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Multi-level nursing workforce planning considering talent management in healthcare with a dynamic quantitative approach

Shila Monazam Ebrahimpour, Fariborz Rahimnia and Alireza Pooya
Ferdowsi University of Mashhad, Mashhad, Iran, and
Morteza Pakdaman
Atmospheric Science and Meteorological Research Center (ASMERC), Climatological Research Institute (CRI), Mashhad, Iran

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Abstract

Purpose – Workforce planning must answer how many workforces, in which positions, and talents, and when each organization is needed. To find the requirements workforce, organizations need to know the organizational position and talents pools. Clarifying the number of workforces required in each pool requires attention to workforce flows, including hiring, promotion, degradation, horizontal movement, and exiting the organization. It is a dynamic issue and must be addressed over several periods over a specific duration, which adds to the complexity. According to the talent management presented in this research, all the above complex questions are answered by applying the optimal control (OC) model according to talent management presented in this research.
Design/methodology/approach – This research presents a dynamic model by using a linear-quadratic optimal control model, which was solved by Pontryagin's maximum principle, to achieve an optimal number of workforce requirements for each of the positions of nursing services manager, supervisor, head nurses and nurses in the health sector according to the required talents in each position.
Findings – The results have shown that the target value of workforce numbers has been achieved in the planning period, and the validation test and sensitivity analysis justified the model by reaching the workforce planning targets.
Originality/value – This study provides a dynamic model for achieving quantitative workforce planning targets; the model presented in this manuscript has included an important qualitative factor, namely workforce talents. According to the authors' review, there is no comprehensive research devoted to workforce planning through optimal control models by attention to workforces skills.

Keywords Workforce planning, Talent management, Dynamic quantitative approach, Optimal control method, Nurses' hierarchy

Paper type Research paper

1. Introduction

Human resource management (HRM) is a comprehensive approach to employment management that seeks to achieve a competitive advantage through the strategic deployment of competent workforces. One of HRM practices is workforce planning in which organizations can be a winner of war for talent in the knowledge economy.

Inefficient healthcare workforce planning is the most crucial constraint on achieving the United Nations (UN) Millennium Development Goals' welfare goals. Many trustee organizations, such as the World Health Organization (WHO) and the Global Health

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Workforce Alliance, requested purposeful and inclusive efforts and innovative methods to workforce planning (Turner, 2018). The surplus of the health workforce leads to economic inefficiency and workforce inflation. The deficiency of the health workforce leads to a loss of quantity and quality of medical care and imposing overload work on existing physicians and nurses (Lopes *et al.*, 2015). In other words, the endeavor to obtain adequate workforces, "the right people with the right skills, the right numbers, at the right position and at the right time" is one definition of workforce planning in health and talented workforce to accomplish all duties in health-sector systems. The workforce planning was affected by changing demographics, the fragmented workplace, the overwhelmed employee, diversity and workforce participation, and these are the predominant and inevitable changes in a business environment. As Turner (2018) mentioned, aging outcomes can be the increased risk of no communicable disorders and a more comprehensive explanation of what is followed by the definition of health, which presently belongs to the whole of human health, spreading ahead a small biomedical view. In its present appearance, health is a state of entire human life (mentally and physically), not solely the lack of illness or debility. These factors and pressures set the context for health services on health budgets and increasing the requirement for a return on investment in health. Health services have long been considered essential to national economies. Indeed, sustaining growth human longevity (Gratton and Scott, 2016) not only require step developments in technology for health but a meaningful improvement in the number of talented health experts (Turner, 2018). A recent nursing talent management survey concludes that the execution of talent management improves nurses' clinical skills, develops the workforce's job satisfaction and strengthens the organization's capability treatment rates of the cases (Mitosis *et al.*, 2021).

Ali Taha *et al.* (2015) mentioned that organizations are undergoing talent lacks and have challenges in finding and selecting talented workforces, particularly for specific positions. Also, the difference between the talents' demands and supplies increases workforce planning issues (weakness to precisely anticipate talent requirements), consequently inducing the incapacity to attain the applicants with the required skills. Holloway *et al.* (2009) admitted there is a lack of balance in the health workforce, and this has been reflected in numbers and particular skills deficiencies in remarkable professions, containing nursing. Squires *et al.* (2017) believed that creating precise and reliable predictions for various healthcare workforces needs a standardized method to analyze and comprehend healthcare professionals' dynamics. Buchan (2007) suggested practical nurse workforce planning principles in his report, such as "Evaluate workforce dynamics and flows among wards and generate a survey investigation to recognize the demand for reform." Managers are looking for more efficient tools to optimize the employment of workforces, intending to maximize or minimize specific functions related to performance and productivity (Bouajaja and Dridi, 2016). This subject is critical in hospitals because most of their workforces are nurses, and they have a crucial role in quality care and health promotion. This problem becomes extra complicated when responding to different hospital wards' workforce demands because it is achieved by relocation, promotion and demotion or out-of-hospital supply. There are many approaches for forecasting the requirement of the workforce and workforce planning. As Walker (1980) mentioned in his book, workforce planning has different approaches that can be classified into three categories: 1) Simple forecasting, 2) optimization approaches and 3) integrated approaches.

The answer to the workforce planning complexities over the workforce planning period is possible by optimal control (OC) of nursing workforce planning. Also, in the studies conducted in research background (which are discussed in detail in the "literature review" section), a comprehensive study has not considered vital factors such as talent management in nursing workforce planning by the OC method. Therefore, this paper aims to present a model for nursing workforce planning by applying the optimal control approach according to the talent management framework. This paper presents nine sections. Section two presents a literature review; section three is described as a workforce planning system with talent management-oriented. The suggested nurses' workforce planning issue's mathematical model is presented as a continuous-time OC model in Section four. Section five, six and seven include a real case study due to applying the real-world model, results and validation discussions and the discussion. Section eight presents practical and managerial implications, and ultimately, Section nine includes conclusions and future directions.

2. Literature review

Given the importance of workforce planning and talent management, in this section, the theoretical foundations of these concepts and background research related to the purpose of the research are discussed.

2.1 Theoretical foundations

Wright and McMahan (1992) offer the following six theoretical perspectives to explain the determinants of HRM practices, which include company resource-based view, behavioral perspective, cybernetic system, agency/transaction costs theory, power/resource dependence perspective and institutionalist view.

Workforce planning can be explained using resource-based perspectives, behavioral perspectives, cybernetic models and transaction/agency cost perspectives. From the enterprise resource-based perspective, workforce planning enables the organization to create a sustainable competitive advantage from its human resources. From a behavioral perspective, organizations focus on workforce planning because it fosters employees' necessary and appropriate behaviors. According to the cybernetic model, workforce planning with proper management of inputs (skills and abilities) and related processes enables organizations to achieve the workforce's desired output. According to the exchange/agency cost perspective, optimal and principled workforce planning reduces the cost of hiring and employing decent human resources. At the same time, workforce planning is rooted in management's science, seeking to find the best decision in its system settings.

Identifying talents within the organization, developing and promoting them in organizations refer to talent management. Talent management has attracted the attention of many human resource experts. Sparrow and Makram (2015) stated that talent management is maturing, and there are now significant debates about the breadth and focus of the function. Boselie *et al.* (2005) believed that talent is not only about the quality of innate skill; it additionally depends on the quality of his/her position. In this respect, some authors in the talent management literature emphasize the significance of suiting people to positions (for example, Collings and Mellahi, 2009). Trepanier and Crenshaw (2013) believed "Uprising stars" should be assigned to projects that empower them to grow professionally and be recognized. For example, in a hospital context, it is suggested to a hospital ward director due to show her/his vital role by adopting hospital-wide different skills. The ideas of proactive workforce planning, evaluating and hiring, and talent retention are among the best practices in talent management. Particular consideration is paid to talent pools, the advantages and disadvantages of hiring employees from outside the organization versus the deployment of employees who outperformed the others (Thunnissen *et al.*, 2013). Uncertainty on the supply issue stems from challenges in predicting requirements and exits of skills and competencies. If the competencies required in future development are significant, a talent pool seems urgent need in the future (Cappelli and Keller, 2014).

2.2 Research background

This sub-section presents the research background in three areas: talent management in the healthcare system, nursing workforce planning through optimization approaches and workforce planning by OC method.

Numerous studies have been conducted on talent management in the healthcare system, some of which are discussed below. Mitosis *et al.*'s (2021) systematic literature review (2010–2020) recognized the organization's sustainable improvement and the talented workers and healthcare services patients associated with talent management exercises properly for healthcare systems by paying attention to PRISMA guidelines. The results of their study categorized the talent management factors into nine divisions: culture, planning, attraction, development, retention, performance appraisal, workplace environment, succession planning and leadership. Bibi (2019) carried out a study to ascertain the effect of talent management on workforce performance amongst workers serving in the healthcare systems of Pakistan. This study applied a cross-sectional design and quantitative method. The study results showed a significantly positive talent management effect, for example, employment and selection for talents and remuneration for talent preservation on workforce appraisal. El Dahshan *et al.* (2018) investigated the talent management effect on the performance of Egyptian hospitals by applying standardized questionnaires. The findings indicated a highly significant positive correlation between organizational performance appraisal and talent management. McDonnell *et al.* (2017) employed a systematic review to discover the development of talent management research. They mentioned that there had been insufficient notice on talents as the analysis unit. In their research, Ingram and Gold (2016) first reviewed novel talent management literature attempting to recognize trends in which scientific discussion proceeds. Furthermore, they presented existing empirical research conducted in five elected healthcare organizations from Poland by semi-structured interviews and expressed theoretical and practical implications. Groves (2011) investigated how healthcare systems manage talent in healthcare systems challenges. His study aimed to present talent management systems using a qualitative case study that analyzed 15 nationwide healthcare organizations; semi-structured interviews gathered data. He has discussed critical gaps in talent management practice and has developed a talent management model.

Various studies have been done on nurse workforce planning with optimization approaches. For example, Kwak and Lee (1997) consider strategic planning and allocating workforces in a healthcare system adopting the goal programming approach. Aickelin and Dowsland's (2004) study employed the genetic algorithm technique. Bard and Purnomo (2005) stated their study goal is to provide a new linear scheduling method for nurses, considering high demand fluctuations, flexibility for working hours and leave due to the growing shortage of nurses, retention of nurses and coverage of services all the time. Lanzarone and Matta (2014) used the mixed integer programming method. Each of them is regarding scheduling nurses, and it is different from workforce planning. Venkataraman and Brusco (1996) hinted at recruitment using the mixed-integer linear programming (ILP) approach to define the workforce requirements for a six-month planning horizon. Maier and Afentakis (2013) investigated the German elderly community and growing requirements for nursing by examining job flexibleness and various job structures (full- and part-time). They recognized methods to enhance the nursing' supply and then applied various stock scenarios applying the full-time equivalents. Drake (2013) examined the relationship between the workforce required and workforce budget to attain a purpose of care and the workforce's needs in Malaysian hospitals. They did it through two stages of semi-structured interviews with specialists. Lopes *et al.* (2015) conducted a study through the literature review method of further 60 years of research to understand the approach's historical sequence of workforce planning. Their findings show that four methods are generally utilized in stock (training, productivity, employee-to-population ratio and skill mix) and three in the field of demand (economic, requirements and service purposes). Apornak *et al.*'s (2020) study proposed a genetic algorithm (GA) for identifying the number of variety nurses. Nikzad *et al.*'s (2021) proposed resource assignment, districting, scheduling and placement decisions simultaneously for a healthcare system through a two-stage stochastic mixed-integer method.

Alizadeh-Zoeram *et al.* (2019) present a dynamic workforce service capacity-based model to explain the death spirals of a quality phenomenon. They suggested that proper planning in healthcare systems guides property growth. Leerapan *et al.* (2021) adopted a system dynamics approach to Thailand's strategic healthcare system workforce planning for the next 20 years. In other words, they used system dynamics modeling to describe the outcomes of policy decisions of healthcare changes in a more inclusive approach.

The above studies have focused on planning or scheduling workforces in the health sector with an optimization approach. However, the study of health sector workforce planning has not adopted the OC approach to workforce planning. So, due to examining how this method is presented in workforce planning studies, the literature about workforce planning through OC is presented.

Sun *et al.* (2005) studied workforce planning in a leasing center of employees. They recommended stochastically OC models for multi-period workforce planning. Pooya and Pakdaman (2018) introduced a continuous-time OC model for the workforce planning system according to promotion from inside the system. They applied a quadratic cost function linear system transition equation for formulating an OC problem. Pooya *et al.* (2020) presented a continuous-time workforce planning model in which the workforce flow occurs considering internal and external employment regarding human resource strategies. Udom (2013) presented the OC model for the workforce's system through stochastic differential equations. Lee *et al.* (2001) introduced a discrete-time OC model owing to schedule workforces on varied tasks to employ and to derogate various types of workforces. Ekhosuehi (2016) investigated the workforce planning system that appointed permanent and temporary workforces to various jobs by an OC model. Mouza (2010) adopted a comparatively dynamic system, including the systematic description of flows and stocks, and then advanced to formulate an OC model due to achieving some preassigned targets.

2.3 Summarize the literature review and explain the theoretical gap

After the studies, it is revealed that talent management in the health system has not been done to workforce planning with an optimal approach, especially the OC method. This gap is shown in Table 1 below.

Author (year)	Recruitment	Promotion	Demotion	Exits	Talent management	The case
Pooya *et al.* (2020)	✓	✓	✓	✓	–	Leather industry
Pooya and Pakdaman (2018)	✓	✓	✓	✓	–	Clothing industry
Ekhosuehi (2016)	✓	–	–	✓	–	Assumed case study
Udom (2013)	✓	✓	–	–	–	The academic staff structure of a university system
Mouza (2010)	✓	✓	–	–	–	Assumed case study
Sun *et al.* (2005)	✓	–	–	✓	–	Employee leasing center
Lee *et al.* (2001)	✓	✓	–	✓	–	Assumed case study
Current study	✓	✓	✓	✓	✓	Healthcare system

Table 1. Summary and comparison of the literature of workforce planning through optimal control models

As mentioned before, despite the importance of predicting requirements and exits of skills and competencies, especially in strategic organizational positions, to our knowledge, there is no comprehensive research concentrated on talent management and workforce planning by OC method simultaneously. De Bruecker *et al.* (2014) provided a combination of technical and managerial knowledge and sought to encourage more realistic and valuable techniques. They reviewed various studies on workforce planning, published from 2004 to 2012. They reviewed cited old articles using the literature review method, claiming that they relied on quantitative solutions to workforce planning in many studies, unaware of real-world consequences. On the other hand, in many management studies describing human consequences in managerial decisions, they have not successfully provided a proper mathematical model for problem-solving. Workforce planning for different organizational hierarchies regarding employment variables, types of exit, promotion and demotion is complicated. When this issue is implemented for several periods, it becomes a complex dynamic issue. Considering that the organization's employees have different talents because their talents must be taken into account when assigning people to different levels adds to the above complexity. Also, in the nursing workforce planning studies, a study done with the OC method and considering their required talents was not found.

In this sub-section, from the point of view of comparing the workforce planning methods used in research, it can be said, optimization approaches are a dominant approach in workforce planning. In this approach, various integer linear models, dynamic programming, OC and system dynamics are used for this purpose. ILP and linear programming and dynamic programming are used in situations where the system's complexity is such that it is possible to model the system. Workforce planning models (ILP and linear programming and dynamic programming) hardly have the possibility of complexity due to feedback, delays and nonlinearities. Dynamic programming, meanwhile, has improvements in dynamic and forward motion, but the gaze is merely a step-by-step look, not a decision on a long-term horizon. In all of these models, the conditions are suitable for simplifying assumptions and provide optimal solutions for the simplified model to the decision-maker. System dynamics models do not have the limitations of previous mathematical models, but they are more suited to policy-making than operational decision-making. OC models are very similar to dynamics system models, can respond to feedback and delays, use similar dynamics systems to differential modeling to show the dynamics of the problem and are suitable for operational decision-making, such as workforce planning. Therefore, this model was utilized for the present research problem.

Hospitals, as part of the healthcare system, on the one hand, must be responsive to the growing number of patients to receive the desired services, and on the other hand, are constantly faced with limited financial resources and workforce concerns in different parts of the hospital. Health professionals experience heavy and complex workloads, while staff-to-patient ratios remain unchanged, regardless of their impact on their ability to provide quality services. This manuscript aims to present an OC model for workforce flows with attention to organizational positions' talents. This possibility could help the decision-makers to manage the workforce during a different time horizon. In summary, this research study's strength is that by applying the dynamic model presented for nurses' workforce planning, the target values for the position of nursing services manager, supervisor, head nurses and nurses are achieved by using workforce flows (Hiring, promotion, demotion, horizontal movement and exit the organization). The organization can monitor the optimal number of hiring, promotion, demotion and exit from the organization at any time in order to achieve the target values of organizational positions. Each organizational position has special characteristics that the people appointed must have these characteristics validated in the talent audit process. As shown in the review of studies, studies often focus on review studies and the impact of talent management on the organizational subject, such as performance, organizational retention, reward, and as McDonnell *et al.* (2017) have pointed out that this has not been addressed as a unit of analysis in studies.

3. System description

This section represents a new model for the nurses' workforce planning system with a detailed practical discussion about the organizational workforce flows by considering talent management. As mentioned before, the nurses' hierarchy of this study is nursing services manager, supervisor, head nurses and nurses, which are called top managers, middle managers, supervisors and employees, respectively, in the presented system.

Blass (2009), in his extensive research on the implementation of talent management in various organizations, found that some issues have been considered in all organizations and therefore calls them the main dimensions of talent management. In the following section, the dimensions that are closer to the subject of this research are discussed.

Talent pool capacity: How many people should be in the organization's talent pool? In response to this question, organizations have taken different approaches. Some organizations identify all members of themselves as talented due to the nature of member's work, although rankings are among them. But defining all members of the organization as talent has disadvantages, some of which include

Limits the possibility of exiting inefficient people out of the talent management set and considers their exiting the pool equivalent to leaving the organization.

According to economic theories, limited resources should be allocated in a way that maximizes efficiency. Identifying all employees of the organization as talented is contrary to this principle and destroys the foundation of talent management. Therefore, the division of employees in the organization is essential. One of the issues that significantly impact the volume of the pool is when people enter it. There are several criteria for this. Some organizations consider achieving organizational levels or being at the top management levels as a criterion, while others rely on newcomers. Decisions in this area are made based on the specific characteristics of the organization.

Inclusion criteria: How easy is it to enter the talent pool? Some organizations set simple criteria for entering the talent pool, while others are rigorous.

Hiring as a source of talent: Where do the organization's talents come supply? Some organizations supply their talents from within the organization, while others see the primary source of talent acquisition from outside the organization.

Development path: The main issue of this section is how organizations will develop after selecting individuals as talent. Some organizations provide general training, while others offer separate development training for their talents.

As shown in Figure 1, applicants ($C(t)$) enter the applicants' pool ($A(t)$). Each applicant is initially evaluated before the selection process, and unsuitable individuals are dismissed ($P(t)$). In the initial evaluation, the suitability of the candidate's conditions with the job description and the requirements for obtaining a job is examined. Other applicants who have been accepted in the initial evaluation can enter the selection process to join the organization. Applicants go through several stages in the selection process; these stages include a job interview, a specialist interview and medical examination. The evaluation process is not step-by-step and eliminative. The evaluation process is a comprehensive evaluation, and a trade-off is done between its strengths and weaknesses. It should be mentioned, due to the nature of the work, the variables involved in the evaluation have a coefficient.

Applicant employees enter the employees' pool after succeeding in the selection process; they also exit the employees' pool and return to the applicants' pool due to laying off [1] ($E_E(t)$). Newcomers to the organization are employed in nonsupervisory positions. Some employees stay in the pool for the rest of their working life, while others are assigned

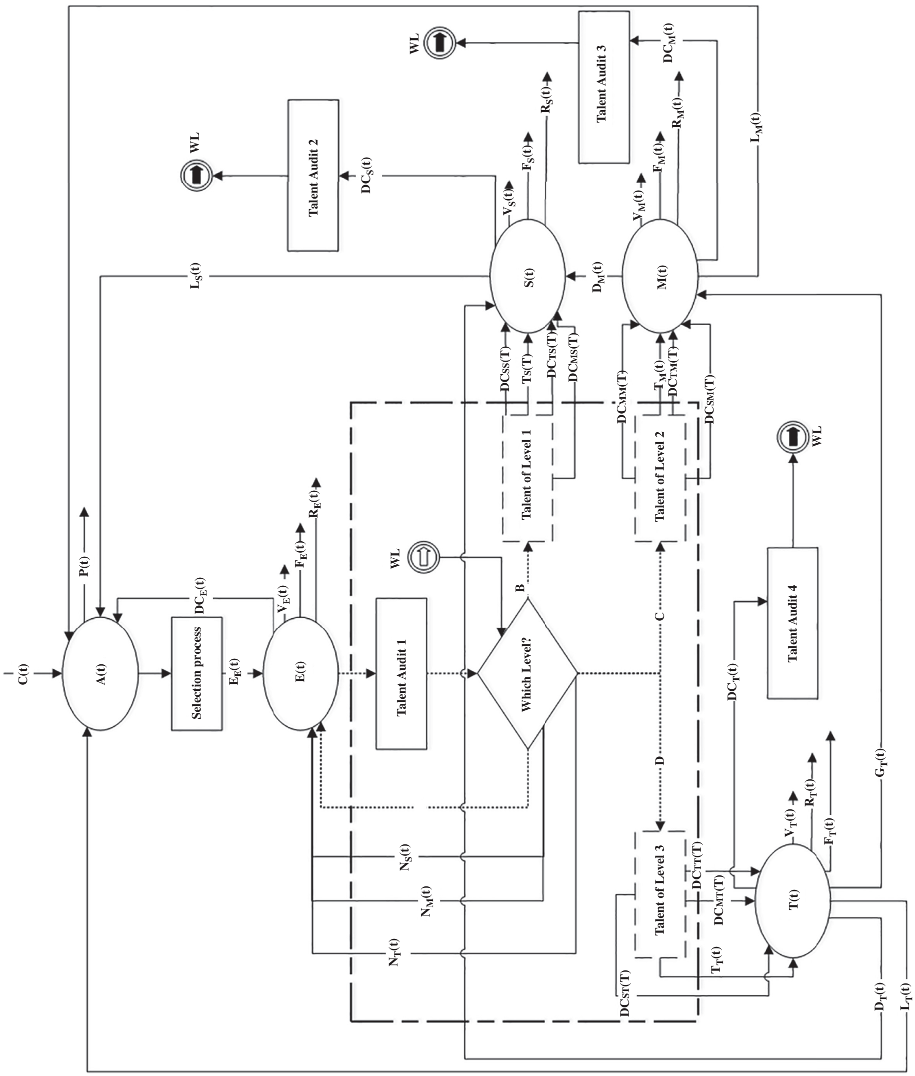

Figure 1.
Flowchart of the proposed workforce planning model

to supervisory and managerial jobs and enter the talent audit process for this purpose. Employee pool flows include voluntary exit ($V_E(t)$), retirement ($R_E(t)$), finished the contract ($DC_E(t)$) and fired ($F_E(t)$). When the employees' contract with the organization is finished or temporarily discharged, they return to the applicants' pool; that is, it is added to the number of applicants' pool to be called back to the organization if necessary. When employees are fired, retired and voluntarily exit, the number of employees is reduced. In talent audit with the aid of developed psychometric assessments, organizations can comprehend their current talent capability and validate their talent pool, ensuring that they have the right people with the right qualities in the right position. It should be mentioned talent audit does not reduce the number of employees' pool, but after allocating to higher levels, it reduces employees' pool. Most significantly, this assures that this organization has the right supervisors and managers for attaining its missions. The dashed line in Figure 1 shows the talent audit process. In this process, qualified people are audited according to their work experience and performance and join the Talent of Levels 1 (supervisor), 2 (middle manager) and 3 (top manager) that are shown by B, C and D dashes. The talent of Level x represents the organization's potential for managerial positions. They do not necessarily mean that individuals have been appointed to the position, so they are indicated by dashes. In other words, these people are both members of the employees' pool and members of the Talent of Level. They are statistically recorded in the number of employees pool and are involved in workforce planning calculations. In contrast, the number of Talent of Level employees has no role in workforce planning calculations. Workforces who do not have qualified for joining the Talent of Level come back (or, better say, remain) in the employee's pool.

At the appropriate time (which depends on the organization's requirements), the workforces who are the member of Talent of Level are appointed to managerial positions ($T_S(t)$, $T_M(t)$ and $T_T(t)$) according to their Talent of Level. After their appointment, they are deducted from the employees' pool and added to the relevant pools (supervisor ($S(t)$), middle manager ($M(t)$) and top manager ($T(t)$)). Each supervisory and managerial pool has the flows of retirement ($R_S(t)$, ($R_M(t)$) and ($R_T(t)$)), fired ($F_S(t)$, $F_M(t)$ and $F_T(t)$), voluntary exit ($V_S(t)$, $V_M(t)$ and $V_T(t)$), temporary dismissal ($L_S(t)$, $L_M(t)$ and $L_T(t)$) and termination of the contract ($DC_S(t)$) (completion of the supervisory and managerial period). What about promotion? Is it the end of everything by the termination of the contract for supervisory and managerial levels? At the end of the supervisor or manager's tenure, he/she reenters the talent audit process (Talent audit 2, 3 and 4) following the individual's organizational level. After the talent audit, it is determined whether he/she is suitable for appointment to higher levels or the same level ($DC_{SS}(t)$, $DC_{SM}(t)$, $DC_{ST}(t)$, $DC_{MS}(t)$, $DC_{MM}(t)$, $DC_{MT}(t)$, $DC_{TS}(t)$, $DC_{TM}(t)$ and $DC_{TT}(t)$) (and consequently contract extension); suppose he/she qualifies through the relevant talent audit process, he/she will be appointed to a supervisor or managerial position and, as a result, will be added to the appropriate pool. If his/her qualifications are not proven, he/she will return to the employees' pool ($N_S(t)$, $N_M(t)$ and $N_T(t)$). In this system, recruitment is done from inside and outside the organization to fill managerial and supervisory positions in an abbreviate and managerial word. The positions of middle managers and top managers are demoted ($D_T(t)$, $G_T(t)$ and $D_M(t)$) because they have a longer tenure than supervisors and have strict work criteria. The middle manager joins the supervisory pool in case of demotion, and the top managers join the middle manager and supervisory pool in case of demotion. Each type of workforce at different levels has a function of the optimal value predicted in the time horizon of workforce planning, which ultimately aims to adjust the amount of recruitment, promotion and demotion of different levels in terms of a dynamic audit of talent to achieve these desired values in time horizon is a very complex and dynamic issue.

4. Optimization model

In this section, we describe the structure of the proposed dynamic optimization model. The proposed model consists of two main parts. The first part, which introduces a system of linear ordinary differential equations with initial conditions, describes the state variables' dynamic behavior and the control variables.

The constraints of the proposed OC model are introduced in this part. The second part of this section is devoted to introducing the objective function, which tries to minimize the differences between the state and control variables and their corresponding targets.

(1) Part 1. Constraints

Considering Table 2 and the flowchart (Figure 1), the following linear system of ordinary differential equations is obtained:

$$\begin{aligned}
\dot{A}(t) &= C(t) + L_T(t) + DC_E(t) + L_S(t) + L_M(t) - E_E(t) - P(t) \\
\dot{E}(t) &= E_E(t) - T_S(t) - T_M(t) - T_T(t) - DC_E(t) + N_T(t) + N_M(t) + N_S(t) - V_E(t) - F_E(t) - R_E(t) \\
\dot{S}(t) &= T_S(t) + D_T(t) + DC_{TS}(t) + D_M(t) - L_S(t) - DC_S(t) + DC_{SS}(t) + DC_{MS}(t) - N_S(t) - V_S(t) - F_S(t) - R_S(t) \\
\dot{M}(t) &= T_M(t) + G_T(t) - D_M(t) - L_M(t) - DC_M(t) - N_M(t) + DC_{TM}(t) + DC_{MM}(t) + DC_{SM}(t) - V_M(t) - F_M(t) - R_M(t) \\
\dot{T}(t) &= T_T(t) - D_T(t) - L_T(t) - DC_T(t) - G_T(t) + DC_{TT}(t) + DC_{MT}(t) + DC_{ST}(t) - V_T(t) - F_T(t) - R_T(t) - N_T(t)
\end{aligned} \quad (1)$$

Table 2. Descriptions of state and control variables

No	Index/State variable	Description
1	$E(t)$	The level of employment at the time t
2	$S(t)$	The level of supervisors at the time t
3	$M(t)$	The level of middle managers at the time t
4	$T(t)$	The level of top managers at the time t
5	$A(t)$	The level of applicants at the time t
6	$C(t)$	The number of applicants in the organization at the time t
7	$P(t)$	The number of applicants is dismissed at the time t
8	$E_E(t)$	The number of employees and exit due to laying off at the time t
9	$DC_i(t)$ *i: E, S, M, T*	The number of workforce i that defines their contracts are terminated at time t
10	$V_i(t)$ *i: E, S, M, T*	The number of workforce i that they separate from the organization due to their own decision at the time t
11	$F_i(t)$ *i: E, S, M, T*	The number of workforce i that they fired from the organization at the time t
12	$R_i(t)$ *i: E, S, M, T*	The number of workforce i that they retired from the organization at the time t
13	$N_i(t)$ *i: S, M, T*	The number of workforce i that the organization audits them for talent again, but they fail at the time t
14	$T_S(t)$ *i: S, M, T*	The number of workforce i appointed to the supervisor position from talent level j pool at the time t; *j: 1 when i:S, 2 when i: M, 3 when i: T*
15	$L_i(t)$ *i: S, M, T*	The number of workforce i that they separate from the organization due to lay-off at the time t
16	$D_i(t)$ *i: M, T*	The number of workforce i that the organization demoted them to the supervisor position at the time t
17	$G_T(t)$	The number of top managers that the organization demoted them to the middle manager position at the time t
18	$DC_{ij}(t)$ *i: S, M, T* *j: S, M, T*	The number of workforce i that defines their contracts are terminated and were assigned to the j position after the audit at time t

Ordinary differential equations:
With initial conditions $(A(t_0), E(t_0), S(t_0), M(t_0), T(t_0)) = (A_0, E_0, S_0, M_0, T_0)$. The theory behind the vector system (1) is the relationships between variables presented in Figure 1. Also, based on Figure 1, tt can use some replacements as presented. Table 3 presented the notation and descriptions of constant parameters.

After replacing equivalent parts below in system (1), It can rewrite this system as (2):

$P(t) = \alpha A(t)$	$V_T(t) = \lambda_{T1} T(t)$
$V_E(t) = \lambda_{E1} E(t)$	$F_T(t) = \lambda_{T2} T(t)$
$F_E(t) = \lambda_{E2} E(t)$	$R_T(t) = \lambda_{T3} T(t)$
$R_E(t) = \lambda_{E3} E(t)$	$G_T(t) = \theta_2 T(t)$
$DC_E(t) = U_1 E(t)$	$D_T(t) = \theta_3 T(t)$
$V_S(t) = \lambda_{S1} S(t)$	$DC_T(t) = \gamma_4 T(t)$
$F_S(t) = \lambda_{S2} S(t)$	$N_T(t) = \phi_3 DC_T(t)$
$R_S(t) = \lambda_{S3} S(t)$	$DC_S(t) = DC_{SS}(t) + DC_{SM}(t) + DC_{ST}(t) + N_S(t)$
$DC_S(t) = \gamma_2 S(t)$	$DC_M(t) = DC_{MS}(t) + DC_{MM}(t) + DC_{MT}(t) + N_M(t)$
$N_S(t) = \phi_1 DC_S(t)$	$DC_T(t) = DC_{TS}(t) + DC_{TM}(t) + DC_{TT}(t) + N_T(t)$
$V_M(t) = \lambda_{M1} M(t)$	$DC_{Si}(t) = \omega_{Si} DC_S(t) \quad i: S, M, T; \sum \omega_{Si} + \varphi_1 = 1$
$F_M(t) = \lambda_{M2} M(t)$	$DC_{Mi}(t) = \omega_{Mi} DC_M(t) \quad i: S, M, T; \sum \omega_{Mi} + \varphi_2 = 1$
$R_M(t) = \lambda_{M3} M(t)$	$DC_{Ti}(t) = \omega_{Ti} DC_T(t) \quad i: S, M, T; \sum \omega_{Ti} + \varphi_3 = 1$
$D_M(t) = \theta_1 M(t)$	
$DC_M(t) = \gamma_3 M(t)$	
$N_M(t) = \phi_2 DC_M(t)$	

$$
\begin{aligned}
\dot{A}(t) &= C(t) + L_T(t) + \gamma_1 E(t) + L_S(t) + L_M(t) - E_E(t) - \alpha A(t) \\
\dot{E}(t) &= E_E(t) - T_S(t) - T_M(t) - T_T(t) - \gamma_1 E(t) + \phi_3 \gamma_4 T(t) + \phi_2 \gamma_3 M(t) + \phi_1 \gamma_2 S(t) \\
&\quad - \lambda_{E1} E(t) - \lambda_{E2} E(t) - \lambda_{E3} E(t) \\
\dot{S}(t) &= T_S(t) + \theta_3 T(t) + \omega_{TS} \gamma_4 T(t) + \theta_1 M(t) - L_S(t) - \gamma_2 S(t) + \omega_{SS} \gamma_2 S(t) \\
&\quad + \omega_{MS} \gamma_3 M(t) - \phi_1 \gamma_2 S(t) - \lambda_{S1} S(t) - \lambda_{S2} S(t) - \lambda_{S3} S(t) \\
\dot{M}(t) &= T_M(t) + \theta_2 T(t) - \theta_1 M(t) - L_M(t) - \gamma_3 M(t) - \phi_2 \gamma_3 M(t) + \omega_{TM} \gamma_4 T(t) \\
&\quad + \omega_{MM} \gamma_3 M(t) + \omega_{SM} \gamma_2 S(t) - \lambda_{M1} M(t) - \lambda_{M2} M(t) - \lambda_{M3} M(t) \\
\dot{T}(t) &= T_T(t) - \theta_3 T(t) - L_T(t) - \gamma_4 T(t) - \theta_2 T(t) + \omega_{TT} \gamma_4 T(t) + \omega_{MT} \gamma_3 M(t) \\
&\quad + \omega_{ST} \gamma_2 S(t) - \lambda_{T1} T(t) - \lambda_{T2} T(t) - \lambda_{T3} T(t) - \phi_3 \gamma_4 T(t)
\end{aligned}
\tag{2}
$$

After some manipulation, we will have

$$
\begin{aligned}
\dot{A}(t) &= C(t) + L_T(t) + \gamma_1 E(t) + L_S(t) + L_M(t) - E_E(t) - \alpha A(t) \\
\dot{E}(t) &= E_E(t) - T_S(t) - T_M(t) - T_T(t) + [-\gamma_1 - \lambda_{E1} - \lambda_{E2} - \lambda_{E3}] E(t) + \phi_3 \gamma_4 T(t) \\
&\quad + \phi_2 \gamma_3 M(t) + \phi_1 \gamma_2 S(t) \\
\dot{S}(t) &= T_S(t) + [\theta_3 + \omega_{TS} \gamma_4] T(t) + [\theta_1 + \omega_{MS} \gamma_3] M(t) - L_S(t) \\
&\quad + [-\gamma_2 + \omega_{SS} \gamma_2 - \phi_1 \gamma_2 - \lambda_{S1} - \lambda_{S2} - \lambda_{S3}] S(t) \\
\dot{M}(t) &= T_M(t) + (\theta_2 + \omega_{TM} \gamma_4) T(t) + [-\theta_1 - \gamma_3 - \phi_2 \gamma_3 + \omega_{MM} \gamma_3 - \lambda_{M1} - \lambda_{M2} - \lambda_{M3}] \\
&\quad \times M(t) - L_M(t) + \omega_{SM} \gamma_2 S(t) \\
\dot{T}(t) &= T_T(t) + [-\theta_3 - \gamma_4 - \theta_2 + \omega_{TT} \gamma_4 - \lambda_{T1} - \lambda_{T2} - \lambda_{T3} - \phi_3 \gamma_4] \\
&\quad \times T(t) - L_T(t) + \omega_{MT} \gamma_3 M(t) + \omega_{ST} \gamma_2 S(t)
\end{aligned}
\tag{3}
$$

No	Constant parameters	Description
1	α	It is a coefficient of applicants' pool that is put off in each period
2	λ_{E1}	It is a coefficient of employees' pool that voluntarily exit of the organization in each period
3	λ_{E2}	It is a coefficient of employees' pool that is fired from the organization in each period
4	λ_{E3}	It is a coefficient of employees' pool that defines the retirement of the organization in each period
5	λ_{S1}	It is a coefficient of supervisors' pool that voluntarily exit of the organization in each period
6	λ_{S2}	It is a coefficient of supervisors' pool that is fired from the organization in each period
7	λ_{S3}	It is a coefficient of supervisors' pool that defines the retirement of the organization in each period
8	λ_{M1}	It is a coefficient of middle managers' pool that voluntary exit of the organization in each period
9	λ_{M2}	It is a coefficient of middle managers' pool that is fired from the organization in each period
10	λ_{M3}	It is a coefficient of middle managers' pool that defines the retirement of the organization in each period
11	λ_{T1}	It is a coefficient of top managers' pool that voluntarily exit of the organization in each period
12	λ_{T2}	It is a coefficient of top managers' pool that is fired from the organization in each period
13	λ_{T3}	It is a coefficient of top managers' pool that defines the retirement of the organization in each period
14	θ_1	It is a coefficient of middle managers' pool in which the organization demoted them to the supervisor position in each period
15	θ_2	It is a coefficient of top managers' pool in which the organization demoted them to the middle manager position in each period
16	θ_3	It is a coefficient of top managers' pool in which the organization demoted them to the supervisor position in each period
17	γ_1	It is a coefficient of employees' pool in which their contracts are terminated in each period
18	γ_2	It is a coefficient of supervisors' pool in which their contracts are terminated in each period
19	γ_3	It is a coefficient of middle managers' pool in which their contracts are terminated in each period
20	γ_4	It is a coefficient of top managers' pool in which their contracts are terminated in each period
21	ϕ_1	It is a coefficient of the number of supervisors whose contracts are terminated, and the result of their audit talent is negative in each period
22	ϕ_2	It is a coefficient of the number of middle managers whose contracts are terminated, and the result of their audit talent is negative in each period
23	ϕ_3	It is a coefficient of the number of top managers whose contracts are terminated, and the result of their audit talent is negative in each period
24	ω_{Si}	It is a coefficient of the number of supervisors whose contracts are terminated, and the result of their audit talent is positive in each period
25	ω_{Mi}	It is a coefficient of the number of middle managers whose contracts are terminated, and the result of their audit talent is positive in each period
26	ω_{Ti}	It is a coefficient of the number of top managers whose contracts are terminated, and the result of their audit talent is positive in each period

Table 3. Notation and descriptions of constant parameters

or

$$
\begin{aligned}
&\dot{A}(t) = C(t) + L_T(t) + \gamma_1 E(t) + L_S(t) + L_M(t) - E_E(t) - \alpha A(t)\\
&\dot{E}(t) = E_E(t) - T_S(t) - T_M(t) - T_T(t) + k_1 E(t) + \phi_3\gamma_4 T(t) + \phi_2\gamma_3 M(t) + \phi_1\gamma_2 S(t)\\
&\dot{S}(t) = T_S(t) + k_2 T(t) + k_3 M(t) - L_S(t) + k_4 S(t)\\
&\dot{M}(t) = T_M(t) + k_5 T(t) + k_6 M(t) - L_M(t) + \omega_{SM}\gamma_2 S(t)\\
&\dot{T}(t) = T_T(t) + k_7 T(t) - L_T(t) + \omega_{MT}\gamma_3 M(t) + \omega_{ST}\gamma_2 S(t)
\end{aligned} \tag{4}
$$

Wherein

$$
\begin{aligned}
&k_1 = [-\gamma_1 - \lambda_{E1} - \lambda_{E2} - \lambda_{E3}]\\
&k_2 = [\theta_3 + \omega_{TS}\gamma_4]\\
&k_3 = [\theta_1 + \omega_{MS}\gamma_3]\\
&k_4 = [-\gamma_2 + \omega_{SS}\gamma_2 - \phi_1\gamma_2 - \lambda_{S1} - \lambda_{S2} - \lambda_{S3}]\\
&k_5 = (\theta_2 + \omega_{TM}\gamma_4)\\
&k_6 = [-\theta_1 - \gamma_3 - \phi_2\gamma_3 + \omega_{MM}\gamma_3 - \lambda_{M1} - \lambda_{M2} - \lambda_{M3}]\\
&k_7 = [-\theta_3 - \gamma_4 - \theta_2 + \omega_{TT}\gamma_4 - \lambda_{T1} - \lambda_{T2} - \lambda_{T3} - \phi_3\gamma_4]
\end{aligned} \tag{5}
$$

or in the matrix form

$$
\begin{bmatrix}\dot{A}(t)\\ \dot{E}(t)\\ \dot{S}(t)\\ \dot{M}(t)\\ \dot{T}(t)\end{bmatrix} = \begin{bmatrix}-\alpha & \gamma_1 & 0 & 0 & 0\\ 0 & k_1 & \phi_1\gamma_2 & \phi_2\gamma_3 & \phi_3\gamma_4\\ 0 & 0 & k_4 & k_3 & k_2\\ 0 & 0 & \omega_{SM}\gamma_2 & k_6 & k_5\\ 0 & 0 & \omega_{ST}\gamma_2 & \omega_{MT}\gamma_3 & k_7\end{bmatrix}\begin{bmatrix}A(t)\\ E(t)\\ S(t)\\ M(t)\\ T(t)\end{bmatrix}
+ \begin{bmatrix}1 & 1 & 1 & 1 & -1 & 0 & 0 & 0\\ 0 & 0 & 0 & 0 & 1 & -1 & -1 & -1\\ 0 & 0 & -1 & 0 & 0 & 1 & 0 & 0\\ 0 & 0 & 0 & -1 & 0 & 0 & 1 & 0\\ 0 & -1 & 0 & 0 & 0 & 0 & 0 & 1\end{bmatrix}\begin{bmatrix}C(t)\\ L_T(t)\\ L_S(t)\\ L_M(t)\\ E_E(t)\\ T_S(t)\\ T_M(t)\\ T_T(t)\end{bmatrix} \tag{6}
$$

System (6) is a linear system of differential equations of the following form:

$$
\dot{X}(t) = MX(t) + NU(t), X(0) = X_0 \tag{7}
$$

$X(t) = [A(t)\ E(t)\ S(t)\ M(t)\ T(t)]^T$ is the vector of state variables, and the vector of zero variables is $U(t) = [C(t)\ \ L_T(t)\ \ L_S(t)\ \ L_M(t)\ \ E_E(t)\ \ T_S(t)\ \ T_M(t)\ \ T_T(t)]^T$.

(2) Part 2. Objective function

The second part of the proposed OC model is the objective function which tries to minimize the differences between the state and control variables and their corresponding targets. It is supposed that $\widehat{X}(t) = [\widehat{A}(t)\ \ \widehat{E}(t)\ \ \widehat{S}(t)\ \ \widehat{M}(t)\ \ \widehat{T}(t)]^T$ is the target value of state variables, the target value of the control values is $\widehat{U}(t) = [\widehat{C}(t)\ \ \widehat{L}_T(t)\ \ \widehat{L}_S(t)\ \widehat{L}_M(t)\ \widehat{E}_E(t)\ \ \widehat{T}_S(t)\ \widehat{T}_M(t)\ \widehat{T}_T(t)]^T$. To attain these target values, we should minimize the distances between the state variables and their targets, as well as the distances between the control variables and their targets. For this purpose, the following objective function can be introduced:

$$J = F(X(t_f)) + \frac{1}{2}\int_{t_0}^{t_f} \{q_1[A(t) - \widehat{A}(t)]^2 + q_2[E(t) - \widehat{E}(t)]^2$$
$$+ q_3[S(t) - \widehat{S}(t)]^2 + q_4[M(t) - \widehat{M}(t)]^2$$
$$+ q_5[T(t) - \widehat{T}(t)]^2 + r_1[C(t) - \widehat{C}(t)]^2 + r_2[L_T(t) - \widehat{L}_T(t)]^2$$
$$+ r_3[L_S(t) - \widehat{L}_S(t)]^2 + r_4[L_M(t) - \widehat{L}_M(t)]^2 + r_5[E_E(t) - \widehat{E}_E(t)]^2$$
$$+ r_6[T_S(t) - \widehat{T}_S(t)]^2 + r_7[T_M(t) - \widehat{T}_M(t)]^2 + r_8[T_T(t) - \widehat{T}_T(t)]^2\}dt \quad (8)$$

Here, $F(X(t_f))$ indicates that it is going to minimize the final values of state variables. Following Pooya and Pakdaman (2018), for each control and state variable, namely g, it can be defined $\Delta g = g - \widehat{g}$. Then equation (8) will be converted as follows:

$$J = F(X(t_f)) + \frac{1}{2}\int_{t_0}^{t_f} \{\lambda_1 \Delta A(t)^2 + \lambda_2 \Delta E(t)^2 + \lambda_3 \Delta S(t)^2 + q\lambda_4 \Delta M(t)^2$$
$$+\lambda_5 \Delta T(t)^2 + \sigma_1 \Delta C(t)^2 + \sigma_2 \Delta L_T(t)^2 + \sigma_3 \Delta L_E(t)^2$$
$$+\sigma_4 \Delta L_S(t)^2 + \sigma_5 \Delta L_M(t)^2 + \sigma_6 \Delta E_E(t)^2$$
$$+\sigma_7 \Delta T_S(t)^2 + \sigma_8 \Delta T_M(t)^2 + \sigma_9 \Delta T_T(t)^2\}dt \quad (9)$$

or in the matrix form:

$$J = F(X(T)) + \frac{1}{2}\int_{t_0}^{t_f} [x^t \Lambda x + u^t \Sigma u]dt \quad (10)$$

wherein $\Lambda = diag\{\lambda_1, \lambda_2, \ldots, \lambda_5\}$ and $\Sigma = diag\{\sigma_1, \sigma_2, \ldots, \sigma_8\}$,
$x = [\Delta A(t)\ \Delta E(t)\ \Delta S(t)\ \Delta M(t)\ \Delta T(t)]^t$, and $u = [\Delta C(t)\ \Delta L_T(t)\ \Delta L_S(t)\ \Delta L_M(t)\ \Delta E_E(t)\ \Delta T_S(t)\ \Delta T_M(t)\ \Delta T_T(t)]^t$. Since $F(X(T))$ is for minimizing the final value of state variables, thus, it can be defined as $F(X(t_f)) = \frac{1}{2}(f_1[A(t_f) - \widehat{A}(t_f)]^2 + f_2[E(t_f) - \widehat{E}(t_f)]^2 + f_3[S(t_f) - \widehat{S}(t_f)]^2 + f_4[M(t_f) - \widehat{M}(t_f)]^2 + f_5[T(t_f) - \widehat{T}(t_f)]^2)$ or equivalently $F(X(t_f)) = \frac{1}{2}x^t F x$ where $F = diag\{f_1, f_2, \ldots, f_5\}$. Finally, the OC model can be summarized as follows:

$$Minimize\, J = \frac{1}{2}x^t F x + \frac{1}{2}\int_{t_0}^{t_f} [x^t \Lambda x + u^t \Sigma u]dt$$
$$s.t.$$
$$\dot{x}(t) = Mx(t) + Nu(t), x(0) = x_0 \quad (11)$$

The proposed model of Equation system (11) is a quadratic model of OC that can be solved by Pontryagin's maximum principle (Pooya *et al.*, 2019) with the proposed Pooya and Pakdaman's (2018) algorithm.

5. A case study

What has been presented so far in the form of continuous OC is then solved in the form under case study. The case study of this study is a clinical unit of a hospital that deals with infectious diseases. This clinical unit currently has 20 applicants, ten employees with various technical and general skills, ten supervisors, six middle managers and four top managers. At the unit level, the hierarchy nurse could play a vital role as a socialization agent, planning a clear path of improvement and evaluating individual responsibility by the newcomer (Tomietto *et al.*, 2015). Workforce planning is the proper answer for doing the best this change. Intelligent workforce planning is not just determining how many employees; it will happen when the workforce planning accompanies the organization's rhythm. The healthcare sector usually struggles to the rise in patients demanding care as they enter the autumn and winter season.

Since the demand is seasonal in the healthcare sector, the policy is to employ temporary nurses as known newcomers and added to the employee pool. On the other hand, the policy for supervisors, middle and top managers is a long time horizon. Another policy is that the hospital has no direct employment for supervisors, middle and top managers since the system is talent audited. Indeed, the supervisors, middle and top managers are selected from the talent audit process. Since the hospital has had an increasing admission of patients in recent years, they will schedule the workforce for two years. Coefficients can be defined through historical data. If historical time series data are available, simple statistical methods, like exponential smoothing, simple and moving average or regression, can be applied. In this research, since the historical time series of the model and variable parameters have seasonal patterns and trends, the moving average time series prediction method has been used. A certain number of past periods similar to the predicted period are selected and used for averaging in the moving average method. Also, after predicting the parameters, the Root Mean Square Error (RMSE) method was used to estimate the error rate, and in all cases, the error rate was less than 5% and is acceptable.

The MSE is calculated through the following equation:

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(X_t - \widehat{X}_t)^2 \tag{12}$$

X_t is the observed parameter value in previous times, $\widehat{X}_t$ is the estimated parameter value in period t stood on the similar approach for estimating the parameter itself and n is the number of previous periods, which is utilized to determine the exactitude of estimation.

For the applied proposed dynamic optimization model, the target value of control variables is considered as zero. The initial state values and their functions are presented as follows:

$$\widehat{A}(t) = 2\widehat{E}(t)$$

$$\widehat{E}(t) = 20t + 10sin(\frac{\pi}{2}(8t-1)) + 25$$

$$\widehat{S}(t) = 15 + 3t$$

$$\widehat{M}(t) = 8 + t$$

$$\widehat{T}(t) = 5 + 0.5t$$

Also the constant parameters are presented below.

$\alpha = 0.3$	$\gamma_1 = 0.5$	$\phi_1 = 0.2$	$r_1 = 1,\ r_2 = 10$
$t_f = 2$	$\gamma_2 = 0.5$	$\phi_2 = 0.1$	$r_3 = 5,\ r_4 = 7$
$\lambda_{E1} = 0.1$	$\gamma_3 = 0.5$	$\phi_3 = 0.05$	$r_5 = 3,\ r_6 = 5$
$\lambda_{E2} = 0.1$	$\gamma_4 = 0.5$	$q_1 = 10$	$r_7 = 7,\ r_8 = 9$
$\lambda_{E3} = 0.05$	$\omega_{SS} = 0.6$	$q_2 = 120$	$f_i = 50,\ \text{For}\ i = 1:5$
$\lambda_{T1} = 0.4$	$\omega_{SM} = 0.15$	$q_3 = 150$	
$\lambda_{T2} = 0.01$	$\omega_{ST} = 0.05$	$q_4 = 180$	
$\lambda_{T3} = 0.1$	$\omega_{MS} = 0.15$	$q_5 = 250$	
$\lambda_{M1} = 0.3$	$\omega_{MM} = 0.55$	$\theta_1 = 0.1$	
$\lambda_{M2} = 0.02$	$\omega_{MT} = 0.2$	$\theta_2 = 0.1$	
$\lambda_{M3} = 0.02$	$\omega_{TS} = 0.15$	$\theta_3 = 0.02$	
$\lambda_{S1} = 0.2$	$\omega_{TM} = 0.2$		
$\lambda_{S2} = 0.05$	$\omega_{TT} = 0.6$		
$\lambda_{S3} = 0.1$			

6. Results and validation

The proposed OC model for this system was applied and solved. The OC model results of clinical unit hospital workforce planning are presented in Figure 2–5 and Tables 4–6.

As shown in the above figures and tables, the target value of state variables has been achieved in the two-year planning period using control variables. For example, the initial value of the middle manager of the clinical unit of the hospital is six persons, and its target value is ten persons. Figure 4 and Table 4 show the initial value and the target value of the top manager, this gap is filled in the third season of the second year of the workforce planning course. More details on workforce flow to achieve the target value of state variables are provided in the next section of this paper.

For validating the model, the initial values of state variables, except for the top managers variable, were changed and defined above the actual value. This change is the opposite of the

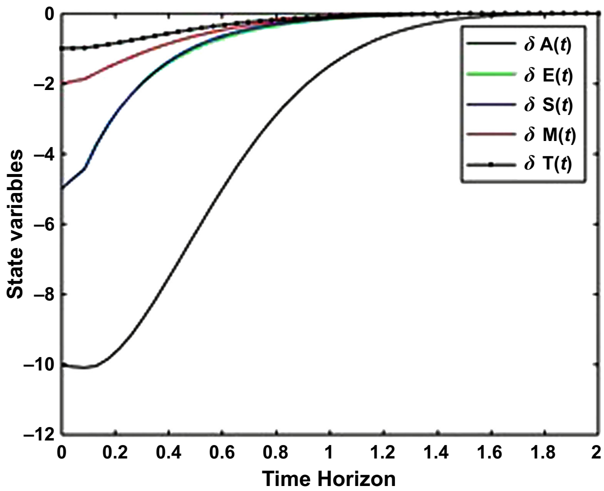

Figure 2.
Difference between the number of workforces and their target

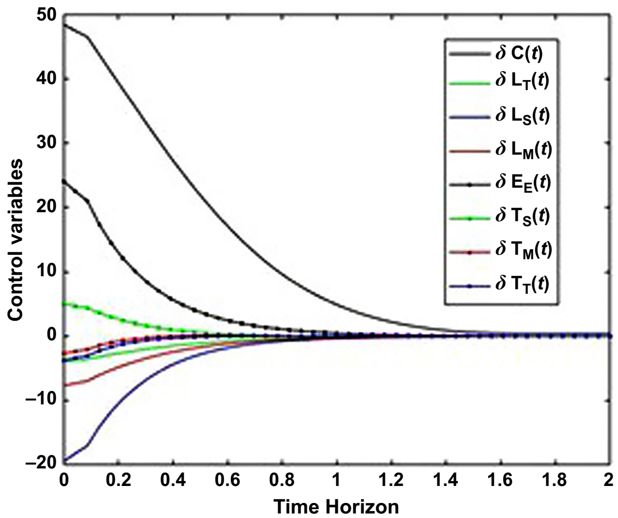

Figure 3.
Difference between the number of movement of workforces in hospital and their target

real situation and can show how well the model can work by changing it. Due to this, the target values are same as real data and consider new initial conditions such as $A(0) = 50,\ E(0) = 25,\ S(0) = 20,\ M(0) = 10, T(0) = 4$, and results of validation test, shown in Figure 5, indicate the system achieves its targets again. Interestingly, top managers' variable behavior before the first year looks like Figure 4. Until the middle of the first year, the system faces inflation of top managers. This behavior is due to the top manager's initial variable not change, but the other initial values change, so the top manager confronts inflation; however, in the end, top managers touch the target.

In addition to examining the model in two cases, which showed that it could provide reliable and valid answers under different conditions, in this study, sensitivity analysis was performed by changing different parameters. Here, this analysis is performed and reported for two parameters: the coefficient of the control variable and the other is the coefficient of a state variable in the objective function. The first parameter is the penalty coefficient of the state variable "S", which means q_3. The value of this coefficient was changed from the initial value of 150–160 and 170 in two steps. The researcher expected the convergence intensification of the S variable to its target value, and as shown in Figure 6-a, this change has happened. The convergence rate has been higher starting from the initial value of S. The second parameter is the penalty coefficient of the control variable "E_E", which means r_5. The target value of this variable is zero, as previously described. As shown in Figure 6-b, by increasing the penalty coefficient from 3 to 5 and 7, both the initial value set by the model for this control variable was closer to zero, and its convergence was higher than the target value. Other parameters provided acceptable results in a similar analysis.

7. Discussion

As mentioned before, authors in the talent management literature emphasize the significance of suiting people to positions. Changes in the healthcare system concerning workforce requirements have anyhow negatively affected organizational effectiveness. It is shown in the managerial hierarchal by attention to multidimensional and vague roles (managerial and clinical skills).

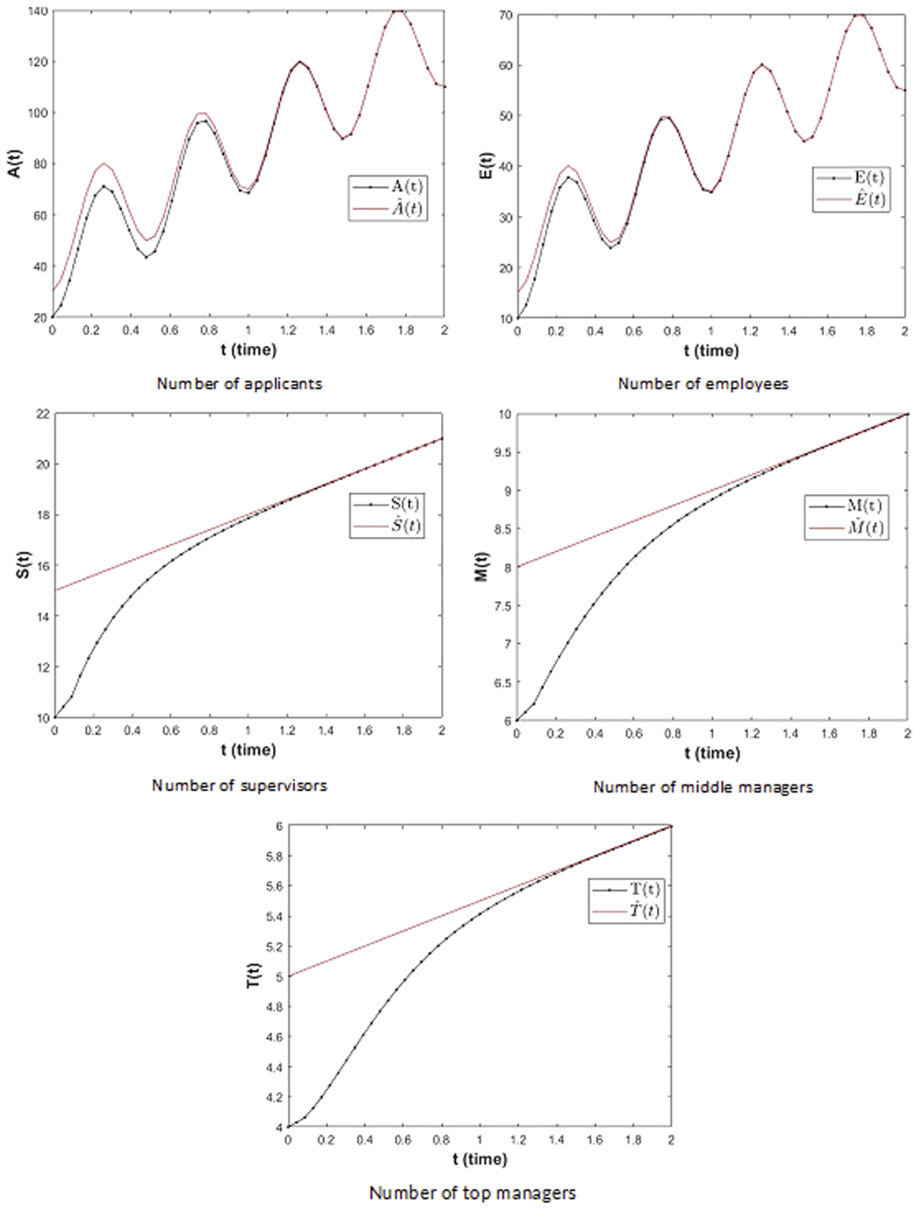

Figure 4.
Number of applicants, employees, supervisors, middle managers and top managers

In this study, Figure 1 and Table 4 want to say the state functions converge to their corresponding target functions by converging to zero. For example, the initial value of applicants ($A(t)$) is 20 persons, and the target value is 110 persons. It means the applicants' pool needs 90 persons and has two years to compensate for this shortage. The number of applicants depends on temporary nurses' seasonal demand. Table 6 shows how many and

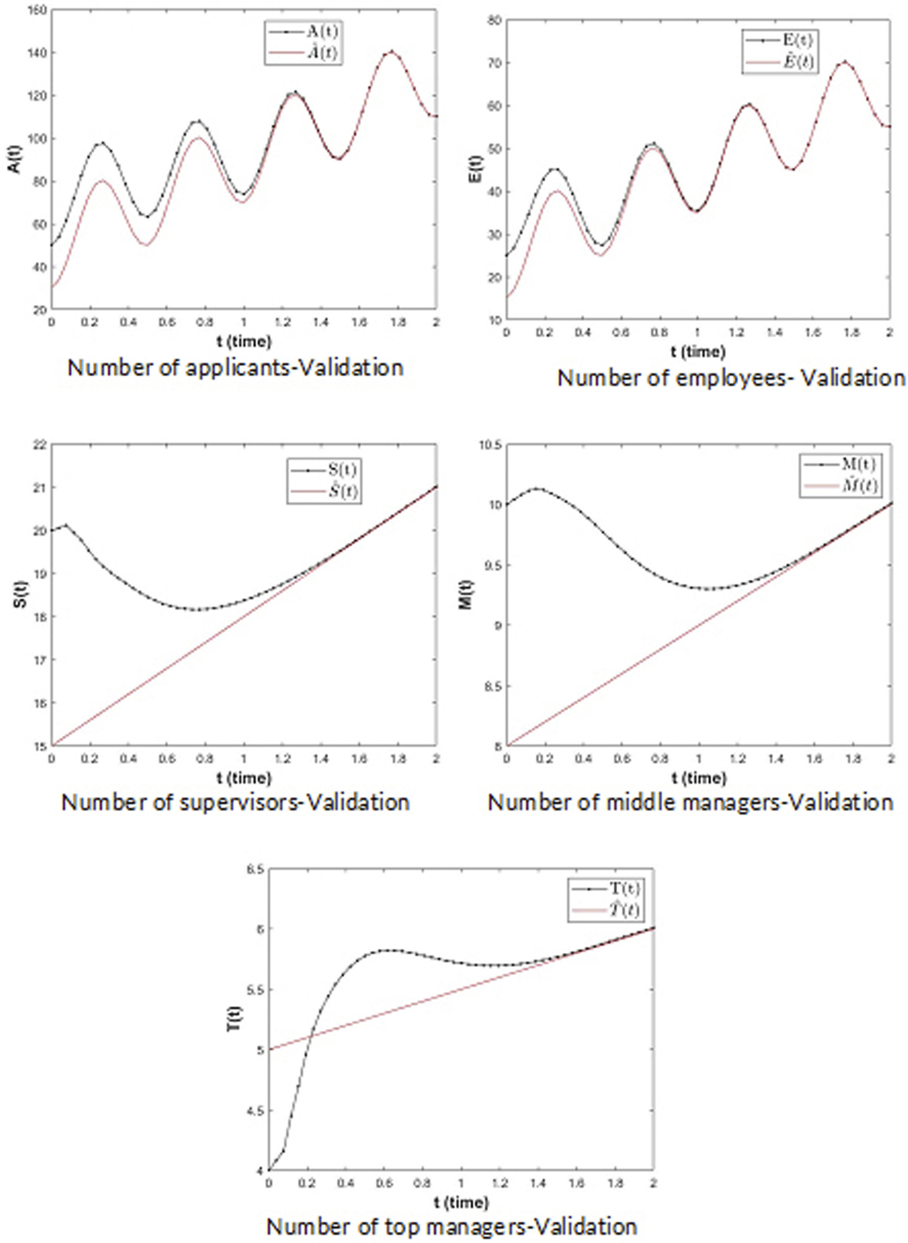

Figure 5.
Number of applicants, employees, supervisors, middle managers and top managers – validation

when they must have recruitment, promotion and exit due to the supply workforce at different times. Figure 3 shows after the first year and before touch the second year, the initial and target value converges to their corresponding target functions. Another evidence for this claim is Figure 1, which shows that $A(t)$ converged to zero between the first and second year.

As mentioned before, applicants number depended on the seasonal demand of temporary nurses; in other words, the number of $A(t)$ depends on $E(t)$ (as shown in the equations of $A(t)$ and $E(t)$). As shown in Figure 1, the convergence of $A(t)$ to zero has a delay compared to $E(t)$. The reason for this delay can be described by mentioning that this system should provide twice the required number of employees to the applicant to select the required people from among the applicants based on the selection process. What about the shortage issue and the ways that the system can compensate for this shortage? This system can compensate for its shortage by control variables. As shown in Figure 2 and Table 5, the number of applicants in the hospital ($C(t)$) and the number of employees and exit due to laying off ($E_E(t)$) help the system for attaining its target by creating a balance between $C(t)$ and $E_E(t)$.

Other figures have the same descriptions. Due to the system's attribute noticed before, promotion is the only way for filling managerial and supervisory positions. It should be attention; shortages cannot be compensated by hiring from outside the hospital for managerial and supervisory positions; also, every state variable has its control variables that help the system attain its targets and compensate for its shortages.

Table 4.
The approximate values of targets of state variables in selected time steps

Year State	2021–1	2021–2	2021–3	2021–4	2022–1	2022–2	2022–3	2022–4
$\widehat{A}(t)$	80	50	100	70	120	90	140	110
$\widehat{E}(t)$	40	25	50	35	60	45	70	55
$\widehat{S}(t)$	15	16	17	18	19	20	21	21
$\widehat{M}(t)$	8	8	8	9	9	9	10	10
$\widehat{T}(t)$	5	5	5	5	5	5	5	6

Table 5.
The approximate values of differences between state variables and their targets in selected time steps

Year State	2021–1	2021–2	2021–3	2021–4	2022–1	2022–2	2022–3	2022–4
$\delta A(t)$	−9	−6	−4	−2	−1	−0.25	0	0
$\delta E(t)$	−2.2	−2.1	−1.6	−1	0	0	0	0
$\delta S(t)$	−2.2	−2.1	−1.6	−1	0	0	0	0
$\delta M(t)$	−1.7	−1	−0.7	−0.1	0	0	0	0
$\delta T(t)$	−0.4	−0.3	−0.2	−0.1	0	0	0	0

Table 6.
The approximate values of control variables in selected time steps

Year Control	2021–1	2021–2	2021–3	2021–4	2022–1	2022–2	2022–3	2022–4
$C(t)$	33	25	18	7	2	1	0	0
$L_T(t)$	−3	−2	−1	0	0	0	0	0
$L_S(t)$	−9	−4	−3	0	0	0	0	0
$L_M(t)$	−4	−2	−1	0	0	0	0	0
$E_E(t)$	8	4	1	0	0	0	0	0
$T_S(t)$	2	1	0	0	0	0	0	0
$T_M(t)$	1	0	0	0	0	0	0	0
$T_T(t)$	1	0	0	0	0	0	0	0

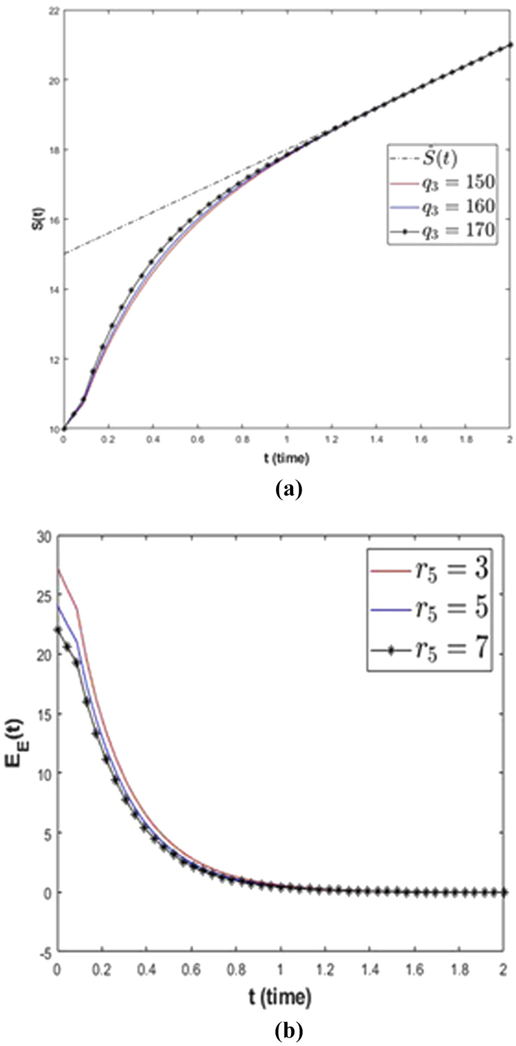

Figure 6.
The result of sensitivity analysis

8. Practical and managerial implications

In order to look at the results of this paper with a more social view for practical implication, it can be acknowledged that workforce planning helps the organization evaluate organizational and environmental changes and adapt the administrative body to the changes that have occurred with the least cost. Therefore, the need to provide a comprehensive and efficient model that can cover all the components of workforce planning in a coordinated manner is an inevitable necessity. Dynamic workforce planning helps the organization ensure the status of its workforce in the planning horizon, surplus workforce, shortage of workforce in different departments and ensuring that the right workforce is appointed to the right jobs at the right time. The OC approach to workforce planning provides a function according to the organizational workforce flows. With this function, the organization enables the organization to be informed about the workforce needs and available organizational human resources. Talent management and workforce planning have common content. Both require placing the right people in the right jobs and managing the supply, demand and flow of people across the organization. Talent management involves a set of HRM actions and activities, such as recruiting, selecting, training and evaluating talent performance. In all these practices, the focus is on talented people. That is, people who are essential to the organization. Talent management focuses on the development of competencies through talent management in the organization. It means the main focus is on creating an artery of talent by managing individuals' career paths. Its primary focus is on replacing, workforce planning and the continuity of talent flow.

This paper has messages for organizational managers that are mentioned in follow. In order to use this research model, hospital decision-makers could estimate the problem parameters of this study, such as $\alpha, \lambda_{Ei}, \theta_i$ in their organization for a two-year time horizon and solve it by including it in the model (11). Once resolved, decision-makers will find the answers to the variables $\widehat{A}(t),\ \widehat{E}(t),\ \widehat{M}(t), \widehat{S}(t)\ and\ \widehat{T}(t)$ for their case.

In case the hospital conditions, in terms of workforce flows and talent audits, are different from the problem described in Figure 1, they should first modify the model according to the state outputs and state inputs and then solve the modified model.

Talent management involves identifying key and strategic jobs and filling them through talent pools. As mentioned earlier, talent management involves identifying key and strategic jobs and filling them through talent repositories. Talent management is the strategic management of the flow of talents in different jobs of the organization. Management planners strive to design tools that focus on creating and developing skills, competencies and behaviors in individuals that make them successful in their jobs and the organization's future. The talent management literature focuses on identifying key positions and jobs that significantly impact the competitive advantage of organizations, which requires a holistic and systematic view of the organization.

9. Conclusions and future directions

In this research, nurse workforce planning has been done, and for this purpose, the OC model has been used. Studies on workforce planning by OC method (as shown in Table 1) do not cover all workforce flows such as recruitment, promotion and exit. The studies examined the crucial variables employment is not engaged, such as talent.

The optimization approach to workforce planning to find the best path for the workforce number according to a set of criteria is among a set of possible answers. In workforce planning, many internal and external variables must be considered. One of them is potential people that can be promoted inside the system and filled the empty positions. Attention to flows in the organization and variables involved in workforce planning equips managers to intelligent workforce planning. They do not be surprised by encountering a vacancy position by applying the OC method that provided a function according to the organization's requirements to find the optimal path. Ekhosuehi (2016) has paid attention to recruitment and exits. Udom (2013) mentioned recruitment, promotion and retirement, and Mouza (2010), Sun *et al.* (2005) and Lee *et al.* (2001) have foreside some workforce flows. A comprehensive study done by Pooya and Pakdaman (2018) considered workforce flows in their study, but none of the studies did not mention talent management. The OC model of this paper presented the optimal number of hiring, promotion, demotion and exit from the hospital's clinical unit at any time to achieve the target values of organizational positions. Each organizational position has special characteristics that the people appointed must have these characteristics, validated in the talent audit process.

In this study, by monitoring the control variables such as recruitment, promotion, degrade and exit, targets of status variables (such as applicants, employees, supervisors, middle and top managers) were achieved. The hospital has a feature that should be considered in hiring.

This feature is the need to upgrade from within the organization. It means no recruitment from outside the organization for managerial positions. The data, the parameters entered in the research, are deterministic and crisp. Since these data are estimated and can be uncertain and uncertain, it can also develop a solution model and method for uncertainty, risk and fuzzy conditions. Talents are audited for appointment to management positions. In each period and after the end of the contract, the talent audit result determines individuals' chances of being appointed to managerial positions. Persons' managerial positions are not a guarantee for their reappointment to the same position; there is a degraded probability for all individuals.

It is recommended for future studies to be considered the cost and succession planning in workforce planning. If an organization has employment outside, it should pay attention to this flow in its dynamic model. In this study, the required skills of each level have not been identified. In other words, the nature of talent auditing has not been addressed.

Note

1. Workforces are discharged temporarily.

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Corresponding author
Fariborz Rahimnia can be contacted at: r-nia@um.ac.ir