



Identification of Key Components in Health System Using System Thinking Approach: A Scoping Review

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Received: 11 Jan 2022

Published: 3 May 2023

Abstract

Background: The dynamic and systemic planning and targeting in the health system require attention to all the system's components and investigation of their causal relationship in order to form a clear view and image of it. Therefore, the present study was designed with the aim of identifying the comprehensive dimensions of the system within a specific framework.

Methods: Key components in the health system were identified through the scoping review method. For this purpose, 61 studies with selected keywords were extracted from international databases, including Scopus, Web of Science, PubMed and Embase, and Persian language databases including Magiran and SID. Inclusion and exclusion criteria in this study were languages, time range, repeated studies, studies related to the health system, appropriateness of studies with the subject and purpose of the present study and the method used. The content of the selected studies and extracted themes were analyzed and categorized in the Balanced Scorecard (BSC) framework.

Results: In health system analysis, key components were divided into 18 main categories and 45 categories. Also, they were categorized according to the BSC framework into five dimensions of population health, service delivery, growth and development, financing, and governance & leadership.

Conclusion: For health system improvement, policymakers and planners should consider these factors in a dynamic system and a causal network.

Keywords: Health System, Complex Systems, Dynamic System, Key Components of the Health System

Conflicts of Interest: None declared

Funding: This article is the result of a doctoral dissertation supported by Kerman University of Medical Sciences grant. No external funding was received.

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Cite this article as: Emami M, Haghdooost AA, Yazdi-Feyzabadi V, Mehrolhassani MH. Identification of Key Components in Health System Using System Thinking Approach: A Scoping Review. *Med J Islam Repub Iran*. 2023 (3 May);37:47. <https://doi.org/10.47176/mjiri.37.47>

Introduction

Health is an essential element of the human rights system, and physical, mental, social, and spiritual health is

the right of all members of society. So, achieving and promoting health has been considered one of the govern-

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↑What is “already known” in this topic:

Having a systemic view and the need to use the science of systems thinking is considered as one of the necessary requirements in dealing with issues related to organizations, and the health care organization, as one of the complex systems, is not exempt from this rule. In the studies that have been done before, have paid attention to this and system thinking has been used in various issues of the health system.

→What this article adds:

One of the principles that must be considered in the investigation and understanding of health systems using systems science is the knowledge of the comprehensive dimensions and components of the system in a dynamic causal relationship, which has not been studied in this field. Therefore, the present study has tried to gather as much as possible all the components and dimensions of the system in a comprehensive framework to provide the necessary background for future studies regarding the examination of the components in a causal network.

ance objectives and constitutional and civil rights in many countries (1, 2). In other words, the existence of health systems (HSs) that respond to all the needs of society while operating efficiently and effectively is very important, and to promote inter- and intra-sectoral collaboration for the promotion and protection of the health of all people, countries have agreed to the Statute of the World Health Organization (WHO), thereby recognizing the WHO as a specialized agency under Article 57 of the UN Charter which guides countries to improve the performance of their HSs (3).

HSs are inherently complex, and as non-integrated social systems consisting of multiple governments, payers, and providers, are responsible for delivering health care services to patients in specific regions (4), which provide extensive networks of feedback loops with time-varying delay and nonlinear relationships within the system. Therefore, to achieve the HS goals, managers and decision-makers need to plan with a comprehensive understanding of the HS dimensions and their relationships, which necessitates the use of systems thinking. It considers the system as a whole and not its individual components and investigates the behavior of the system over time (4, 5).

In addition to the need for a systemic view of the HS, it is necessary to have a comprehensive and evidence-based analysis of it and consider all the components concerning each other with a general and coherent view. In the meantime, the Balanced Scorecard (BSC) framework is one of the most effective and powerful tools for careful consideration and evaluation of the performance of systems in terms of various parameters (2) and in dimensions of financing, internal process, growth and learning, and the customer along with showing their causal relationship simultaneously (6). As a result, the BSC framework is able to provide significant information regarding the internal and external factors of the HS and will lead to its success.

In studies conducted by researchers, the importance of valuable use of the dynamic system for the investigation of complex social systems and issues has been mentioned such as health insurance in Iran (7), the continuation of HIV care in Vancouver (8), investigation of obesity in Australia (9), investigation of the factors of the financial system affecting the BMI of students in primary schools in Taiwan (10), investigation of immunization system in Uganda (11) and investigation of the dynamic system of health care financing in New York (12).

Considering that HSs are open systems, the components of which interact with each other within the context in which the HS is located and form properties beyond the components. Therefore, modeling them with the systems thinking approach while considering and knowing all the key components and analyzing them is an unavoidable necessity. Since there was no study that provides a general and comprehensive description of all key components of the HS, so we have tried to review studies that have addressed the issues of the system with a dynamic system approach and categorized all the components in the framework of the fourth generation BSC for strengthening

it. It is hoped that this will provide the basis for dynamic and systemic planning and targeting at the macro level of the system for developing countries.

Methods

Search strategy

The present study was conducted as a scoping review in October 2020. The steps of the research are shown in Figure 1.

For this purpose, international and Persian language databases were investigated and from a total of 6 websites listed in Appendix 1, about 2722 results were obtained, of which 613 identical results were identified and deleted by EndNote software. As a result, 2109 studies were reviewed. It is necessary to explain that databases were searched based on the title and abstract, and all documents such as reports, conferences, workshops, types of review articles, and original articles were searched. To determine the keywords, first, completely related keywords were considered. Their equivalents, or those related to dynamic systems in the health sector, were then identified by experts as well as Internet searches. Oxford and Thesaurus dictionaries were also searched to determine the equivalent of the specified keywords, and the closest related words were entered into the search strategy.

Study selection criteria

In the first stage, among all the studies searched during 1975-2020, 174 relevant studies entered the study after excluding overlaps from EndNote and unrelated studies according to the title and abstract of the research and mentioning the research in the health sector to review the original text. In the second stage, the studies were divided into three categories based on the relevance of the research subject: completely relevant, relatively relevant, and unrelated. It should be noted that the research team attended a meeting and decided to categorize the studies based on the method used in the study. Accordingly, the studies inves-

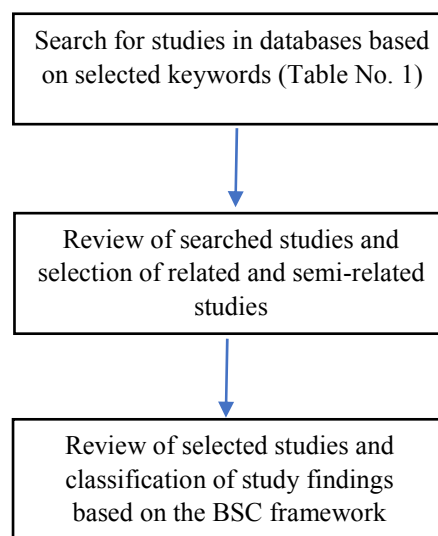


Figure 1. Stages of conducting research

tigating components and relationships in the HS through the dynamic system method were identified as related studies. The studies that have focused on the research subject by other methods were identified as relatively related studies, and others were identified as unrelated studies.

Finally, after excluding irrelevant studies that did not agree with the subject in terms of the study results, about 61 sufficiently qualified studies were selected. As a result, the important results and the main messages delivered by them were carefully investigated.

Data extraction

At this stage, the full text of related and semi-related studies was referred to. In addition to ensuring that the study's subject was relevant to the objective of this research, it attempted to identify and categorize its main messages. In this study, special attention was paid to the important parts of the study that contained its central message. These sections included the results and messages presented in the study's discussion, especially the conclusion section. The information was investigated and extracted by one of the research team members who were completely aware of the subject. On the other hand, to increase the accuracy of the work, all studies were read by

one person so that interpersonal differences do not cause errors.

Data analysis method

Finally, each of the selected studies was meticulously read to identify key concepts. The assessment of all extracted data by analyzing the final studies were conducted through framework analysis. In fact, in a study by Mehroolhassani et al. it has been discussed to present the BSC framework for monitoring the HS, which is derived from the global model provided by WHO (2). After completing the table of data extraction, two members of the team coded the data separately and categorized prominent themes emerging from the evidence within the framework. Each concept was coded according to the related study in numbered style. Disagreements in coding and classification were resolved by holding a meeting with all the research team members, and an agreement was reached.

Results

In this study, Figure 2 shows the stages of obtaining the final studies.

While studying the selected articles, their content is displayed in Tables 1, 2, 3, 4, and 5. It should be noted that

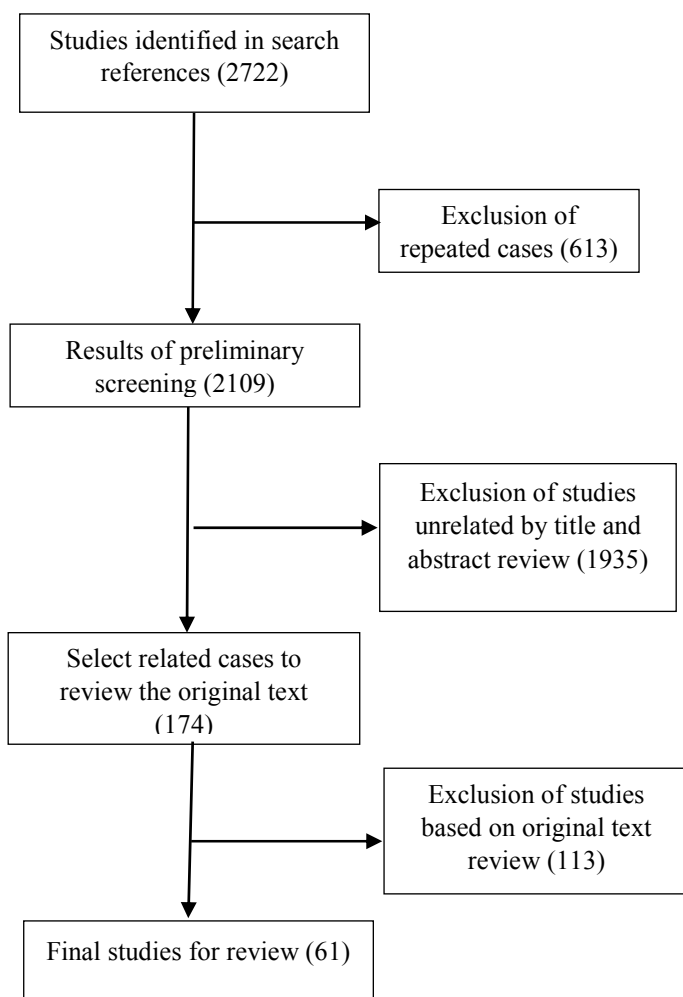


Figure 2. Search and achievement stages of the main findings in the studied databases

Table 1. Key components for the dimension of population health

Main categories	Categories	Sub-categories	Number of studies mentioned
Demographics	Population / patient demographic factors	Total and base population (13, 14) Birth and fertility rate (15) Population growth (16) Elderly population and effects of aging (17-21) Effect of gender composition (19, 22) Effect of socio-economic determinants, training, and public welfare (16, 17, 23, 24)	12
High-risk behaviors and risk factors	Changes in the life-style of the population	The phenomenon of urbanization (17, 25) Immigration of individuals (26)	3
	Behavioral factors	Physical activity and obesity (19, 21, 27, 28) Addiction and tobacco (14, 21, 28) and alcohol (19) consumption Chronic disorders such as high cholesterol, high blood pressure, and diabetes (28)	6
	Environmental factors	Psychosocial stress and life of people in society alone (17, 21) Food security and access to healthy food (29) Security at work in the health sector (26)	4
	Health, economic and social indicators	Hospital waste (24) Housing policy (30) Individual health level (19) Life expectancy (31) Quality of life-related to health (14) Improvement rate (15)	8
Society health status	Incidence of diseases	Total mortality rate based on different disease groups (13, 15, 28, 32, 33) Type of disease/change in disease status/change in disease spectrum (16, 25, 34) The severity of the disease (34) Change in patient population (35) Number of patients (decreasing/increasing rate of patients (13, 22, 36-38) Time of Incidence of diseases (15)	10

most of the studies used in this study are original and have been investigated in the HS, especially at the hospital level. In addition, the studies have been selected from all continents with different revenue levels. Most of these studies were related to countries such as the United States, the United Kingdom, China, and Australia. Also, most of the studies have been designed in two quantitative and qualitative (mixed methods) phases. The qualitative phase has been carried out using Delphi, working group meetings, semi-structured interviews, literature review, and reports review. For data modeling and analysis, software such as Arena, Stella, and especially Vensim have been used (Full information of these articles is provided in Appendix 2).

Generally, more studies in the HS focused on service delivery (26%) and financing (22%) and paid less attention to governance and leadership (14%).

For population health, the components extracted in each of the items of demographics, high-risk behaviors, and risk factors, and the health status of the population (with health, social and economic indicators, and incidence of disease) were categorized. In this regard, components such as increasing the elderly population and the effects of aging, social and economic determinants on the health of society, physical activity, addiction and tobacco and alcohol consumption, mortality rate based on different disease groups and the number of patients are among the components that are mentioned in most studies (Table 1).

In the dimension of service delivery, effective components on different levels, such as prevention services, medical services, support and palliative, and rehabilitation

services, as well as components of quality improvement, leveling and service delivery levels, were addressed. Accordingly, the components of training society members with an emphasis on self-care and improving their health awareness level in the field of prevention services, the number of patients and patient admission rate in the field of medical services, average patient waiting time (equity and access to services), duration of the patient's stay and his shift in inpatient units (a component of service efficiency) in the field of improving quality of services have been the most effective components according to the mentioned studies (Table 2).

Generally, in the dimension of growth and development, the components of manpower management, knowledge, information, equipment, medicine, and the legal nature of organizations are investigated. In this study, some of the effective components in each of the above fields are also discussed. Therefore, the quantity of manpower, such as the number of physicians, workload and manpower turnover, behavioral components such as competence, skills, commitment, and motivation of manpower, job satisfaction, strengthening of knowledge management, employees training, and the number of hospital beds are the most important components discussed in the present study (Table 3).

For the dimension of financing, the components affecting the financial situation in the HS were identified for four functions of financing, i.e., resource collection, resource pooling, resource allocation, and service purchase. In this regard, the component of budget in the field of resource collection, the component of the number of people

Table 2. Health key components for the dimension of service delivery

Main- Categories	Categories	Sub-Categories	Number of studies mentioned
Preventive service	Society empowerment	Percentage of literacy rate among adults (31)	7
		Training people in society with an emphasis on self-care (7, 14, 29, 30)	
		Advertising and media programs (29, 39)	
	Society care covered	Enhancing the level of health awareness of individuals and patients (7, 40, 41)	5
		Preventive health measures (7, 42, 43)	
		Improving quality and access to primary care in the regional health development plan (21, 44)	
Medical service	Outpatient services delivered	Capacity and load of referral and regional outpatient visits (32, 36)	2
	Inpatient services delivered	Number of new outpatient cases (36)	10
Number of patients (24, 45, 46)			
Percentage of patients admitted from the region and referred (36, 38)			
	Coverage of palliative and supportive care in the country	Admission rate (hospitalization) (hospitalized patients / population * 1000) (18, 34, 36-38, 46)	2
		Services (type of care with high cost, etc.) (22)	
		Bed capacity and occupancy (36, 47)	
Support and palliative services	Coverage of palliative and supportive care in the country	Number of patients in an emergency including triage, shock room, emergency room, and operating room (22)	2
		Reinforcement of palliative interventions (17)	
Rehabilitation services	Coverage of rehabilitation care in the country	Increasing the capacity of long-term care by up to 20% through the establishment of nursing homes (18)	1
		Care in nursing homes, including rehabilitation, social services at the local authority level, conscious care in society, and private/voluntary services (30)	
Improving service quality	Result of medical measures/observance of patient rights	Services (type of care with high cost, etc.) (22)	4
		Bed capacity and occupancy (36, 47)	
		Number of patients in an emergency including triage, shock room, emergency room, and operating room (22)	
	Equity and access to service	Reinforcement of palliative interventions (17)	12
		Increasing the capacity of long-term care by up to 20% through the establishment of nursing homes (18)	
		Care in nursing homes, including rehabilitation, social services at the local authority level, conscious care in society, and private/voluntary services (30)	
	Service effectiveness	Care in nursing homes, including rehabilitation, social services at the local authority level, conscious care in society, and private/voluntary services (30)	8
		Patient satisfaction (48)	
		Number of patient complaints (23) and medical crimes (30)	
	Service efficiency	Discharge with personal consent and the total number of patients who leave the hospital without a visit (46)	9
		Mean waiting time and queue for a patient (11, 25, 18, 36, 39, 40, 45)	
		Physical access and access time to health services and centers (13, 24, 26, 31)	
	Service effectiveness	Exploitation of services (13, 19, 26)	8
		Financial problems and, finally, access restrictions (26)	
		Immunization rate for communicable diseases (15)	
	Service efficiency	Improving the quality of medical services (7, 49)	9
		Implementation of accreditation standards, and clinical, diagnostic, and therapeutic procedures (33, 47, 50)	
		Early diagnosis of the disease (38, 41)	
	Service efficiency	Percentage of nosocomial infections (33)	9
		Pharmaceutical side effects in each dose distributed (33)	
		Change in technical efficiency and allocation of services (51)	
	Service efficiency	Average duration of stay (30, 36, 37, 46, 52) / Average patient stays more than six hours in an emergency (33)	9
		Improving patient shifts in inpatient and inter-hospital units (31, 53, 54)	
		Unscheduled readmission (33)	
Leveling and service delivery levels	Improving the referral system in the HS	Canceled surgeries (33)	3
		General practitioner and family physician referral pattern (30, 55)	
		Strengthening referral system and monitoring referrals of skilled personnel facilities to hospitals (56)	
	Features and capacity defined for each level of service	Number and capacity of hospitals (31)	5
		Hospital specifications and scale (22, 57)	
		Hospital grading (49, 55)	

covered by insurance in the field of resource pooling, and the cost of services and treatment resources in the field of resource allocation and service purchase were among the components discussed in most studies. In addition, components such as inflation, the revenue of individuals and patients, and the rate of financial compensation and return on assets are among the most important components affecting the inflow of financial resources into the HS (Table 4).

The dimension of governance and leadership is a key component at the heart of the model, which is the most complex but the most sensitive and vital component, and adjusts and adopts strategies and policies of other dimen-

sions of the system with a comprehensive and coordinated view. In this study, structural factors (consisting of the power and role of political factors in the HS; roles, tasks, and participation in implementation and inter-sectoral communication and collaboration), the development of rules and regulations, and customer protection are mentioned. In this regard, the dynamism of power among actors, strengthening advocacy in the HS, awareness of the issue in the policy-making process, leadership structure and skills, participatory decision-making and leadership at the society level for policy-making and implementation, networking and open and transparent communication for implementation, organizational culture, political guide-

Table 3. Health-effective components for the dimension of growth and development

Main categories	Categories	Sub-categories	Number of studies mentioned
Manpower	quantity of manpower	Number of physicians per 1000 people / Number of physicians in a context (30, 58)	15
		Number of nurses and midwives per 1000 people (31)	
		Number of trained manpower employed and labor force capacity (46, 59)	
		Appropriate levels of hospital employees in the inpatient department (54)	
		Reducing the working hours of the deterrent factor in the face of population demand (20)	
		Manpower / Clinical force workload (26, 37, 60)	
		Manpower migration and employee's occupational complications (26, 33)	
		Manpower turnover and patterns of change and transfer of tasks (26, 39, 40)	
	Behavioral factors of employees	Multidisciplinary teams working between social care and health departments (30)	
		Manpower competence, skills, motivation, and self-confidence (39, 40, 61, 62)	14
		employee's satisfaction and professional identity (25, 33, 60)	
		Work ethic, commitment and motivation, and service values of employees (26, 59, 60, 63, 64)	
		Pursuing stakeholder profitability and trust among manpower (16, 60)	
		Revenue pressure and efforts by employees for better revenue and informal revenue (36, 65)	
Information system	Quality of manpower training	Physician prescription behavior (16, 25)	8
		Corruption rate in the organization (60)	
		Strengthening knowledge management and training of employees (40, 66, 67)	
		Deep understanding and knowledge of various components of the system (23)	
	Research	Duration of training (20)	4
		Per capita training hours for employees on arrival and during service (33)	
		Use of advisory and support assistance and implementation of ethical courses (56)	
		Coaching and motivating employees (61)	
		Use of evidence (39)	
		Gaps in research (39)	
Medicine and medical equipment	Information processing	Number of research-based innovations (33, 64)	6
		Standardization with innovation (23)	
		Analysis and flow of health information and submission of necessary reports (63)	
	Medical facilities and equipment in the HS	Desired level of information exchange in the HS (63)	6
		Existence of an information reporting and monitoring system (36, 56)	
		Information technology (IT) support in clinical decision-making, data collection, and analysis (67)	
	Pharmaceutical system in the HS	Information and evidence on the effectiveness of health promotion plans (59)	3
		Number of hospital beds per 100 people (30, 31, 34, 35, 38)	
		Medical technology in hospitals (13)	
		Pharmaceutical capacity at stages of production, import, and export of equipment and drugs (37)	
		Sale and consumption of drugs (48)	
		Supply of drugs and consumables (26)	

lines, patient preferences and patient demand level in the field of customer protection were considered as the most effective components of governance and leadership according to the present studies (Table 5).

Discussion

In this study, using the results of the studies, key components in the HS were categorized and considered in dimensions of population health, service delivery, growth and development, financing, and governance & leadership.

For the dimension of population health, exposure to risk factors and the occurrence of high-risk behaviors and, consequently incidence of diseases, as well as the phenomenon of urbanization and increasing aging population, are considered important components affecting population health based on the number of studies and repetitions. Shongkour also stated that life expectancy in all birth

years, the literacy rate among adults, primary school enrollment, etc., are considered positive and effective factors in population health and affect public health care costs (31).

In most of the studies reviewed in this study, more attention has been paid to the number of patients and the effects of population aging (7, 13, 17, 18, 20, 21, 35, 36, 46). In some studies, it is clearly stated that increasing the number of older people in society and preserving their health requires higher costs. Furthermore, the introduction of new drugs and technologies for diagnosis and treatment, increasing supplementary insurance and surpluses, along with growing expectations of the educated population, will inevitably necessitate a larger volume of costly diagnostic procedures and hospital costs (71), and also increase in the number of patients, especially patients in need of hospitalization, in addition to the cost burden and the possibility of a shortage of hospital beds, will reduce the quality of services and negative consequences on pop-

Table 4. Health-effective components for the dimension of financing

Main categories	Categories	Sub-categories	Number of studies mentioned
Resource collection	Total resources	Percentage of total health cost of GDP (31) The growth rate of health share of GDP (49)	2
	public resources	Percentage of total public cost on the HS (31) The public cost of health care in connection with demographic groups (31)	1
	government resources	Contribution of government cost in the HS (31) Total government budget in the HS (15, 60, 68)	4
	Private resources	Out-of-pocket payments (7) Informal payments (65)	2
	External resources	Out-of-HS assistance (60, 68)	2
	Factors affecting the volume of financial resources in the HS	The volume of financial resources compared to other resources and its prediction and variability over time (51) Rate of Compensation and Return on Assets (49, 69) Delays in financing (49) Revenue of society members and patients (33, 68) Inflation rate (19, 59, 68)	7
	Insurance mechanism	Number of people covered by insurance (7, 23, 70) Fair participation of insurance organizations in the HS (7, 13) Change in cost-effectiveness and financial protection of consumers (51) Change in resources at the time of providers access (19, 51)	6
	Resource allocation pattern	Allocation of resources to local needs across services, facilities, and regions (51) Evaluation of logic of prioritization and fair allocation of resources (60) Reduction in patients' bills due to more rational use of resources (36)	3
	Medical service resources	Cost of treatment services and resources (19, 24, 45) The total cost of diseases per month (45) Total pharmaceutical cost per month (45) Total laboratory cost per month (45) Total outpatient cost per month (45) Internal resources of the hospital (35) Total monthly rehabilitation cost (45) Other costs (45)	5
	Health service resources	Costs of occupational disability (45) The financial burden of overweight and obesity (19, 27) Costs of expensive medical technology in the future (19) Cost of effects of aging (19) The ratio of bonuses and salaries of employees to total expenses (33) The average cost of immunization per person (15) Cost related to training of teachers regarding smoking (14) Annual medical cost for smokers (14) Cost of cardiovascular complications and other risk factors (21)	7
Resource pooling	Purchasing	Insurance strategic purchase (7) Adjustment of treatment costs by insurance companies (7) Insurance induction demand (7) Insurance payment models (7)	1
	Tariffs and pricing	The total price of medicine (68) Adjusting price index of medical services (13, 49) Change in transaction costs (such as new governance arrangements, monitoring, etc.) (51) Price/value of medical employees (49, 57)	5
	Payment systems	The shift from a fee-for-service system to a fixed rate to make the financing system more equitable through activities such as manpower rationalization and diagnostic and therapeutic behaviors (36) Pay-per-performance (48)	2

ulation health (36).

For the dimension of service delivery, we have considered service delivery levels, referral systems, and the need for logical and correct communication between levels and improving the quality of services. The governmental sector of the system is organized in order to be more efficient and effective, as well as to create equity and the possibility of individual access to the first, second, and third levels, which according to the leveling of services, people access to more specialized services through referral system is possible. It is very important to pay attention to this in the dimension of service delivery. Accordingly, the major cost of health services (both financial and human) is

related to hospitals, which is inevitable. However, if 80-90% of patients at the first level of health care can be diagnosed and treated, there will be a significant reduction in costs, and consequently, the service will be effective (65). In many studies, much attention has been paid to prevention services and improving the quality of services at the first level of service delivery (13, 38, 47).

WHO has also advised governments moving towards universal service coverage to pay special attention to primary health care, especially in countries where health inequalities in terms of income, training, employment status, geographical location, and membership in different ethnic, racial or religious groups are quite evident. The

Table 5. Health-effective components of health for the dimension of governance and leadership

Main categories	Categories	Sub-categories	Number of studies mentioned
Structural factors	The power and role of political factors in the HS	Utility of power dynamics among actors (56, 60)	5
		Strengthening and increasing advocacy (39, 59)	
		Awareness of the issue in the policy-making process and acceptability (top-down approach) (39, 59)	
		Accountability with flexibility or delay in policy processes such as bureaucracy (23, 39)	
	Roles, tasks, and participation in the implementation	Political support and integrity of policies (39)	6
		Governance and leadership structure (59, 64)	
		Management and leadership skills (60, 64)	
	Inter-sectoral communication and collaboration	Society participation (60) / consulting with the public in policy-making (39)	5
		Participation of policymakers in the governance of the hospital (62, 69)	
		Inter-sectoral cooperation processes and changing priorities (collaboration policies) (71)	
		Communicating openly and transparently about organizational priorities (58, 67)	
Develop rules and regulations	Internal organizational rules	Communication and strategic opportunities for networking (39, 67)	6
		Levels of diversity and dependence among health stakeholders (23)	
		The impact of time and resources in order to build lasting relationships (23)	
		International obligations (39)	
	Effective external organizational rules	Organizational Culture (60, 67)	6
		Full understanding of governance perspective in the HS (62)	
		Existence of strategic framework (59)	
		Requirement of more detailed clinical instructions (40)	
		Executive instructions (39)	
		Political guidelines (39, 59)	
Customer protection	Supporting the health level of society/individuals	Decentralized disciplinary mechanisms (63)	7
		Taxes on snacks and related rules/marketing (21)	
		Prohibition of smoking at work and in public places (21)	
		Reduction in interventions in judicial systems (56)	
	Financial support (25)	Judicial crimes (33)	1
		Organizational needs consistent with the system needs (21)	
		Design of healthcare packages (30)	
		Patients' preferences (34) / clinical decisions according to patients' preferences (40)	
		Patient demand level for services and resources (16, 24, 37)	
		Supporting monitoring and reporting of population health (59)	

reason is that primary health care will increase efficiency by increasing the access of society to prevention and protection services and reducing hospital admissions. As a result, improving population health in low-, middle-, and high-revenue countries will indirectly achieve macroeconomic benefits (72).

In addition, Richard et al. (2020), during the Covid-19 pandemic, argued that to prevent an increase in patient mortality, more intensive care beds should be provided using existing facilities. On the other hand, due to the cost burden incurred in the HS, it is necessary to take health preventive measures such as isolating patients, quarantining at home, and social distancing to reduce the infection of other people in society (42).

For the dimension of growth and development, the components that promote and affect the existing infrastructures in the HS have been addressed. The existing manpower and the components affecting presence and employment, behavioral factors of employees, quality of manpower training, research, information infrastructures, drugs, and medical equipment are among the most important components of this dimension.

Since the highest added value in any organization belongs to the organization's manpower, the number of manpower working in the HS, especially physicians, is

very important in terms of quantity and quality given the population and their distribution. In this study, the number of physicians, job satisfaction, manpower commitment, and motivation are considered important factors of the manpower sub-components. The shortage of physicians in many countries including Uganda (58) and their low commitment and motivation and instability in their positions have forced countries to reform the HS (20).

The hospital beds are considered the most important and costly resources of the HS, the primary unit for calculating the capacity of medical services in a region and also the vital capacity of patient care, and their unjust allocation in different parts of the country may lead to a lot of displacement of patients and as a result, irreparable health problems. Unfortunately, there is also a shortage of hospital beds and long waiting lists in many countries, including Italy, Bangladesh, China, and Canada (7, 31, 34, 37).

The component of the information system is also one of the important and basic components in this dimension. Because to ensure the responsible use of financial and human resources, health professionals are increasingly expected to commit to evidence-based decision-making, and this type of decision is highly dependent on timely access to correct and accurate information. The information is not only needed for policymakers to make more

effective decisions but can also be used by first-level service providers to improve the quality and efficiency of health plans. On the other hand, data and information provide the necessary knowledge, and knowledge development and management provide the power to create effective interventions (66). As Merrill et al. stated that the desired level of information exchange in the HS should be influenced by national standards, and the gap between it and electronic health information should be reduced to zero over time as a standard. In this regard, the time and expertise of available resources have been considered to fill this gap (68).

The information can also be extracted through health research. This research is related to health services, policies, HS, and general Hygiene. Health research is often influenced by global policies and investments rather than the specific philosophy of that country (73). gaps in research in countries like Fiji have had a detrimental effect on access to and use of evidence for decision-making (38).

In order to address the issues related to health financing, issues related to functions of financing should be addressed. In other words, it is necessary to determine where the funds are collected from and what is the share of insurance and risk pooling in the HS. In addition, the efficiency of the payment system to providers, strategic purchase of services, and tariffs are also important issues in this dimension. It should be noted that each of these functions, in addition to positive or negative relationships and effects on each other, will affect health costs, the level of equity, and the financial protection of individuals against costs. For example, Yabin and Congdong argued that determining the price index of medical services in the service purchase function is affected by factors such as GDP growth rate, service quality, the value of medical personnel, hospital ratings, etc. (49).

Governance and leadership, according to the World Health Organization statement, are defined as part of the functioning of a government and are responsible for the health and well-being of society and pay attention to the level of trust and legitimacy of government activities among the people. On the other hand, it is a function through which it will be possible to achieve the three objectives of HSs. In addition, the process of deciding on the essential and important needs of the system and ensuring their fulfillment is also in the scope of governance and leadership performance (64). Therefore, it is very important to pay attention to it in the present study.

According to the present study results, the existing components in structural factors, development of rules and regulations, and customer protection are among the most critical components for the flourishing of governance and leadership in the HS. As Littlejohns et al. stated that the implementation of any plan and policy in the health sector, for example, the health promotion program requires a central factor of governance and leadership and strengthening and increasing advocacy (59).

Conclusion

In the present study, components related to all dimensions of the HS such as population health (demographics,

high-risk behaviors and risk factors, and the health status of the population), service delivery (prevention services, medical services, palliative and rehabilitation services, as well as components of service quality improvement, and leveling and service delivery levels), growth and development (manpower management, information system, medicine and medical equipment), financing (resource collection, pooling and allocation, and service purchase), and governance & leadership (structural factors, the development of rules and regulations, and customer protection) were identified that policymakers and planners should consider improving the HS in a causal network dynamically.

Study strengths and limitations

In all the studies mentioned, the researchers have pointed out the importance of the valuable use of the dynamic system to investigate HS and its related issues. However, the point that has not been considered in all studies is exploring the comprehensive dimensions of the system and the causal relationships between them. Therefore, in the present study, we have used the fourth-generation BSC model to address this. It should be noted that identifying effective components and their causal relationships requires more accurate methodologies, such as interviews with key people in this field, which will be addressed in future studies.

Acknowledgments

The authors would like to thank the Kerman University of Medical Sciences for the library support of this study.

Author's contributions

Conception and design: ME, AAH and MHM. Acquisition of data: ME, VYF and MHM. Analysis and interpretation of data: ME and MHM. Drafting the manuscript: ME and MHM. Critical revision of the manuscript for important intellectual content: ME, AAH, VYZ and MHM and final approval of the version to be published: ME, MHM.

Ethics approval and consent to participate

The study received ethical approval from the Research Ethics Committees of the Kerman University of Medical Sciences (IR.KMU.REC.1397.287).

Conflict of Interests

The authors declare that they have no competing interests.

References

1. Mehrdad R. Health system in Iran. *Japan Med Assoc J.* 2009;52(1):69-73.
2. Mehroolhassani M, Haghdoost A, Dehnavieh R, Abolhallaje M, Emami M. The proposed framework for monitoring health system (letter to editor). *Iran. J. Epidemiol.* 2017;12(5), Special Issue (Efficiency and Financial Protection in the Health System of Iran):92 -96. [Persian]
3. International Health Conference. Constitution of the World Health Organization. 1946. *Bull World Health Organ.* 2002;80(12):983.
4. Martínez-García M, Hernández-Lemus E. Health Systems as Complex Systems. *Am J Oper Res.* 2013;3:113-126.

<http://mjiri.iums.ac.ir>

Med J Islam Repub Iran. 2023 (3 May); 37:47.

5. Lipsitz LA. Understanding health care as a complex system: the foundation for unintended consequences. *JAMA*. 2012;308(3):243-244.
6. Lin QL, Liu L, Liu HC, Wang DJ. Integrating hierarchical balanced scorecard with fuzzy linguistic for evaluating operating room performance in hospitals. *Expert Syst Appl*. 2013;40(6):1917-1924.
7. Yousefi Nezhad V, Izadbakhsh H, Ghanbar Tehrani N, Ataiepoor S. Simulating the financial health system of Health insurance with System dynamics approach. *Hakim Res J*. 2015;18(4):306-315. [Persian]
8. Kok S, Rutherford AR, Gustafson R, Barrios R, Montaner JS, Vasarhelyi K. Optimizing an HIV testing program using a system dynamics model of the continuum of care. *Health Care Manag Sci*. 2015;18(3):334-362.
9. Allender S, Owen B, Kuhlberg J, Lowe J, Nagorcka-Smith P, Whelan J, et al. community based systems diagram of obesity causes. *PLoS One*. 2015;10(7):1-12.
10. Lan TS, Chen KL, Chen PC, Ku CT, Chiu PH, Wang MH. An investigation of factors affecting elementary school students' BMI values based on the system dynamics modeling. *Comput Math Methods Med*. 2014:1-7.
11. Rwashana AS, Williams DW. System dynamics modeling in healthcare: the Ugandan immunisation system. *Int J Comput Sci*. 2008;1(1):88-98.
12. Ratanawijitrasin S. The dynamics of health care finance: A feedback view of system behavior [Doctoral dissertation]. State University of New York at Albany: Nelson A. Rockefeller College of Public Affairs and Policy, Graduate School of Public Affairs, Department of Public Administration; 1993. ProQuest Dissertations Publishing.
13. Li M, Zhang Y, Lu Y, Yu W, Nong X, Zhang L. Factors influencing two-way referral between hospitals and the community in China: A system dynamics simulation model. *Simulation*. 2018;94(9):765-782.
14. Tengs TO, Osgood ND, Chen LL. The cost-effectiveness of intensive national school-based anti-tobacco education: results from the tobacco policy model. *Prev Med*. 2001;33(6):558-570.
15. Tebbens RJ, D, Thompson KM. Priority shifting and the dynamics of managing eradicable infectious diseases. *Manage Sci*. 2009;55(4):650-663.
16. Li M, Zhu Y, Xue C, Liu Y, Zhang L. The problem of unreasonably high pharmaceutical fees for patients in Chinese hospitals: A system dynamics simulation model. *Comput Biol Med*. 2014;47:58-65.
17. Fraher EP, Knapp A, Sheldon GF, Meyer A, Ricketts TC. Projecting surgeon supply using a dynamic model. *Ann Surg*. 2013;257(5):867-872.
18. Groeneveld EI, Murtagh FE, Kaloki Y, Bausewein C, Higginson IJ. Determinants of healthcare costs in the last year of life. *J Pain Symptom Manage*. 2013;45(2):342-342.
19. Homer J, Milstein B, Labarthe D, Orenstein D, Wile K, Trogon J, et al. Peer reviewed: Simulating and evaluating local interventions to improve cardiovascular health. *Prev Chronic Dis*. 2010;7(1).
20. Lymer S, Brown L. Developing a dynamic microsimulation model of the Australian health system: a means to explore impacts of obesity over the next 50 years. *Epidemiol Res Int*. 2012.
21. Srijariya W, Riewpaiboon A, Chaikledkaew U. System dynamic modeling: an alternative method for budgeting. *Value Health*. 2008;11:S115-S123.
22. Faezipour M, Ferreira S. Assessing water sustainability related to hospitals using system dynamics modeling. *Procedia Comput Sci*. 2014;36:27-32.
23. Tsis P, Evans J. M, Owen S. Reframing the challenges to integrated care: a complex-adaptive systems perspective. *Int J Integr Care*. 2012;12.
24. Butow P, Maclean M, Dunn S, Tattersall M, Boyer M. The dynamics of change: cancer patients' preferences for information, involvement and support. *Ann Oncol*. 1997;8(9):857-863.
25. Ager AK, Lembani M, Mohammed A, Ashir GM, Abdulwahab A, de Pinho H, et al. Health service resilience in Yobe state, Nigeria in the context of the Boko Haram insurgency: a systems dynamics analysis using group model building. *Confl Health*. 2015;9(1):1-14.
26. Au N. The health care cost implications of overweight and obesity during childhood. *Health Serv Res*. 2012;47(2):655-676.
27. Sabounchi NS, Hovmand PS, Osgood ND, Dyck RF, Jungheim ES. A novel system dynamics model of female obesity and fertility. *Am J Public Health*. 2014;104(7):1240-1246.
28. Maglio PP, Cefkin M, Haas PJ, Selinger P. Social factors in creating an integrated capability for health system modeling and simulation. The International Conference on Social Computing, Behavioral Modeling, and Prediction; 2010 March 30-31; Bethesda: USA; 2010.
29. Royston G, Dost A, Townshend J, Turner H. Using system dynamics to help develop and implement policies and programmes in health care in England. *Syst Dyn Rev*. 1999;15(3):293-313.
30. Roy S. Determinants of healthcare expenditure on human capital and economic growth in Bangladesh: a longitudinal data analysis from 1995-2010. *Asian J Pharm Res Health Care*. 2014;6(1).
31. Ciplak N, Barton JR. A system dynamics approach for healthcare waste management: a case study in Istanbul Metropolitan City, Turkey. *Waste Manag Res*. 2012;30(6):576-586.
32. Hooshmand E, Zomorodi Niat H, Ebrahimipour H, Esmaili H, Vafaei Najari A. Designing a performance evaluation model based on balanced score card and analytic hierarchy process methods: Montaserieh Hospital. *Health Scope*. 2018;7(2).
33. Xu X, Li L, Wu, H. Cooperation policy simulation in urban Health Care System. The 2008 IEEE International Conference on Service Operations and Logistics, and Informatics; 2008 Oct 12-15; Beijing; 2008. p. 447-451.
34. Wong HJ, Morra D, Wu RC, Caesar M, Abrams H. Using system dynamics principles for conceptual modelling of publicly funded hospitals. *J Oper Res Soc*. 2012;63(1):79-88.
35. Goldsmith D, Siegel M. Improving health care management through the use of dynamic simulation modeling and health information systems. *Int J Inf Technol Syst Approach*. 2012;5(1):19-36.
36. Romano E, Guizzi G, Chiocca D. A decision support tool, implemented in a system dynamics model, to improve the effectiveness in the hospital emergency department. *Int J Procure Manag*. 2015;8(1-2):141-168.
37. Stasse S, Vita D, Kimfuta J, Da Silveira VC, Bossyns P, Criel B. Improving financial access to health care in the Kisantu district in the Democratic Republic of Congo: acting upon complexity. *Glob Health Act*. 2015;8(1):25480.
38. Waqa G, Moodie M, Snowdon W, Latu C, Coriakula J, Allender S, et al. Exploring the dynamics of food-related policymaking processes and evidence use in Fiji using systems thinking. *Health Res Policy Syst*. 2017;15(1):1-8.
39. Fun W, Wu D, Cheong Y, Noordin NM, Lee K. Evaluation of Economic Impact of tuberculosis control In Malaysia Using Dynamic Transmission Model. *Value Health*. 2015;18(3):A244.
40. Taylor K, Dangerfield B, Le Grand J. Simulation analysis of the consequences of shifting the balance of health care: a system dynamics approach. *J Health Serv Res Policy*. 2005;10(4):196-202.
41. Karemere H, Ribesse N, Kahindo JB, Macq J. Referral hospitals in the Democratic Republic of Congo as complex adaptive systems: similar program, different dynamics. *Pan Afr Med J*. 2015;20.
42. Wood RM, McWilliams ChJ, Thomas MJ, Bourdeaux ChP, Vasilakis Ch. COVID-19 scenario modelling for the mitigation of capacity-dependent deaths in intensive care: computer simulation study. *Health Care Manag Sci*. 2020;1-10.
43. Liu S, Bi Y, Liu Y. Modeling and dynamic analysis of tuberculosis in mainland China from 1998 to 2017: the effect of DOTS strategy and further control. *Theor Biol Med Model*. 2020;17:1-10.
44. Clouth J, Knoll S, Eichmann F. Evaluating health care using system dynamics modelling—A case study in Schizophrenia. *Gesundheitsökonomie & Qualitätsmanagement*. 2009;14(06):302-310.
45. Hajjarsaraei H, Shirazi B, Rezaeian J. Scenario-based analysis of fast track strategy optimization on emergency department using integrated safety simulation. *Saf Sci*. 2018;107:9-21.
46. Rashwan W, Ragab M, Abo-Hamad W, Arisha A. Evaluating policy interventions for delayed discharge: a system dynamics approach. The 2013 Winter Simulations Conference (WSC); 2013 Dec 8-11; Washington, DC: USA; 2013. P. 2463-2474.
47. Demir E, Gunal MM, Southern D. Demand and capacity modelling for acute services using discrete event simulation. *Health Systems*. 2017;6(1):33-40.
48. Edaibat EA, Dever J, Tanju B, Stuban SM. A System dynamics simulation modeling: health information exchange adoption in the U.S healthcare system. Proceedings of the 2014 Winter Simulation Conference; The George Washington University, Washington, DC 20052: USA; 2014.
49. Keshtkar L, Rashwan W, Abo-Hamad W, Arisha A. A hybrid system dynamics, discrete event simulation and data envelopment analysis to investigate boarding patients in acute hospitals. *Oper Res Health Care*.

- 2020;26.
50. Li Y, Xing X, Li C. Dynamic pricing model of medical services in public hospitals in China. *Curr Sci*. 2015;109(8):1437-1444.
 51. Maliapen M, Dangerfield BC. A system dynamics-based simulation study for managing clinical governance and pathways in a hospital. *J Oper Res Soc*. 2010;61(2):255-264.
 52. Witter S, Toonen J, Meessen B, Kagubare J, Fritsche G, Vaughan K. Performance-based financing as a health system reform: mapping the key dimensions for monitoring and evaluation. *BMC Health Serv Res*. 2013;13(1):1-10.
 53. Lucidi S, Maurici M, Paulon L, Rinaldi F, Roma M. A simulation-based multiobjective optimization approach for health care service management. *IEEE Trans. Autom Sci Eng*. 2016;13(4):1480-1491.
 54. Broyles JR, Cochran JK, Montgomery DC. A Markov decision process to dynamically match hospital inpatient staffing to demand. *IIE Trans Healthc Syst Eng*. 2011;(2):116-130.
 55. Hofmann PB. Decisions Near the End of Life: Resources Allocation Implications for Hospitals. *Camb Q Healthc Ethics*. 1992;1:229-237.
 56. Li Y, Lu H, Xing X. Research on the pricing model of medical services in China based on system dynamics method. *J Inf Comput Sci*. 2014;11(16):6039-6046.
 57. Li Y, Li C. Research on the simulation model of medical service pricing. The 2015 4th International Conference on Computer Science and Network Technology (ICCSNT); 2015. P. 14-18.
 58. Zakumumpa H, Dube N, Damian R, Rutebemberwa E. Understanding the dynamic interactions driving the sustainability of ART scale-up implementation in Uganda. *Global Health Research and Policy* 2018; 3(1):1-12.
 59. Littlejohns LB, Baum F, Lawless A, Freeman T. The value of a causal loop diagram in exploring the complex interplay of factors that influence health promotion in a multisectoral health system in Australia. *Health Res. Policy Syst*. 2018;16(1):1-12.
 60. Barasa EW, Molyneux S, English M, Cleary S. Hospitals as complex adaptive systems: a case study of factors influencing priority setting practices at the hospital level in Kenya. *Soc Sci Med*. 2017;174:104-112.
 61. Barasa EW, Cleary S, English M, Molyneux S. The influence of power and actor relations on priority setting and resource allocation practices at the hospital level in Kenya: a case study. *BMC Health Serv Res*. 2016;16(1):1-13.
 62. Kuntz L, Pulm J, Wittland M. Hospital ownership, decisions on supervisory board characteristics, and financial performance. *Health Care Manage Rev*. 2016;41(2):165-176.
 63. Topp SM, Chipukuma JM, Hanefeld J. Understanding the dynamic interactions driving Zambian health centre performance: a case-based health systems analysis. *Health Policy Plan*. 2015;30(4):485-499.
 64. Mitleton-Kelly E. A complexity theory approach to sustainability: A longitudinal study in two London NHS hospitals. *Learn Organ*. 2011;18(1):45-53.
 65. He AJ, Qian J. Hospitals' responses to administrative cost-containment policy in urban China: the case of Fujian Province. *China Q*. 2013;216:946-969.
 66. Al-Khatib IA, Eleyan D, Garfield J. A system dynamics approach for hospital waste management in a city in a developing country: the case of Nablus, Palestine. *Environ Monit Assess*. 2016;188(9):1-9.
 67. Best A, Berland A, Herbert C, Bitz J, van Dijk MW, Krause C, et al. Using systems thinking to support clinical system transformation. *J Health Organ Manag*. 2016;30(3):302-323.
 68. Merrill JA, Deegan M, Wilson RV, Kaushal R, Fredericks K. A system dynamics evaluation model: implementation of health information exchange for public health reporting. *J Am Med Inform Assoc*. 2013;20(e1):e131-e138.
 69. Kalantari M, Hayati Z, Shahmoradi-moghadam H, Phishvayi MS. Investigating the effect of Subsidy Targeting Plan on drug supply chain using systems dynamics. *Tomorrow Management* 2014; 41(13):19-34 [Persian].
 70. Afriyie SO, Kong Y, Lartey PY, Kaodui L, Bediako IA, Wu W, et al. Financial performance of hospitals: A critical obligation of corporate governance dimensions. *Int. J. Health Policy Manag*. 2020;35(6):1468-1485.
 71. Milstein B, Homer J, Briss P, Burton D, Pechacek T. Why behavioral and environmental interventions are needed to improve health at lower cost. *Health Aff (Millwood)*. 2011;30(5):823-832.
 72. Yusefzadeh H, Salem Safi P, Nabilou B. Health system reform plan and performance of hospitals: an Iranian case study. *Mater Sociomed*. 2017;29(3):201-206.
 73. Bhandar TR. Health system research: development, designs and methods. *Int J Health Allied Sci*. 2013;3(1):68-72.

Appendix 1. Structured search method of databases and findings obtained in preliminary search based on the names of the studied databases

Total number of findings	Keywords	Database name	Raw
492	(dynamic OR dynamics OR "system dynamics" OR "Dynamic model" OR "Nonlinear Dynamics" OR "Complex system") AND ("health center" OR "medical services" OR Hospitals OR "medical institution" OR "clinic" OR infirmary OR sanatorium OR "nursing home" OR "convalescent home" OR "Health system" OR hospice) AND (financing OR "financial performance" OR "financial ratio" OR "financial affairs" OR funding OR resource generation OR subsidy OR health information system OR financial OR "human resources" OR "financial state" OR "cash flow" OR budget OR cost OR payments OR "equipment & drugs" OR "leadership & governance" OR "health services delivery" OR "health provision" OR stewardship OR "consumer health" OR "population health")	Scopus	1
27	(dynamic OR dynamics OR "system dynamics" OR "Dynamic model" OR "Nonlinear Dynamics" OR "Complex system") AND ("health center" OR "medical services" OR Hospitals OR "medical institution" OR "clinic" OR infirmary OR sanatorium OR "nursing home" OR "convalescent home" OR "Health system" OR hospice) AND (financing OR "financial performance" OR "financial ratio" OR "financial affairs" OR funding OR resource generation OR subsidy OR health information system OR financial OR "human resources" OR "financial state" OR "cash flow" OR budget OR cost OR payments OR "equipment & drugs" OR "leadership & governance" OR "health services delivery" OR "health provision" OR stewardship OR "consumer health" OR "population health")	Web of Science	2
956	(dynamic OR dynamics OR "system dynamics" OR "Dynamic model" OR "Nonlinear Dynamics" OR "Complex system") AND ("health center" OR "medical services" OR Hospitals OR "medical institution" OR "clinic" OR infirmary OR sanatorium OR "nursing home" OR "convalescent home" OR "Health system" OR hospice) AND (financing OR "financial performance" OR "financial ratio" OR "financial affairs" OR funding OR resource generation OR subsidy OR health information system OR financial OR "human resources" OR "financial state" OR "cash flow" OR budget OR cost OR payments OR "equipment & drugs" OR "leadership & governance" OR "health services delivery" OR "health provision" OR stewardship OR "consumer health" OR "population health")	PubMed	3
1125	(dynamic OR dynamics OR "system dynamics" OR "Dynamic model" OR "Nonlinear Dynamics" OR "Complex system") AND ("health center" OR "medical services" OR Hospitals OR "medical institution" OR "clinic" OR infirmary OR sanatorium OR "nursing home" OR "convalescent home" OR "Health system" OR hospice) AND (financing OR "financial performance" OR "financial ratio" OR "financial affairs" OR funding OR resource generation OR subsidy OR health information system OR financial OR "human resources" OR "financial state" OR "cash flow" OR budget OR cost OR payments OR "equipment & drugs" OR "leadership & governance" OR "health services delivery" OR "health provision" OR stewardship OR "consumer health" OR "population health")	Embase	4
29	Dynamic system (In Persian)+ health sector (In Persian)	Magiran	5
3	Simulation (In Persian)+ health sector (In Persian)		
49	System dynamics (In Persian)+ health sector (In Persian)		
26	Dynamic system (In Persian)+ health sector (In Persian)		
0	Simulation (In Persian)+ health sector (In Persian)	SID	6
10	System dynamics (In Persian) + health sector (In Persian)		
2722	Total sum		
			7

Appendix 2. Full information of articles

Software used	Scope of study	Data collection method	Purpose of the study	Study place	Type of study	Language	Year	Name of author / authors	Row
No specific software is mentioned in this article.	Hospital	Literature review	Provides a guidance on better hospital management.	America	Review article	English	1992	PAUL B. HOFMANN	1
No specific software is mentioned in this article.	Hospital	Cancer patients looking for two medical oncologists at an outpatient clinic at a teaching hospital in Australia completed a questionnaire before, after a consultation and before their next consultation and Wilcoxon and Kruskal-Wallis statistical tests were used to analyze the results.	Search for stability and possible predictors of patients' expressed preferences in order to obtain information and participate in decision making.	Australia	Original article	English	1997	P.N. Butow, M. Maclean, S. M. Dunn, M.H.N. Tattersall & M.J. Boyer	2
STELLA software	Hospital	Using the data obtained from published sources and the opinions of the expert group, dynamic system modeling in disease screening and emergency care was performed.	Using the system dynamics to develop and implement health care related policies and programs	England	Original article	English	1999	Royston G, Dost A, Townshend J, Turner H	3
Vensim 4.0 software	Health system	Collecting secondary data and designing a dynamic system model to calculate expected costs and public health gains of any related policy or intervention over time	valuating the cost-effectiveness of school education programs based on anti-smoking education for adolescents relative to the status quo	California-USA	Original article	English	2001	O. Tengs T, D. Osgood N, L. Chen L	4
No specific software is mentioned in this article.	Health system	Using dynamic system modeling based on numerical assumptions derived from ten national databases	Investigating the effect of behavioral and environmental interventions on improving health at lower costs	America	Original article	English	2003	Bobby Milstein, Jack Homer, Peter Briss, Deron Burton, and Terry Pechacek	5
Linear regression model and STELLA software	Hospital	Cross-sectional analysis of secondary data obtained from the Department of Homeland Security	Build, validate and simulate a dynamic model of the financial system and compare it with the usual method.	Thailand	Original article	English	2004	Witsanuchai Srijariya, Arthorn Riewpaiboon, Usa Chaikledkaew	6
STELLA / ithink software	Hospital	Collect data from sources such as archival data, observations and interviews with senior health care professionals, create a simulation model and analyze the feedback structure and model calibration in the cardiac catheterization services in the UK. The key outputs of the model were the main trends displayed by the waiting lists, the average waiting time, the patient's cumulative referrals, the patient's cumulative activity, and the cumulative overall costs.	Simulate the consequences of health services at home and provide the necessary insight by searching for the basic structure of feedback	England	Original article	English	2005	Taylor K, Dangerfield B, Le Grand J	7

Appendix 2. Continued

Software used	Scope of study	Data collection method	Purpose of the study	Study place	Type of study	Language	Year	Name of author / authors	Row
No specific software is mentioned in this article.	Hospital	Semi-structured and group interviews and workshops	The purpose of this article is to show the author that organizational sustainability is not a continuation of the status quo, but also in terms of organizational point of view, a continuous and dynamic process of simultaneous evolution with changing environment	England	Original article	English	2007	Eve Mitleton-Kelly	8
No specific software is mentioned in this article.	Health system	Agent-Based Modeling and simulation are used as a tool to create a practical health care system and evaluate cooperation policy that can divide beds and physicians between the community health system and the medical delivery system. Cooperation between these two systems can make the service easier and more cost-effective.	Evaluate policies between the public health system and the medical delivery system in a way that satisfies the types of demand according to available resources.	China	Original article	English	2008	Xuyan Xu, Lefei Li, Haidong Wu	9
Vensim software	Health system	1. Conducting initial interviews to identify issues and key stakeholders. 2. Using field studies to determine the full range of activities and challenges related to immunization. 3. Determining factors affecting immunization coverage as well as policies related to it. 4. Determining the conceptual model based on causal loop diagrams. 5. Approval of diagrams by various stakeholders. 6. Convert causal loop diagrams to flow and stock diagrams and convert to a quantitative model. 7. Determining causal relationships between variables and performing simulation of key variables.	To understand immunization problems, generate insights that may increase the effectiveness of immunization coverage, develop and simulate a health care policy design model using a system dynamics modeling approach.	Uganda	Original article	English	2008	Agnes Semwanga Rwashana, Ddembe Wileese Williams	10
No specific software is mentioned in this article.	Health system	Using a dynamic system simulation approach and applying flow and stock diagrams in a complex health system	Using a dynamic system simulation approach to map complex relationships across health care systems to help policymakers and decision makers estimate financial performance over time	Washington	Original article	English	2009	Emad A. Edaibat, Jason Dever, Bereket Tanju, Steven M. F. Stuban	11
Use flow and stock models and does not mention specific software in this regard.	Hospital	In this study, flow and stock models have been used. Based on that, it has used the current number of physicians as stock and the new inputs from medical education and graduate retraining as inflows and exit due to death, retirement and job failures as outflows.	Development of a model to predict the number of heads and balanced supply of full-time surgeons by age, sex, and specialty in the United States from 2009-2028.	America	Original article	English	2009	Erin P. Fraher, Andy Knapton, George F. Sheldon, Anthony Meyer, and Thomas C. Ricketts	12
No specific software is mentioned in this article.	Health system	Using a hypothetically predetermined dynamic model and examining several different decision rules according to the vaccination policy against infectious diseases	Change the priority and dynamics of eradicating infectious diseases management	Boston-USA	Original article	English	2009	J. Duintjer Tebbens R. M. Thompson K	13

Appendix 2. Continued

Software used	Scope of study	Data collection method	Purpose of the study	Study place	Type of study	Language	Year	Name of author / authors	Row
No specific software is mentioned in this article.	Hospital	Review reports and interviews with key stakeholders of the organization	Investigating how the network of actors and the organizational framework emerge over time and paying attention to their performance in dynamic environments	Congo	Original article	English	2010	Hermès Karemère, Nathalie Ribesse, Jean-Bosco Kahindo, and Jen Macq	14
No specific software is mentioned in this article.	Hospital	1. Five members of the hospital's focal working group were actively involved in the model development process. 2. A visual walkthrough of the business processes was also conducted and a more complex model was developed during the workshops. 3. Knowledge extracted and relationships between players identified. 4. Study participants were interviewed to investigate their perceptions about learning and using SD models for decision-making, and also, a questionnaire consisting of 40 questions was created to investigate hospital managers' views on SD-based VI models. 5. Finally, the responses were analyzed descriptively in four dimensions, i.e. model characteristics, manipulation, evaluation and performance.	This study provides a system dynamics based decision support tool to hospital managers and clinicians to examine the possibility of clinical pathways.	Australia	Original article	English	2010	Maliapen, M and Dangerfield, BC	15
Vensim DSS software and Venapp	Hospital	Step 1: Identify variables related to disease treatment Step 2: Classify and relate the variables using mathematical algorithms that aim to model as close to reality as possible. Step 3: Modeling, reviewing the basic structures of the model, manipulating input variables and performing simulations at different times	Evaluation of health care in schizophrenia using dynamic system modeling	Germany	Original article	English	2010	Clouth J, Knoll S, Eichmann F	16
STELLA and ithink software	Hospital	1. Select four hospitals to study 2. Measurement of general and hazardous waste weight for seven consecutive days in each hospital 3. Consider the following factors in the study: number of beds, type of hospital, level of hospital services, number of inpatients, number of outpatients, number of staff and hospital departments. 4. Making a causal loop diagram that was affected by birth rate and mortality. 5. Generate flow and stock diagram 6. Simulation of system dynamics model and implementation of different scenarios in the study environment in order to make decisions.	System dynamic modeling for predicting hospital waste	Palestine	Original article	English	2010	Issam A. Al-Khatib & Derar Eleyan & Joy Garfield	17

Appendix 2. Continued

Software used	Scope of study	Data collection method	Purpose of the study	Study place	Type of study	Language	Year	Name of author / authors	Row
No specific software is mentioned in this article.	Health system	Step 1: Collect study data from many sources in the United States on all adults who have never experienced a cardiovascular accident. Step 2: Simulation of pathways leading to cardiovascular risk factors from 1990-2040 and evaluation of 29 interventions. The main consequences in this model, cardiovascular accidents and resulting deaths and the total costs involved were considered. Step 3: Sensitivity analysis to evaluate the importance of unknown parameters.	Develop a simulation model to evaluate several approaches to the prevention and management of cardiovascular risks	America	Original article	English	2010	Homer J, Milstein B, Wile K, Trogon J, Huang Ph, Labarthe D, Orenstein D	18
Vensim software	Hospital	Data analysis using dynamic modeling and performed in vensim software (Understanding the problem, determining the key causal relationships within and between the three categories of main problems affecting the subject of the study, building a conceptual model based on joint discussions with clinical experts and hospital management, and designing sustainable strategies to improve the problem)	In this article, the issue of long-term hospitalization of patients in the emergency department of a hospital has been investigated. From this analysis, an organizational model has been developed that is a roadmap for achieving sustainable improvement while waiting in the emergency department.	Canada	Original article	English	2010	HJ Wong,, D Morra, RC Wu, M Caesar and H Abrams	19
No specific software is mentioned in this article.	Hospital	A review of the literature and the Markov chain has been used to estimate the service process, predict transient stock, and formulation for an inpatient unit.	Using the Markov decision-making process for dynamic staffing in the inpatient ward and matching staffing with demand.	America	Original article	English	2011	James R. Broyles, Jeffery K. Cochran, Douglas C. Montgomery	20
No specific software is mentioned in this article.	Health system	In-depth and semi-structured interviews with government officials, health deputies, medical insurance managers, hospital managers and physicians from five selected hospitals in the province	Investigating the response of public hospitals to administrative instructions for cost control and its consequences	Fujian Province, China	Original article	English	2011	Alex Jingwei He and Jiwei Qian	21
Vensim software	Hospital	A dynamic model has been developed to investigate two problems, namely unfair drug prices and higher drug costs relative to patients' medical costs, and possible solutions have been proposed.	The aim of this study is to construct a dynamic model to accurately express the behaviors of drug systems to identify the causes of two problems, namely unfair drug prices and high drug costs in the overall medical costs of patients in a Chinese hospital.	China	Original article	English	2012	Meina Li, Yangang Zhu, Chen Xue, Yuan Liu, Lulu Zhang	22
No specific software is mentioned in this article.	Hospital	Use of survey data in micro-simulation and Monte Carlo indices (uses micro-units at the analysis level).	Investigating the effects of obesity over the next 50 years on the health system	Australia	Original article	English	2012	Sharyn Lymer, Laurie Brown	23

Appendix 2. Continued

Software used	Scope of study	Data collection method	Purpose of the study	Study place	Type of study	Language	Year	Name of author / authors	Row
No specific software is mentioned in this article.	Hospital	Use of data recorded in the hospital HIS in simulation and drawing flow and stock diagrams	Better understanding of hospital performance and healthcare management through dynamic system simulation and health information systems	Japan	Original article	English	2012	Daniel Goldsmith, Michael Siegel	24
Vensim PLE software	Hospital	Observation and interviews over a period of three months and then simulate the hospital recycling management	Develop a system to support the selection and planning of future treatment capacity	Turkey	Original article	English	2012	Nesli Ciplak and John R Barton	25
No specific software is mentioned in this article.	Hospital	A discrete event simulation model is used that uses quantitative data.	Using the dynamic system method to draw the dynamic flow of elderly patients in the health care system	Ireland	Review article	English	2012	Rashwan, Wael; Ragab, Mohamed; Abo-Hamad, Waleed; Arisha, Amr	26
No specific software is mentioned in this article.	Hospital	After identifying the variables related to the study subject, the effect of overweight status on non-hospital Medicare costs was estimated using two-part models and generalized and one-part linear models.	Investigating childhood overweight and how long it takes on increasing health care costs	Australia	Original article	English	2012	Au N	27
No specific software is mentioned in this article.	Hospital	Collect data from a focus group of a diverse sample of Toronto health care professionals using the snowball method and conduct a semi-structured interview to extract people's ideas and experiences of integrating health systems. The CAS framework was used to describe and analyze the data, and this framework was tailored to the dominant themes in the participants' responses.	Application of the view of complex adaptive systems in integrated care	Canada	Original article	English	2012	Tsasis P, M. Evans J, Owen S	28
No specific software is mentioned in this article.	Hospital	Systematic review	Identify the factors affecting the costs of health care in different centers and determine the relative importance of these cost factors	The UK	Systematic review article	English	2013	E. Iris Groeneveld, Fliss Murtagh, Yvonne Kaloki, Claudia Bausewein, Irene Higginson	29
It only refers to flow and stock diagrams without mentioning the software.	Health system	Drawing diagrams of the causal loop during the centralized focus group discussions and confirming it by online group checking and reviewing documents.	Assess the complex dynamics in implementing electronic health information exchange to report public health at the national level and identify policy implications in similar implementations	New York	Original article	English	2013	Jacqueline A Merrill, Michael Deegan, Rosalind V Wilson, Rainu Kaushal, Kimberly Fredericks	30

Appendix 2. Continued

Software used	Scope of study	Data collection method	Purpose of the study	Study place	Type of study	Language	Year	Name of author / authors	Row
No specific software is mentioned in this article.	Health system	Literature review	Describe a comprehensive framework for monitoring and evaluating health system reform	Bergen Province, Norway	Review article	English	2013	Sophie Witter, Jurrien Toonen, Bruno Meessen, Jean Kagubare, György Fritzsche and Kelsey Vaughan	31
Vensim PLE 6.3 software	Hospital	Using Delphi method and field survey of 15 hospitals, preliminary data were obtained and then simulation was performed using dynamic system theory.	Improving the pricing process of medical services	China	Original article	English	2014	Yabin Li, Xiaohui Xing and Congdong Li	32
No specific software is mentioned in this article.	Health system	Interview and direct observation of operations in four medical centers	Investigating the relevance and usefulness of an adapted conceptual framework to improve our understanding of causal mechanisms and pathways affecting health care performance	Zambia	Original article	English	2014	Stephanie M Topp, Julien M Chipukuma and Johanna Hanefeld	33
No specific software is mentioned in this article.	Health system	First, an experimental model for data analysis to determine health care costs under human capital and economic growth was obtained, and then the dynamic relationships between health care costs, human capital and economic growth were investigated using the OLS model.	Examining the determinants of health care costs in Bangladesh between 1995 and 2010 using global development indicators.	Bangladesh	Original article	English	2014	SHONGKOUR ROY	34
No specific software is mentioned in this article.	Hospital	Dynamic modeling method with the help of vensim software has been used to build a medical services pricing simulation model. The weighted average of the coefficients was calculated by Delphi method.	Provides the pricing process of medical services to analyze the relationships between different factors using dynamic models.	China	Original article	English	2014	Yabin Li, Hong Lu, Xiaohui Xing	35
iThink simulation software	Hospital	Step 1: Literature review carefully and analyze the health care factors Step 2: Develop causal models for health care sustainability Step 3: Carrying out a supplementary study on water sustainability related to hospitals in order to identify a set of factors and relationships in the form of a causal model	Evaluation of water sustainability of hospitals using dynamic system modeling	Arlington, Texas, USA	Original article	English	2014	Faezipour M, Ferreira S	36
No specific software is mentioned in this article.	Health system	Obtaining data from 63 pregnant women and modeling the dynamic system of obesity in women in pregnancy, childbirth and postpartum phases and testing various strategies in family health while considering the effective relationship between related variables and outcomes such as fetal weight, postpartum body mass index, Risk of death and ...	Creating a dynamic system model for weight gain and obesity in women of childbearing age that can inform future health policies and create potential for pre-pregnancy interventions targeting obese women	America	Original article	English	2014	S. Sabouchi N, S. Hovmand P, D. Osgood N, F. Dyck R, S. Jungheim E	37

Appendix 2. Continued

Software used	Scope of study	Data collection method	Purpose of the study	Study place	Type of study	Language	Year	Name of author / authors	Row
Vensim software	Health system	Literature review and draw causal loop and flow & stock diagrams	In this project, with the design of an appropriate model, the effect of cash subsidy distribution on the level of people's satisfaction and its distribution on the profit of the entire drug supply chain is examined.	Iran	Original article	Persian	2014	Kalantari M, Hayati Z, Shahmoradi Moghadam H, Pishvaei M.S	38
Vensim software	Health system	First, by reviewing the literature and semi-structured interviews with insurance and health experts, the variables affecting the financial system were identified, and then the causal model and flow& stock diagram were simulated and implemented.	Simulation of health insurance financial system to predict the financial status of insurance according to its resources and uses in the coming years	Iran	Original article	Persian	2015	Yousefinejad V, Izadbakhsh H.R, Ghanbar Tehrani N, Ataiepour S	39
No specific software is mentioned in this article.	Hospital	In this paper, using simulation techniques based on dynamic systems and continuous logics, it is examined what can be done to improve the performance of the emergency department.	The purpose of this article is to immediately clarify the current state of a general emergency room and to suggest any improvement by identifying any problems.	Italy	Original article	English	2015	Elpidio Romano, Guido Guizzi and Daniela Chiocca	40
Vensim PLE software	Hospital	1. Analysis of the cyclical process of the pricing model: 1.1 Step 1. Balance the cost of medical services 1.2 Step 2. Calculate the value of time. 1.3 Calculation of the coefficient of technical value of medical services in period t 1.4 consideration of the grading of hospitals 1.5 Calculate the average rate of return on investment in period t 1.6 Calculation of compensation for medical services in period t 2. Dynamic equilibrium analysis of medical services pricing based on the causal relationship model 3. Creating a dynamic model of medical service pricing system and simulation	Simulation of medical services pricing based on dynamic system theory	China	Original article	English	2015	Yabin Li, Congdong Li	41
No specific software is mentioned in this article.	Health system	SPLASH approach to simulate health care	Development of correct behavioral and social models in the health sector and their integration with simulation models	Berlin-Heidelberg	Review article	English	2015	Paul P. Maglio, Melissa Cefkin, Peter J. Haas, and Pat Selinger	42
No specific software is mentioned in this article.	Hospital	Action Research: analyze the problem, formulate hypotheses, identify solutions, implementation and evaluation of actions	Provide accurate report of deep reforms in the local health-care system to improve access to care at the appropriate level in Kyzantv in Congo	Congo	Original article	English	2015	Ste 'phanie Stasse, Dany Vita, Jacques Kimfuta, Vale 'ria Campos da Silveira, Paul Bossyns and Bart Criel	43

Appendix 2. Continued

Software used	Scope of study	Data collection method	Purpose of the study	Study place	Type of study	Language	Year	Name of author / authors	Row
Vensim software	Health system	Conducting structured interviews with 39 stakeholders from 3 levels of local government and holding group meetings to build a model with 11 senior stakeholders using participatory scripts to review thematic analysis of interviews and develop a basic system model considering the relationship between variables	Identify the main threat routes to present and emerging response and compatibility routes	Nigeria	Original article	English	2015	Ager A.K, Lembani M, Mohammed A, Ashir G.M, Abdulwahab A, de Pinho H, Delobelle P, Zarowsky Ch	44
Use of NVivo software in thematic analysis	Hospital	Data collection was conducted through literature review, expert meetings and interviews with doctors, executives, managers and board members, and finally, the data collected were displayed in a general model in the form of causal loops thematically.	Use a complex system framework to investigate mechanisms that enable or limit the implementation of clinical guidelines in different clinical settings.	Columbia	Original article	English	2015	Best A, Berland A, Herbert C, Bitz J, W van Dijk M, Krause Ch, Cochrane D, Noel K, Julian Marsden J, McKeown Sh, Millar j	45
No specific software is mentioned in this article.	Hospital	Step 1: Study the burden of disease in the state Step 2: Random selection of medical records of patients from public clinics and hospitals Step 3: Analyze the total direct costs of TB management Step 4: Perform dynamic modeling to predict the disease and its economic burden over a ten-year period	Assessing the economic impact of TB control using a dynamic transfer model	Malaysia (State of Selangor)	Original article	English	2015	Fun W.H, Wu D.B, Cheong Y.M, Mohamad Noordin N, Lee K.K	46
No specific software is mentioned in this article.	Hospital	Step 1: Holding focus group discussions to prepare performance evaluation indicators based on the balanced scorecard approach and finalize it by Delphi method Step 2: Describe the strategic plan of the hospital based on the objectives and complete the standard questionnaires of the Analytical Hierarchy Process (AHP) Step 3: Prioritize prospects and indicators with an adjustment rate of less than 0.1 with the opinion of 14 experts Step 4: Evaluate the realization of each of the perspectives and indicators and the performance of the hospital in 2015	Evaluating the performance of the hospital using the balanced scorecard approach	Mashhad-Iran	Original article	English	2015	Hooshmand E, Zomorodi Niat H, Ebrahimipour H, Esmaili H, Vafaeenajar A	47
R software and simulation software (Simul8)	Hospital	Literature review and discrete event simulations	Capacity and demand modeling for acute services over a 5-year period using discrete event simulations	the UK	Original article	English	2016	Eren Demir, Murat M. Gunal and David Southern	48
No specific software is mentioned in this article.	Hospital	In-depth interviews with national policymakers, hospital managers and providers, review of accounting documents, meetings and reports and non-participatory observation over a seven-month period.	Investigating the effect of power relations between different actors in the implementation of priority cases and resource allocation processes in public hospitals	Kenya	Original article	English	2016	Edwine W. BarasaEmail author, Susan Cleary, Mike English and Sassy Molyneux	49

Appendix 2. Continued

Software used	Scope of study	Data collection method	Purpose of the study	Study place	Type of study	Language	Year	Name of author / authors	Row
STATA Version 11 software	Hospital	ANOVA and regression analysis were used to test the hypothesis that decision about board size and composition is related to financial performance and can explain performance differences.	Explain the differences in the financial performance of hospitals in relation to ownership by studying the size and composition of supervisory boards.	Germany	Original article	English	2016	Ludwig Kuntz, Jannis Pulm, Michael Wittland	50
Arena 14.7 simulation software	Hospital	1. Using the discrete event simulation model to show the flows of patients from the emergency room to the obstetrics ward. 2. Model validation to ensure its accuracy. 3. Using the simulation model to estimate some performance indicators related to the processes of interest. 4. Using a derivative-free multi-objective algorithm considering the dual-objective nature of the problem and connecting it to the simulation model using a suitable interface and comparing it with previous performance results.	Using a simulation-based optimization approach for health care service management	Italy	Original article	English	2016	Stefano Lucidi, Massimo Maurici, Luca Paulon, Francesco Rinaldi, and Massimo Roma	51
No specific software is mentioned in this article.	Hospital	In this study, by conducting in-depth interviews with national policymakers, hospital managers and physicians at the implementation level and reviewing documents such as hospital plans and budgets, accounting minutes and documents, and non-participatory observations of prioritization and resource allocation operations in a period of 7 months, causal loops were constructed based on complex adaptive systems in the hospital.	Identify processes affecting prioritization operations, examine how these factors affect the process, and provide lessons and suggestions for hospital prioritization.	Kenya	Original article	English	2017	Barasa E.W, Molyneux S, English M, Cleary S	52
Vensim software	Health system	Invite the Ministry of Health and the Ministry of Agriculture to hold three 180-minute workshops to build the model on three consecutive days in each ministry with policymakers involved in developing food-related policies to prevent non-communicable diseases. Relevant workshops mapped the food policy process and the contribution of scientific and local evidence to the process, and identified measures to increase the use of evidence in policy. In this regard, causal loop diagrams in each ministry were designed in the framework of 4 activities of consultation, interaction with stakeholders, access and use of evidence and delays in policy processes.	Applying systems thinking to identify the causes and consequences of poor use of evidence in food policy in government ministries in Fiji and strengthening the use of evidence in policy-making	Fiji	Original article	English	2017	Waqar G, Moodie M, Snowdo W, Latu C, Coriakula J, Allender S, Bell C	53

Appendix 2. Continued

Software used	Scope of study	Data collection method	Purpose of the study	Study place	Type of study	Language	Year	Name of author / authors	Row
Vensim DSS software	Hospital	Build a dynamic system model as follows: Step 1: Identify the problem and define the system boundary. Step 2: obtaining variables and conceptual framework of the model based on studies conducted in line with the subject of research in other countries. Step 3: making causal diagrams. Step 4: Select the variables through analysis. Step 5: Formulate mathematical equations and determine the initial conditions. Step 6: Analyze and calibrate the compatibility between model and reality. Step 7: simulation and obtaining conclusions.	Attention to effective factors in hospital-community referrals	China	Original article	English	2018	Li M, Zhang Y, Lu Y, Yu W, Nong X, Zhang L	54
ARENA Discrete Event Simulation Software	Hospital	Step 1: Using hospital information systems and interviewing staff to collect patient records and patient circulation in the emergency department. Step 2: Using discrete event simulation to evaluate the effect of each scenario and combining it with system dynamics simulation to describe the main and sensitive variables while considering the effective relationships between them that affect the key performance indicator of the emergency department.	Providing quantitative measures to evaluate the impact of alternative operational strategies on the fast track system in the emergency department	Shahid Rajaei Hospital in Tonekabon, Mazandaran Province	Original article	English	2018	Hajjarsaraei H, Shirazi B, Rezaeian J	55
NVivo software in thematic analysis and Vensim PLE software in drawing diagrams	Health system	By carefully analyzing 20 strategic government documents and interviewing 53 stakeholders from several sectors, key findings and prominent themes were presented in the form of causal loop diagrams.	The use of complex systems approach to examine key factors influencing health promotion policies in a multisectoral health system in Australia	Australia	Original article	English	2018	Littlejohns L.B, Baum F, Lawless A, Freeman T	56
STATA software	Health system	Using the mix method in two phases as follows: Phase 1: Survey of 195 health centers that provided ART services between 2004 and 2009. Phase 2: Targeted selection of six health centers and in-depth and semi-structured interviews with them. Quantitative data analysis by thematic coding and analysis and quality data management with STATA software.	Discovering the interactions between the components of the health system and their impact on the sustainability of antiviral therapy (ART)	Uganda	Original article	English	2018	Zakumumpa H, Dube N, Shumbusho Damian R, utebemberwa E	57

Appendix 2. Continued

Software used	Scope of study	Data collection method	Purpose of the study	Study place	Type of study	Language	Year	Name of author / authors	Row
No specific software is mentioned in this article.	Hospital	Primary and secondary data were used to collect study data. For the initial data, structured and non-structured questionnaires were used in 125 hospitals. Secondary data were obtained from board meetings, financial statements and reports on selected hospitals from 2010 to 2017. The data were then sorted to obtain the required information on CEO presence, board relations, governance dynamics, gender diversity, and financial performance.	Investigating the effects of corporate governance mechanisms on the financial performance of hospitals	Ghana	Original article	English	2019	Afriyie S.O, Yusheng Kong Y, Lartey P.Y, Kaodui Li, Isaac A	58
Use of open access software with easy use (does not mention the name of the software.)	Hospital	A stochastic discrete event simulation model has been used to show the dynamic key variables in the Covid 19 patient admission process for intensive care. In this study, the effect of a number of possible interventions is simulated. In other words, the input variables in the model were the levers available for the planners as well as the key output variables were considered as the time available at maximum capacity, peak daily mortality and total mortality.	Estimating the reduction in capacity-dependent deaths through demand-driven initiatives such as non-pharmacological interventions and supply-oriented measures such as increasing surgical capacity or reducing residence time	England	Original article	English	2020	Richard M Wood, Christopher J McWilliams, Matthew J Thomas, Christopher P Bourdeaux, Christos Vasilakis	59
No specific software is mentioned in this article.	Health system	In this study, using a dynamic model, the effect of control strategy on TB transmission as well as new vaccine production and treatment improvement has been investigated. The problem of optimal control and minimization of the total number of infected people at the lowest cost is presented and analyzed using the principle of Pontryagin maximization and numerical simulations have been used to show theoretical results.	Mathematical modeling and dynamic analysis of tuberculosis and understanding the impact of DOTS strategy on tuberculosis control in order to design preventive strategies	China	Original article	English	2020	Siyu Liu, Yingjie Bi and Yawen Liu	60
AnyLogic 7 software	Hospital	In this study, quantitative data such as the use of hospital information system (HIS) and local databases and qualitative data such as interviews and observations were used to collect data. Then, in the data analysis stage, discrete event simulation and system dynamics are used. In this study, Causal loop diagrams and sub-system diagrams are used; In fact, the exact details of the process from the real system are expressed through discrete event simulation and the conceptual model of feedback is done through system dynamics.	Using a combined simulation approach to create an opportunity for hospital managers to investigate the problem of patient boarding in different locations in the hospital	Ireland	Original article	English	2020	Leila Keshtkar, Wael Rashwan, Waleed Abo-Hamad, Amr Arisha	61