Simulation of Performance Evaluation Model for Medical-Elderly Care Integrated Institutions Based on System Dynamics

Yongqiang Shi
South China University of Technology

Fangfang Fan (1398078911@qq.com)
South China University of Technology

Zhiyong Zhang
South China University of Technology

Research Article

Keywords: medical-care integration models, performance evaluation, system dynamics, sensitivity analysis

Posted Date: March 15th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1441341/v1

Simulation of Performance Evaluation Model for Medical-Elderly Care Integrated Institutions Based on System Dynamics

Yongqiang Shi[1], Fangfang Fan[1], Zhiyong Zhang[1]*

[1]Department of Electronic Business, South China University of Technology, No. 382, Waihuan East Road, Xiaoguwei Street, Panyu District, Guangzhou, Guangdong, 511400, PR China

**Corresponding author: 1398078911@qq.com*

Abstract

Background: This paper takes the Chinese medical-elderly care integration model as the background, and aims to quantitatively explore the impact of different investment levels on the performance of the medical-elderly care integrated institutions.

Methods: Using the method of system dynamics, this paper divides the performance evaluation system of the medical-elderly care integrated institutions into three subsystems: input subsystems, output subsystems, and result subsystems, establishes a system dynamics model of performance evaluation for the medical-elderly care integrated institutions. Then set the integrated medical-elderly care service content, human input, material input, and policy support as the key elements, and finally use Vensim PLE software for simulation.

Results: The four key elements have different degrees of improvement in the performance of the medical-elderly care integrated institutions. Among them, the integrated medical-elderly care service content and the human input have the most significant impact on the performance of institutions. The model simulation results show that the system appears emergence phenomenon: the improvement rate of the combined effect of multiple factors is always higher than the sum of the improvement rates of the individual factors.

Conclusion: The integration of service content and resource investment in the combination of medical and elderly care can promote the performance of elderly care institutions effectively. Policy support plays an important role in promoting the development of institutional medical-care integration models. Managers should formulate the development strategy of elderly care institutions from a systematic perspective, and pay attention to the integration of "medical" and "elderly care" resources.

Keywords: medical-care integration models; performance evaluation; system dynamics; sensitivity analysis

Introduction

According to the results of China's seventh census in 2020, China's elderly population aged 60 and above has exceeded 264 million, and the proportion of elderly people is close to 1/5, indicating that China is about to enter a moderately aging society. According to the survey data of the Chinese Centers for Disease Control and Prevention, more than 3/4 of the elderly people are suffering from chronic diseases. Traditional elderly care institutions only provide a single daily care service, which can no longer meet the medical needs of the elderly [1]. The phenomenon of "difficult and expensive medical treatment" in medical institutions is particularly serious among the elderly, and the development of the medical-elderly care integrated institutions has attracted more and more attention from all walks of life.

In 2013, the State Council of the People's Republic of China clarified the development concept of the "Integration of medical care and elderly care". Since then, the medical-elderly care integrated institutions have entered a stage of rapid development. By the end of 2020, more than 90% percent of elderly care institutions in China can provide different forms of medical service for the elderly.

The medical-elderly care integrated institutions play an important role in integrating medical and elderly care resources, improving the happiness and satisfaction of the elderly, and helping the development of healthy aging in China. However, at present, there are still problems of the blind resource investment and low service efficiency in the medical-elderly care integrated institutions [2[3]. In this context, this paper uses the system dynamics method to analyze the performance of the medical-elderly care integrated institutions and quantitatively explores the impact of institutional resource input, policy support, and other factors on the performance level of the institutions, to provide direction for the formulation of relevant policies and the transformation of traditional elderly care institutions.

Performance evaluation of elderly care institutions

The high demand for the integration of medical and elderly care has put forward higher requirements for the service content and service quality of elderly care institutions. The academic community has accumulated some research experience in the service evaluation of elderly care institutions. Guo HY (2013) already pointed out the importance of the institutional evaluation system as early as 2013. By analyzing the characteristics of the American elderly care institutional evaluation system, she believes that an effective way to improve the service quality of the medical-elderly care integrated institutions is to establish a suitable evaluation system [4]. After that, Yin HR (2017) established an index system including two parts: “input” and “output” to evaluate the service capability of urban non-profit elderly care institutions [5]. Wang LJ (2017) pointed out that the development of comprehensive elderly care institutions is an important measure to adapt to aging, and it is necessary to explore the quality assessment methods of elderly care institutions. According to the SERVQUAL method, he established a service evaluation model for elderly care institutions

covering life services, cultural entertainment, medical care, etc. [6]. Zhu L, Yang XJ (2019), etc. combined sampling method and Delphi method, based on the survey results of elderly care stations and community care centers, constructed an evaluation index system for the service quality of community home-based elderly care centers combining medical care and elderly care [7]. Zhang LW (2019) based on three-dimensional theory, made a comprehensive evaluation of Xiamen elderly care institutions, constructed an evaluation index system for institutional service quality according to "structure-process-result", and put forward relevant suggestions for institutional elderly care service standards [8]. Xiao XH, Huang ZM (2019), etc. adopted the expert consultation method and the analytic hierarchy process, and divided the performance evaluation system of the medical-elderly care integrated institutions into three dimensions: system input, service output, and service result. The research results showed that the dimension of service output plays an important role in the institutional performance evaluation system [9]. The above studies have established the evaluation system of elderly care institutions from different perspectives and provided an important research basis and ideas for this paper.

To sum up, the construction of a performance evaluation system is of great significance to improving the quality of institutional elderly care services. Existing studies have established a relatively complete performance evaluation system for the medical-elderly care integrated institutions, but there are also certain limitations: the lack of quantitative analysis of the impact of different factors on the performance level of institutions. And no research has included policy support into the evaluation system, so it is impossible to clarify the impact of policy support on institutional performance. The system dynamics method allows researchers to combine qualitative and quantitative analysis. After sorting out the causal logic of the performance evaluation system of

the medical-elderly care integrated institutions, this research simulates the actual operation of the medical-elderly care integrated institutions through computer simulation and quantitatively explores the trends in the impact of different factors on institutional performance levels. The results can provide a reference for decision-makers to plan the investment of medical and elderly care resources.

System structure analysis

Based on the research ideas of Xiao XH (2019) [7], this paper divides the performance evaluation system of the medical-elderly care integrated institutions into three subsystems: input subsystem, output subsystem, and result subsystem. Through qualitative analysis, the relationship between the three subsystems and the overall structure of the system is determined as shown in Fig. 1. The resource input of the medical-elderly care integrated institutions can be transformed into the service output of the institutions. The output subsystem has a promoting effect on the result subsystem, and the final result subsystem will react to the initial input of the system. There is a positive feedback relationship in the system; the performance level of the institutions is the result of the joint action of the three subsystems.

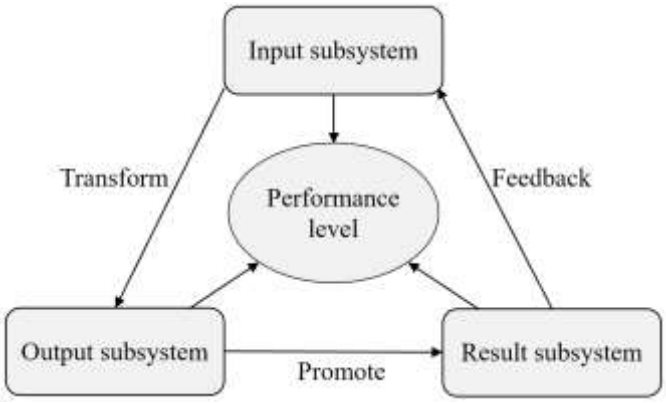

Fig. 1 Conceptual model diagram of the system

Model construction

The analysis of system dynamics is mainly based on the close and interdependent relationship between the internal mechanisms of the system, involving two different aspects: qualitative analysis and quantitative analysis. The qualitative analysis includes the analysis of the correlation between the factors in the system and the creation of a causal relationship diagram; quantitative analysis is to construct a system dynamics flow diagram based on the causal relationship diagram, which is used to display the flow and velocity in the system, to improve the quantitative analysis proceeded holistically [1011] (Masilionyte, M; Mashal Farid; 2020).

Causal relationship diagram and system dynamics flow diagram

The input subsystem includes human input and material input. The medical-elderly care integrated institutions focus on the integration of products and services in terms of "medicine" and "elderly care". Therefore, the input subsystem will be analyzed based on the integration of medical and elderly care resources. In terms of human resources investment, factors such as medical personnel, elderly care workers, and the proportion of people receiving professional training are comprehensively considered; the material resources investment is mainly based on medical facility, nursing beds, health monitoring equipment, etc., and a health management system for the elderly for information sharing is also considered. The main indicators of the output subsystem include the service capability, service content, service quality, and service sustainability of the integrated medical care and elderly care, etc. It is worth noting that this paper adds the input conversion rate on the basis of the indicators of the output subsystem, both of which jointly affect the output of the system. Satisfaction and institutional profitability constitute the result subsystem, in which satisfaction includes institutional employee satisfaction, elderly satisfaction the satisfaction of their guardian and families, and public satisfaction.

Through the transformation and utilization of the system input resources, the medical-elderly care integrated institutions can enrich the service projects of the institution, ensure the quality and sustainability of the institution's medical and elderly care services, improve the social public image and profitability of the institution, and ultimately have a positive role in promoting organizational development and performance improvement. At the same time, the improvement of institutional performance can further attract social investment and financial subsidies and expand the investment level of the institution. According to the analysis of the system causal relationship, the causal relationship diagram and the system dynamics flow diagram of the performance evaluation model of the medical-elderly care integrated institutions are constructed, as shown in Fig. 2 and Fig. 3, respectively.

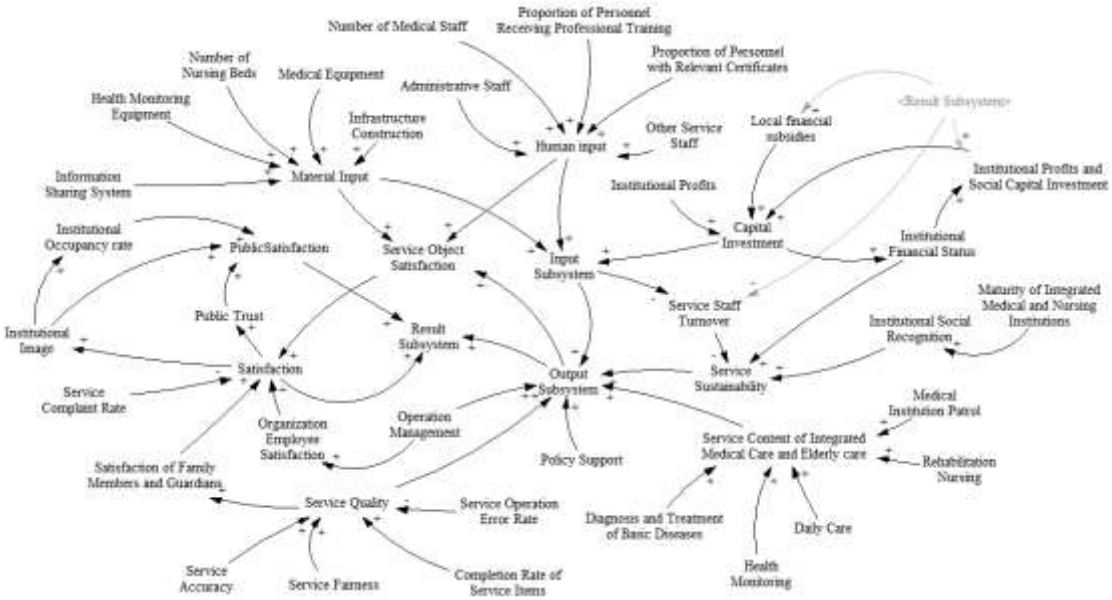

Fig. 2 The causal relationship diagram of the performance evaluation of the medical-elderly care integrated institutions

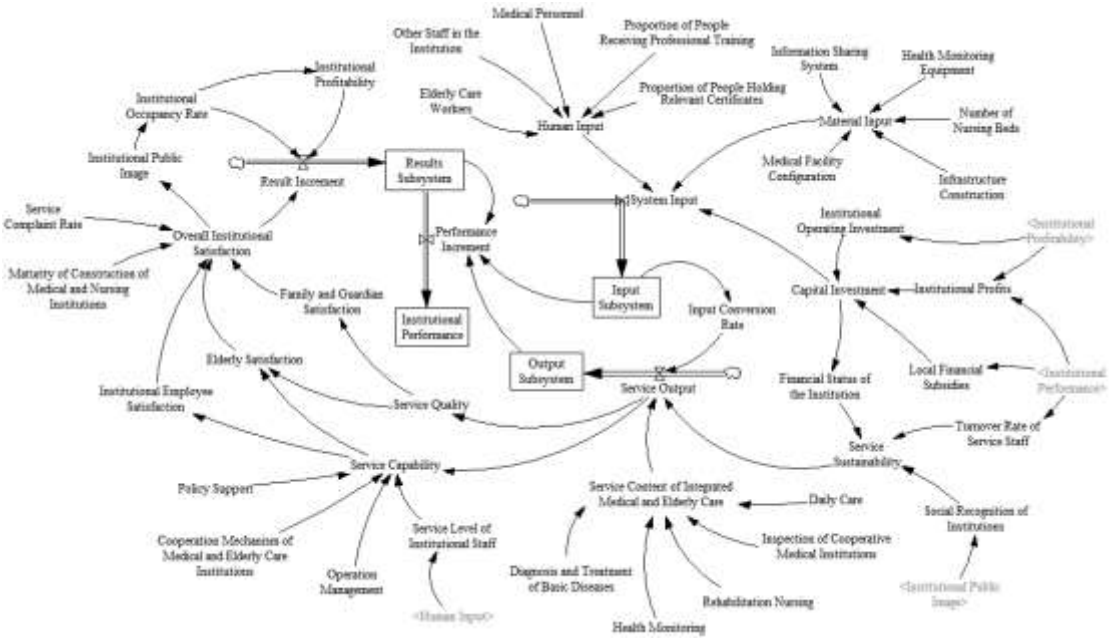

Fig. 3 Dynamic flow diagram of the performance evaluation system of the medical-elderly care integrated institutions

Equation construction and parameter setting

The performance level of the medical-elderly care integrated institutions is determined by three factors: input, output, and outcome. That is, the performance can be regarded as the comprehensive output of three subsystems: input subsystem, output subsystem, and result subsystem. Therefore, this paper introduces the economic mathematical model " Cobb-Douglas production function ", and set the calculation formula for performance as:

$$\boldsymbol{Y = \mu A I^{\alpha} O^{\beta} R^{\gamma}} \quad (1)$$

Among them, Y represents the performance of the medical-elderly care integrated institutions, that is, the output created by the input of production factors. The production factors include the input subsystem, the output subsystem, and the result subsystem, which are represented by I、O and R respectively, and α、β、γ are the elasticity coefficient of output provided by three production factors. It is assumed here that the production efficiency is not affected by the production scale, so

$\alpha + \beta + \gamma = 1$. By sorting out the researches of Wang LJ, Zhang LW, Zhu L, and other scholars, this paper determines the elastic coefficients $\alpha = 0.2163$, $\beta = 0.5762$, $\gamma = 0.2075$. A in formula (1) is the conversion efficiency of production factors to the system output. On the premise of not affecting the simulation results, this paper sets it as A=1, μ=0.1.The main equations in the model are shown in Tab. 1.

Tab. 1 Main Equations in Performance Evaluation SD Model

serial number	Main simulation equations
1	Performance Increment = 0.1*(Input Subsystem$^{0.2163}$) *(Output Subsystem$^{0.5762}$) *(Result Subsystem$^{0.2075}$)
2	Elderly Satisfaction = SMOOTH (Service Quality * 0.3 + Service Capability * 0.2, 1.5)
3	Institutional Employee Satisfaction = SMOOTH (Service Capability, 1)
4	Input Conversion Rate = DELAY1I (Input Subsystem, 12, 0)
5	Service Capability = SMOOTHI (1, 6, Policy Support*200) *STEP (Service Output, 3) *(0.5182*Operation Management+0.347*Service Level of Institutional Staff+0.1347*Medical Care Institution Cooperation Mechanism)
6	Institutional Operating Investment = STEP (0.4, 0) + Institutional Profitability
7	Local Financial subsidy=0.3*PULSE TRAIN (1, 1, 12 ,120) +0.002* Institutional performance
8	Medical Facility Configuration = RANDOM NORMAL (0.2, 1, 0.3, 1, 0.3)
9	Service Sustainability = SMOOTH (0.327487* Social Recognition of Institutions + 0.329174* Financial Status of the Institution, 4) – SMOOTH (0.343339* Turnover Rate of Service Staff, 6)
10	Institutional Public Image = DELAY1I (Overall Institutional Satisfaction *0.2, 2, 0)

Model simulation and sensitivity analysis

This paper uses Vensim PLE software to simulate and sets the total simulation time as 120 months and the simulation step size as 1. In order to unify the units of various variables in the system, the variables are dimensionless first. Set the value range of each variable as [0,1], the initial stock value of output system, result system, and institutional performance is 0, and the initial stock value

of input system is 3.

Model validity test

The model adopts the extreme condition test, which puts the system investment, the content of integrated medical and elderly care services, and policy support elements under extreme conditions, that is, the relevant variables take the value of zero, and the results are shown in Fig. 4. Under extreme conditions, institutional performance improves slowly, and the performance level is always far lower than the normal situation, showing that in the absence of resource input related to the combination of medical and elderly care, institutions can only rely on the original facilities to provide basic elderly care services, and cannot carry out the integrated medical and elderly care services, at this time the institution is unable to obtain good income, indicating that the test results are in line with reality.

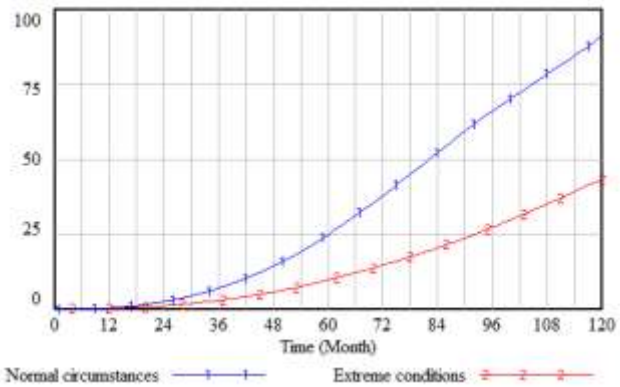

Fig. 4 Comparison of institutional performance levels under normal and extreme conditions

The results of the model validity test prove that the simulation model of performance evaluation of the medical-elderly care integrated institutions built in this paper conforms to the operating state of the real system, which can more realistically reflect the dynamic changes in the performance of the medical-elderly care integrated institutions when different variables and parameters change and can provide useful information. The model has a certain validity.

Model simulation

Running the simulation model, the institutional performance and its increment are shown in Figure 5. In order to clearly reflect the changing trend of the curve, this paper puts the institutional performance and performance increment in two coordinate systems. The variation range of the institutional performance level in Fig. 5 is [0~100], and the range of performance increment is [0~2].

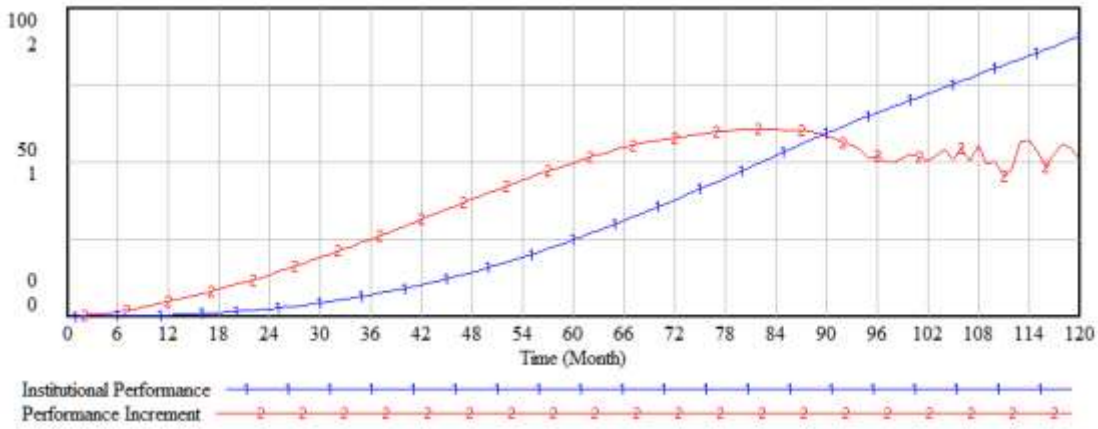

Fig. 5 Performance increment vs. performance aggregate in model simulation

It can be seen from the system simulation results that the overall performance of the medical-elderly care integrated institutions shows an upward trend. On the one hand, as the input resources are gradually transformed into the output of the institution, the service quality and service capability of the institution are improved. Influenced by the positive feedback relationship between the amount of resource input and the institution's performance, the growth rate of the institution's performance in the early stage of simulation continues to accelerate. On the other hand, due to the time delay between institutional input and output, the early-stage institutional performance increment is relatively low. With the improvement of institutional development and resource conversion rate, although the increment of performance in the latter stage fluctuates up and down, it gradually stabilizes at about 1, so the growth rate of institutional performance tends to be stable.

Sensitivity analysis

Keep the values of other factors in the system unchanged, respectively increase the values of the four key factors related to human input (In the figure6, it is represented by “H”）, material resources (represented by “M”), service content of the integrated medical and elderly care (represented by “S”), and policy support (represented by “P”) based on their initial values, and then carry out the model simulation to get the corresponding Scenario1, Scenario2, and Scenario3. The output results of the four key factors are shown in Fig. 6.

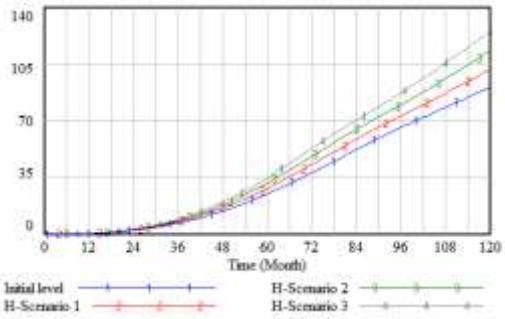

Fig.6- 1 Sensitivity analysis of human input

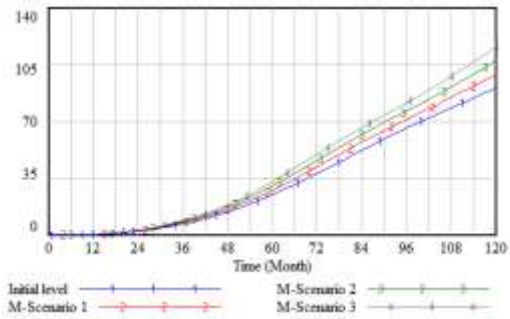

Fig.6- 2 Sensitivity analysis of material input

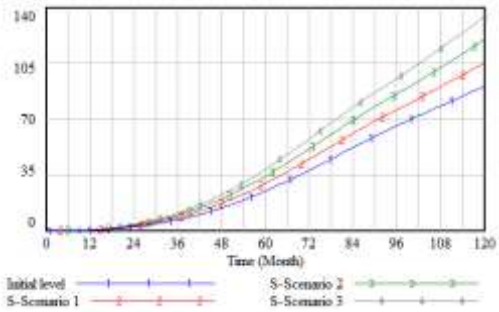

Fig.6- 3 Sensitivity analysis of service content

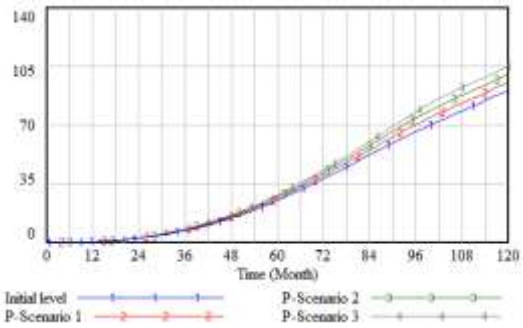

Fig.6- 4 Sensitivity analysis of policy support

Fig. 6 Sensitivity analysis of four key factors

In order to more intuitively compare the influence of the four key factors on the performance of the medical-elderly care integrated institutions, the improvement effect of each factor change on the performance of the institution is expressed as a percentage, as shown in Fig. 7. During the entire simulation cycle, the service content of the integrated medical and elderly care has a great effect on

improving the performance of the institutions, and the improvement rate is up to 60%. The influence of human input and material input on institutional performance fluctuates greatly, which improvement rate increases rapidly in the early stage, and shows a U-shaped trend in the later stage, and the improvement effect of human input on institutional performance is always higher than that of material investment. In contrast, policy support has the least impact on institutional performance, but the overall improvement rate is relatively stable, maintained at about 15%.

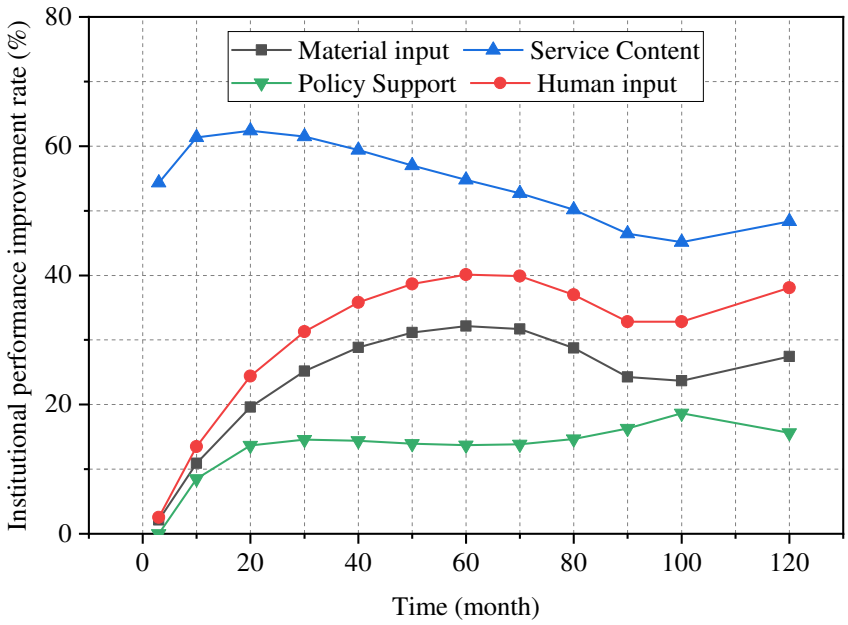

Fig. 7 The improvement rate of four key factors on institutional performance

Simultaneously increase the values of the four factors for comprehensive simulation analysis, and compare the improvement rate of the comprehensive simulation results and the sum of the improvement rates of the individual factors on the performance of the medical-elderly care integrated institutions as Fig. 8. The result shows that the system has an emergent effect, that is, the whole is greater than the sum of its parts. In the whole simulation process, the improvement rate of the four factors' combined effect on the performance of the institutions is always greater than the sum of the improvement rates of the single factors, and the gap between the two is the largest at the

90th month of the simulation. The sum of the improvement rates of the individual factors is 120.6%, while the improvement rate of the comprehensive simulation is over 230%.

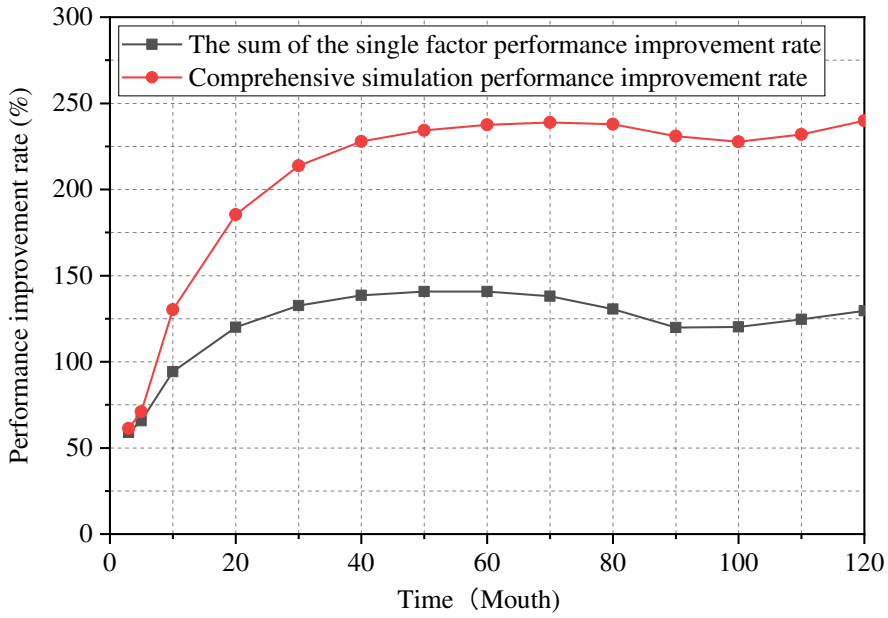

Fig. 8 Comparison of the improvement rates of single-factor and multi-factor simulations on institutional performance

Discussion

This paper divides the performance evaluation system of the medical-elderly care integrated institutions into three subsystems: input, output, and results. Then establishes a system dynamics model for the performance evaluation of institutions. The validity test results show that the model can better reflect the real-world impact of key factors on institutional performance. The model simulation results show that the two factors of the service content integrated medical and elderly care and human input have the most significant impact on the performance of the institution. Measures such as enriching the service content of the integrated medical care and elderly care, improving service quality, improving the professionalism of staff in elderly care institutions, and improving the construction of talent team in elderly care institutions have a very positive effect on

improving the performance level of institutions. In addition, the simulation results also prove that the various elements in the system are not independent of each other, and the comprehensive change of the key elements can improve the performance of the medical-elderly care integrated institutions much higher than the sum of the individual elements.

According to the author's investigation, this paper is the first to apply the system dynamics method to the performance evaluation system of elderly care institutions. By combining the SD model with institutional performance level, this paper quantitatively evaluates the change of performance level of the medical-elderly care integrated institutions under different resource investment levels. The establishment of SD models can help simplify the real-world operating conditions of research objects, and present actionable information to decision-makers concisely. It is worth noting that the simulation results of the SD model in this study are not predictions, but demonstrate the potential effects of different resource input levels on the development of the medical-elderly care integrated institutions and the changing trends of institutional performance.

Additionally, there are still several limitations to this article. First of all, the advancement of science and technology has changed the operation mode of many industries. For example, in the elderly care service industry, whether the application of intelligent technology in the future can replace some of the jobs of nurses, enrich the content of medical and elderly care services, and reduce the demand for nurses? Whether the science and technology investment should be included in the system and the proportion of human investment should be reduced? Secondly, the requirement of normalizing the prevention and control of the COVID-19 has also forced people to change their lifestyles. Should the performance evaluation system of elderly care institutions take the level of epidemic prevention and control into consideration? The above factors may have a certain impact

on the conclusions of this study, so in the future, further research will be conducted in combination with social reality.

Conclusion

Based on the above analysis, this paper believes that the integration of service resources of "medical" and "elderly care" is the decisive factor for the good development of the medical-elderly care integrated institutions. In the process of transformation, traditional elderly care institutions should pay attention to starting from a systematic point of view. The strategic planning of institutions should be combined with the national policy line, the level of institutional resource investment, the operation status of institutions, the demand characteristics of the elderly, and other factors, in order to make the best use of existing resources to improve the quality of medical and elderly care services and improve the institutional service system. At the same time, policy support also plays an indispensable role in the development of the medical-elderly care integrated institutions. Improving the talent training mechanism and attracting the participation of social capital will play an important role in promoting the expansion of resource investment in institutions, improving the professional level of the talent team, and continuing to carry out better medical and elderly care services.

Declaration

Acknowledgements

Not applicable.

Authors' contributions

Y.S. designed the study, Y.S., F.F., and Z.Z. performed data analysis, Y.S. produced all tables, F.F. produced all figures, and all authors participated in the writing, revision, and final review of the manuscript, who read and approved the final manuscript.

Funding

This research was funded by the General Program of National Natural Science Foundation of China (No.72071081). From the National Natural Science Foundation of China, People's Republic of China. The funding committee said the funding agency had no direct role in the study design, analyzing the data, or writing the manuscript.

Availability of data and materials

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable. This study does not require ethical approval or participant consent

Competing interests

I declare that the authors have no competing interests as defined by BMC, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

Consent for publication

Not applicable.

Reference

[1] Su K. "Four Measures" to Improve the Satisfaction of Medical and Elderly Care Services [J]. People's Forum, 2019, {4}(21):72-73.

[2] Jiang XJ, Zhou ST. Analysis of Interprovincial Differences in Rearing Efficiency of Elderly Care Institutions Based on DEA Model [J]. Business Economics Research, 2017(14):191-192.

[3] Wang HN. Service Efficiency and Influencing Factors of Medical and Nursing Aged Care

Institutions——Based on Data Analysis of 226 Medical and Nursing Aged Institutions in Shandong Province[J]. Chongqing Social Sciences,2020(05):129-140.

[4] Guo HY, Peng JL, Lei Y, Wang L, Xie H. Characteristics and enlightenment of service quality evaluation in American elderly care institutions[J]. Chinese Journal of Nursing,2013,48(07):652-654.

[5] Yin HR, Yuan H, Peng X, Li WT, An LB. Construction of an evaluation index system for the elderly service capability of urban non-profit elderly care institutions [J]. Chinese Journal of Gerontology, 2016, 36(14): 3560-3565.

[6] Wang LJ, Feng Y, Wang C. Research on Service Quality Evaluation of Elderly Care Institutions [J]. Population and Development, 2017, 23(06): 96-102.

[7] Zhu L, Yang XJ, Zhang Q, Wang FL, Zhang XL, Xing FM. Research on the construction of the evaluation index system for the supply service quality of community home-based elderly care centers combined with medical care and elderly care [J]. Chinese General Medicine, 2019,22(02):199- 205

[8] Zhang LW, Zeng YB, Fang Y. Construction and application of comprehensive evaluation index system of service quality in elderly care institutions [J]. China Health Statistics, 2019,36(04):525-527+531.

[9] Xiao XH, Huang ZM, Wu YF, Yan MQ, Li B. Construction of service performance evaluation index system of medical and elderly care institutions[J]. Chinese General Practice,2019,22(26):3233-3237.

[10] Masilionyte Milda et al. Estimating the impact of lifestyle changes on treatment outcomes for people with knee osteoarthritis through system dynamics simulation modelling[J]. Journal of the Operational Research Society, 2021, 72(12): 2649-2660.

[11] Mashal Farid and Nancy Purdy and W. Patrick Neumann. Using system dynamics modelling to show the effect of nurse workload on nurses' health and quality of care[J]. Ergonomics, 2020, 63(8): 952-964.