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RESEARCH ARTICLE **Open Access**

A New Dynamic Nursing Workforce Planning Considering Skills Required at the Different Organizational Hierarchy: An Optimal Control Method

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Abstract
As a vital practice in human resources management, workforce planning determines that the organization is needed how many workforces, when, and which position. Workforce planning is not formed in a vacuity, and job variables such as skill, ability, and knowledge affect the planning. This study examines workforce planning in the health sector concerning the workforce's flows such as recruitment, promotion, degradation, fired, retention, and termination of the contract according to the skill audit and the role of performance appraisal results in this program. For this purpose, a dynamic model has been applied that can provide optimal answers to the number of workforces required and the workforce's flows at any time during the planning periods. This model has been implemented in a hospital ward with two levels of hierarchy: nurses, supervisors, and nursing directors. The results show that the designed system can converge the existing values to the optimal values by noting delays by the optimal control model.
Keywords: Nursing workforce dynamic planning, optimal control, Workforce's flows, Skill audit, Hospital ward

Introduction

The opinion that companies "compete by people" highlights that obtaining prosperity depends more on a company's capacity to manage human capital. In other words, industrial economies are shifting from exploiting natural resources to the use of intellectual capital in essence (Jaafari et al., 2021). The human capital terms explain the economic value of the workforces' skills, knowledge, and abilities. Although the advantage of these assets might not do abruptly directly on a business's balance sheet, this value nevertheless has an enormous impact on a company's performance (Snell et al., 2018). Organizations need effective and efficient managers and employees to achieve their goals for comprehensive growth and development. To make it attainable for an organization to reach its goals, its employees must do their job satisfactorily (Sabet and Razeghi, 2019). The foundation of developing countries and organizations is related to the creativity and

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innovation of human resources. This need is more felt in healthcare organizations that provide, maintain, promote health, control, and prevent diseases. Because one of the essential components of health care organizations is management, and the manager is considered the key to solving many problems. Full awareness of hospital efficiency as the most extensive and cost-effective health system unit is essential (Latifian and Karimi, 2018). In addition to having general management tasks such as planning, organizing, directing and controlling, innovation and motivation, coordination, budgeting, and other items, managers of health care services have a more critical task. They focus on supportive plans to achieve long-term and short-term conquest and enhance their performance (Syyadi Toornaloo et al. 2020). They must respond to the people's needs and demands and try to save people's lives or improve their health, increasing the sensitivity and importance of their work. Due to the dynamic, vibrant, and evolving nature of health care, the managers of this department should keep pace with changes and developments (Bourgault et al., 2006). In these complicated, unstable, rapidly developing, and unexpected situations, the competitive benefit is also one of the primary objectives of organizations (Saharkhiz Roshandel et al. 2022). By looking more thoroughly and systematically at the functional impact of HRM in the current health system, compared to the past, it would be understood that the human resources management practices are a single-functional job and a multi-functional process. It meant the functional harmony of all subsystems operating within the health system (Hassani et al., 2013). For many reasons, several countries lack the human resources demanded to perform vital health interventions, including inadequate production capability, migration of health workforces, the unproductive mix of skills, and demographic asymmetries. It is frequently accepted that the health workforce's efficient mobilization is the most crucial obstruction to enhancing the achievement of health systems and reaching essential health purposes (WHO report, 2010). The greatest concentration to hospital efficiency as the most considerable and most cost-effective unit of the health system is significant (Latifian and Karimi, 2018). Efficient workforce planning has been described as “the appropriate forecast of possible future inequalities among the skills supply and demand, empowering performance” or “workforce requirements systematic assessment and the perceptions of the procedures needed to match those requirements”. These descriptions indicate the difficulty of interpreting an organization’s programs and purposes into scheduling demands. Simultaneously, workforces are propounded the numerous worthy elements of this process; they are also multiple tense and potentially inconstant (Al-Sawai and Al-Shishtawy, 2015). An essential aspect is the approach workforce markets conduct the organization indoors. Internal workforce market theory was extended to recognize how extended organizations function. Internal workforce markets assign to workforce mobility among posts within organizations (Curson et al. 2010).

Health specialists experience substantial and complicated workloads, while nurse-to-patient ratios endure consistently, despite impacting their capacity to present quality services. Also, most hospital workforces are nurses who play a critical role in the feature and development of health. This dilemma shifts difficult for a hospital when reacting to the requirements of workforces of different hospital wards by supplying workforces to other wards at different levels through relocation, upgrade, and degradation of out-of-hospital requirements over time. In this view, it is essential to pay attention to the skills required by different wards when providing and develop skills resulting from working in different wards over time. Therefore, optimizing the workforce according to their skills in the health sector is one of the issues. Insufficient attention to the skills required for each ward leads to bankruptcy to accurately perform tasks, increases organizational costs, and reduces efficiency and performance. In the realm of health, which often deals with human life, a lack of attention to appropriate skills can lead to disaster.

Workforce planning has various approaches to identify the organization's requirements for the workforce. In simple workforce planning approaches, it analyzes the current demand for the workforce, assuming that the conditions are constant. Methods such as trend analysis and ratio analysis predict the number of workforces required by the organization, assuming that workforce planning factors are constant. At the same time, they do not have to respond to the workforce’s flows in the organization. The optimization approach makes it possible to achieve a specific target. For example, the target in workforce planning can be minimizing costs, minimizing workflow among employees, targeting the proportion of women and Minorities in certain groups, achieving a combination of specific talents or other targets. An integrated approach refers to computer simulation and is a process that provides the ability to propose inputs, processes, and outputs in a real situation, in fact facilitating management decisions by relying on the evaluation and analysis of various policies and controls the risk (Walker, 1980). The optimization approach to planning means changing how the workforce planning process is performed to minimize costs, minimize delays, etc. According to a set of possible answers, this approach provides the most suitable workforce number according to criteria. All managers in workforce planning must identify the factors and variables that affect this to achieve goals and use the potential of resources. Variables affecting workforce planning are divided into two general categories of external and internal variables (Andrew, 1988). Among the internal factors, it can be mentioned job factors, of which job skills are a subset. Nevertheless, there still endures a “Skill Gap” between companies and applicants. On the one hand, firms are eager to explore skillful talents due to their critical business campaigns (Xu et al., 2018).

Several investigations have worked on nursing planning; for example, Lanzarone and Matta (2014) used a mixed-integer-programming. Aickelin and Dowsland's (2004) research using the genetic algorithm method. Bard and Purnomo (2004) applied the integer programming method and solved the model through an innovative algorithm based on column generation. Kwak and Lee's (1997) study strategic planning and allocation for limited human resources in a healthcare organization uses the goal programming method. All of them are about scheduling nurses, not workforce planning.

Venkataramana and Bruscob (1996) proposed a scheduling and recruitment system analyze the management policies of nurses at a private hospital in the United States. They used mixed-integer-linear programming for determining the cumulative worker needs for a six-month horizon of planning. Subsequently, they used the mixed-integer-linear programming model for separating the nurse work schedule into two-week work schedules. Integrated systems allow for a rapid assessment of the impact of scheduling and recruitment policies, which in this study also studied the impact of both on labor costs. Their findings suggest that there are significant interactions between scheduling and recruitment policies. Drake (2013) investigated the relationship between the worker budget, the workforce number to reach a care target level, and the human resources exact number in seven hospitals in Malaysia. They have done it in two steps by Semis-tructured interviews model with experts. Maier and Afentakis (2013), in their study concerning the German elderly society and increasing demand for nursing professionals in the following years by analyzing job flexibility and different job structures (full-time, part-time, and the number of working hours per week). They identified ways to increase the supply of nursing professionals and then used different supply scenarios using the full-time equivalents (FTEs). In a study, Lopes et al. (2015) performed the literature-review method of more than sixty years of documentary study to get the historical chain of methods. Their conclusions indicate four approaches broadly used in supply (training, potency, employee-to-population ratio, and competency) and three in the field of demand (economic, needs, and service aims). Gird acknowledged that careful workforce planning in the health sector requires an integrated and flexible approach, especially in terms of supply and demand (potential and practical) and with more tangible factors such as the combination of skills and productivity. Davis et al. (2014) considered the permanent issue of nurse workforces level estimation following requirement uncertainty as a newsvendor method.

Studies have specifically addressed the issue of workforce planning with optimization methods (such as Maier and Afentakis (2013) and Venkataramana and Bruscob (1996)) which have used uncontrollable approaches for this purpose. Some researchers challenge these approaches due to the lack of cybernetic (feedback) and system dynamics. One of the most practical methods of workforce planning is mathematical models, especially optimal control (Udom (2014) and Mouza (2008)). Numerous investigations have been conducted on staffing planning by optimal control approach; for example, Pooya et al. (2020) performed the continuous manpower planning model. The workers' flow in the internal and external organization concerning human resource management strategies. Pooya and Pakdaman (2018) suggested the continuous-time optimal control model due to workforce planning by cost-function-linear equation quadratic form for workers' organizational flow. Udom (2014) showed the optimal control model for the manpower's flows by stochastic-differential-equations. Ekhosuehi (2016) examined manpower planning by appointing permanent and temporary workers to different situations. This article, for presenting the economic staff-mix for the staff system by an optimal control model. Also, Mouza (2010) systematically utilized a dynamic system that includes the flows and pools description, then suggested formulating the optimal control model to achieve preassigned objectives. Some of the manpower planning studies by optimal control are presented in Table 1.

Table 1.
Review and Contrast of optimal control workforce planning literature

Author (year)	Hiring	Promotion	Type of Exit				Degradation	Skill Audit	The case
			Fired	Voluntary	Retirement	Contract termination			
Pooya et al. (2020)	yes	yes	yes	yes	yes	no	yes	no	Leather industry
Pooya and Pakdaman (2018)	yes	yes	yes	yes	yes	no	yes	no	Clothing industry
Ekhosuehi (2016)	yes	no	no	no	yes	yes	no	no	Assumed case study
Udom (2014)	yes	yes	no	no	yes	no	no	no	A University In Nigeria
Mouza (2010)	yes	yes	**Not determined**				no	no	Assumed case study
Current study	yes	yes	yes	yes	yes	yes	yes	yes	A hospital ward

Notwithstanding the significance of predicting flows of skills and competencies, to our knowledge, there is no comprehensive healthcare systems study focused on workforce planning by optimal control method and concerning all the workforce's flows (kinds of exit, promotion, and demotion) and required skills concurrently. This research proposes a dynamic model (optimal control) for nursing workforce planning for Supervisors and Nurses through the workforce's flows (recruitment, promotion, degradation, and exit the hospital) by attention to skill audit. In the following, this manuscript performed six sections. Section Two was defined as a nursing workforce planning system. In Section Three recommended nursing workforce planning problem's mathematical model is conferred by an optimal control model. Section Four run the model for hospital case of study, and Section Five includes results and validation discussions. Following was presented practical implications, and eventually, Section Seven comprises conclusions and future directions.

System Description

The following section describes a novel model for a workforce-planning system, including a precise practical analysis of the workforce's flows by requiring supervisors and workforces' skills. The research strategy for designing a conceptual model for nursing workforce planning based on their skills is the causal-effect method, which determines how each variable affects the other variable and how the workforce flow is investigated. The dominant strategy in the optimal control model design phase and its solution is the linear optimal control method. To design a conceptual model, the researcher used the opinions of experts familiar with nursing workforce flows. The criteria were determined to obtain the criterion of having a post related to human resource management decisions and two years of work experience in a hospital. According to the expert criteria of these people, they are supervisors, nursing services managers, and hospital human resources managers. In this study, theoretical saturation was reached with semi-structured interviews of the hospital's human resources manager, nursing services manager, and three supervisors to design a conceptual model. In this study, theoretical saturation was reached with semi-structured interviews of the hospital's human resources manager, nursing services manager, and three supervisors to design a conceptual model. As shown in Fig. 1, this system has two pools for the front-line workforce, nurses, $N(t)$ and supervisors $S(t)$, and the middle manager is two persons, and there is no need to consider a pool for them. Each pool has a value that can be specified based on the opinion of organizational experts and organizational data such as the demand for product/service and plans. How does the front-line workforce pool achieve its target? As shown in Fig. 1, the nurses pool $N(t)$ has inputs (increased) and outputs (reduction), referred to as the workforce's flows. These flows are recruitment $(E_N(t))$, promotion $(P_N(t))$, retirement $(R_N(t))$, voluntary exit $(V_N(t))$, contract termination $(D_N(t))$, degraded supervisors $(G_S(t))$, fired $(F_N(t))$, and remain in their position (front-line workforce) $(A_N(t))$. The front-line workforce promotion $(P_N(t))$ to this system is based on an audit process (Skill Audit N) that requires specific work experience (τ) to enter the process. In addition to promotion, the audit process leads to retention in the organization or dismissal. The triple output of this process is obtained based on obtaining the minimum scores determined for each output. Supervisors face a similar fate to the front-line workforce, except that they are either retained, demoted, or fired after the performance appraisal and skill auditing process, depending on the score they earn. According to the top manager's opinion, the promotion happened to these people in a middle manager position.

In summary, workforce planning is represented in a system with two pools (nurse and supervisor that are called state variables) that have optimal targets. These targets can be achieved by control recruitment, promotion, retention, dismissal, voluntary exit, and contract termination (which are called control variables). Also, promotion, retention, and dismissal in this system depend on the process of performance appraisal and skill audit scores. This dynamic view of workforce planning was presented in the form of an optimal control method.

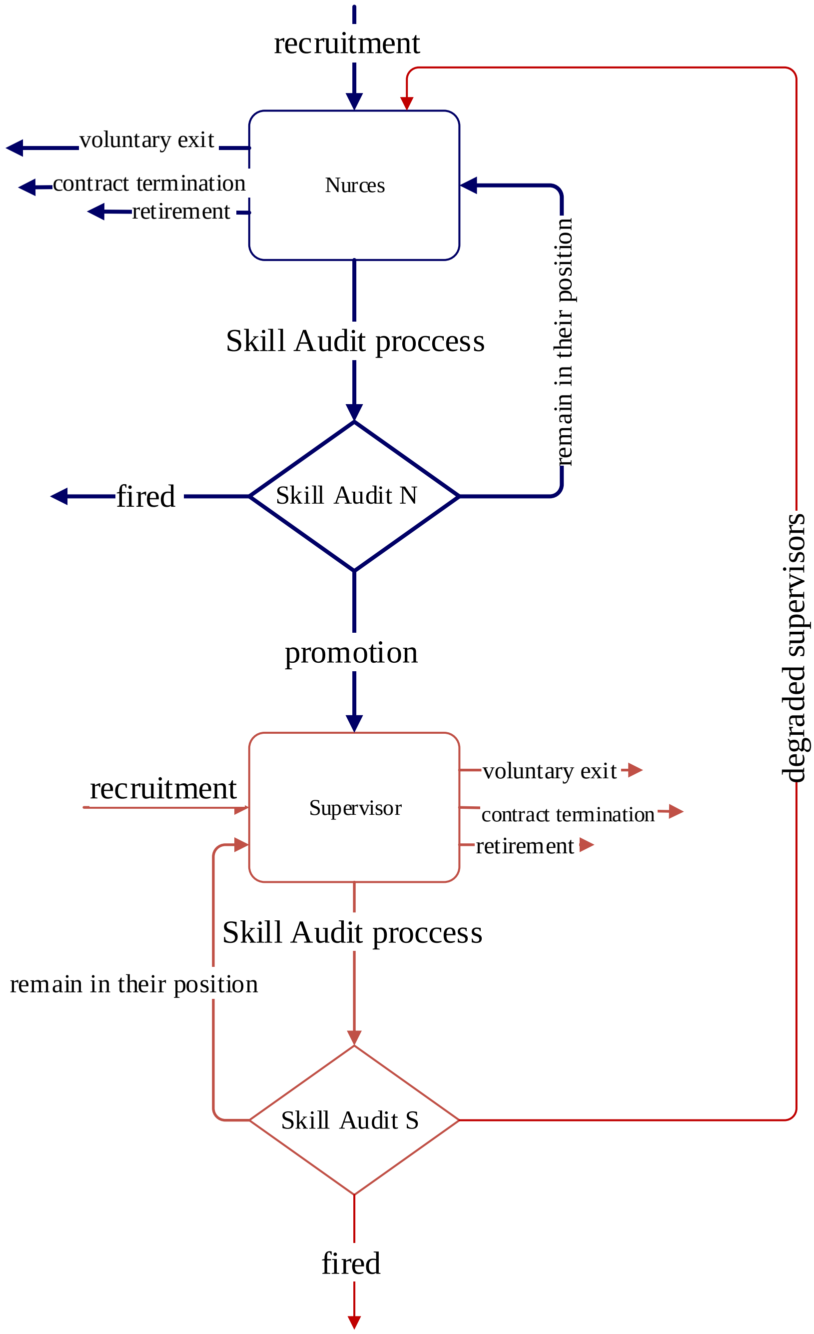

Figure 1. *The proposed workforce planning model flowchart*

Based on Fig. 1, it can extract the following system of two ordinary differential equations:

$$\dot{N}(t) = E_N(t) - EV_N(t) - D_N(t) - V_N(t) - R_N(t) + G_S(t) + A_N(t) \quad (1)$$

$$\dot{S}(t) = E_S(t) + \acute{P_N}(t+\tau) - D_S(t) - V_S(t) - R_S(t) - EV_S(t) + A_S(t)$$

wherein that was depicted people destination in the performance appraisal process:

$$EV_N(t) = F_N(t) + P_N(t) + A_N(t)$$
$$EV_S(t) = F_S(t) + G_S(t) + A_S(t)$$

Since $\acute{P_N}(t+\tau) = P_N(t)$ thus $\acute{P_N}(t) = P_N(t-\tau)$ and $\acute{P_N}(t+\tau) = P_N(t)$. On the other hand, $E_S(t) = {}^1\!/_2\, \acute{P_N}(t)$, thus $E_S(t) = {}^1\!/_2\, P_N(t-\tau)$. After substituting, can be had the following form of equation (1):

$$\dot{N}(t) = E_N(t) - F_N(t) - P_N(t) - A_N(t) - D_N(t) - V_N(t) - R_N(t) + G_S(t) + A_N(t)$$
$$\dot{S}(t) = {}^1\!/_2\, P_N(t-\tau) + P_N(t) - D_S(t) - V_S(t) - R_S(t) - F_S(t) - G_S(t) - A_S(t) + A_S(t)$$

Taylor's expansion can be used and provide the following approximation for $\frac{1}{2}P_N(t-\tau)$:

$$\frac{1}{2}P_N(t-\tau) = \frac{1}{2}\alpha N(t-\tau) \approx \frac{1}{2}\alpha\left(N(t) - \tau\dot{N}(t)\right)$$

In (4), $\dot{N}(t)$ can be replaced by its values from the first equation of system (3). On the other hand, had have:

$$D_N(t) = \lambda_N N(t)$$
$$V_N = \theta_N N(t)$$
$$R_N = \gamma_N N(t)$$
$$D_S(t) = \lambda_S S(t)$$
$$V_S = \theta_S S(t)$$
$$R_S = \gamma_S S(t)$$
$$P_N(t) = \alpha N(t)$$

Here should be explained the meaning of the λ_N, θ_N, γ_N, λ_S, θ_S, γ_S, and α. These are notations of constant parameters. By surveying the organizational data and expert's opinion, was shown some of the workforce's flows like the front-line workforce promotion ($P_N(t)$), retirement ($R_i(t), i: N, S$), voluntary exit ($V_i(t), i: N, S$) and contract termination ($D_i(t), i: N, S$) are constants of the front-line workforce and the supervisor pools. These notions have good news for computational efficiency, and authors should focus on a more limited number of variables in solving the model, which is called model control variables. These control variab (2) front-line workforce recruitme), fired ($F_i(t), i: N, S$), and supervisors degraded ($G_S(t)$).

After some calculations and substitutions, system (3) can be rewritten as the following system:

$$\begin{bmatrix}\dot{N}(t)\\ \dot{S}(t)\end{bmatrix} = \begin{bmatrix}k & 0\\ k_n & k_s\end{bmatrix}\begin{bmatrix}N(t)\\ S(t)\end{bmatrix} + \begin{bmatrix}1 & -1 & 1 & 0\\ -\frac{\tau\alpha}{2} & \frac{\tau\alpha}{2} & -\left(\frac{\tau\alpha}{2}+1\right) & -1\end{bmatrix}\begin{bmatrix}E_N(t)\\ F_N(t)\\ G_S(t)\\ F_S(t)\end{bmatrix} \qquad (3)$$

Along with ini (4) nditions $N(0) = N_0$ and $S(0) = S_0$. In (5) have:

$$k = -(\alpha + \lambda_N + \theta_N + \gamma_N)$$
$$k_n = \frac{3\alpha}{2} - \frac{\tau\alpha}{2}\mathrm{k}$$
$$k_s = -(\lambda_S + \theta_S + \gamma_S)$$

Suppose that:

$A = \begin{bmatrix}k & 0\\ k_n & k_s\end{bmatrix}$, $B = \begin{bmatrix}1 & -1 & 1 & 0\\ -\frac{\tau\alpha}{2} & \frac{\tau\alpha}{2} & -\left(\frac{\tau\alpha}{2}+1\right) & -1\end{bmatrix}$, $X(t) = \begin{bmatrix}N(t)\\ S(t)\end{bmatrix}$

and $U(t) = \begin{bmatrix}E_N(t)\\ F_N(t)\\ G_S(t)\\ F_S(t)\end{bmatrix}$. Thus, system (5) car (6) rewritten in the following form:

$$\dot{X}(t) = AX(t) + BU(t), X(0) = X_0$$

Suppose that the state target values variables $X(t)$ and control variables $U(t)$ are defined by $\hat{X}(t)$ and $\hat{U}(t)$ respectively. Due to attain the target values, the following objective function can be tried to minimize:

$$J = \frac{1}{2}\int_{0}^{t_f} [x^t P x + u^t Q u] dt \tag{7}$$

Wherein:

$$P = \begin{bmatrix} p_1 & 0 \\ 0 & p_2 \end{bmatrix}, \quad Q = \begin{bmatrix} q_1 & 0 & 0 & 0 \\ 0 & q_2 & 0 & 0 \\ 0 & 0 & q_3 & 0 \\ 0 & 0 & 0 & q_4 \end{bmatrix}, \quad x = x(t) = X(t) - \hat{X}(t) \text{ and } u = u(t) = U(t) - \hat{U}(t).$$

Indeed, two matrices P and Q are constant diagonal coefficients (Objective function coefficients) for minimizing the gaps between the variables of state and control and their value of targets (that named penalty). Finally, the objective function (7) can be considered along with the constraints (6), as the proposed optimal control model. See (Pooya and Pakdaman, 2018; Pooya et al. 2020) for more details about this trick.

A Case Study

What has been shown in the previous section in the dynamics model format has been applied in a hospital ward. As it was mentioned, the conceptual model of the research according to the workflow of the hospital was extracted through semi-structured interviews with experts, and then the conceptual model was formulated mathematically and solved with actual organizational data. The conceptual study model and its formulation is a comprehensive category that can be implemented in organizations with similar work fields. The replacement result in the mathematical model depends on organizational data and the workforce flow. Regarding the study of this research, the results of replacing the organizational data (what is stated in the case study) in the proposed mathematical model (sets 1 to 7) are as follows. At present, this ward has 42 nurses and ten supervisors with several scientific and humanities skills. Supervisors work under the supervision of two nursing directors. The nursing director is under the hospital human resources manager's supervision. T s no pool for the two nursing directors bec the appointment to this position is based on the hospital human resources manager's decision and is independent of the workforce’s flows. As discussed in the previous section, to implement the nursing workforce planning optimal control model, it needs to identified the behavior of pools by reviewing organizational data and should be determined target values according to experts' opinions and surveying the organizational plans. Other requirements for model implementation in this hospital ward are presented below. This system is modeled for two periods, and each period is four months (2022-2023), which means the system has two four-month periods to achieve its targets. During this period, the nurses' pool (state variable) must achieve its target using the workforce’s flows. In the meantime, the hospital's internal law must be observed that promoting from the nurse position to the supervisor position requires at least two years of work experience; also, the supervisor pool has the workforce’s flows similar to nurses (except for promotion) achieve its target.

Identified pool behaviors of nurses and supervisors are;

$\hat{N}(t) = 40 + 3t$

$\hat{S}(t) = 8 + t$

In this ward, the target values of control variables set to zero, other target values and the constant parameters are;

$t_f = 4$, $N_0 = 42$, $S_0 = 10$

$\lambda_N = 0.05, \theta_N = 0.15, \gamma_N = 0.04$

$\lambda_S = 0.05, \theta_S = 0.25, \gamma_S = 0.04$

$\alpha = 0.1, \tau = 2\ periods$

According to experts’ opinion, the coefficients of the objective function are;

$$p_1 = 100, p_2 = 180, q_1 = 2, q_2 = 5, q_3 = 8, q_4 = 9$$

Results

The stated nursing workforce planning optimal control model was utilized and solved. The results are shown in Fig. 2-3 and Table 2. As shown, the state target variables determining value has been reached by using control variables in the two-year periods, and other flow variables constantly play their role. As shown in Table 2, the available number of nurses is 42, and by the end of the planning horizon, it has the opportunity to reach the target number of 52 with the help of workforce flows, and after the first season, which had an increase of two people in the number of workforces, until the end, the horizon of the program is that two people will be added to the stock almost every season. The available number of supervisors in the stock is eight people, and the target of 12 people has been reached on the planning horizon with an increase of one person almost every two seasons. The gap between initial and target value is compensated by using the workforce flow in the planning period. The nurses and supervisor's actual and the target value have been converged to their specified target for each period. It should be mentioned that the supervisor's pool actual value and the target value converge later than the nurse's pool because the promotion from the nurse pool, which depends on skill auditing and entering the audit process, requires two years of experience. It causes the actual value and the target of the supervisor's pool to converge with a delay. This model tries to balance and bring the system to the target of recruitment, promotion, and demotion management. The alternatives of reducing working hours and temporary transfer to other levels in compliance with the organization's requirements are presented to the decision maker of the hospital. According to what has been presented so far about the research model, it can be acknowledged that the nursing workforce planning model, in terms of the skills required at the organizational levels of nurses in the hospital, can help this organization to allocate its human resources to the position optimally. This planning can create foundations for other human resource management practices, such as training, and compensation management, by attention to terms and conditions.

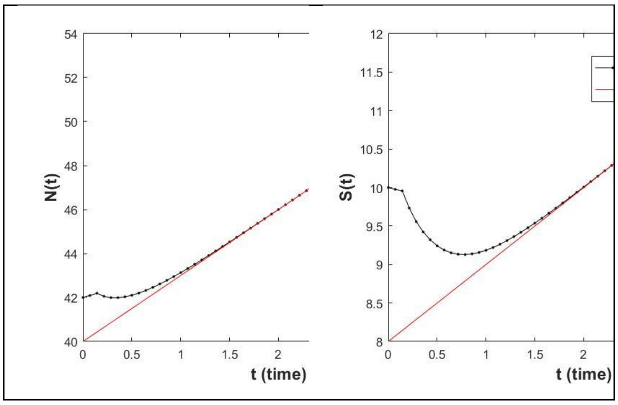

Figure 2. *The gap between the initial value and the value of nurse (N(t)) and supervisor (S(t))'s target*

Table 2.
The approximate target values of state variables

Year State	2022-1	2022-2	2022-3	2022-4	2023-1	2023-2	2023-3	2023-4
$N(t)$	42	43	44	46	47	49	50	52
$S(t)$	8	9	9	10	10	11	11	12

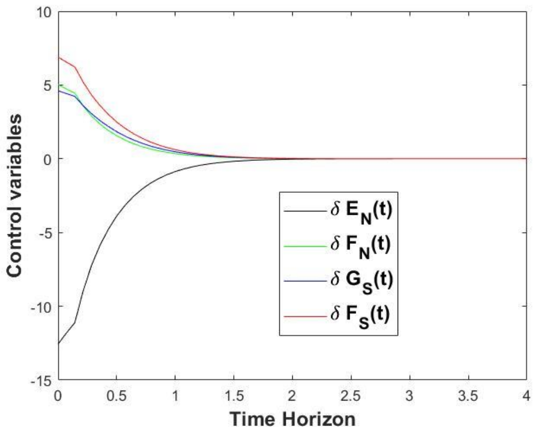

Figure 3. *The gap between the workforce's numbers and their target*

Due to validating the presented research model, sensitivity analysis is a procedure that is executed after extracting the optimal answer. This method specifies the sensitivity of the optimal solution to explicit changes in the prior model (Pichery, 2014). One of the ways to estimate the model's sensitivity is to alter the coefficients of the objective function to a distinctive value. Based on this procedure, the penalty values of the coefficient of the number of nurses were increased and decreased. The nurses' number becomes its target later by declining the penalty coefficient. The variable acquires the target more swiftly than the target variable by raising the penalty. Also, by receding and enriching the hiring nurses' penalty coefficient, the control variable contacts their target value the latest and more quickly than the variable target path. The target attainment by applying modifications demonstrates the model's validity. It implies that the model provides the predicted functionality.

Conclusions and Future Directions

According to the auditing skill and appraisal process, the following study solved workforce planning using the optimal control approach. There are various researches on workforce planning through optimal control methods, but what is clear is a one-sided view of workforce planning. Some studies were done with a mere quantitative view without regard to qualitative factors, such as required skills and their effect on the workforce planning process. Some studies did not have an accurate and timely response to the workforce required by relying on a qualitative view. Meanwhile, in workforce planning, numerous variables are necessary recognized. Notice to the workforce's flows, and variables concerned in workforce planning provide comprehensive and dynamic answers. It seems more necessary to adopt this view when it comes to health services and human life. In the reviewed works of literature (as shown in table 1.), Pooya et al. (2020) presented a good optimal control model for workforce planning in the leather industry by considering diverse workforce's flows. Pooya and Pakdaman (2018) studied the workforce planning of a firm's cloth industry for some of the workforce's flows. Ekhosuehi (2016) proposed an optimal control workforce planning for an assumed case study regarding recruitment. Udom (2013) presented a workforce planning model by optimal control approach in a University in Nigeria. None of these studies have been done in the health sector. While studies on workforce planning in the health sector (such as Maier and Afentakis (2013) and Venkataramana and Bruscob (1996)) have not been performed through the optimal control method, and unable to provide an optimal response at any point in the planning periods. They have drawbacks by investigating the prior investigations about workforce planning with optimal control approach, as well as quantitative studies ignoring the effects of the real world and qualitative studies due to the ineptitude to equip a proper mathematical model to solve the issue. This study has tried to provide innovation in this kind of planning regarding the process of skill audit in workforce planning and depending on the flow of promotion, firing, demotion, and retention on the result of skill audit. Also, in this study, attention has been paid to all the hierarchy involved in workforce planning of multiple organizational units, while studies such as Ekhosuehi (2016), and Mouza (2010), have only been solved for one level of the organization and sometimes with an assumed case study.

In this research, by controlling the workforce's flows, such as recruitment, degradation, and firing, state variables targets (nurse and supervisor) were obtained. The skill audit and appraisal process are essential in the hospital ward studied in this study. The destination of nurses with at least two years of work experience depends on the grade they earn in the audit process. Depending on the score, they are either promoted, retained, or fired. Supervisors are either retained, demoted, or fired based on the score gained from the process. This model can be applied to other organizational changes due to organizational characteristics such as hierarchy levels and other qualitative variables involved in human resource planning. Future studies suggest studying workforce planning by optimal control methods for other hospital wards and how they are managed. Also, in many organizations, various promotions and conditions result from the classification of jobs. Regarding each promotion base with a minimum share or the rank resulting from the classification of jobs as different stocks, it is achievable in the model provided development.

Declarations

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-**Conflicts of interest/Competing interests**: The authors declare that have no conflict of interest.

-**Availability of data and material**: The data of this research are available upon request.

-**Authors' contributions**: All authors have contributed equally in terms of intellectual content and have approved the final version.

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