Int. J. Nonlinear Anal. Appl. 14 (2023) 1, 557–573
ISSN: 2008-6822 (electronic)
http://dx.doi.org/10.22075/ijnaa.2022.26916.3449

Designing a human resource productivity model with a system dynamics approach in the health sector

Leila Baibordy[a], Alireza Bafandeh Zendeh[b,*], Samad Aali[b]

[a] *Department of Public Administration, Tabriz Branch, Islamic Azad University, Tabriz, Iran*

[b] *Department of Industrial Management, Tabriz Branch, Islamic Azad University, Tabriz, Iran*

(Communicated by Javad Vahidi)

Abstract

The present study aimed to model and present a model of human resource productivity with a system dynamics approach in the health sector of East Azerbaijan province using a systemic approach. The research method was developmental in terms of purpose and had a qualitative approach. The questionnaires and open interviews with experts in addition to the literature review were used to collect data. Data were analyzed according to the systems dynamics approach by drawing cause and effect loops, and flow diagrams in Vensim DSS software, and thus the system behavior and the impact of different policies on it were tested. In the present research, the important factors in calculating the human resource productivity included the labor number in the organization, education and especially in-service education, the existence of appropriate geographical coverage of health facilities in the province, and staff research activities. After creating a stock and flow diagram and determining quantitative and mathematical relationships for variables with the help of experts in the health sector, the human resource productivity model was first tested and validated in terms of overall structure and relationships between components. Finally, the model was simulated to examine the dynamics hypothesis, and scenarios were presented for improving the level of human resource productivity in the health sector compared to the current status.

Keywords: productivity, human resource productivity, health, dynamic system
2020 MSC: 92D25, 37A50

1 Introduction

The health sector is an important service sector and an index of social development and welfare; hence, the economic recognition of this sector is extremely important. Health systems are large sectors of the world economy. Global healthcare costs account for approximately 8% of gross domestic product (GDP). The rapidly rising costs of healthcare have challenged economists, managers, physicians, and nurses worldwide to find new ways to limit costs and increase efficiency.

Iran's 2025 Perspective Document emphasizes the first place among the countries in terms of various issues one of which is health. The issue of government spending efficiency in the health sector is extremely important and its slightest change will have a significant impact on economic variables [19].

*Corresponding author
Email addresses: l.baibordy@yahoo.com (Leila Baibordy), a.b.zendeh@gmail.com (Alireza Bafandeh Zendeh), samad.aali@iaut.ac.ir (Samad Aali)

Received: November 2021 *Accepted:* February 2022

The importance of quality of health services in recent years has caused healthcare managers to pay attention to the improvement of the quality of health services. In many countries, regardless of their size or wealth, there are major concerns about healthcare and the way of providing effective and cost-effective healthcare through resources. Evaluation of these services is also a necessity for all health service managers. Furthermore, increasing costs and inefficiency have become important concerns for financiers in the health sector. Therefore, the collective interest in determining effective services and improving existing approaches to managing and providing healthcare has been strengthened [2]. Undoubtedly, purposive and integrated productivity movement in achieving the goals, and thus, decision-making for the future movements of the organization can be considered as the most important solution for organizations that in turn creates a competitive advantage for organizations.

Human resources are the most important resources by which the managers can strive to achieve the organizational goals. Effective manpower is the main factor in the continuation of success and achievement of organizational goals [14]. Paying attention to human resources as the basis of production and service delivery in organizations is a basic strategy for increasing the efficiency and productivity of organizations [4]. Human resources in all fields such as selection, employment, retention of human resources, and generally, human resource management, affect foresight, organizational innovation, and development. New ideas and radical changes, which have arisen in the field of human resource management, have been slowly and easily accepted and paved the way for the higher utilization of the specialized capacity of employees without facing resistance [5].

Given the limited and expensive resources, and the need to reduce costs to have the necessary power in a competitive market, productivity has been the main concern of management in recent decades, and it has practically affected the survival of organizations. Therefore, improving productivity plays an important role in helping organizations [1].

Furthermore, models and patterns have been often designed and developed for organizations and industrial sectors of Iran that are not suitable for the health and medical sectors. Therefore, making efforts to improve human resource productivity is a priority of the health sector. Accordingly, detecting the factors affecting the improvement of human resource productivity, and then strengthening these factors can be a small step in this regard to provide a basis for human resource managers' decisions about human resource planning and maintenance, and reduce costs of employee turnover.
The productivity and its improvement in the health sector double the importance of this issue due to its unique features, including severe resource constraints, the need of all people for health services, the lack of economic thinking, the need for human thinking in providing services, and expensive equipment [22] but the way by which the manpower is productive or increase productivity is a question that has various answers in different institutions and organizations according to their mission and the employees' needs. Even though these needs and factors may be similar, their intensity and priority of impact on employee productivity are not certainly the same [17].

There are studies in this field. Junbok Lee et al. (2017) conducted a study titled "The method of measuring human resource productivity for a structural framework". Farnad Nasirzadeh et al. [15] conducted a study titled "Dynamic Modeling of Labor Productivity in Construction Projects" based on the system dynamics approach for labor productivity. Vladimir Bures [3] conducted a study titled "Labor Productivity and its Opportunities through the Expansion of Knowledge Management Aspects" and discussed manpower productivity and its relationship with the knowledge-based movement in today's society. Mohed Sahar Sauian [20] conducted a study titled "Labor Productivity in service sectors of Malaysia". Furthermore, Ibrahim Mahamid [10] conducted a study titled "The determinants of staff productivity in governmental construction projects in Saudi Arabia from the perspective of contractors".

Despite the high volume of resources allocated to the health sector, there is a gap between the growth of available resources and the resources needed by the health sector, highlighting the need for effective use of resources. Poor management wastes resources such as money, manpower, buildings, and equipment. Such a waste means that a certain share of services (outputs) can be obtained by spending fewer resources. The prevention of the loss of financial and human resources can provide better, high-quality, and cost-effective services [7]. The costs of health system operations and the inefficiency of health systems raise questions about the way of consuming resources by domains. When issues related to the provision of capital and manpower are combined with the lack of full utilization of existing tools and equipment, which is due to the work and administrative tradition methods, in developing or underdeveloped countries, the level of efficiency or productivity is suspended and a kind of waste in capital and manpower raises at the same time as scarcity; hence, studies must be conducted to reflect the current status and provide solutions to improve the efficiency and productivity of health systems in this group of countries [18].

In a developing country like Iran, the problem of unemployment cannot be solved without improving productivity. To improve productivity, waste in any form, such as waste in materials, machinery, time, human resources, and other forms, as well as processes, which do not create value-added, must be detected and eliminated. Given that better working status cannot be provided for active people without optimal use of modern facilities, equipment, abilities, skills, experience, expertise, science, and knowledge of human resources, productivity aims to maximize the use of human resources, capital, time, and other available resources in a completely practical way, and also reducing costs to expand the market, increase employment, and try to increase the real wages of individuals to facilitate achievement of the above-mentioned goals and find the desired position for management (Hosseini, 2011).

To model the human resource productivity in the health sector using a dynamic system in the present research, we sought to provide the basis for the development of human resources by managers and policy-makers.

Methods

The research method was developmental in terms of purpose and had a mixed-methods approach. The research method was exploratory and used the systematic approach and causal loops. The human resource productivity system and its basic factors were considered as its subsystems as a whole, and its components were examined in this whole. Furthermore, it examined the interaction between the components and also the interaction of the components and the environment. It counted the effective factors and their mechanisms of action by causal loops.

The statistical population and sample in the creation of the system dynamics model included the healthcare system of East Azerbaijan province. The statistical population consisted of all experts who had knowledge about the human resources productivity in the health sector. They might include managers and heads of public and private hospitals, managers of nursing services, and head nurses of wards. Therefore, the sampling method was purposive. Among the research population, 20 managers and experts in human resources and productivity were selected as an expert panel to conduct interviews and answer questions at various stages, especially to create a dynamics model. The indices for determining the experts were as follows:

1) Having a Ph.D. and at least 3 years of executive experience in the health sector
2) Familiar with productivity and human resource productivity issues
3) Interested in participating in interviews about the present study

In the meta-synthesis part of the present study, all dimensions, components, and indices extracted from the studies were first considered as codes, and then the codes were examined and classified into a similar concept considering the meaning of each code. Therefore, the concepts (themes) of the research were formed and the concepts were classified in a more general category called dimensions [12]. This step was performed using Maxqda 2021 software, and the results were presented in tables and figures related to the structures obtained from the meta-synthesis.

In system dynamics modeling, the initial causal models extracted from the comprehensive literature review and research background were presented after expressing the dynamic hypothesis in the system conceptualization step, and finally, the results of interviews and the final causal model were presented. At the formulation stage, the stock and flow diagram model was created based on the causal diagram, and then the model was formulated based on the documents, level, rate, and covariate variables. After validation, the model was simulated using the "Vensim" software.

To create a dynamics model of human resource productivity in the health sector in accordance with the common approach of Sterman [23] for the methodology of system dynamics, the process of system dynamics modeling included five stages that were fully interacting with each other.

Given the changes in healthcare systems and limitations in obtaining some information about the past of some variables, the time horizon was set from 2011 to 2031. Therefore, the time steps of the annual model and the 11-year horizon, which had a look at the status of the variables in the last 10 years, were selected.

Formulation of the simulation model and creation of the stock and flow diagram

Human resources are the most important input resources, and thus, human resource productivity is widely used to measure total productivity. Furthermore, human resource productivity is a close substitute for overall productivity and an important economic and social index. Equation (1.1) presents the method of calculating human resource productivity in a simple mathematical model.

$$\text{Human resource productivity} = \frac{\text{Total Output (TO)}}{\text{Labor Number (LN)}} \tag{1.1}$$

Equation (1.1) presents a very simple form of calculating human resource productivity in which only quantifiable variables are presented in a simple model.

Given the importance of training, the per capita training rate (training productivity) is obtained from the ratio of the number of training hours (TH) during the specified period to the Labor Number (LN) according to the following equation.

$$\text{Per capita education rate (education productivity)} = \frac{\text{number of training hours (TH)}}{\text{Labor Number (LN)}} \tag{1.2}$$

This ratio indicates the rate of training provided (as an index) to improve the quality of the labor. A high per capita training rate indicates the management's attention to the development and improvement of labor quality, and conversely, a low per capita training rate indicates the lack of proper performance of the organization in terms of continuous improvement of labor quality.

According to the above trend, this research modeled the human resource productivity with a system dynamics approach in the healthcare sector by creating stock and flow structures and defining logical mathematical equations about each variable with respect to the causal relationships between each variable of the model (as it was tried to show in causal-loop diagrams to some extent). The following figure shows the stock and flow diagram for this issue. Given that statistical data were entered directly in the model, the system dynamics software of Vensim DSS was used instead of the usual version of PLE to create the stock and flow model.

Model review and validation

After forming a stock and flow diagram and determining quantitative and mathematical relationships of variables with the help of experts in the health sector in the present research, the human resource productivity model was first tested and validated in terms of overall structure and relationships between the components.

For investigating the relationships and outputs of primary models to the expert group, the content review approach of the primary model was examined by six senior experts and professionals active in the field of health in the province to prevent one-sided researcher bias in modeling as much as possible and make changes in the relationships between the components of the model and the mathematical relationships between the variables. To this end, the initial stock and flow model with relevant appendices, including outputs in the form of figures and statistical tables for the estimation of each endogenous variable in the stock and flow was sent to the experts to review and explain, and their comments (in general) about the structure of the model, equations, and mathematical modeling were asked. Their views on the completion of the model were applied and the final structure of the models was approved. After ensuring the validity of the model structure to an acceptable level and resolving its problems in accordance with the respected experts' views, the model was finalized in three rounds and the final relationships between the variables were formed.

In this regard, the answers of the corresponding experts were scored separately for each question and were placed in the following equation. The judgment was also made about the quality of the structure validity evaluation in the model formation. The quorum was considered in the structure validity evaluation in the model formation based on research by Heidari Chroudeh [8] and Taghizadeh [24].

Sensitivity analysis of the model

Validation in the dynamic systems approach emphasizes more on data behavior over time, indicating the accuracy of the relationship between the structure and the behavior [11]. Sensitivity analysis is a management tool that helps to determine the effects of different values of the independent variable(s) in one or more intervals on one or more dependent variables. When the implementation of the sensitivity analysis process is properly designed, it provides a valuable tool for the model evaluation because it may provide information about the integrity and robustness of model predictions and outputs. This information can help improve the credibility of the model. Furthermore, sensitivity analysis can be useful in the process of interpreting model results. To perform sensitivity analyses in the DSS version of Vensim, the primary data entry method was selected as RANDOM_TRIANGULAR from the relevant menu, and the exogenous variables were entered into the analysis process in groups and individually in detail to obtain the sensitivity analysis outputs. The number of simulations in each period is set to 500 and the numerical value of the Noise seed is set to the amount set by the software.

In the equation, N is the number of experts and i is the score of experts in the conceptual structure test of the model.

Differential approach to dynamic systems

In most text books, the horizontal mass-springer-damper system (Figure 1) is introduced as conforming to the following second-order linear ordinary differential equation:

$$m\frac{d^2\overrightarrow{x}(t)}{dt^2}+b\frac{d\overrightarrow{x}(t)}{dt}+k\overrightarrow{x}(t)=\overrightarrow{F}(t)\quad [N] \tag{1.3}$$

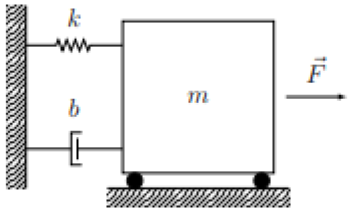

Figure 1: Elements of mass-springer-damper system

The first part relates to the force $\overrightarrow{F}_m = m\overrightarrow{a}$ involved with the mass according to Newton's Second Law, the second part relates to the damping force $\overrightarrow{F}_b = b\overrightarrow{v}$ and the last part to the spring force $\overrightarrow{F}_k = k\overrightarrow{x}$ according to Hooke's Law. To (numerically) solve this differential equation, the second-order ordinary differential equation in $[N]$ needs to be rewritten as a system of two first-order linear ordinary differential equations. For this the variables u_1 and u_2 are introduced:

$$u_1(t)=\frac{d\overrightarrow{x}(t)}{dt}\quad [\frac{m}{s}]$$
$$u_2(t)=\overrightarrow{x}(t)\quad [m]$$

As can be seen, u_1 relates to the *velocity* of the mass-springer-damper system and u_2 to its *position*. With this transformation, the mass-springer-damper system $\mathcal{S}$ can mathematically be formulated as:

$$\mathcal{S}:\begin{cases}\dfrac{du_1(t)}{dt}=\dfrac{1}{m}\overrightarrow{F}(t)-\dfrac{b}{m}\dfrac{dx(t)}{dt}-\dfrac{k}{m}\overrightarrow{x}(t) & [\,\frac{m}{s^2}\,] \quad (1.4)\\ \dfrac{du_2(t)}{dt}=u_1(t) & [\,\frac{m}{s}\,] \quad (1.5)\end{cases}$$

Equation (1.4) relates to the *acceleration* of the mass-spring-damper system and (1.5) to its *velocity*. For the numerical integration of this continuous time (dt) system of differential equations, each equation needs to be formulated as a discrete time (Δt) first-order difference equation:

$$\mathcal{S}:\begin{cases}u_1(t+1)=u_1(t)+\Big(\dfrac{1}{m}\overrightarrow{F}(t)-\dfrac{b}{m}\overrightarrow{v}(t)-\dfrac{k}{m}\overrightarrow{x}(t)\Big)\Delta t & [\frac{m}{s}] \quad (1.6)\\ u_2(t+1)=u_2(t)+u_1(t)\Delta t & [\mathrm{m}] \quad (1.7)\end{cases}$$

As can be seen, equation (1.6) has $\left[\frac{m}{s}\right]$ as units, i.e. this difference equation relates to the *velocity* of the mass-springer-damper system. Likewise, difference equation (1.7), with units in $[m]$, relates to the *position* of the system. Note that in (1.6), the derivative $\frac{d\overrightarrow{x}}{dt}$ that appears in (1.4) is reformulated as the velocity $\overrightarrow{v}$. During the transformation from the differential equations to difference equations, mathematical integration has taken place. This is indicated by the change in units of the equations. Apparently, the difference equations are not so much discrete differential equations but rather discrete integral equations. Consequently, it can be concluded that the derivatives used as input to the modeling process, have become integrations at the output. This inconsistency can be taken as a sign for the fact that differentiation is something that does not really take place in nature but is a construction of the modeler. The price to pay for the modeler, from a calculus point of view, is a mathematical formulation that is the complete opposite of the mathematical from used at the beginning.

Hidden accumulations

From the previous section, it become apparent that the mathematical description of the behaviour of mechanical systems inevitably involves integration, i.e. during the modeling process, the derivatives at the input transform into integrations at the output, irrespective if the solutions are analytically or numerically obtained. This implies that the derivatives used at the input hide mathematical integrations in the from of physical accumulations, lest the modeling of mechanical systems can be done consistently. The first dynamic mechanical element to be considered in this respect, is a mass m. Newton's Second Law describes the way force $\overrightarrow{F}$, mass m and acceleration $\overrightarrow{a}$ are related:

$$\overrightarrow{F}(t) = m\overrightarrow{a}(t) = m\frac{d^2\overrightarrow{x}(t)}{dt^2} = m\frac{d\overrightarrow{v}(t)}{dt} \quad [N] \tag{1.8}$$

Solving (1.8) for velocity $\overrightarrow{v}$ leads to:

$$\begin{aligned} \overrightarrow{F} &= m\frac{d\overrightarrow{v}}{dt} \Longleftrightarrow \\ \overrightarrow{F}dt &= md\overrightarrow{v} \Longleftrightarrow \\ \int \overrightarrow{F}dt &= m\int d\overrightarrow{v} \Longleftrightarrow \\ \int \overrightarrow{F}dt &= m\overrightarrow{v} \end{aligned}$$

The product $m\overrightarrow{v}$ is the momentum $\overrightarrow{p}$ of the mass m and is the time integral of the exerted force $\overrightarrow{F}$ upon the mass system:

$$\overrightarrow{p}(t) = \int \overrightarrow{F}(t)dt \quad [Ns] \tag{1.9}$$

Equation (1.9) describes the process of a mass m that accumulates the force $\overrightarrow{F}$ exerted upon it throughout time in the from of momentum $\overrightarrow{p}$. The momentum $\overrightarrow{p}$ and mass m are inversely proportional related to each other with respect to the velocity $\overrightarrow{v}$:

$$\overrightarrow{v}(t) = \frac{\overrightarrow{p}(t)}{m} \quad [\frac{m}{s}] \tag{1.10}$$

Based upon (1.9) and (1.10) a mass system can dynamically be defined by its momentum state variable $\overrightarrow{p}$, input $\overrightarrow{F}$ and output $\overrightarrow{v}$.
The second dynamic mechanical element to be considered from an accumulation point of view, is a spring k. Hook's Law describes the linear relationship between the displacement $\overrightarrow{x}$ of a spring and the spring constant k in terms of the spring force $\overrightarrow{F}$:

$$\overrightarrow{F}(t) = k\overrightarrow{x}(t) \quad [N] \tag{1.11}$$

Just as Newton's Second Law, Hook's Law hides an accumulation that can be found by rewriting the displacement $\overrightarrow{x}$ as velocity $\overrightarrow{v}$:

$$\overrightarrow{x}(t) = \int \overrightarrow{v}dt \quad [m] \tag{1.12}$$

Equation (1.12) indicates that the input to a spring system is a velocity $\overrightarrow{v}$ across the spring. The spring k accumulates the velocity $\overrightarrow{v}$ across itself throughout time in the form of a displacement $\overrightarrow{x}$, the state variable of the spring system. By means of Hook's Law (1.11) the resulting spring force $\overrightarrow{F}$ can be determined as the output of the spring system.

Note that masses and springs between reciprocally; i.e. the input to a mass is a force $\overrightarrow{F}$ and the output is a velocity $\overrightarrow{v}$, whereas the input to a spring is a velocity $\overrightarrow{v}$ and the output is a force $\overrightarrow{F}$. Both masses and spring are *dynamic* system elements in the sense that their behaviour is dependent on time. Consequently, any change in the state of theses system elements involves inertia, i.e. the increase or decrease of accumulation takes time.

Results

Determining the model boundary (key variables)

In the system dynamics model, the model boundary diagram is used to classify the variables in the model. In this diagram, the main variables are collected from data and information related to the research topic and population, previous research, interviews with experts, books, and other articles of the researchers, and the meta-synthesis method extracted in the previous step. Table 1 presents the boundary diagram of the problem model in the present study.

Table 1: A model boundary in the research problem

Endogenous variables	**Exogenous variables**
1. Human resource productivity	1. The rate of training hours for health workers (person/hour) in a period
2. Number of published research articles (in a period)	2. The ratio of the gap in health facilities and services
3. Number of research and development projects in the health sector (in a certain period)	3. The level of facilities related to in-service training of employees
4. Level of applied skills in human resources	4. The level of health services, facilities, and facilities provided for the public compared to the expected status
5. Educational productivity of health staff (excluding physicians)	5. Annual recruitment rate of health sector employees
6. Educational productivity of administrative staff	6. Number of active employees in the health system
7. Physicians' educational productivity	7 . Index of access to health services
8. Educational productivity of all employees	8. Rate of access to skilled human resources
9. The level of public satisfaction with the healthcare system services in the province	9. Excess demand for health services
10. Intra-organizational research projects compared to the total number of research projects	10. Level of access to excess services
11. Level of staff motivation in the organization	
12. Service access level	
13. Recruitment index in the healthcare system (service demand)	
14. Research and development outputs and innovative, pragmatic, and operational projects	
15. Rate of presentation of innovative and pragmatic projects	
16. Research and development productivity	
17. Published scientific-research articles	
18. Number of skilled administrative staff in the healthcare system	
19. Number of skilled and experienced physicians in the healthcare system	
20. Number of skilled and experienced health workers (excluding physicians) in the healthcare system	
21. Working pressure on staff in the healthcare system	
22. The ratio of physicians to other health workers	

Subsystem diagram

The results of the meta-synthesis approach from the previous step of the research indicated that the main components affecting the human resource productivity in the health sector included organizational and managerial factors, factors related to planning and directing staff performance, knowledge, environmental, technological, and psychological, and motivating factors related to strengthening the sense of belonging, commitment, and loyalty in employees, as shown in Figure 2.

Causal loop diagram (CLD)

The following questions are examined in reviewing and evaluating the validity of the causal loop model structure: "1- Is the model structure compatible with the rules, procedures, facts, and decision-making process in the human resource management of the health system of the province?" and "2- Can the whole and components of the proposed model be considered to evaluate the human resource productivity in the healthcare system of the province?". The content review of the initial model by 6 active health experts in the province was utilized to investigate the questions to prevent the one-sided bias of the researcher in modeling as much as possible and apply changes requested by them in the relationships between the components of the model to review and provide appropriate answers to the above questions. To this end, the initial causal loop model prepared by the researcher was sent to each of the experts for

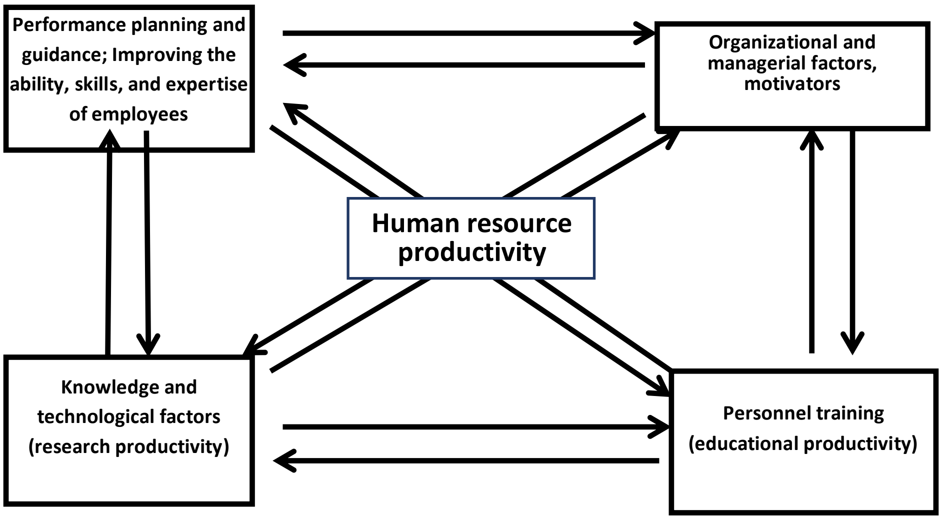

Figure 2: Diagram of human resource productivity subsystem Source: Summary of the output of meta-synthesis findings

review and explanation and their opinions were asked. Then, their views on completing the model were applied and the final structure of the model was approved by them. After ensuring the validity of the model structure to an acceptable level and fixing its problems in accordance with the respected experts' views, the model was finalized and the relationships between the relevant variables and loops were formed. Figure 3 shows the causal loop diagram of human resource productivity in the health sector of East Azerbaijan province.

The causal loop diagrams determine the relationship between all variables identified in the problem. These diagrams detail the relationship between the variables and they consist of loops and subsystems. Each loop and main and sub-systems of the human resource productivity model in the health sector are described as follows.

The loops in the causal loop diagram have two types: the reinforcing loops represented by the symbol R, and the balance rings with the symbol B. Since all loops are not visible in a diagram, they are shown in separate diagrams for better clarity and understanding of the reader.

Stock modeling

At this stage, the stock and flow diagram was first formed by the researcher and the coefficients of some variables were determined using the experts' opinions on the healthcare system. After 14 re-examinations and minor and general revisions, the model was formed as shown in Figure 4.

Figure 4 of the stock and flow diagram for the research problem shows that for entering some problem data such as longitudinal data related to the number of employees, in-service training hours of employees, levels of health and medical services provided compared to expected services and levels of expected facilities in accordance with the upstream documents in the Sixth National Development Plan, they are included in the model as a lookup and not simulated in accordance with the common approach through common methods such as linear regression estimates. It is because of the non-linearity of the growth and decline of data over time, and consequently, the high value of the estimation error of the allowable value (even if the data is homogenized by obtaining Ln, etc.) to ensure the likelihood of the simulation of dynamic system models. Despite this and the limitations in forming a mathematical equation for variables of the lookup type, the model can predict the trend of change in the variables by relying on the input of original data and estimating values for the future through statistical predictions using time series. The Appendix section presents the additional information on time series estimation for the data.

Model structure and boundary adequacy tests

According to the findings of the final round and the adapted evaluation table from Heidari Chroudeh [8] and Taghizadeh [24] in evaluating the content validity and the general structure of the model, and the mathematical and

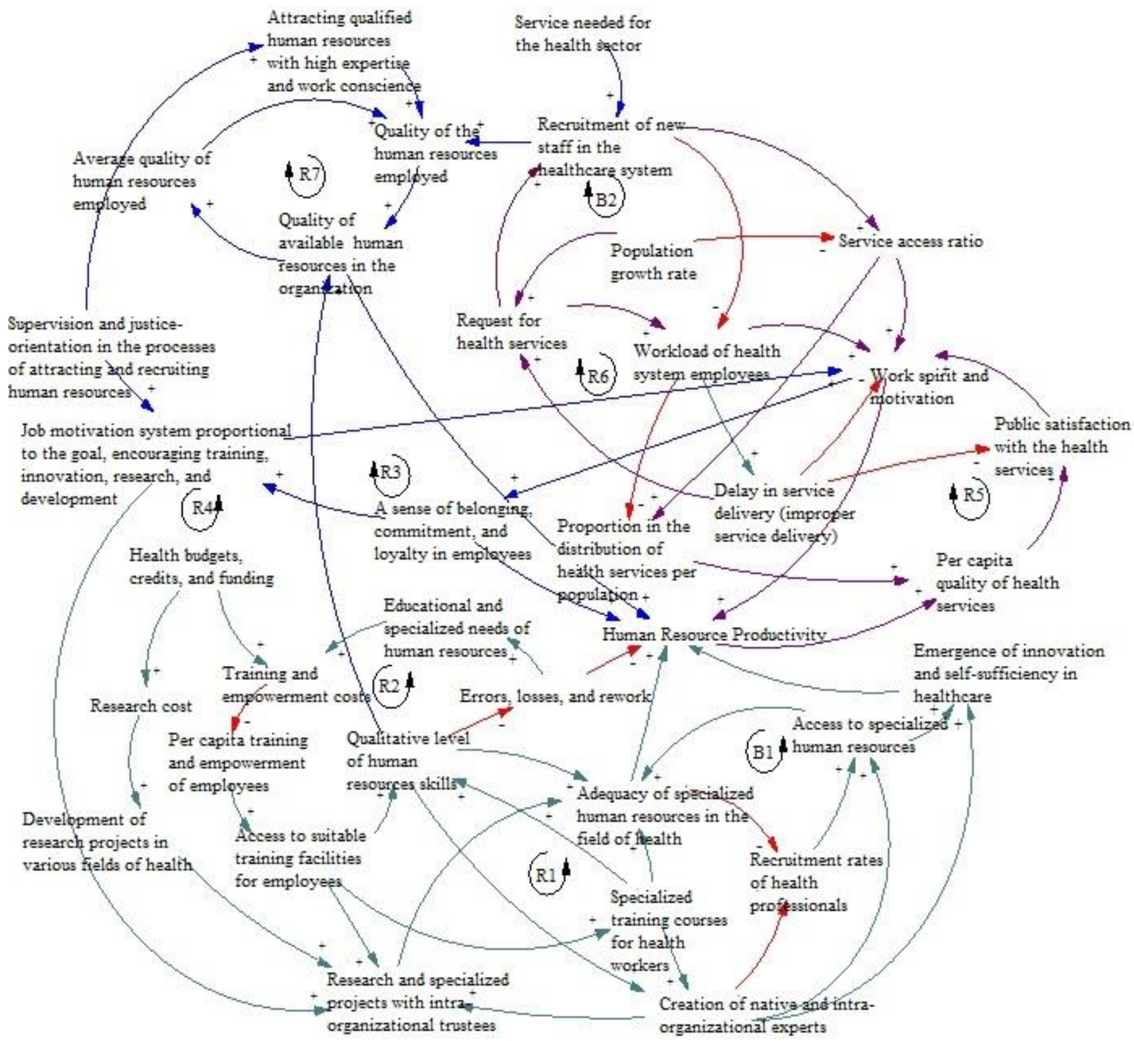

Figure 3: Causal loop diagram of human resource productivity in the health sector

logical relationships between its variables, and according to the final round findings in the table 2, the validity of the model was at an optimal to very optimal level from a structural point of view in the third round after revision based on the opinions of experts. Furthermore, the boundary adequacy of the model was optimal. Since there was no specific case raised by experts for review in the third round, the process of reviewing and modifying the structure of the model stopped in the third round.

Table 2: Results of scores of the evaluation rounds of the conceptual structure of the model

Conceptual structure test questions	SA_{Index}		
	First round	Second round	Third round
1	66.67	75	75
2	66.67	83.33	91.67
3	75	92	91.67
4	66.67	75	75

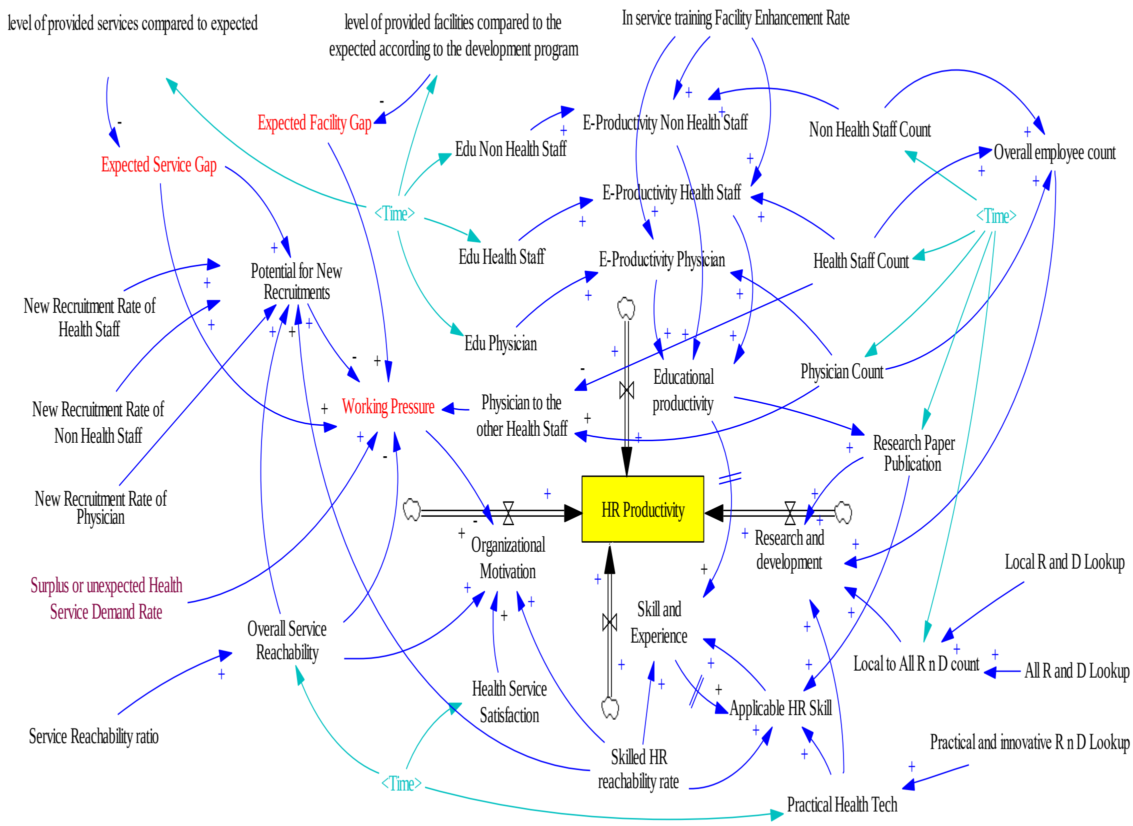

Figure 4: Stock and flow diagram

Sensitivity analysis results

Figure 5a shows the process of changes in human resource productivity by considering the sensitivity of data related to the recruitment of new employees within the framework and range defined in the model. According to the figure, the range of changes in the first years of the simulation was very limited and became more open over time, indicating that the low and high limits of recruitment of new staff affected the HR productivity index in the tolerance range of about 18 units over time (from 2011 to 2031). The changes related to human resource productivity in the sensitivity analysis of staff recruitment were less volatile but the degree of uncertainty with a high percentage (100%) increased over time. Even though changes in human resource productivity were visible, the changes were less sensitive in the range of their changes in terms of recruiting new staff.
In summary, the sensitivity analysis of changes in recruiting new staff indicated that the outputs related to endogenous indices for modeling human resource productivity were relatively appropriate.

Figure 5b shows the range of longitudinal changes in the level of human resource motivation by considering the sensitivity analysis process of access to specialized human resources according to the $s2$ sensitivity analysis settings. According to the figure and the level of sensitivity in human resource motivation according to the $s2$ sensitivity analysis settings, which showed changes in reasonable frameworks, the level of motivation was increasing slowly and with a very gentle slope, and the distribution of uncertainty levels was balanced over time.
Figure 5c shows the process of changes in the essential and functional skills of human resources according to the $s2$ sensitivity analysis settings. According to the uncertainty ranges of the outputs, and the interval of changes in the uncertainty quartiles [0 and 108] and the interval in the $s1$ [0 and 6000], the uncertainty quartiles in the above two cases indicate the existence of more areas within the second quartile of the uncertainty levels in $s2$ compared to $s1$.

Figure 5d shows the level of sensitivity of changes in human resource productivity by considering the rates of facilities that can be provided for in-service training of employees over time. According to this figure, the levels of uncertainty increased for estimating the variable over time.
Finally, Figure 5e shows the process of publishing scientific and research articles and the implementation of sensitivity analysis of dynamic modeling. According to the figure, the passage of time decreases the levels of uncertainty for esti-

mating the variable. It is consistent with the nature of the processes of science production, research, and dissemination of scientific works in the real world.

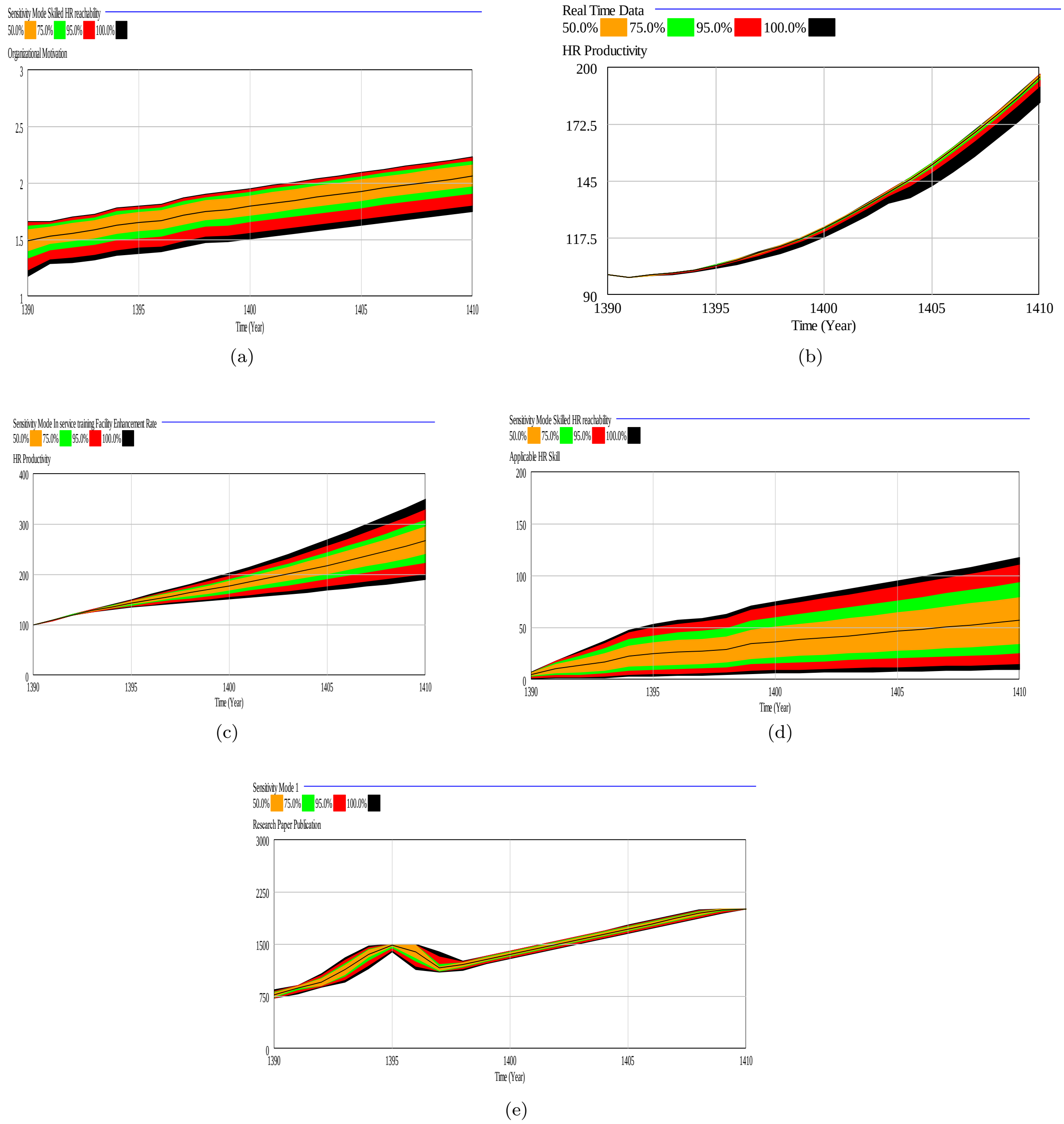

Figure 5: a) Changes in human resource productivity, b) Changes in human resource motivation by considering the process of sensitivity analysis of access to specialized human resources according to the settings of sensitivity analysis s2, c) Process of changes in the essential and functional skills of human resources according to the settings applied for sensitivity analysis with s2 values, d) Sensitivity of changes in human resource productivity by considering the number of facilities that can be provided for in-service staff training, e) The sensitivity of the variable of publishing scientific and research articles

Dynamics model simulation findings (scenario design)

The final step in examining the dynamics of the problem is to simulate the model to test the dynamic hypothesis and provide scenarios for improving the level of human resource productivity in the health sector compared to the current status. The analysis and presentation of related policies and strategies are presented in the “results” section. Therefore, the behaviors related to the system variables in the form of “the continuation of the current status” scenario are studied by implementing the model with the basic parameters of the system. Therefore, the simulation findings of the dynamics model are presented without applying the usual changes to form scenarios in the continuation of the current status in the form of the first scenario. The changes in the variables are applied based on the capacities of the system and subsequent scenarios are formed.

Scenario 1: Continuation of the current status

Figure 6 shows the dynamic problem simulation output findings in the continuation of the current status for rate variables (training productivity, research productivity, skill, experience, and organizational motivation).

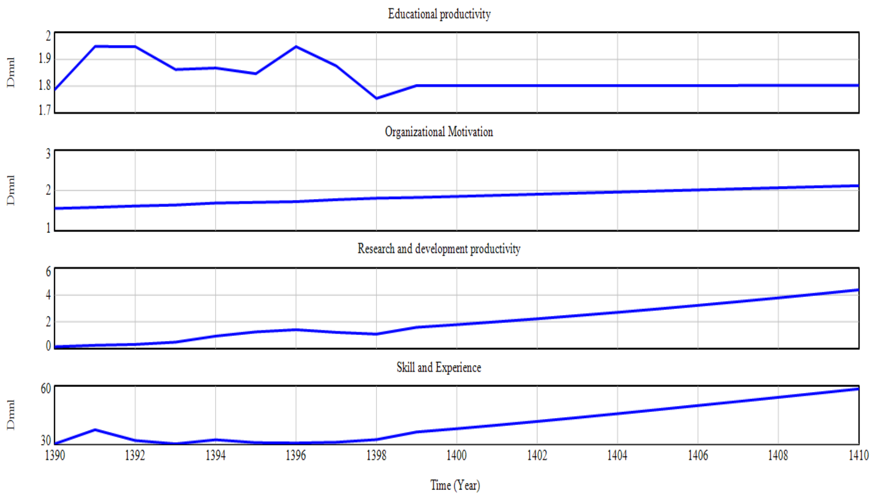

Figure 6: Dynamic problem simulation output findings for rate variables

Scenario 2: Improving the recruitment rate of active human resources in the health sector (separately)

The promotion of the recruitment rate of active human resources in the health sector (separately) was examined and evaluated in the first scenario. Due to the acceptable capacities in the system, the rate of human resources recruitment increased by 8% to 20% respectively for physicians, other health workers, and administrative staff according to experts. It was estimated at the geometric mean annual growth rates for HR employment over the past 10 years for each row of operations, ranging from 0.039972 to 0.043522 for physicians, 0.00945 to 0.01142 for other health workers, and 0.024633 to 0.026587 for administrative staff.

Comparing the human resource productivity with changes applied in Scenario 2 with the reference data (Scenario 1) in Figure 7 indicates that the amount of the index in the reference mode was 352.778 which reached 382.012 in 2031. It shows a growth of about 30 units in human resource productivity by applying changes associated with Scenario 2 to the reference state.

Scenario 3: Improving the facilities related to the empowerment of health sector staff

The promotion of the expertise and experience level along with the improvement of physical facilities of the healthcare system related to the quality of in-service training to properly deal with health problems and issues were the subject of scenario 3. It was possible by providing related facilities along with allocating heavy costs for the organization. In this regard, the empowerment of staff specialized in the field of health through the promotion of human resource training facilities and equipment related to human resource empowerment and training was studied in scenario 2. To study the empowerment scenario of specialized personnel in the field of health, we examined the promotion of in-service training facility enhancement rate to 0.2. It meant that 20% was added to the facilities

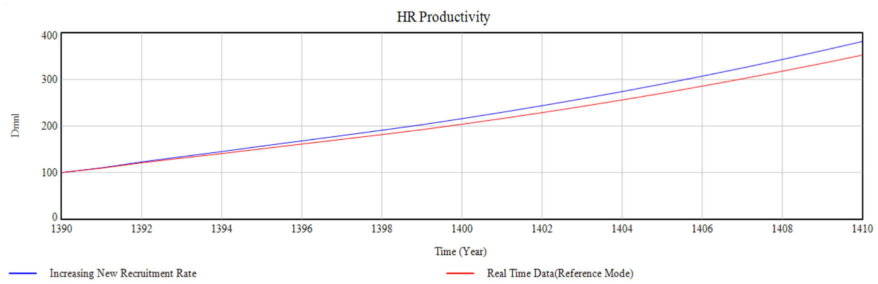

Figure 7: Comparison of human resource productivity with changes applied in Scenario 2 with reference data (Scenario 1)

predicted and allocated from 2021 to 2031 in the simulation of this scenario to improve the capacity and empowerment of healthcare system staff. Therefore, the promotion of Edu Health Staff from 5246 to 5800 and the promotion of Edu Physician from 10432 to 10800 were the most important consequences of this change.

Figure 8 shows the impact of implementing Scenario 3 on improving human resource productivity. Accordingly, the human resource productivity index in the final year (2031) from 352 to 425.7 had an increase of about 74 units.

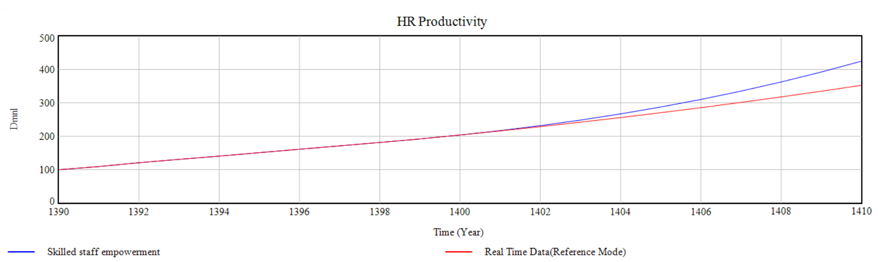

Figure 8: Impact of scenario 3 implementation on improving human resource productivity

Scenario 4: Improving in-service training hours for employees: 20% increase in training hours for active human resources in the field of health in the province (Edu Time)

Given the current capacities of in-service training in accordance with the health documents of the province and the available facilities in terms of educational space and available professors and according to the expert group, a maximum of 20% can be added to the predicted in-service training capacities during the next 10 years. Therefore, the present scenario is simulated in an acceptable and practical framework for the organization in the province. Increasing the training hours of human resources by 20% means that the training hours of physicians reached from 8652 to 10383, the training hours of health workers (other than physicians) from 3904 to 4685, and the training hours of administrative staff from 1352 to 1622 in the target year (2031). Therefore, Figure 9 shows changes made before and after the promotion of human resource training hours by 20% more than expected in the scenario (Edu Time) for different categories of healthcare workers based on the items mentioned in the current paragraph and in the upcoming period (2021-2031).

Figure 10 shows the rate of change in human resource productivity based on the application of a 20% improvement in in-service training hours based on Scenario 4. Accordingly, the amount of human resource productivity index in the final year (2031) from 352 to 361 shows a slight increase of 9 units.

Conclusion

The present study titled "Modeling human resource productivity with a system dynamics approach in the health sector of East Azerbaijan province" detected the most important variables in a system model for the human resource productivity in the health sector. In the continuation of the analysis process of the present study, the factors extracted from the previous approach were designed and analyzed by the system dynamics model using Vensim DSS 6 software.

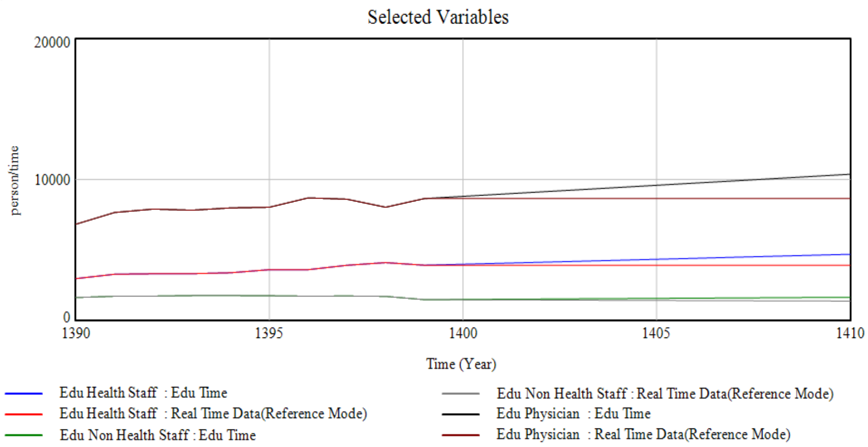

Figure 9: Changes before and after the promotion of human resources training hours by 20% more than expected, for different categories of healthcare workers

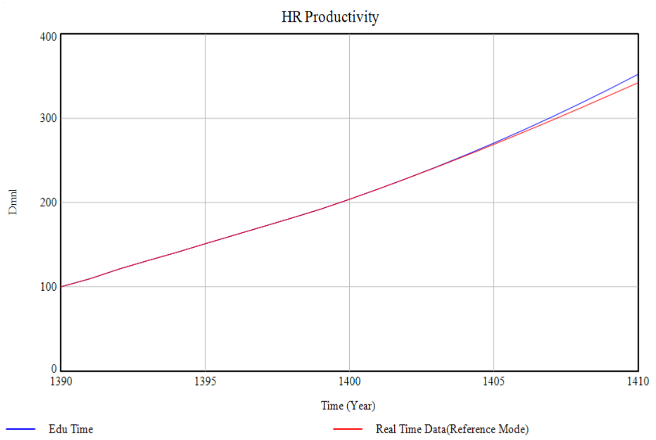

Figure 10: Changes in total human resource productivity based on the application of a 20% improvement in in-service training hours based on scenario 4

Therefore, the subsystem diagrams and causal loop models were formed as conceptual and qualitative models before finalizing the dynamics model, and the conceptual framework of the model was drawn through them. The simulation model was formulated and the stock and flow diagram was formed by creating an initial model. After validation of the model through structural validity tests, model boundary adequacy, sensitivity analysis, and final limit, changes were made in the model and the final model was extracted. In the next step, the stock and flow (rate) diagrams were modeled as dynamo equations and the system behavior was simulated over time. The findings showed that the dynamic model of the present study seemed to be structurally and generally similar to the model resulting from research by Nasirzade [16] who examined the factors affecting human resource productivity with a dynamic system approach. It is worth noting that Nasirzade's model (2020) identified and examined many factors affecting the human resource productivity in the health sector due to its qualitative nature but the process of evaluating human resource productivity was quantitative in the present study. Finally, the findings of simulating the dynamics model were extracted and scenarios for improving human resource productivity were formed. The presented scenarios are summarized as follows:

Scenario 1: Continuation of the current status.

Scenario 2: Improving the recruitment rate of active human resources in the health sector (separately).

Scenario 3: Improving the facilities related to the empowerment of health workers.

Scenario 4: Improving in-service training hours for employees: 20% increase in active human resources training hours in the field of health in the province.

The results of Scenario 1, i.e. the continuation of the current status, indicate that the process of changes in human resource productivity was ascending with a gentle slope for the period of 2021 to 2031 and reached from the reference amount of 100 to 352.778, indicating that the amount was 3.5 times higher in the mentioned period in terms of considering its beginning and end. The improvement of the recruitment rate of active human resources in the health sector by considering the capacities and needs in the second scenario indicated that the level of human resource productivity with the changes applied in comparison with the reference data was improved from 352.778 to 382.012 in 2031, indicating a growth of about 30 units in human resource productivity by making changes related to Scenario 2 compared to the reference state. The improvement and changes in facilities related to the empowerment of health workers in the form of the third scenario indicated that the amount of human resource productivity index increased from 352 to 425.7 and promotion of about 74 units in the final year (2031). Furthermore, the amount of human resource productivity index in the final year (2031) increased from 352 to 361 in the fourth scenario with a slight improvement of 9 units compared to the reference scenario. In summary, scenarios 3, 2, and 4 respectively had the highest changes in the HR productivity index compared to the reference scenario. Scenario 3 proposed the improvement of facilities related to the empowerment of health workers and required higher costs than other scenarios. The improvement of the recruitment rate of new human resources compared to the reference status causes reasonable and tolerable costs for the organization, and it makes this scenario more attractive than the previous scenario of the organization. Finally, scenario 4, i.e. a 20% increase in in-service training hours for active health human resources in the province causes the lowest cost for the organization, and a slight 9-unit increase in human resource productivity puts this scenario at a lower level of attractiveness to policymakers than scenarios 2 and 3.

The findings of the present study were consistent with parts of a study by Javadian et al. [9] who presented a model for human resource productivity, including seven main indices (structural-managerial factors, cultural factors, personal factors, economic factors, environmental factors, factors causing intimacy and cooperation, and socio-psychological factors) and 56 sub-indices. Furthermore, Sharifi et al. [21] presented a conceptual model of human resource productivity for NAJA, and it was very similar and confirmed parts of the meta-analytical model of the present study. Hakkak et al. [6] and Nazarzadeh et al. [17] emphasized social capital to improve human resource productivity and also found findings that were consistent with the present study.

Molaei et al. [13] discussed and compared the findings of meta-analysis with the findings of similar studies using a meta-analysis approach. In a meta-analysis on the factors affecting the human resource productivity in organizations, they collected and reviewed 30 studies on the factors affecting the human resource productivity, and finally selected 17 studies and performed a meta-analysis on them. In terms of the number of studies and scope of analysis and outputs, the findings of the present study were slightly more complete and mature than the study by Molaei et al. [13].

According to the findings obtained for the qualitative section of the research and emphasis on strengthening "factors related to organizational support and the service compensation system", "environmental factors", "cultural and social factors", "managerial factors", and "occupational factors" in improving the level of human resource productivity, we can provide suggestions for human resource managers and policy-makers in the health sector. Accordingly, the suggestions of this research are presented in the following paragraphs:

Organizing systems for detecting and strengthening the competencies and talents of healthcare workers to improve their expertise and job position: to motivate employees and eliminate shortages or lack of work commitment. It is recommended that healthcare decision-makers should make effort to achieve a kind of alignment between the career path system of employees (especially health specialists and physicians) and their individual goals from the perspective of setting a roadmap of activities. To this end, much attention should be paid to the process of allocating activities to the interests and tastes of employees. It is suggested that managers should identify the talents and competencies of employees based on their potentials, and potential interests to assign tasks. It seems very useful to use systems to identify and strengthen the talents of employees (especially active employees in the middle and lower ranks in the health sector).

The establishment and development of human resource competency identification systems: Special emphasis on the competencies, interests, and capacities of individuals in employment can help to remove individual barriers to effectiveness. Therefore, it is necessary to emphasize the individual capacities regardless of their job position and expertise and effectively use their potential competencies in the field of management and staff organization. Therefore, it is necessary to create a system to detect competencies and extract them for each employee in different sectors. In this regard, we can start by collecting records, and scientific and research achievements, and using science for specialist staff and physicians.

Further researchers are suggested to investigate the role of job burnout, work stress, and organizational silence in the quality of health system outputs and human resource activities, as well as the outcome of employee productivity in the organization in the form of a control variable that can provide practical results.

References

[1] M. Almasi, E. Rostami and S. Fattahi, *Mediating effect of correct pattern of consumption on the relationship between factors affecting the human resource productivity*, Organ. Resourc. Manag. Res. **5** (2015), no. 1, 1–23.

[2] M. Alvani and P. Ahmadi, *Design of total pattern of affecting factors on human resource productivity*, J. Modares **5** (2002), no. 1.

[3] V. Bures and A. Stropkova, *Labor productivity and its opportunities through the expansion of knowledge management aspects*, Procedia Soc. Behav. Sci. **109** (2014), 1088–1093.

[4] M. Dieleman, B. Gerretsen and G.J. Van der Wilt, *Human resource management interventions to improve health workers' performance in low and middle-income countries: a realist review*, Health Res. Policy Syst. **7** (2009), no. 1.

[5] S.L. Dolan, S. García, C. Cabezas and and S.S Tzafrir, *Predictors of "quality of work" and "poor health" among primary health-care personnel in Catalonia: Evidence based on cross-sectional, retrospective and longitudinal design*, Int. J. Health Care Qual. Assur. **21** (2008), no. 2, 203–218.

[6] M. Hakkak, M.M. Mofrad and A. Saedi, *The effect of immaculate leadership on human resource productivity: The role of social capital*, J. Prod. Manag. **15** (2021), no. 57, 81–105.

[7] H. Hatami, *The relationship between quality of working life with organizational commitment and productivity of medical sciences staff in Jahrom*, New Approach Educ. Manag. **2** (2011), no. 3, 25–60.

[8] M. Heidari Chroudeh, *Guide to measuring validity and reliability in cultural and social research*, Mashhad University Jihad Publication, First Edition, 2010.

[9] A. Javadian, A. Mehrara and M.R. Bagherzadeh, *Human resource productivity with a structural equation modeling approach in the organization*, Urban Manag. Stud. **12** (2020), no. 42, 71–82.

[10] I. Mahamid, A. Al-Ghnamy and M. Aichouni, *Major factors influencing employee productivity in the KSA public construction projects*, Int. J. Civil Envir. Engin. IJCEE-IJENS **14** (2013), no. 1, 16–20.

[11] Z. Mahmoudi, A. Sayadi and A. Rajabzadeh ghatari, *Provide a dynamic model for evaluating the productivity of the mining workforce (Case study: Chadormelo Mining and Industrial Complex)*, Industrial Management, Faculty of Management, University of Tehran, **8** (2016), no. 2, 287–308.

[12] F. Mehrabian, A.A. Nasiripour, R. Farmanbar and S. Keshavarz Mohammedian, *Determination of manpower productivity promotion factors in terms of faculty members and free-university lecturers of Guilan University of Medical Sciences*, Res. Med. Sci. **3** (2011), no. 2, 58–63.

[13] J. Molaei, M. Bagheri and B. Gholami, *Meta-analysis of factors affecting human resource productivity in the organization*, Sci. Quart. NAJA Human Resourc. **11** (2020), no. 61, 79–102.

[14] A.M. Mosadeghrad, *Strategic collaborative quality management andemployee job satisfaction*, IJHPM **2** (2014), no. 4, 167–174.

[15] F. Nasirzadeh, *Dynamic modeling of labor productivity in construction projects*, Int. J. Project Manag. **31** (2013), no. 6.

[16] A. Nasirzade, S. Eslami and M. Reza Shahali, *Investigating the mediating role of social responsibility in the impact of intellectual capital and cultural capital on human resource productivity (Case study: Isfahan General Directorate of Sports and Youth)*, J. Motor Behav. Sci. **3** (2020), no. 2, 200–207.

[17] M. Nazarzadeh, I. Nikpay and A. Madandar Arani, *A comparative study of quantum management, human resource productivity, and organizational empathy in higher education (Case Study: Lorestan Universities and Lorestan University of Medical Sciences)*, Manag. Educ. Perspec. **3** (2021), no. 1, 109–138.

[18] A. Rezapour, *The economic behavior of generals hospital of Iran university of medical sciences from 1997 to 2004*, J. Shahrekord univ. Med. Sci. **8** (2006), no. 3, 12–14.

[19] M. Sadeghi Fard, S. Sayadi, M. Pourkiani, S. Salajegheh and H. Babaei, *A model for factors involved in human*

resource productivity in the affiliated offices of a government organization, Agricu. Market. Commerc. J. **4** (2020), no. 1, 290–304.

[20] M. Sahar Sauian, N. Kamarudin and R. Mat Rani, *Labor productivity of services in Malaysia: Analysis using input-output approach*, Procedia Soc. Behav. Sci. **7** (2013), 35–41.

[21] M. Sharifi, M.R. Motadel, A. Toloie Eshlaghy and T. Sohrabi, *Presenting a conceptual model of the NAJA human resource management information system productivity*, Resource Manag. Police J. Manag. **36** (2021), no. 2, 31–64.

[22] I. Soltani, *Productivity improvement management cycle in production organizations*, Athir Website, Comprehensive Management Site, 2008.

[23] J. Sterman, *Interactive web-based simulations for strategy and sustainability: The MIT Sloan learningEdge management flight simulators*, Part I and Part II, Syst. Dyn. Rev. **30** (2014), no. 1-2, 89–121.

[24] H. Taghizadeh, *Research method with dissertation structure*, in Persisn, Taymaz Publishing, Tehran, 2017.