue, job stress, and dissatisfaction among nurses. In general, the scheduling of nurses is a hard and time-consuming task for the head nurse and can be even more challenging when trying to include the aspects of satisfaction and fairness in addition to fulfilling nurse's coverage and regulations. Because of these reasons, NSP has been receiving much attention in the literature in an effort to improve nurses' well-being through more efficient nurse schedules, however, only a handful of research considering the dynamic nature of hospital settings, for example, variations in patients' arrival and duration of stay. This results in the proposed model from the literature not practical for implementation in the real case.

This paper proposed an NSP optimization framework for a case study of an operating room at a private hospital in Pathumthani, Thailand. An interview with the head nurse who is responsible for nurse scheduling was conducted. So far, the nurse scheduling is manually handled by the head nurse one month in advance, where the

fairness of the assignment is somewhat considered but not optimized, also, the preferences of nurses, as well as their satisfaction, have not been taken into account. The major concerns are the high variation in patient's arrival, as well as the duration used in each surgery, which is often delayed. These variations sometimes cause understaffing and overloading for the nurses working during peak hours resulting in stress and dissatisfaction. Note that it also results in lower hospital performance considering patients waiting time and service level. The stochastic optimization framework is proposed as a guideline for the development of models to tackle uncertainties emerge in the case, as well as improving efficiency and robustness of current nurse scheduling method in terms of nurse coverage and enhancement of overall nurses' satisfaction.

References

1. Uekata, S., Kato, C., Nagaura, Y., Eto, H., Kondo, H.: The impact of rotating work schedules, chronotype, and restless legs syndrome/willis-ekbom disease on sleep quality among female hospital nurses and midwives: a cross-sectional survey. Int. J. Nurs. Stud. **95**, 103–112 (2019)
2. Thompson, B.J.: Does work-induced fatigue accumulate across three compressed 12-hour shifts in hospital nurses and aides? PLoS ONE **14**(2), 1–15 (2019)
3. Halawi, A.H., Khashfeh, R.: Effect of rotating shifts on work-life balance. Int. J. Multidiscip. Tho. **7**(2), 153–172 (2018)
4. Duka, E.: Nurse scheduling problem. Eur. Sci. J. **2**, 53–63 (2015)
5. El Adoly, A.A., Gheith, M., Fors, M.N.: A new formulation and solution for the nurse scheduling problem: a case study in Egypt. Alex. Eng. J. **57**(4), 2289–2298 (2018)
6. Respicio, A., Moz, M., Pato, M.V., Somensi, R., Flores, C.D.: A computational application for multi-skill nurse staffing in hospital units. BMC Med. Inform. Decis. **18**(1), 1–9 (2018)
7. Lin, C.C., Kang, J.R., Liu, W.Y., Deng, D.J.: Modelling a nurse shift schedule with multiple preference ranks for shifts and days-off. Math. Probl. Eng. **2**, 1–10 (2014)
8. Huang, Y.C., Hsieh, Y.H., Hsia, F.Y.: A study on nurse day-off scheduling under the consideration of binary preference. J. Ind. Prod. Eng. **33**(6), 363–372 (2016)
9. Agyei, W., Obeng-Denteh, W., Andaam, E.A.: Modeling nurse scheduling problem using 0-1 goal programming: a case study of Tafo government hospital, Kumasi-Ghana. Int. J. Sci. Tech. **4**(3), 5–10 (2015)
10. Ang, B.Y., Lam, S.W.S., Pasupathy, Y., Ong, M.E.H.: Nurse workforce scheduling in the emergency department: a sequential decision support system considering multiple objectives. J. Nurs. Manag. **26**(4), 432–441 (2018)
11. Santos, D., Fernandes, P., Cardoso, H.L., Oliveira, E.: A weighted constraint optimization approach to the nurse scheduling problem. In: 18th IEEE International Conference on Computational Science and Engineering, pp. 233–239 (2015)
12. Mischek, F., Musliu, N.: Integer programming and heuristic approaches for a multi-stage nurse rostering problem. In: 11th International Conference of the Practice and Theory of Automated Timetabling, pp. 245–262 (2016)
13. Youssef, A., Senbel, S.: A bi-level heuristic solution for the nurse scheduling problem based on shift-swapping. In: 8th IEEE Annual Computing and Communication Workshop and Conference, pp. 72–78 (2018)

14. Lin, C.C., Kang, J.R., Chiang, D.J., Chen, C.L.: Nurse scheduling with joint normalized shift and day-off preference satisfaction using a genetic algorithm with immigrant scheme. Int. J. Distrib. Sens. Netw. **11**(7), 1–10 (2015)
15. Knust, F., Xie, L.: Simulated annealing approach to nurse rostering benchmark and real-world instances. Ann. Oper. Res. **272**(1–2), 187–216 (2019)
16. Cetin, E., Sarucan, A.: Nurse scheduling using binary fuzzy goal programming. In: 6th International Conference on Modeling, Simulation, and Applied Optimization, pp. 1–6 (2015)
17. Legrain, A., Omer, J., Rosat, S.: An online stochastic algorithm for a dynamic nurse scheduling problem. Eur. J. Oper. Res. **285**, 1–15 (2018)
18. Bagheri, M., Devin, A.G., Izanloo, A.: An application of stochastic programming method for nurse scheduling problem in real word hospital. Comput. Ind. Eng. **96**, 192–200 (2016)
19. Maass, K.L., Liu, B., Daskin, M.S., Duck, M., Wang, Z., Mwenesi, R., Schapiro, H.: Incorporating nurse absenteeism into staffing with demand uncertainty. Health Care Manag. Sci. **20**(1), 141–155 (2017)