دانشگاه فردوسی مشهد

Ferdowsi University of Mashhad

JOURNAL OF SYSTEMS THINKING IN PRACTICE

Print ISSN: 2980-9460

Online ISSN: 2821-1669

Volume 2, Issue 4, Fall, 2023

Editor-in-Chief

Alireza Pooya (Prof.)

JOURNAL OF SYSTEMS THINKING IN PRACTICE (JSTINP), Quarterly

Web: jstinp.um.ac.ir

In the Name of God, the Compassionate, the Merciful

Journal of Systems Thinking in Practice (STINP)

FERDOWSI UNIVERSITY OF MASHHAD
Editorial Office:Systems Thinking In Practice Group, Faculty of Economics and Administrative sciences, Ferdowsi University of Mashhad, Mashhad, Iran. Phone: +98(51)3880-6356

JOURNAL OF SYSTEMS THINKING IN PRACTICE (JSTINP), Quarterly

Web: jstinp.um.ac.ir

About the journal

- **Publisher:** Ferdowsi University of Mashhad, Iran
- **Adheres to:** the guidelines of the Committee on Publication Ethics (COPE)
- **Review time:** 65 days
- **Frequency:** Quarterly
- **Open access:** Yes
- **Licensed by:** CC BY 4.0
- **Policy:** Duble blind peer-reviewed
- **Indexed and Abstracted:** Yes
- **Language:** English
- **Article Processing Charges:** No
- **Contact email:** jstinp@um.ac.ir

Publication Date:

Journal of Systems Thinking in Practice (JSTINP) is published 4 times a year. Volume 2, Issue 4, December 2023.

JOURNAL OF SYSTEMS THINKING IN PRACTICE (JSTINP), Quarterly

Web: jstinp.um.ac.ir

Volume 2, Issue 4, 2023

TABLE OF CONTENTS

FERDOWSI UNIVERSITY OF MASHHAD
Editorial Office:Systems Thinking In Practice Group, Faculty of Economics and Administrative sciences, Ferdowsi University of Mashhad, Mashhad, Iran. Phone: +98(51)3880-6356

Ferdowsi University of Mashhad

Journal of Systems Thinking in Practice
JSTINP, *QUARTERLY*
Homepage: jstinp.um.ac.ir
Online ISSN: 2821-1669, Print ISSN: 2980-9460
Research Article
DOI:10.22067/JSTINP.2023.85540.1079
JSTINP 2023; Vol. 2, No. 4

Designing a Model and Simulating the Production Chain of the Metal Industries in a System Dynamics Approach (Case Study: Shablon Tajhiz Company)

Farzad Amiri[a]*

[a] *Department of Industrial Engineering, Faculty of Engineering Management, Kermanshah University of Technology, Kermanshah, Iran.*

How to cite this article

Amiri, F., 2023. Designing a Model and Simulating the Production Chain of the Metal Industries in a System Dynamics Approach (Case Study: Shablon Tajhiz Company). *Journal of Systems Thinking in Practice* 2(4), pp.1-16. doi: 10.22067/jstinp.2023.85540.1079.
URL: https://jstinp.um.ac.ir/article_44690.html

ABSTRACT

The supply chain includes all the activities required to deliver a product or service to end customers. By adopting the above approach to the supply chain, production and distribution functions are added to the chain as part of the flow of goods and services. The supply chain in this approach includes three areas: procurement, production, and distribution. This article results from a research project commissioned by the Kermanshah Industry, Mining, and Trade Organization to improve the production capacity of metal industries in the province. Based on this, effective loops were identified with the initial introduction of 26 selected companies active in the province and conducting several rounds of interviews with the management and experts of these companies. With the suggestion of the Industry, Mining, and Trade Organization and with the agreement and participation of the best and most complete company active in this context (Shablon Tajhiz), it was modeled and executed. The formulation was designed with the participation of the panel of experts and in the form of discussion sessions based on the trial and error method. In order to confirm the results, the statistical data of the company was extracted from 1390 and compared and validated with the results obtained from the model's output. Since the nature of these loops and their constituent variables change over time in the actual state. A dynamic systems approach has been used to simulate the model and consider dynamic conditions and their mutual effects. The structure of the results was checked and confirmed through the sensitivity analysis of the findings. It is worth mentioning that the analysis and drawing of the results were done using Vensim software.

Keywords

Model design, Production chain simulation, Metal industries, System Dynamics, Missing loops.

Article history

Received: 2023-11-25
Revised: 2023-12-19
Accepted: 2023-12-20
Published (Online): 2023-12-28

Number of Figures: 11 **Number of Tables: 1** **Number of Pages: 16** **Number of References: 12**

***Corresponding author**
Email: : f.amiri@kut.ac.ir

1. Introduction

During the 1960s and 1970s, organizations were trying to increase their competitive power by standardizing and improving their internal processes to come up with products featuring better qualities and lower costs. At that time, the prevalent thought was that strong engineering, designing, and coherent and coordinated operations were prerequisites for attaining market demands and acquiring a larger market share. For the same reason, organizations direct all their efforts toward increasing efficiency. It did not take them too much time before they became aware of the reality that mere attention to production and technology cannot guarantee the success of the manufacturing companies and factories; thus, their gradual move towards the other factors influencing the production cycle was placed atop of the companies' agenda. This critical issue became the prelude to forming an important concept named supply chain management (Soori et al., 2023). The supply chain encompasses all the activities related to the goods flow and materials conversion, from the procurement of the raw material to the delivery of the final goods to the customer, planning, and management of the demand and supply, preparation of materials, service, or goods production and scheduling, warehousing, inventory control and distribution, delivery and service to the customer (Asha et al., 2023).

Some have limited supply chains to the relationships between the buyer and seller, and this approach is only concentrated on the first order purchase operation in an organization. Another group adopts a broader approach to the supply chain and considers it to include all of an organization's supply sources. With this definition, the supply chain includes all the first, second, third, and higher rank suppliers. Such an approach towards the supply chain includes all the activities required to offer a product or service to the final customer. With the approach mentioned above towards the supply chain, the manufacturing and distribution functions are added as part of the goods and services flow to the chain. In this perspective, the supply chain embraces three areas: provisioning, production, and distribution. Although supply chains are used in manufacturing and service organizations, the chain's complexity may vary significantly from one industry to another and from one company to another (Shehzad et al., 2020).

The supply chain is comprised of the following five essential principles indicating its importance (Osborne and Dempsey, 2023):

- Connectivity
- Collaboration
- Synchronization
- Leverage
- Scalability

The supply chain is a set of factors that create added economic value. The incorrect performance of this chain disrupts the creation of added value at the macroeconomic level. Although the "production chain" in the project title is meant in a macro way, since the effective factors in forming the production chain are placed inside a package, the main focus in the future sections will be directed toward the supply chain. In a systematic approach, the production chain forms the supply chain network as part of the supply chain loop (Ni and Sun, 2019).

2. Method

According to the research classifications, the present study's modeling is a developmental and applied type because data have been collected from a manufacturing-distributive business entity besides employing the system dynamics technique, and improvement policies are being presented for it. Moreover, considering the nature of the issue investigated in the present study, a dynamic approach of the qualitative-quantitative type will be adopted for the system. The present study will apply diverse library research methods, field studies, questionnaires, interviews, and dynamic modeling based on the needs. For performing data analysis, Vensim Ple 6.1 Software's capabilities will be utilized to draw policy analysis diagrams and investigate the model's structure. The behavioral pattern of the model's parts will be analyzed by investigating the possible scenarios. Deep semi-structured interviews will be conducted with the addressees in the field investigations. The interviewees have been selected regarding each of the production sectors from amongst the industry owners, executives (private sector), employees and experts of manufacturing entities, state sector specialists in the area of the industry, and professors of the universities. The methods used for gathering information required by the study are as follows:

(1) Statistical methods
(2) Library research (reference to articles, researches, dissertations, reports and so forth)
(3) Field study (interview)
(4) Holding brainstorming sessions and forums

2.1. The Study population, sampling method and sample volume calculation

The project executive(s) were the managers and experts of the manufacturing businesses (metal industries' sector of Kermanshah Province) and managers and specialists of the policy-making (governmental) sector. Sampling was conducted purposively and from amongst the identified addressees. Thus, the sample volume pattern was not found applicable in this regard.

2.2. Study objectives

(1) Designing a model and simulating the production chain in the metal industries with an approach to a system dynamics

(2) Determining and suggesting the missing links affecting the model

(3) Predicting the behaviors of the production model's essential variables (provincial metal industries)

2.3. The supply chain

It is a network of organizations involved in processes and activities based on top-to-bottom relationships. It creates value through products and services provided to end customers. Everyone working in the supply chain aims to increase competition or improve customer service levels. Today, from the point of view of final customers, an organizational unit alone is not responsible for the competitiveness of products or services, and the customer considers the supply chain of the entire organization at once. The competition of companies has been drawn towards supply chains, based on which activities such as supply and demand planning, material procurement, product production and programming, goods storage services, inventory control, distribution, delivery, and customer service at the level now the company is moving towards the supply chain level (Soori et al., 2023). A supply chain generally includes all parts that directly or indirectly contribute to meeting customers' needs. The supply chain does not only include suppliers and manufacturers, but in addition to the transportation sector, wholesalers, retailers, and even their customers are also other components of the chain (De Giovanni and Vinzi, 2012).

The industrial supply chain should be considered as a set of supply chains related to a specific industry in an industrial area and parallel to the integration of various supply activities required by each component of the entire extended chain and communication flows. (Engelseth et al., 2019). These links must be in the product supply chain to complete the supply process. However, because of their absence, the produced in the background of the supply chain must be sent outside the industrial area to experience more value. It adds processes and then returns to the industrial area. The absence of these rings, like the presence of critical rings, reduces its cost-effectiveness due to the scale and spatial limitations of the industrial area.

The increasing competitiveness or the very elevation of service-providing to the customers because, nowadays, from the perspective of the final customers, an organizational unit is not alone responsible for the competitiveness of the products or services, and it considers the supply chain of the whole organization all at once. The companies' competition has been dragged towards the supply chains, based on which activities like planning demand and supply, material procurement, product manufacturing and programming, goods maintenance services, inventory control, distribution, delivery, and service to the customers were all previously carried out in the company level are now being transferred to the supply chain level (Soori et al., 2023). Generally, a supply chain includes all the parts directly or indirectly engaged in completing the customers' needs. The supply chain does not solely incorporate the suppliers and producers. Instead, besides the transportation sectors, wholesalers, retailers, and even their customers are among the other components of the chain (De Giovanni and Vinzi, 2012).

An industrial supply chain should be considered as a collection of supply chains related to a specific industry, located inside an industrial region and working parallel to the integration of the various supplying activities needed by each component of the whole wide chain as well as the connective flows related to them (Engelseth et al., 2019). The product supply chain loops were necessary to finish the supply process. However, due to their absence, the product manufactured in the backend of the supply chain has to be sent outside the industrial district to undergo the subsequent value-adding processes and transferred back to the industrial region afterward. The absence of these loops, like the existence of critical loops, mitigates the cost-effectiveness stemming from scale and the spatial constraints of the industrial region.

The most important result of this research is the identification of excess, missing, and critical capacities in this industry, which requires decisions such as planning the export of products in the loops leading to excess capacity and completing the capacities of critical loops by improving the situation. The quality and quantity of these links are controlled through various incentives and licenses to design, develop, and create missing links (Chari et al., 2022).

2.4. System dynamics

Dynamics of the system is an evaluation method for increasing learning in the area of complex systems as well as a method for perceiving the intricacy of system dynamics and designing effective policies. Recording and investigating the critical functional points of the systems is one of the best ways of organizing the correct and rapid reactions to the issues related to the systems; it takes the form of a prospective scenario that takes as its criterion the past and the present behavior of the system's environment. Recording this scenario entails applying the knowledge and technique that correctly identifies the problem by taking advantage of a systematic method and presenting the fastest and most proper reaction to overcome the created challenges. This knowledge is called system dynamics (Lai and Nagarajaiah, 2019).

2.5. The variables interrelationships

Some of the model's critical key relations have been obtained from "if-then" functions, "reference models" and "time delays" that have been pointed out in Table 1.

Table 1. Main equations.

ID	Name	Type	Formula/Amount
1	Missed sales	State	M.S = (0.9) * (Sh)
2	Income	Auxiliary	I = S * (S.Pri) - (M.S) - (Vat)
3	Cost of advertisement and marketing	Auxiliary	A.M.C = (0.01) * (I)
4	Product demand	Level	P.D = (1000) * (A.M.C) / (S.Pri)
5	Shortage	Auxiliary	Sh = (P.D) - (P.V)
6	Sales	Auxiliary	S = Rcos * Pv
7	Missed sales: stock/demand	Auxiliary	M.S = 0.9 * St / D
8	Working capital	Auxiliary	W.Ca = I + F.E.I + B + B.F + Int.B.R
9	Production potential	Auxiliary	P.Po = Rco P.Po * W.Ca
10	Development of industrial units	Auxiliary	DEV.IU = P.Po + E.Ma + O.p + R&D + P.D + Em.mo
11	Effective management	Auxiliary	E.Ma = Po.Man + In.Fea + Ma.rB + Ma.rIn&Tax + Ma.rW + Ma.rTra
12	Quantitative development of industrial units	Auxiliary	Quan.DEV.IU = Rco Quan.DEV.IU * DEV.IU
13	Production volume	Level	P.V = (P.CA + R.M.D) * P.Te
14	Human workforce potential	Auxiliary	Po.Man = (Tr * A.E.H.R) + W.Ca

[1] Source: Study findings.

3. Fundings

3.1. Causal loop diagram of industrial production chain

Various variables can influence the performance of metal industries' production chains, hence the functioning of metal industries. Thus, the system dynamics method has been utilized to analyze and investigate how these variables improve the performance of metal industries' production chains. In order to achieve this, the relevant variables were first gathered, and Figure 1's Causal loop diagram for this model was created.

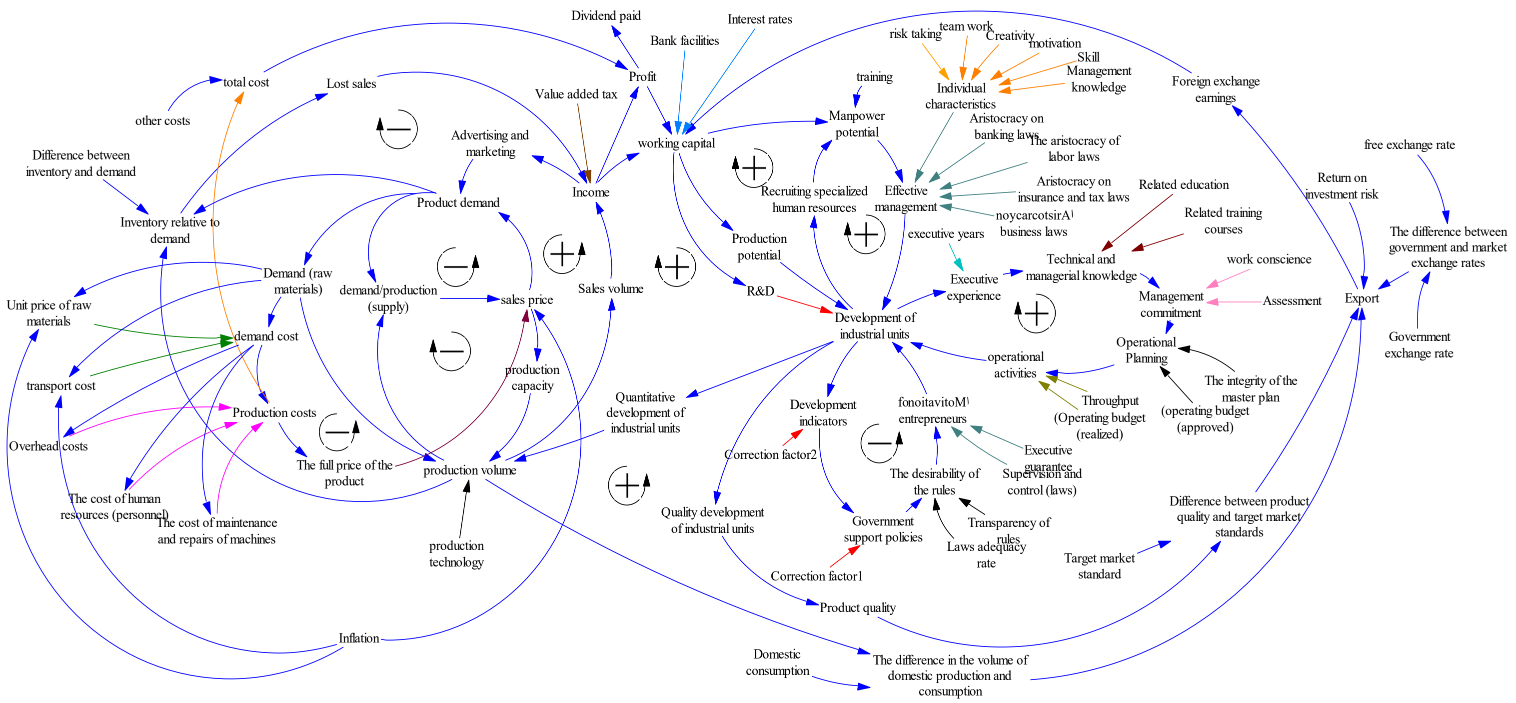


Figure 1. Causal loop diagram for the effect of the related variables on the production chain of the metal industries in provincial level.

3.2. Stock and flow diagram

The relevant stock and flow diagram is drawn and simulated based on the related causal loop diagrams. Figure 2 illustrates the stock and flow diagram related to identifying the missing loops in the metal industries' production chain in Kermanshah Province.

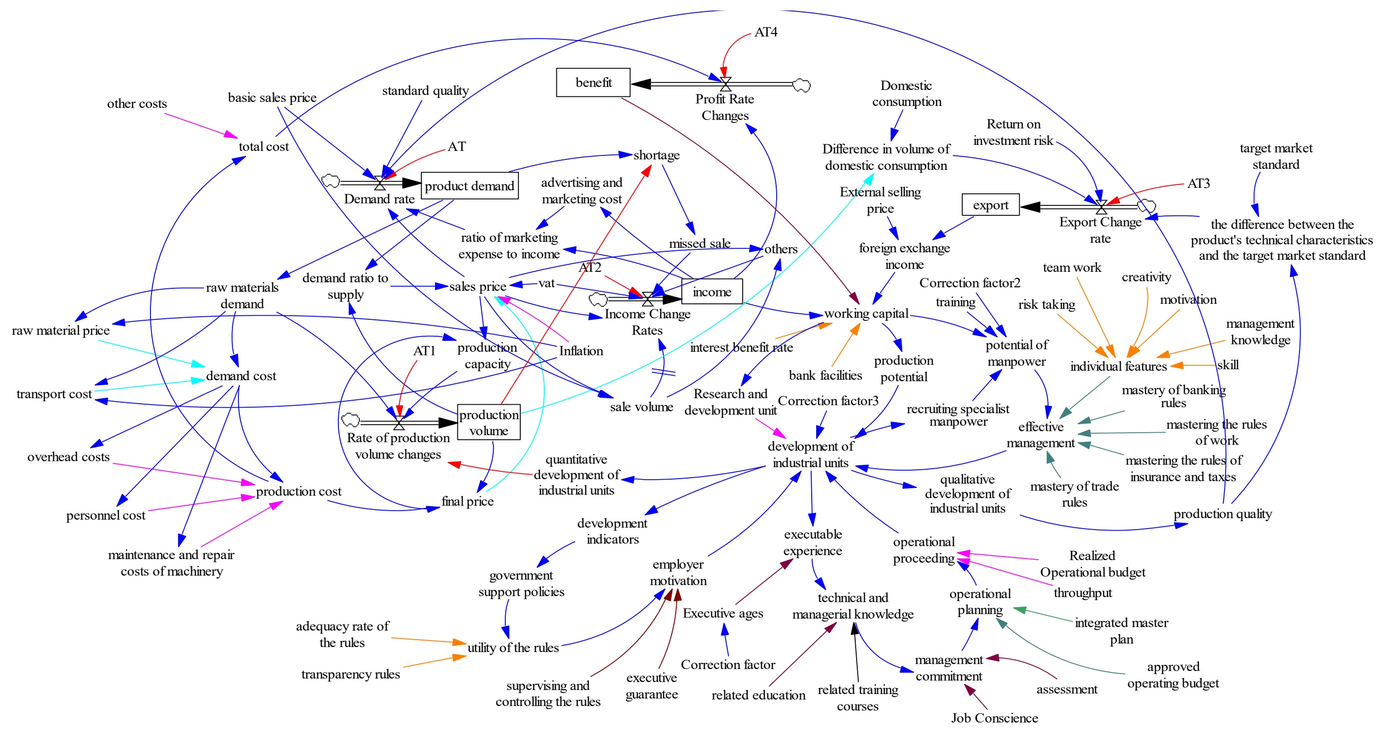


Figure 2. Stock and flow diagram for identifying the missing loops of the metal industries' production chain in Kermanshah Province.

 DOI: 10.22067/jstinp.2023.85540.1079

Implementing the Simulation Model of Metal Industries' Supply Chain in Kermanshah Province.

After inserting numbers in the model and writing the functions and equations, the model is correctly implemented, and the diagram of some of the model's accumulations takes the following form after a stage of execution:

3.2.1. Analysing the behaviour of sale price and product demand in the model

Undoubtedly, one of the most critical concerns of the persons involved in the industry is predicting and properly understanding the variables influencing future business development (Loxton et al., 2020). The product's sale price(goods price) is among these variables. By correct prediction of the contingent sale price with a suitable risk, the business income flow can be computed during the future years. In line with this, the importance of the product price in the sustainability of the business is dealt with in the analysis and prediction of this variable's effect on the future behavior of the model. It is evident that the sale price of the product is a function of many indicators, and, naturally, the investigation of all these factors would cause complexity of the issue and increase the risk of improper identification, making it rather infeasible. However, using the Pareto analysis (20-80 rule), It is evident that the selling price is influenced by the ratio of product supply to demand on the one hand and, on the other hand, by the cost price (Aslam et al., 2021). It is evident that inflation also influences the sale price and annually increases it. The potential demand is reduced with the relative increase in the product price that would, per se, cause a reduction in the product supply-to-demand ratio, eventually causing a reduction in the price growth gradient (acceleration). In other words, the price increases will face a reduction in the growth gradient concerning a prior state (Ghasemzadeh et al., 2021). It is worth mentioning that in the evaluation of the behavior of the model, due to the necessity of conducting long-term research on the variables affecting the production chain, as well as the single rate stabilization of the exchange rate by the government, the effect of short-term and emotional behavior of the exchange rate has not been considered. The related diagrams are presented in Figures 3, 4, and 5.

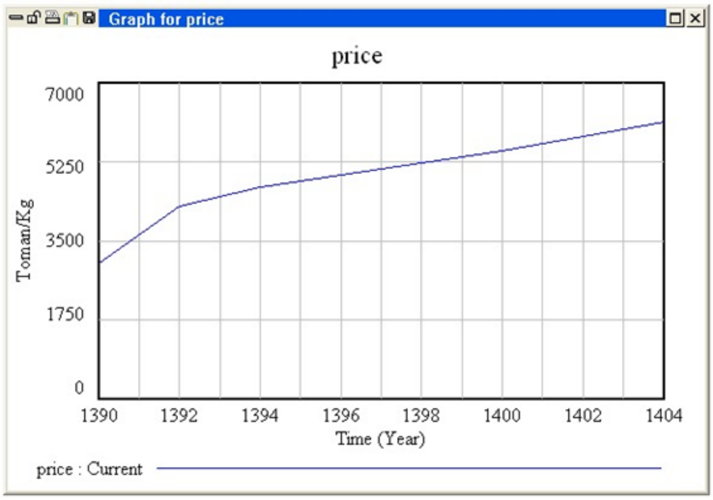


Figure 3. Price diagram.

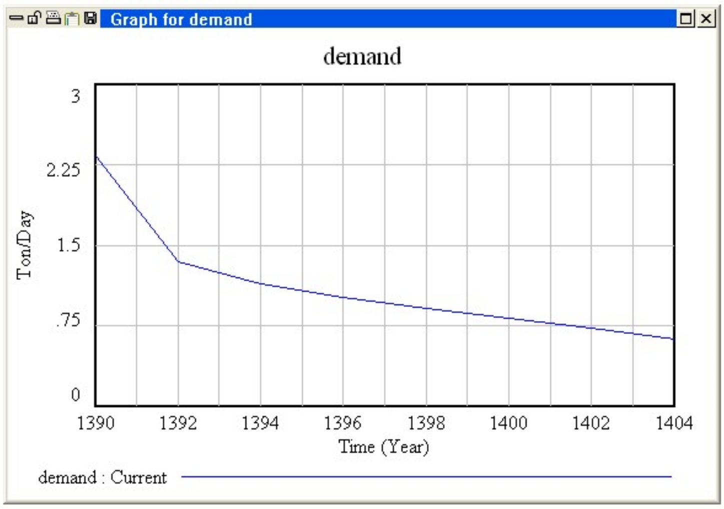
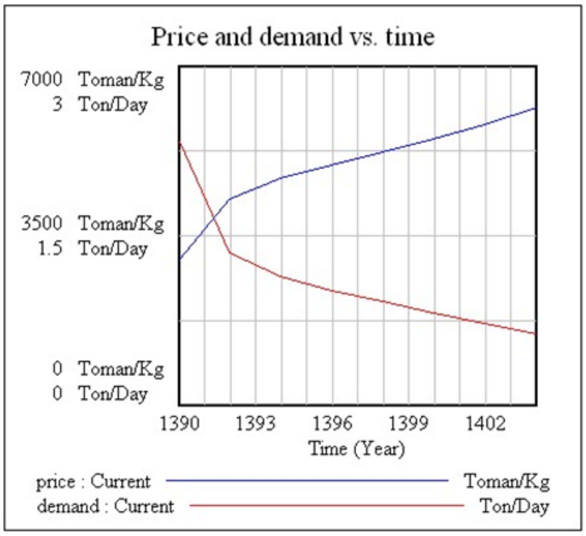


Figure 4. Demand diagram.



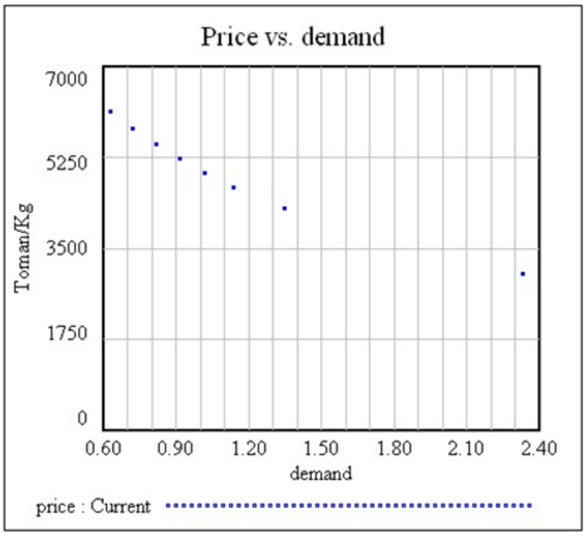


Figure 5. Comparison of the price and demand diagrams.

3.2.2. Analysing the behavior of the variable "production volume" in the model

In the simulated graph, the production volume of about 3000 tons per year is considered a long-term goal based on the company's capacity development plan, despite the decrease in domestic demand due to the increase in price and the profitability of exports. In addition, in construction, this volume exceeds the domestic consumption and is intended for export. It should be noted that the government is obliged to pay serious attention and support to manufacturing industries to maintain this growth trend until 1404. The planning period between 1390 and 1404 is considered due to the importance of the 1404 horizon in the country's development vision document. Figure 6 shows the production volume diagram.

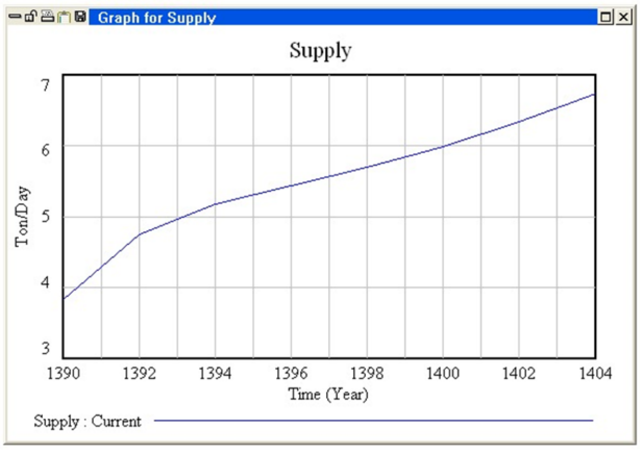


Figure 6. Diagram of production volume.

3.2.3. Analysing the behavior of income flow in the model

In the explanation of the income circulation chart, it should be mentioned that this amount of income from 1390 to 1404 was due to the development of other sectors of the metal industry, including rail protection and switchboards, as well as stability in the construction process. which requires the allocation of a suitable part of the development process in the construction industry, as shown in Figure 7.

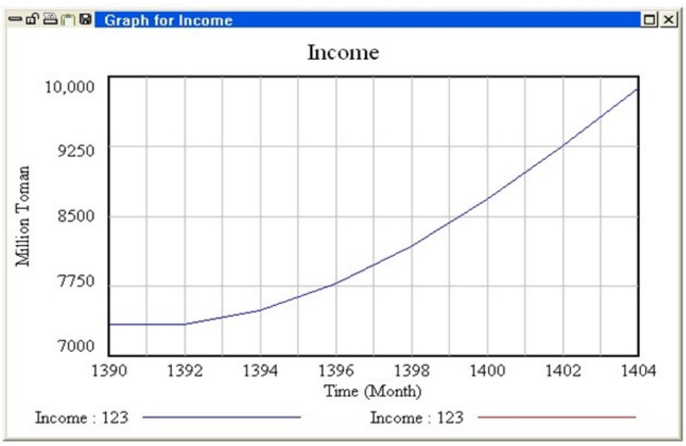


Figure 7. Diagram of income.

 DOI: 10.22067/jstinp.2023.85540.1079

3.2.4. Analysing the behavior of the variable "working capital" in the model

Although the working capital was smaller than the actualized income at the beginning of the simulation, the company's financial power is found to gradually increase in a desirable gradient, as observed in the diagram, with the improvement in the country's economic conditions and the possibility of acquiring loans in reasonable interest rates as well as improving and developing the product export and the return of part of the foreign currency income and its subsequent addition to the working capital. This diagram has been shown in Figure 8.

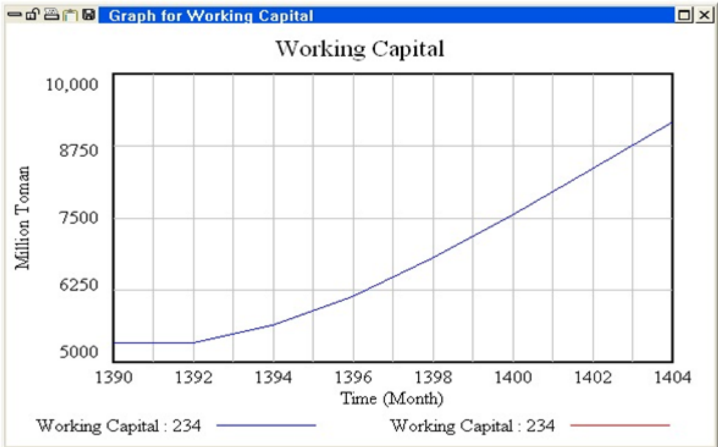


Figure 8. Diagram of the working capital.

3.2.5. Analysing the behavior of the variable "industrial units' development" in the model

In this diagram, the total growth and development of the metal industries sector of the province has been taken into account for the years from 1390 to 1404 based on an average 6-percent growth rate per year and export development, which means that about 340% of the growth can be witnessed in contrast to the base year in 1404. This diagram has been shown in Figure 9.

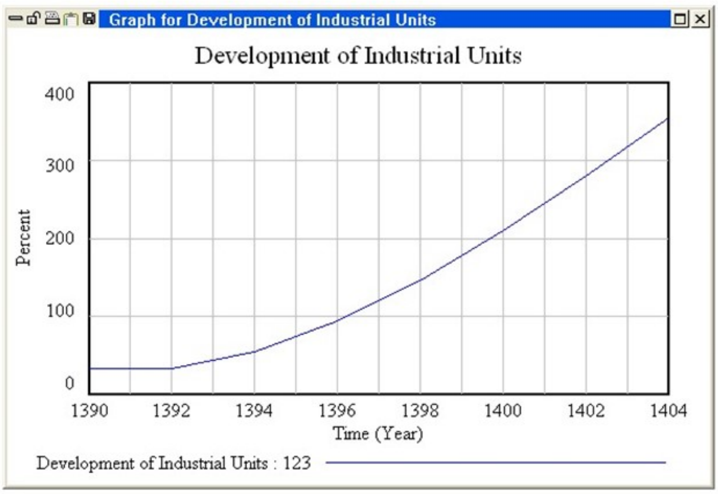


Figure 9. Diagram of the industrial units' development.

 DOI: 10.22067/jstinp.2023.85540.1079

3.2.6. Analysing the behavior of the variable "exports" in the model

At the beginning of the new presidential term, the export rate was set at 800 tons per year, and according to the government's policies in the agreement on the comprehensive program of joint action and improving the conditions for signing foreign contracts, it was about 1200 tons per year in 1396 (in all export products) Increased. This year, the sharp decrease in exports occurred due to the political tensions between Iran and the United States and the possibility of the United States withdrawing from the JCPOA and its final withdrawal. Of course, it is expected that with the correct and effective management of the foreign policy in 1397, based on the strategies devised by those in charge, the issue will be resolved, and the export rate will eventually reach 3000 tons per year. The 1404 horizon of this diagram is given in Figure 10.

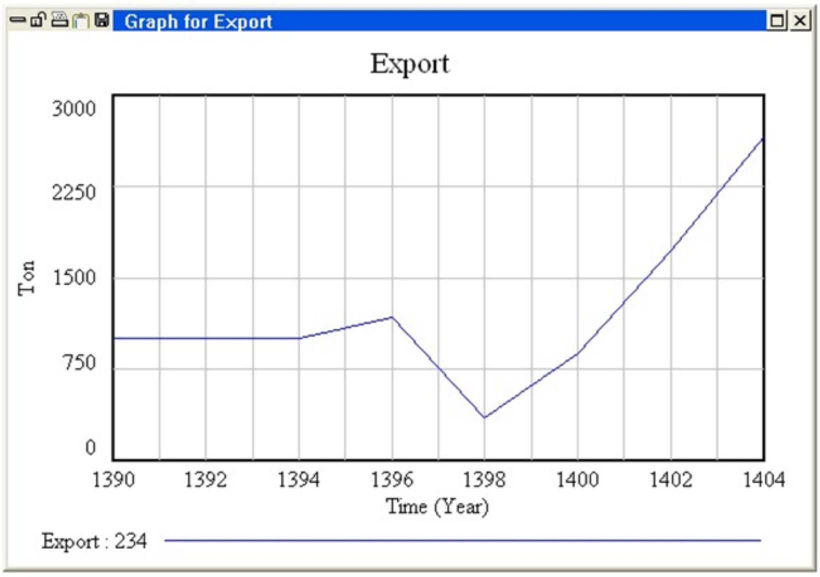


Figure 10. Diagram of export.

3.2.7. Analysing the behavior of the variable "the missed sale" in the model

This chart shows the behavior of lost sales in the model. Based on this, this production unit has faced an average annual loss of sales of 400 tons. This amount has slightly increased due to the specific time conditions of 1396 and 1397 and the JCPOA crisis. However, it is expected to decrease with the resumption of stability in the production market and the balance between demand and supply. However, due to many factors affecting the production market in Iran, it may never reach zero. The graph of lost sales is given in Figure 11.

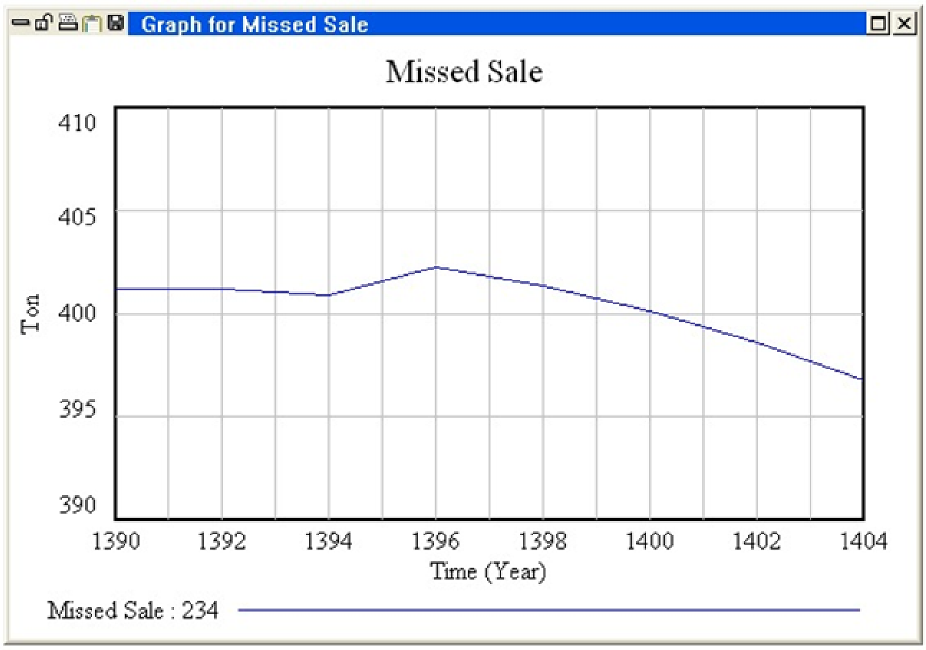


Figure 11. Diagram of the missed sale.

The diagrams for some of the other variables, like effective management or supportive policies, have not been presented herein for their lower importance and the high risk of calculation risk.

4. Conclusion

The existence of the missing loops has caused the province's metal industries to encounter numerous challenges in industrial and business activities. By identifying these loops, the province's metal industries can overcome their challenges, turn the threats into opportunities, and take maximum advantage of them. There is a significant difference between application and research in improving and assessing supply chain performance. It is expected that this research can bridge the gap by identifying the factors influencing the performance of the supply chain. Since resolving such issues based on the current mathematical and linear methods is confronted with many limitations, the present study tried to use a systematic approach for identifying and analysing the missing loops of the production chains in the metal industries of Kermanshah Province. One of the most significant ways to achieve this is by applying a strategy known as system dynamics. Evidently, the changes do not co-occur, and they undergo a dynamic process. Due to the same reason, the mutual interaction of various factors is needed for them to originate because it is not easy to comprehend and curb the dynamic phenomena, and this leads to an increase in their complexity; hence, the recognition of the correct direction for change would become very difficult. Therefore, one of the major challenges for the manufacturing units of the industries is recognizing the proper change and taking measures to make it happen. The present study endeavored to identify and offer an appropriate analysis of a supply chain to recognize the missing loops influencing the chain's performance, thereby evaluating their interrelationships and effects on the entire system. The simulated model of the chain was designed using these variables based on the "system dynamics" technique using Vensim Software. According to the real nature of the studied industrial unit and the existence of sufficient information on the behavior of these variables in the unit above, the simulated behaviors were compared with reality. The results were tested based on the available methods. According to the high match between the simulated model's performance and the real performance of the chain, it can be stated that the identified variables have predominantly been the same main and effective variables influencing the behavior of the chain performance. To improve the scales defined in the identification of the missing loops of the supply chain, the policies that are comprised of such suggestions as changing the amounts of some variables, changing some relations, eliminating some variables from the model, and/or adding several variables to the model were offered that finally led to the presentation of the several following policies:

(1) In this business, the revision and corroboration of marketing activities were investigated as the first scenario for reaching a higher market share and profitability. For now, the intended industrial unit does not see much of a marketing activity.

(2) The participation policies and bank supports that cause the availability of good loans with low-interest rates to the business units and provide them with sufficient cash supplies.

(3) Omission or reduction of the tax on added value for reducing the price of the product sale causes an increase in the income; the implementation of this policy would cause a reduction in the price of the product and enhance the units' competitive power, and the business entity can receive a larger volume of the market demand to have its income finally increased and be provided with a more significant number of financial resources.

(4) The government's sponsoring policies through consideration of the governmental subsidies, cash or non-cash, like giving a share in the production basket of the steel factories that would bring about a reduction in their referring to the intermediaries and finally reduction in the finished price of the products in such a way that a 5-percent reduction will be seen followed by a 50% increase in the demand.

(5) Activation and development of R&D units.

(6) Supporting exports within the format of creating relationships between the manufacturer and buyer, reducing the difference between the governmental and free currency rates and/or accurate currency rate payments, and guaranteeing the capital return in export.

(7) Revision and reviewing of the tax regulations and granting of tax exemptions to key and growing industries

Acknowledgements

The author expresses his appreciation and gratitude for the support of the Shablon Tajhiz Company.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Asha, AA., Dulal, M. and Habib, A., 2023. The influence of sustainable supply chain management, technology orientation, and organizational culture on the delivery product quality-customer satisfaction nexus. *Cleaner Logistics and Supply Chain*, *7*, p.100107. https://doi.org/10.1016/j.clscn.2023.100107.

Aslam, J., Saleem, A., Khan, N.T. and Kim, Y.B., 2021. Factors influencing blockchain adoption in supply chain management practices: A study based on the oil industry. *Journal of Innovation & Knowledge*, *6*(2), pp.124-134. https://doi.org/10.1016/j.jik.2021.01.002.

Chari, A., Niedenzu, D., Despeisse, M., Machado, C.G., Azevedo, J.D., Boavida-Dias, R. and Johansson, B., 2022. Dynamic capabilities for circular manufacturing supply chains—Exploring the role of Industry 4.0 and resilience. *Business Strategy and the Environment*, *31*(5), pp.2500-2517. https://doi.org/10.1002/bse.3040.

De Giovanni, P. and Vinzi, V.E., 2012. Covariance versus component-based estimations of performance in green supply chain management. *International Journal of Production Economics*, *135*(2), pp.907-916. https://doi.org/10.1016/j.ijpe.2011.11.001.

Engelseth, P., Molka-Danielsen, J. and White, B.E., 2019. On data and connectivity in complete supply chains. *Business Process Management Journal*, *25*(5), pp.1145-1163. https://doi.org/10.1108/BPMJ-09-2017-0251

Ghasemzadeh, Z., Sadeghieh, A. and Shishebori, D., 2021. A stochastic multi-objective closed-loop global supply chain concerning waste management: A case study of the tire industry. *Environment, Development and Sustainability*, *23*, pp.5794-5821. https://doi.org/10.1007/s10668-020-00847-2

Lai, Z. and Nagarajaiah, S., 2019. Sparse structural system identification method for nonlinear dynamic systems with hysteresis/inelastic behavior. *Mechanical Systems and Signal Processing*, *117*, pp.813-842. https://doi.org/10.1016/j.ymssp.2018.08.033

Loxton, M., Truskett, R., Scarf, B., Sindone, L., Baldry, G. and Zhao, Y., 2020. Consumer behaviour during crises: Preliminary research on how coronavirus has manifested consumer panic buying, herd mentality, changing discretionary spending and the role of the media in influencing behaviour. *Journal of risk and financial management*, *13*(8), p.166. https://doi.org/10.3390/jrfm13080166.

Ni, W. and Sun, H., 2019. The effect of sustainable supply chain management on business performance: Implications for integrating the entire supply chain in the Chinese manufacturing sector. *Journal of Cleaner Production*, *232*, pp.1176-1186. https://doi.org/10.1016/j.jclepro.2019.05.384

Osborne, D. and Dempsey, F., 2023. Supply chain management for bulk materials in the coal industry. In *The Coal Handbook* (pp. 619-664). Woodhead Publishing. https://doi.org/10.1016/B978-0-12-824328-2.00004-2

Shahzad, F., Du, J., Khan, I., Shahbaz, M., Murad, M. and Khan, M.A.S., 2020. Untangling the influence of organizational compatibility on green supply chain management efforts to boost organizational performance through information technology capabilities. *Journal of cleaner production*, *266*, p.122029. https://doi.org/10.1016/j.jclepro.2020.122029

Soori, M., Arezoo, B. and Dastres, R., 2023. Artificial Neural Networks in Supply Chain Management, A Review. *Journal of Economy and Technology*. https://doi.org/10.1016/j.ject.2023.11.002

Journal of Systems Thinking in Practice
JSTINP, *QUARTERLY*
Homepage: jstinp.um.ac.ir
Online ISSN: 2821-1669, Print ISSN: 2980-9460
Research Article
DOI:10.22067/JSTINP.2023.85830.1083
JSTINP 2023; Vol. 2, No. 4

Examining the Emigration of Elites from Iran: A System Dynamics Approach

Nasser Safaie[a*], Farhad Chakmehchi Khiavi[a], Mohammad Sadegh Shahsavar[a]

[a] *Department of Industrial Engineering, K. N. Toosi University of Technology, Tehran, Iran.*

How to cite this article

Safaie, N., Chakmehchi Khiavi, F., Shahsavar, M. S., 2023. Examining the Emigration of Elites from Iran: A System Dynamics Approach, *Journal of Systems Thinking in Practice*, 2(4), pp.17-32. doi: 10.22067/jstinp.2023.85830.1083.
URL: https://jstinp.um.ac.ir/article_44691.html

A B S T R A C T

Nowadays, countries are leading in growth and development, with their managers having a systematic approach and perspective toward external phenomena. In the past, the slow pace of changes and transformations in societies made it easier to analyze current and future conditions. However, in today's world, complex phenomena are non-linear and multidimensional. The migration of skilled and educated human resources from developing to developed countries is also considered one of these phenomena, which is influenced by numerous variables and factors that change and evolve over different periods. The system dynamics approach is a precise modeling method that allows us to simulate complex and dynamic systems computationally, both qualitatively and quantitatively. By utilizing the obtained results, more effective policies and organizations can be designed. This paper discusses the migration of elites from Iran to developed countries from a dynamic systems perspective. The problem is modeled and simulated using the software "Vensim". Important variables in elite migration are identified and adjusted. The model's outputs indicate the positive impact of the presence of elites in a country on its level of economic development.

Keywords

Elite migration, System dynamics, Socio-economic variables, Computer simulation, Scenario analysis.

Article history

Received: 2023-12-11
Revised: 2023-12-16
Accepted: 2023-12-22
Published (Online): 2023-12-28

Number of Figures: 14 **Number of Tables: 3** **Number of Pages: 16** **Number of References: 21**

****Corresponding author***
Email: : nsafaie@kntu.ac.ir

1. Introduction

The movement and migration of populations across borders have a long history in human civilization. However, this phenomenon has been rapidly increasing in recent years. International migration has been on the rise since 1970, and every year, a significant number of individuals migrate from developing countries to industrialized countries. According to the studies by Vakili and Mobini (2023) shown in Figure 1, the number of migrants worldwide approached 300 million in 2020, which accounts for about 4% of the total global population.

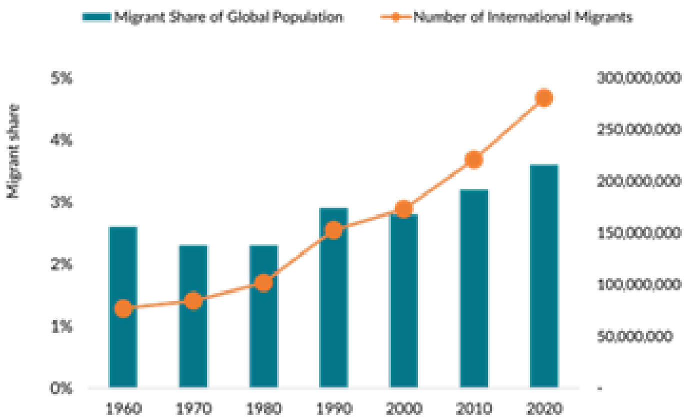


Figure 12. The number and share of immigrants worldwide

Throughout history, Iran has been famous for its numerous internal and external migrations and immigrations. However, the importance and complexity of international migration have increased in recent decades due to the increasing young population of the country. The Iranian migrant population in the world, based on the latest available and reliable statistics in 2020, is 1.87 million people, which constitutes 2.23% of the Iranian population, as indicated in Table 1. However, according to the Secretariat of the Supreme Council of Iranians Abroad, the estimated population of Iranian migrants outside the country is 4.04 million, which can be verified based on international sources (Sadeghi and Seyyed Hosseini, 2019).

Table 2. The status of Iranian immigrants in domestic and global statistics

Annual Population Factors	Statistics Based on International Sources				Internal Statistics
Year	1990	2000	2010	2020	2020
The population of Iranian immigrants in the world (million people)	0.82	1.15	1.49	1.87	4.04
Total population of Iran (million people)	56.4	65.6	73.8	83.99	83.99
The share of Iranian immigrants in the total population of Iran (percentage)	1.45	1.75	2.02	2.23	4.81

Since most of the emigrants are the elites and the skilled human resources of society, their departure from the countries of origin is often described as "brain drain" a term that the Royal Society of England first coined to describe the migration of scientists from England to North

America after World War II (Ha et al., 2016). Migration can lead to a decrease in the skilled and educated workforce in the country of origin, resulting in a reduction in economic capabilities, the inability to meet domestic needs, and a decrease in industrial competitiveness (Beine et Al., 2001).

Therefore, the emigration of elites at the caliber level can cause the backwardness of the countries of origin, and, in addition to being an economic and social issue, it has political and cultural consequences in the country. Since various factors influence these concerns, it is vital to investigate them using a methodology that addresses their dimensions. On the other hand, simple analyses and breakdowns do not provide suitable solutions for this issue because the influential factors change over time. For this reason, a systems dynamics approach is used in this regard, as this approach considers the time variable, provides a more realistic view of the problem, and can examine the effects of various factors in different dimensions. Finally, with the presentation of scenarios to improve the current situation, systems dynamics can have a more comprehensive impact on investigating the issue of elite emigration.

In this study, after reviewing previous studies and identifying the factors and variables used and the methods employed, the system dynamics will be introduced, and the advantages of using this approach will be discussed. The issue of elite emigration will be modeled qualitatively and quantitatively, and various scenarios will be implemented to discuss the resulting outputs and provide managerial solutions in this field.

2. Literature review

According to the definition provided by the United Nations, migration is the act of changing one's country of residence regardless of its nature, motivation, or legal status. However, in general, the goal of a migrant is to achieve better conditions and escape existing problems and challenges in the country of origin. Zuckerman (1977) also introduces the concept of an elite individual in his book "The Scientific Elite," who is the most successful and powerful person in a society in one or more outstanding and efficient fields.

Vakili and Mobini (2023) found that the outflow of talent from Iran is mainly influenced by external factors (such as attraction factors from developed countries) and internal incapacities (such as push factors). The migration rate is rapidly increasing; therefore, it is necessary to analyze and manage this phenomenon using existing theories in the field of attraction and push factors, Maslow's hierarchy of needs, and rational choice theory. Mozafari (2023) concluded that the current political atmosphere, economic sanctions, and lack of research opportunities have led to an increase in the emigration of elites and the departure of talented professionals from Iran. This trend is expected to continue with the increase in the number of talented Iranian scientists seeking better opportunities and resources abroad. Moftakhari et al. (2021) investigated the impact of social capital on talent outflow in member countries of the Cooperation Organization of Shanghai from 2009 to 2018. The results indicate that social capital has a non-linear and threshold effect on talent outflow. Given that the coefficient of social capital is positive and the second power coefficient is negative, increasing social capital at lower levels exacerbates talent outflow from the countries under study. However, increasing social capital beyond the threshold level hurts talent outflow. By determining the threshold level in these societies and striving to enhance social capital to that level, as an effective factor in preventing talent outflow, one can prevent the emigration of elites in these countries.

By examining the situation of Iranian elites' migration, postgraduate students, married individuals, dissatisfied with their income, and individuals with high economic and social status, Derakhshan et al. (2023) found that the mentioned groups had a greater inclination towards migration. The inclination for migration had an inverse relationship with four dimensions of origin and destination conditions (economic, political, social, and cultural). Essential factors influencing student migration included various cultural, economic, occupational, and socio-political variables. A significant relationship was found between the inclination for migration and variables such as gender, educational region, educational degree, religion, having relatives and friends abroad, foreign travel experience, foreign language proficiency, number of published articles, and membership in the National Elite Foundation. Vedadhir and Eshraghi (2023) study aimed to explain the inclination for migration and found that migration reasons can be categorized into two main groups: attraction factors of the destination and push factors of the origin. Data analysis resulted in the extraction of two main categories:

(1) push factors, which included five subcategories of economic-occupational factors, socio-cultural factors, political-religious factors, educational factors, and personal factors, and (2) attraction factors of the destination, which included five subcategories of legal and relationships, security, welfare-financial conditions, educational and occupational opportunities. Ghorbanian and Salehi (2021) using a system dynamics approach, concluded that by implementing policies to reduce tensions in international relations, it is impossible to impact the emigration rate of elites significantly, and their number cannot be reduced. However, implementing policies to improve fair remuneration, job security, and employment status of

elites can lead to changes in the rate of elite migration and the number of immigrants. Therefore, implementing these two policies can effectively prevent the outflow of elites from the country and strengthen them. Hajigholamsaryazdi et al. (2017) modeled the factors of elite migration using a system dynamics approach and by collecting a group of scientific and technological elites to model this phenomenon with a systemic perspective. The current model showed that the main hypothesis of the article, which states that elites themselves play a role in creating the brain drain structure and are also influential in rectifying it, is valid. Mousavirad and Ghodsian (2015) also adopted a system dynamics approach, which, by implementing government policies to support entrepreneurship and increasing the level of cultural education, does not result in a change in the rate of elite formation. The elite development rate initially decreases due to a decrease in the migration rate in the first few years. Therefore, it cannot be said that implementing these two policies has led to the nurturing of elites in the country. Considering that the number of immigrants has also remained insignificant, it can be concluded that these policies have been unsuccessful in reducing the trend of brain drain. The current study attempts to reexamine elite migration under novel situations by expanding the variables of Shahsawaripour et al. (2019) model and updating the data of the scenarios under investigation.

A summary of the above studies can be reviewed in Table 2 in the form of a research background:

Table 3. An overview of the research background

Title	Researchers	Method	Results
An overview of brain drains, causes & policy issues in Iran	Vakili & Mobini (2023)	Review	The simultaneous effect of external attractiveness and internal disability
Science in Iran: A victim of political torn ail	Mozafari (2023)	Review	The role of political-economic and scientific parameters
Emigration pattern among medical & Non-medical Iranian elite & its associated factors: A review of literature	Derakhshan et al. (2023)	Review	The effect of scientific factors such as parent's education level and language proficiency
Investigating the effect of social capital on brain drain in the member countries of the Shanghai Cooperation Organization	Moftakhari et al. (2023)	Econometrics	Non-linear effect of social capital variable
The effect of economic complexity and globalization on elite migration in selected member countries of the Organization of Islamic Cooperation	Shahabadi and Pouran (2022)	Statistics	The inverse effect of research and development costs and globalization index on immigration
Presenting the study model of the phenomenon of elite evasion	Ghorbanian and Salehi (2021)	SD	The lack of impact of improving foreign relations on immigration statistics
Tendency to migrate in Iran's medical community	Vedadhir and Eshraghi (2019)	Inductive quality	Explaining the factors of repulsion of the origin and attraction of the destination
Analyzing the dynamics of elite migration using associative modeling	Hajigholamsaryazdi et al. (2017)	SD	Elites are responsible for increasing or decreasing the rate of immigration
Analysis of elite immigration and the effect of restrictive policies	Mousavirad and Ghodsian (2015)	SD	Lack of effect of government support policies
Comparative analysis of brain drains at micro and macro levels	Chalabi and Abbasi (2005)	Survey Secondary analysis	The influence of income-quality level of life and cultural development

3. Methodology

This study uses the system dynamics approach is used as a modeling method. One of the basic challenges in developing human societies is to predict the real world in the future. System dynamics (SD) analysis is a very efficient and well-known method for studying system behavior (Safaie et al., 2022). System dynamics refers to system changes and behaviors over time under different conditions. Professor Forrester (1961), in the book Industrial Dynamics, defines system dynamics as the study of information and feedback characteristics of industrial activities to show how organizational structure, reinforcement (policies), and time delays (in decisions and actions) affect the success of the company. The main features of this method include the existence of a complex system, the change of system behavior over time, and a closed feedback loop (Langroodi and Amiri, 2016).

The implementation of the system dynamics method in this research, according to Figure 2, has been implemented in five stages and recursively in the Vensim software, version PLE10, from 2006 to 2036.

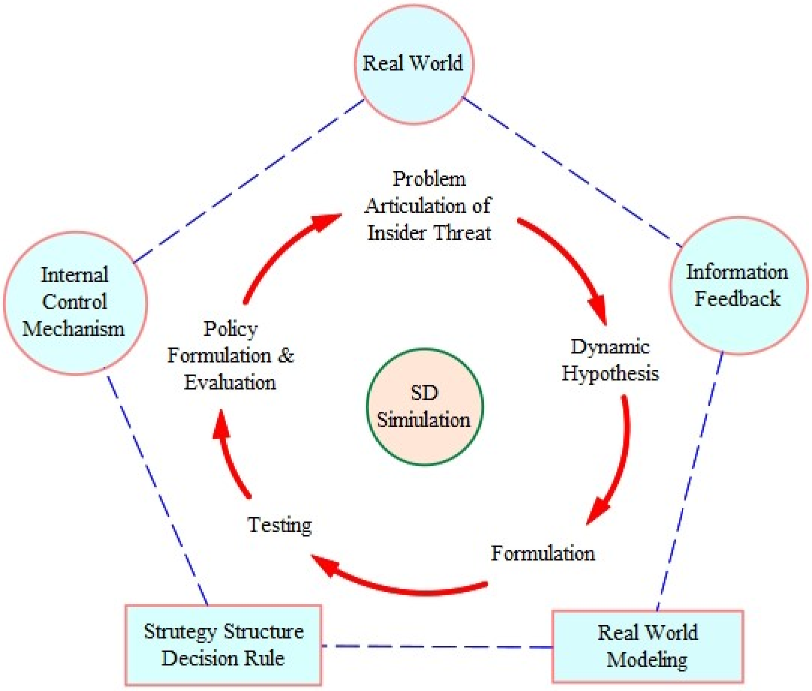


Figure 13. Implementation steps of the system dynamics method

4. Modeling, review and analysis of data

The modeling work is to be started after enlightening with the method and steps of the work. The necessary information about the studied problem must be collected and categorized, and a mental and descriptive model should be formed according to the above steps.

4.1. Dynamic hypothesis

In order to implement the elite migration model, the first step is to have a dynamic hypothesis about migration. The elites who intend to migrate, economic, cultural, and social factors influence their decision to migrate. If the above factors do not match the individual's wishes, the existing conditions are not entirely consistent with the individual's ideals. Therefore, in this hypothesis, the high migration rate is caused by unfavorable conditions in the country of origin.

4.2. Causal loop diagram (CLD)

The causal diagram depicts the cause-and-effect relationships between the various variables in the problem. It is used to record mental models and the mutual effects of the variables on each other.

The causality structure of a model is shown by a causal loop diagram, which is shown in Figure 3 for the discussed problem:

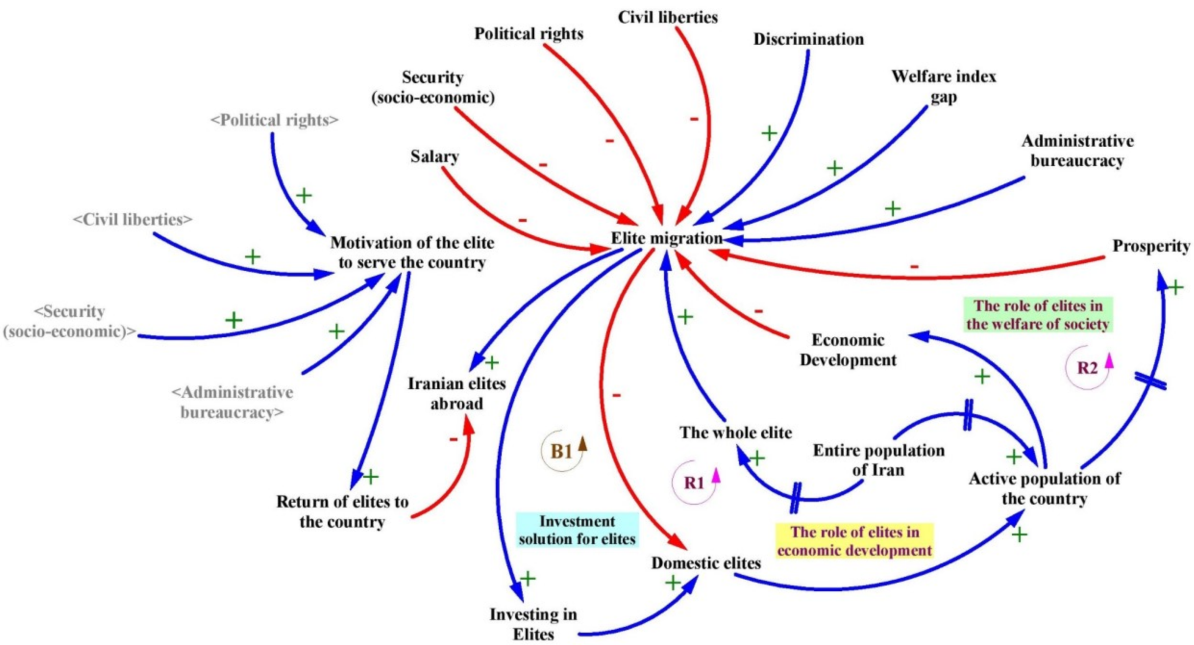


Figure 14. Causal loop diagram of elite migration

The diagram of causality has 3 feedback loops as follows:

(1) The role of elites in economic development (R1): With the reduction of elite immigration, the population of elites inside the country increases, and these people become the country's active population. As a result, with the activity of these people in the economy, the GDP increases. With the improvement of the country's economic situation, the immigration statistics of other elites decrease (Figure 4).

 DOI: 10.22067/JSTINP.2023.85830.1083

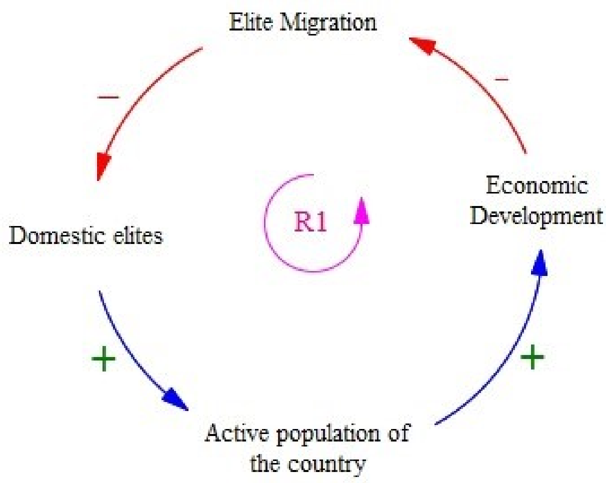


Figure 15. The role of elites in economic development

(2) The role of elites in society's welfare (R2): With the decrease in the number of immigrant elites and the continued increase in the number of resident elites, their entry, and activation in the country's economy has increased per capita income and general well-being, leading to a decrease in their migration statistics (Figure 5).

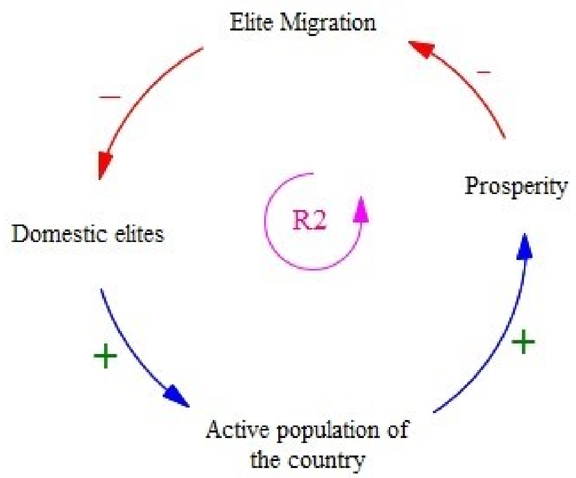


Figure 16. The role of elites in society's welfare

(3) The role of elites in economic development (B1): By increasing the investment in the elites through the solutions mentioned in the management recommendations section (section 5), the longevity and population of the elites in the country increased, and with the increase in the participation of the elites in economic activities, the economic growth and development of the country improved. It was found that with the improvement of the country's macroeconomic variables, the amount of migration of elites has decreased. As a result, the need for more investment in this field is decreasing (Figure 6).

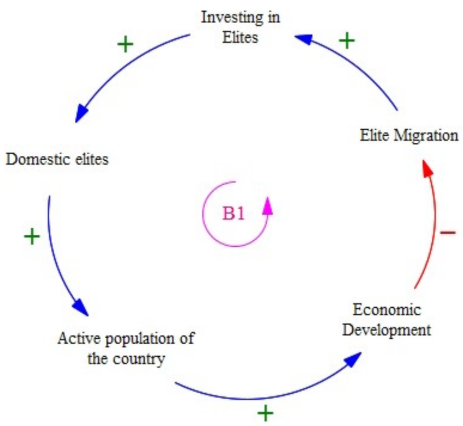


Figure 17. Investment solution for elites

4.3. Stock-flow diagram (SFD)

Causality diagrams are very useful in many situations. However, despite these advantages, they have limitations; one is their inability to show the state structure and system flow change. This problem can be solved by using the flow state diagram, and by displaying the state variables and flows, it is possible to track the state variables along the path (Sterman, 2002).

The state and flow diagram of the developed model is based on the study of Shahsawaripour et al. (2019) and is designed according to Figure 7:

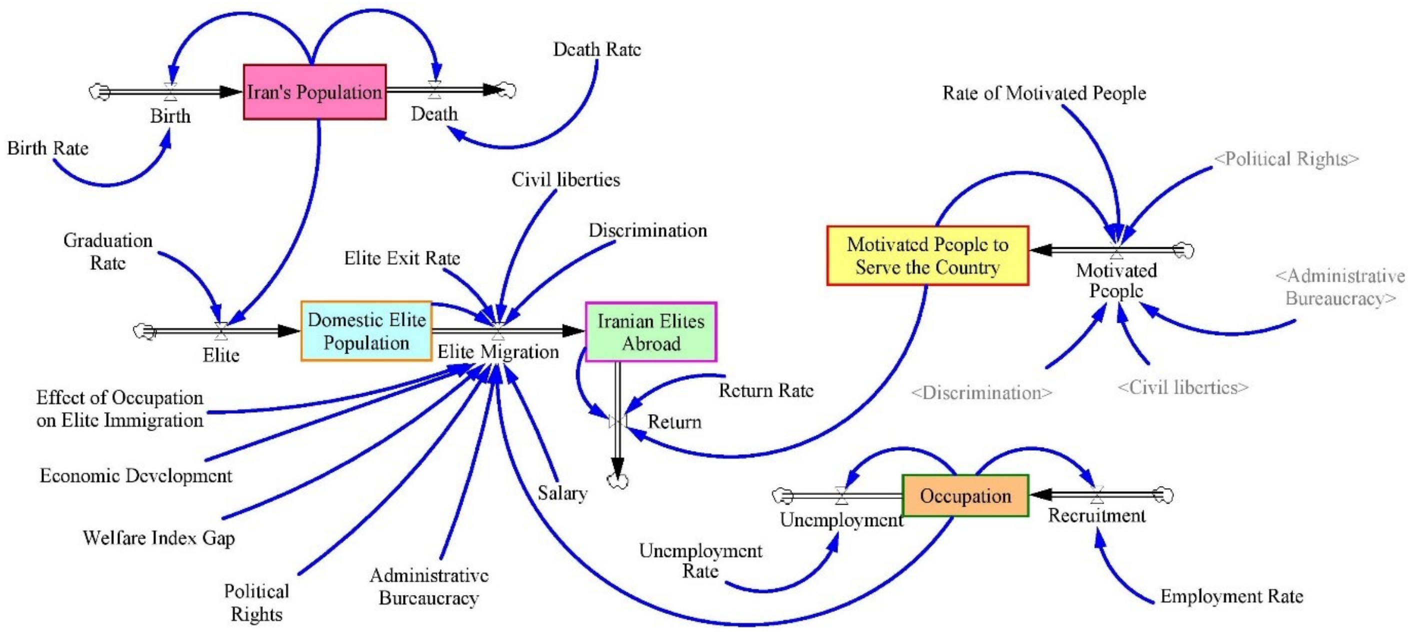


Figure 18. Stock-Flow diagram of elite migration

4.4. Formulation

The quantification of the model was done based on the stock-flow diagram in the form of mathematical relationships and by separating variables involved in the problem according to Table 3:

Table 4. Significant mathematical equations of model variables

Variable	Description	Formula	Unit	Type
Iranian Elites Abroad	Total of Iranian elites in other countries	INTEG (4e+06, Elite Migration -Return)	People	State
Domestic Elite Population	Number of elites living inside the country	INTEG (220649, Elite - Elite Migration)	People	State
Elite Migration	Number of immigrant elites per time unit	Domestic Elite Population × Elite exit rate – (Occupation × Effect of Occupation on Elite Immigration) – (Economic Development + Political Rights + Civil Liberties + Discrimination) × Domestic Elite Population + (Administrative Bureaucracy + Welfare index gap + Salary) × Domestic Elite Population	$\frac{\text{People}}{\text{Year}}$	Rate
Return	Number of elites returning to the country	(Motivated People to Serve the Country × Return Rate)+(Iranian Elites Abroad × Return Rate)	$\frac{\text{People}}{\text{Year}}$	Rate
Elite exit rate	Growth of departure of elites from the country	0.1583	1/Year	Constant
Return Rate	Return of elites to the country	0.03	1/Year	Constant
Economic Development	Qualitative changes in the economic structure of a society	0.0096	1/Year	Constant

4.5. Model validation

After the implementation of the model, to ensure the validity of the proposed model, 3 validation tests are performed on it.

4.5.1. Test of the model structure

As an experimental tool, this test compares the form of equations and models with the relationships in real systems. The work was done in the Vensim software, according to Figure 8.

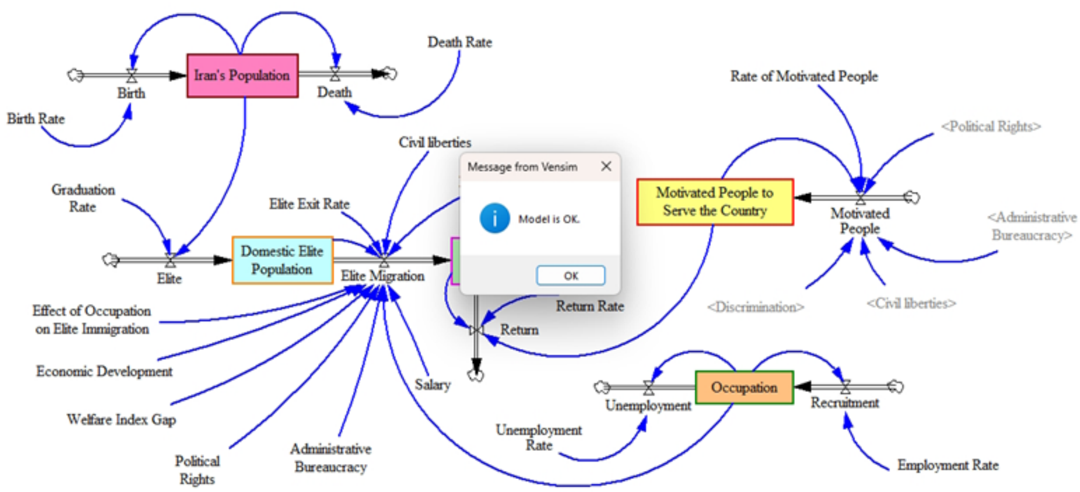


Figure 19. Model check

4.5.2. Test of the dimensional consistency

This test includes checking the right and left sides of the equation in terms of the dimensions of the variables, which must be the same. Based on the introduction of the unit of all the variables in the model, this test can also be performed in the Vensim software, according to Figure 9.

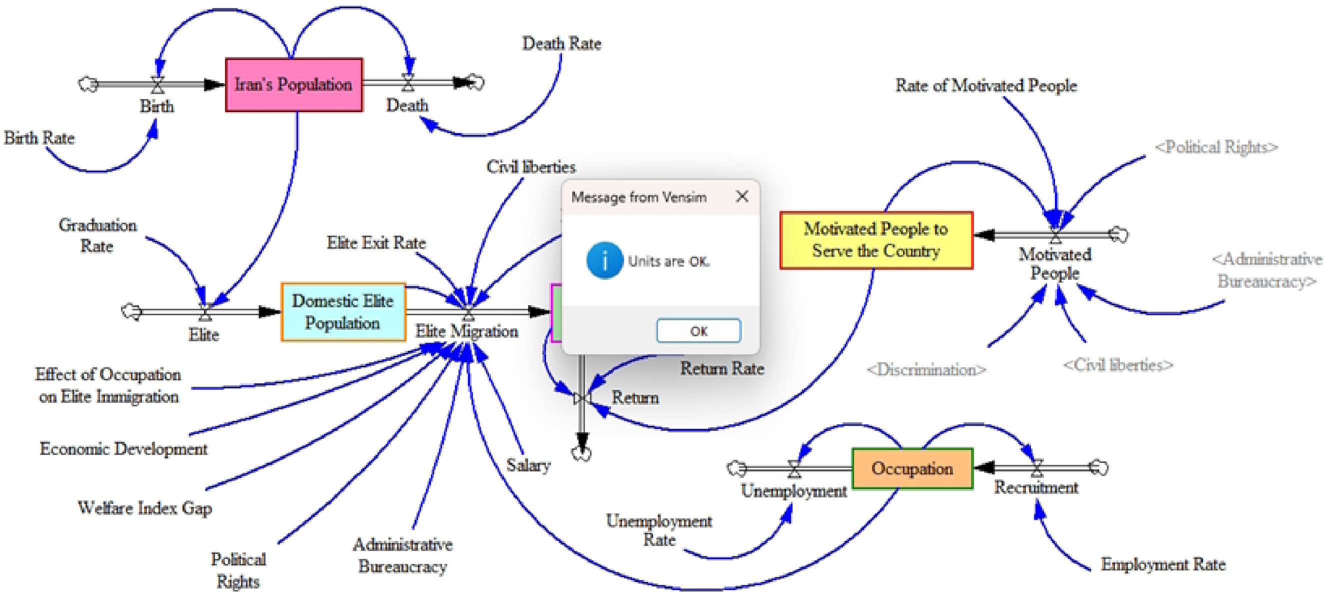


Figure 20. Units check

Here, as an example, the equality of units on both sides of the equation related to the variable " Elite Migration " is shown:

Elite Migration {People/Year} = Domestic Elite Population {People} × Elite Exit Rate {1 /Year} –

People/Year

(Occupation {People} × Effect of Occupation on Elite Immigration {1 /Year}) – (Economic

People/Year

Development {1 /Year} + Political Rights {1 /Year} + Civil Liberties {1 /Year} + Discrimination

1/Year

{1 /Year}) × Domestic Elite Population {People} + (Administrative Bureaucracy {1 /Year} +

People/Year 1/Year

Welfare index gap {1 /Year} + Salary {1 /Year}) × Domestic Elite Population {People}

People/Year

People/Year = People/Year

4.5.3. Limit condition test

This test aims to measure the model's sensitivity to values far from reality and the limits of model decay. Here, by setting the return rate of the elites to a high value, as shown in Figure 10, we see an increase in the number of domestic elites and their gradual equalization with the total elites of the country, which means they all stay.

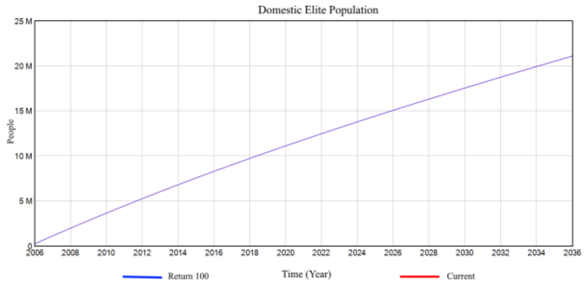


Figure 21. The boundary condition test in the case of the return of all elites to the country

4.6. Model output detailed analysis (Results)

Figure 11 shows the status of foreign elites, which shows that the increase in the number of university graduates, especially in the supplementary education courses, as well as the conditions of recent years, the increase in their number can be justified.

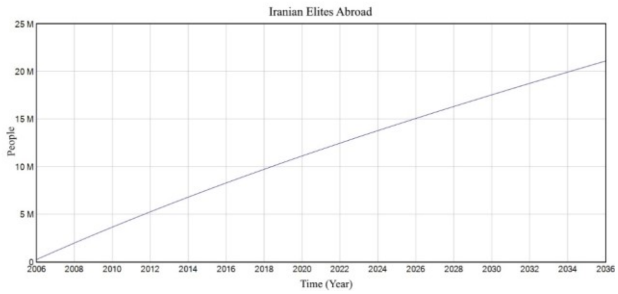


Figure 22. The elite population living abroad

Figure 12 is the trend of the main flow variable of this model, which clearly shows the alarming situation of elite immigration; if there is no change in the variables related to immigration, the increase will continue.

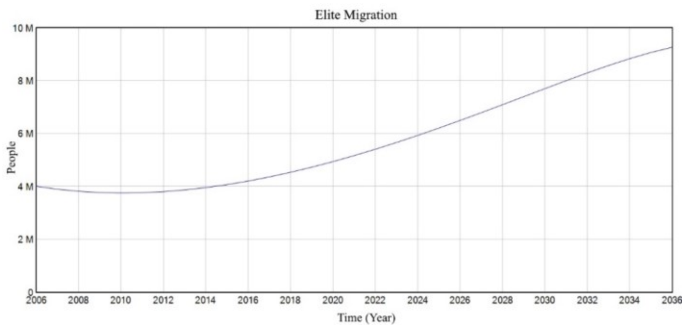


Figure 23. The process of elite migration in the simulation period

4.7. Assessing policies and scenarios

System dynamics is one of the approaches in simulation methods. Simulation models benefit from learning about complex problems and testing interventions (Beigian et al., 2022). At this stage, by setting values to selected model variables that are considered close to the economic variables of the seventh development plan, the simulation results are compared with the base state, and the most suitable options for management decisions are suggested in this issue.

4.7.1. Salary increases scenario

If we increase the wage index to 65%, according to Figure 13, the rate of elite migration will continue to increase, but it will have a lower slope compared to the current trend.

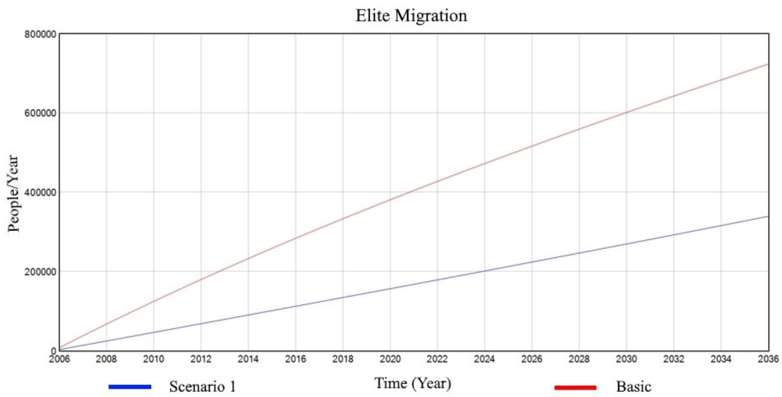


Figure 24. The rate of elite migration under the wage increase scenario

4.7.2. Economic development scenario

If the rate of economic development increases by 8% (according to the perspective of the country's seventh development plan), the elite migration rate will decrease, as shown in Figure 14. In other words, it will be noticed reverse migration.

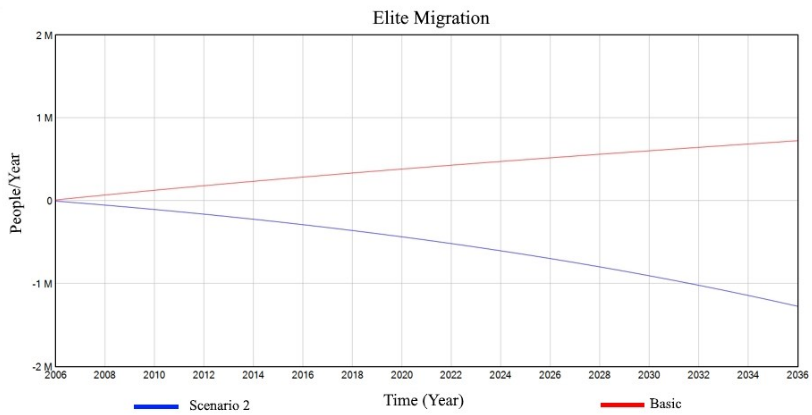


Figure 14. The rate of elite immigration under the scenario of improving economic development

 DOI: 10.22067/JSTINP.2023.85830.1083

5. Management recommendations

The scenarios examined in the present study have focused on the economic factors in the issue of elite immigration. Therefore, in this regard, there are several managerial points worth mentioning for policymakers. Given the lower level of service rates and wages within the country, considering the exchange rate parity of the national currency against foreign currencies and comparing it with other countries, especially developed and immigrant-receptive countries, it is necessary to review the pattern of determining salaries and wages, especially for specialists. Despite the possibility that this pattern may lead to an increase in income inequality among other social classes, it is possible to regulate the gap in the welfare level of this group with other income brackets through non-inflationary supportive measures. In this regard, in addition to improving salaries, it is possible to mention the improvement of working conditions ethically by increasing the attractiveness and competitiveness of the domestic job market by providing government incentives, especially for startups and new companies, which are run mainly by educated young forces. Moreover, providing professional and research opportunities for developing university elites' skills, cooperation with elites in industrial and technological sectors, and scientific and technological collaborations with other countries can improve the elites' internal migration deterrent indices.

6. Discussion and conclusion

Psychologically and politically, people prefer to identify the cause of any problem as an external factor rather than finding it within themselves. Despite our capacity for analysis and the advancement of technology, problems like elite migration continue to exist because they are fundamentally systemic—that is, they emerge from the unfavorable behaviors inherent in the system's structure. These issues will disappear when the courage and wisdom to restructure the system is gained (Meadows, 2008). The present research was conducted to simulate a dynamic model for the phenomenon of elite migration, in which a combination of quantitative and qualitative variables was implemented in an interactive relationship with each other over thirty years. Compared to mathematical models, this dynamic model has great flexibility in making changes, scenario planning, and sensitivity analysis. The output of the model shows the undeniable effect of the increase in economic development and the level of public welfare as a result of the role of elites in different fields of the country; the same discussion that is mentioned under the title of the meritorious year that has also been mentioned in past studies such as Shahsawaripour et al. (2019). On the other hand, improving economic components will reduce elite migration and even reverse migration. Of course, the impact of improving the economic variables of the society on the improvement of other components of the cultural, social, and political fields, as well as multi-dimensional issues such as the migration of elites, is an experienced and undeniable matter.

7. Limitations and suggestions

The presented model may include only some variables involved in elite migration, such as the security variable (economic, political, social), for which reliable data was unavailable to the authors. In addition to the components discussed in this research, the influence of social and cultural policies and scenarios and non-economic motivational factors in the migration of elites can be investigated by converting them into quantitative parameters.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Beigian, S., Safaie, N. and Sepehri, M.M., 2022. Hospital cost reduction modeling thorough scenario planning in system dynamics. *International Journal of Hospital Research*, *11*(3). https://doi.org/LBL_COMMENTED_AT/ijhr.2022.319064.1503

Beine, M., Docquier, F. and Rapoport, H., 2001. Brain drain and economic growth: theory and evidence. *Journal of development economics*, *64*(1), pp.275-289. ; https://doi.org/10.1016/S0304-3878(00)00133-4

Chalabi, M., & Abbasi, R.,2005. Comparative analysis of brain drains at micro and macro levels. *Journal of humanities*, 41-42, pp.13-32, [In Persian]. Available from: https://sid.ir/paper/428775/fa.

Derakhshan Shahrabad, H., Saeedi, M., Yazdanparast, A. and Ghazanfarpour, M., 2023. Emigration Pattern among Medical and Non-medical Iranian Elite and Its Associated Factors: A Review of Literature. *Medical Education Bulletin*, *4*(2), pp.687-701. https://doi.org/10.22034/MEB.2023.403848.1077.

Forrester, J. W., Ratings, T., Gaddis, P. O., Galbraith, J., & Stillwagon, G. B., 1961. *Industrial Dynamics*. The MIT press & John Wiley & sons Inc.

Ghorbanian, Z., & Salehi, M.,2021. Presenting a model for examining the phenomenon of elite flight with systems dynamics approach. *3rd National Conference of Systems Dynamics Society* [In Persian].

Ha, W., Yi, J. and Zhang, J., 2016. Brain drain, brain gain, and economic growth in China. China Economic Review, 38, pp.322-337. ; https://doi.org/10.1016/j.chieco.2015.02.005.

Hajigholamsaryazdi, A., Gholami, S., and Pilehvar-e-mohammadabadi, E., 2017. Analyzing the dynamics of elite migration using associative modeling. *The second international industrial management conference* [In Persian].

Langroodi, R.R.P. and Amiri, M., 2016. A system dynamics modeling approach for a multi-level, multi-product, multi-region supply chain under demand uncertainty. *Expert Systems with Applications*, *51*, pp.231-244. https://doi.org/10.1016/j.eswa.2015.12.043.

Meadows, D.H., 2008. *Thinking in systems: A primer*. chelsea green publishing.

Moftakhari, A., Jafari, M., Abounouri, A., & Nademi, Y., 2023. Investigating the effect of social capital on brain drain in the member countries of the Shanghai Cooperation Organization. *Journal of economic studies and policies*. *10*(19), pp.153-174. [In Persian]; https://doi.org/10.22096/esp.2023.523940.1484.

Mousavirad, S., & Ghodsian, H., 2015. Analysis of elite immigration and the effect of restrictive policies using system dynamics. *Journal of strategic management research*. *21*(59), pp. 37-62. [In Persian].

Mozafari, M., 2023. Science in Iran: a victim of political turmoil. *The Lancet*, *401*(10390), pp.1768-1769. https://doi.org/10.1016/S0140-6736(23)00926-1.

Sadeghi, R. and Seyyed Hosseini, S.M., 2019. Tendency of Youth toward International Migration and Its Determinants in Tehran. *Strategic Studies on Youth and Sports*, *18*(43), pp.9-26.

Safaie, N., Kaveie, M., Mardanian, S., Mohammadi, M., Abdol Mohamadi, R. and Nasri, S.A., 2022. Investigation of factors affecting COVID-19 and sixth wave management using a system dynamics approach. *Journal of Healthcare Engineering*, *2022*. https://doi.org/10.1155/2022/4079685.

Shahabadi, A., & Pouran, R., 2022. The effect of economic complexity and globalization on elite migration in selected member countries of the Organization of Islamic Cooperation. *Journal of modern economy and business*. *17*(1), pp.109-133. [In Persian].

Shahsawaripour, N., Ghafouri, S., & Parizad, B., 2019. Analyzing and introducing practical solutions to the phenomenon of brain drain using system dynamics. *17th International Industrial Engineering Conference* [In Persian].

Sterman, J., 2002. *System Dynamics: systems thinking and modeling for a complex world*. Irwin/McGraw-Hill, Boston.

Vakili, S. and Mobini, M., 2023. An Overview of Brain Drain, Causes, and Policy Issues in Iran. *Medical Education Bulletin*, *4*(2), pp.715-726. https://doi.org/10.22034/MEB.2023.404566.1078.

Vedadhir, A., & Eshraghi, S., 2019. Tendency to migrate in Iran's medical community. *Journal of research and planning in higher education*. *25*(2), pp.23-42. [In Persian].

Zuckerman, H., 1977. *Scientific elite: Nobel laureates in the United States*. Free Press, New York.

Journal of Systems Thinking in Practice
JSTINP, *QUARTERLY*
Homepage: jstinp.um.ac.ir
Online ISSN: 2821-1669, Print ISSN: 2980-9460
Research Article
DOI: 10.22067/JSTINP.2023.84746.1077
JSTINP 2023; Vol. 2, No. 4

Topic Modeling on System Thinking Themes Using Latent Dirichlet Allocation, Non-Negative Matrix Factorization and BER Topic

Rouhollah Bagheri [a]*, Nahid Entezarian [a], Mohammad Hossein Sharifi [a]

[a] *Department of Management, Faculty of Economics and Administrative sciences, Ferdowsi University of Mashhad, Mashhad, Iran.*

How to cite this article

Bagheri, R., entezarian, N., Sharifi, M. H., 2023. Topic Modeling on System Thinking Themes Using Latent Dirichlet Allocation, Non-Negative Matrix Factorization and BERTopic. *Journal of Systems Thinking in Practice*, *2*(4), pp.33-56. doi: 10.22067/jstinp.2023.84746.1077.
URL: https://jstinp.um.ac.ir/article_44582.html

ABSTRACT

In recent years, there has been a growing interest in Systems Thinking (ST) as a significant area of research. It has become increasingly crucial to provide a detailed overview of the ST domain and to identify the prevailing research focuses and trends within this realm. This study represents the most comprehensive and pioneering effort, using topic modeling analysis to analyze the landscape of ST research from the past to the present. The primary objective of this study was to identify the current state of research and the predominant areas of focus within articles related to ST. To achieve this research aim, a search was conducted on August 20, 2023, using the Scopus database, yielding 1400 articles. The bibliometric analysis findings of this study indicate a substantial surge in the number of publications in this field, especially since 2016, with a significant majority of these studies originating from the United States. While the research is characterized by its interdisciplinary nature, most publications fall within social science. Employing Latent Dirichlet Allocation (LDA), Non-Negative Matrix Factorization (NMF), and Bidirectional Encoder Representations (BER) Topic algorithms for topic modeling analysis, the study classified the articles into ten distinct topics. These topics encompass "comprehending and modeling complex systems," "sustainability in business," "interdisciplinary learning and problem-solving in education," "enhancing healthcare delivery," "system dynamics modeling," "engineering education," "chemistry education," "enhancing patient outcomes," "environmental sustainability," and "improving organizational performance." The most prominent topics that represent common research areas in the field of Systems Thinking include "system dynamics modeling," "enhancing healthcare delivery," "interdisciplinary learning and problem-solving in education," "comprehending and modeling complex systems," "environmental sustainability," and "improving organizational performance". In conclusion, this study is expected to provide valuable guidance for future research in the field of Systems Thinking by aiding in identifying research interests and trends.

Keywords

System Thinking, Topic Modeling, BER Topic, Latent Dirichlet Allocation, Non-Negative Matrix Factorization.
.

Article history

Received: 2023-10-11
Revised: 2023-12-03
Accepted: 2023-12-10
Published (Online): 2023-12-28

Number of Figures: 12 **Number of Tables: 3** **Number of Pages: 24** **Number of References: 61**

***Corresponding author**
Email: : rbagheri@um.ac.ir

1. Introduction

Systems thinking is a multidisciplinary approach that emphasizes understanding the interconnectedness and interdependencies within complex systems (Hossain et al., 2020). It has evolved as a cognitive process (Grohs et al., 2018) and an essential framework for addressing complex problems and promoting holistic understanding. Systems thinking has garnered significant attention across various fields, including management, engineering, ecology, and social sciences (De Souza, 2022). The literature on systems thinking encompasses various topics, theories, and applications, reflecting the diverse perspectives and methodologies researchers and practitioners employ in this domain.

In recent years, topic modeling techniques have gained prominence as a method for uncovering latent themes and patterns within textual data. Prominent topic modeling approaches such as Latent Dirichlet Allocation (LDA), Non-Negative Matrix Factorization (NMF), and BERTopic have been utilized to extract and analyze themes from textual corpora. While these techniques have been widely applied in diverse domains, their specific application to systems thinking literature remains an area of exploration that holds promise for gaining deeper insights into the field's fundamental concepts and emerging trends.

This research seeks to investigate the application of LDA, NMF, and BERTopic in the context of systems thinking themes, aiming to uncover the salient topics, trends, and challenges within the literature. By employing these topic modeling techniques, this study sheds light on the underlying themes and dynamics that characterize systems thinking discourse, thereby contributing to a more nuanced understanding of this interdisciplinary domain. Therefore, the current research examines the following questions in the existing literature on systems thinking (ST):

1) What salient themes can be extracted from the ST investigations using LDA, NMF, and BERTopic based on textual analysis?
2) Given the evolution of ST literature over time, how do the topics derived from LDA, NMF, and BERTopic reflect the current and emerging trends in systems thinking literature, and how can better insights be gained?
3) What are the evolving trends and challenges in systems thinking research, and how do these trends manifest in the topics generated by LDA, NMF, and BERTopic?

Through the exploration of topic modeling on systems thinking themes, this research aims to address the following key objectives: to identify and analyze the prevalent themes within systems thinking literature, to compare and contrast the outcomes of LDA, NMF, and BERTopic in extracting these themes, and to discern the evolving trends and challenges in systems thinking scholarship. This study seeks to provide valuable insights that can inform future research, practice, and argument in systems thinking by addressing these objectives. This research uncovers the prevalent themes associated with systems thinking by employing rigorous textual analysis and natural language techniques.

The key contribution of this research is its ability to reveal the current state of the field, research interests, and evolving trends within systems thinking. Applying advanced topic modeling techniques adds depth and nuance to the analysis, allowing for a more comprehensive literature assessment. As a result, the study provides valuable insights for researchers, practitioners, and policymakers, guiding future research directions and facilitating a deeper understanding of the multidisciplinary aspects of systems thinking. Overall, the main contribution of this research is its pioneering use of advanced topic modeling techniques to illuminate the complex and evolving landscape of systems thinking research.

The paper's structure is as follows: Following the Introduction, section 2 provides an introduction to the theoretical background, methods, and models employed. Section 3 details the research methodology and data collection process for topic modeling. Section 4 presents the findings of the descriptive analysis. Section 5 discusses the datasets, describes data pre-processing, and analyses the results. Section 6 encompasses the discussion, conclusion, and suggestions for future work.

2. Theoretical background

2.1. System thinking

Systems thinking emerged around 1960 as a framework for comprehending the dynamic behavior of complex systems, as linear cause-and-effect thinking became inadequate for generating comprehensive solutions (Ratter, 2012). Adams and Keating (2011) assert that grasping the principles of system theory, in conjunction with the thought process developed in systems thinking, is a fundamental step in comprehending complex systems. Systems thinking is a conceptual framework, a body of knowledge and tools developed over the past seventy years to make the full patterns more transparentand help us see how to change them effectively (Senge, 2006).

However, systems thinking is not merely a tool. However, it represents a broader worldview, a way of perceiving the world that evolves as an individual's capacity and willingness to consider it holistically grows. The disciplined use of systems thinking tools and skills (Nagahi et al., 2020) not only supports but can also potentially alter one's worldview, influencing the decisions made regarding applying these tools (Shin et al., 2022). Building on the extensive history of applying systems thinking in business and its more recent integration in K-12 education (National Research Council, 2012), systems thinking can be defined in practical terms as the capacity to perceive a problem or phenomenon as a system comprised of interacting elements that produce emergent behaviors (Shin et al., 2022) presented the importance of different perspectives, definitions, and taxonomies of systems thinking developed over the years. Figure 1 exhibits the development of influential systems thinking perspectives, methods, and tools. The intent is not to provide an exhaustive list of scholars' works but to indicate the progress and expansion of the systems thinking domain.

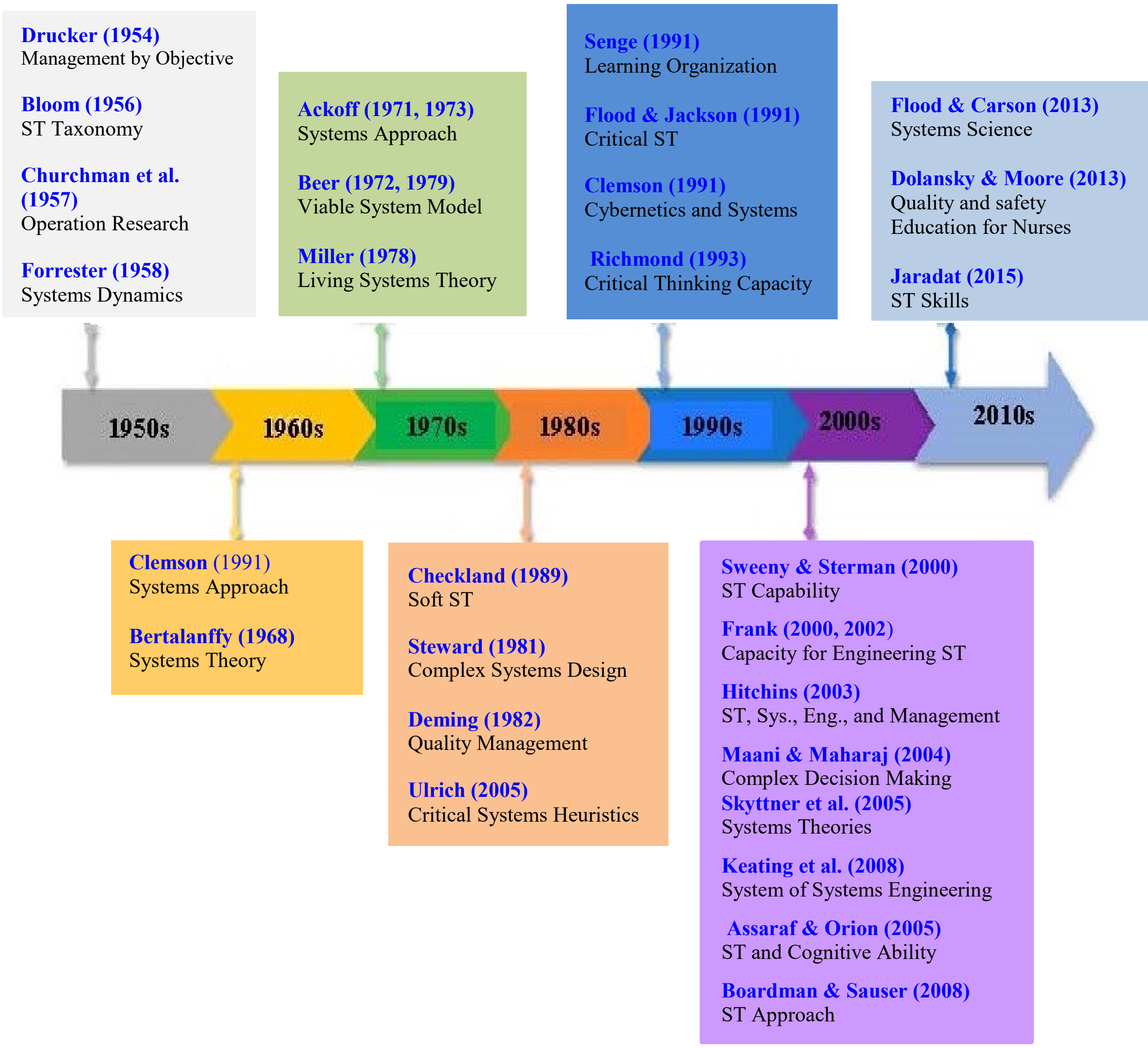


Figure 25. Top impacting systems thinking tools, methods and approaches over time
(Source: Hossain et al.,., 2020).

It is clear from Figure 1 that various perspectives, methods, tools, and approaches to systems thinking have evolved and advanced over the years. The primary focus of most of these influential research works has been on the complex nature of systems and the introduction of methods and approaches related to systems thinking.

Systems thinking is based on the understanding of interrelationships and emergent behaviors. It is often associated with theories, frameworks, and methodologies to understand complex situations and design interventions to address them. Papers published and conferences conducted in traditional systems forums have a bearing on theoretical developments, conceptual advancements, and methodological applications of ST. However, use cases of ST as a cognitive skill that can be applied without traditional systems frameworks and methodologies are rare (Chowdhury, 2023a).

The history of systems thinking can be divided into four distinct stages or waves. The first wave, which emerged in the post-World War II era, focused on the interconnectedness of social and organizational systems and aimed to manage complex problems. This wave, known as complicated systems thinking, was influenced by the belief that social reality could be improved and managed with a functionalist mindset. Methodologies associated with the first wave included Systems Analysis, Systems Engineering, System Dynamics, Organizational Cybernetics, and the Viable System Model. However, this wave faced criticism for its emphasis on prediction and control and its neglect of human agency (Chowdhury, 2023b).

The criticism of the first wave led to a significant paradigm shift and the emergence of the second wave, known as soft systems thinking. This wave, characterized by scholars Checkland (1981), emphasized interpersonal relationships, open dialogue, and learning. Methodologies associated with the second wave included Strategic Assumption Surfacing and Testing, Soft Systems Methodology, Interactive Planning, Interactive Management, and Structured Dialogical Design. However, the second wave also faced criticism for its inability to address power dynamics and hidden influences, leading to a growing fragmentation between hard and soft systems thinking.

To bridge this fragmentation, the third wave, critical systems thinking (CST), emerged with a focus on liberation and emancipation. This wave employed recent developments from complexity theory and emphasized the importance of human interaction and interrelationships. The foundational methodologies of critical systems thinking included Critical Systems Heuristics, Methodological Pluralism, and Systemic Intervention. This wave aimed to address the criticisms of the previous waves and provide a more comprehensive approach to understanding and addressing complex systems (Chowdhury, 2023b). Criticizing the third wave, Jackson (2019) proposed the System of Systems Methodology (SOSM) as a framework for understanding the strengths and weaknesses of various systems methodologies.

An emerging fourth wave of systems thinking unifies and advances the field by identifying the DSRP as underlying the diversity of the three waves. The fourth wave of systems thinking introduces a new focus on simple rules to address complexity, universality, content agnosticism, and an emphasis on metacognition for deeper understanding and emotional intelligence. These elements enable us to directly confront VUCA (Volatility, Uncertainty, Complexity, and Ambiguity). The fourth wave achieves a newfound balance between the systems and the thinking aspects of systems thinking.

2.2. Topic modeling

Topic modeling is an unsupervised method used to uncover hidden topics within a collection of documents (Alami et al., 2021). It is employed to analyze textual documents and automatically extract their underlying themes (Sharma et al., 2021). Topic modeling can link words with the same context and differentiate between the uses of words with different meanings (Barde & Bainwad, 2017). These models aim to identify structural patterns in texts to extract meaningful information. The topic models create clusters of words representing the main subjects in the given collection, providing an automated way to identify common themes in the presented papers (Gurcan et al., 2021; Principe et al., 2021). In Topic modeling, a range of statistical and probabilistic approaches is used to estimate the probability of a particular sequence of words appearing in a sentence. Topic modeling analyzes large text corpora to form the basis for predicting words. These models are more efficient when compared to other methods because they consider the meaning and semantics of words and sentences, as well as the relationships between words.

Various approaches, including algorithms such as LDA, NMF, and BERTopic, can be used for performing topic modeling. Applying these algorithms will help uncover the hidden topic patterns in the text's metadata. However, it is imperative to acknowledge that each model has strengths and weaknesses, and the findings necessitate in-depth qualitative interpretation (Egger & Yu, 2022).

2.2.1. Latent dirichlet allocation (LDA)

LDA is Latent Dirichlet Allocation, a graphical probabilistic model for analyzing text. It operates on a bag-of-words representation, treating each document as a compact numerical vector. LDA outlines its underlying generation process: a) It calculates the likelihood that a specific document is responsible for producing a particular topic. b) It determines the likelihood that a topic generates a specific word. This model involves drawing topic distributions from a Dirichlet distribution, where each element (or topic) in the sampled mix is independent of the others. This generative procedure defines a combined probability distribution covering visible documents and the concealed topic structure. LDA then endeavors to deduce these hidden topics based on the observable words (Abdelrazek et al., 2022). Previous works have shown that LDA approaches are beneficial and valuable in topic modeling (Jelodar et al., 2019). This paper investigated scholarly articles related to systems thinking (ST) using the LDA algorithm to discover the research development, current trends, and intellectual structure of systems thinking.

2.2.2. Non-negative matrix factorization (NMP)

Both LDA and NMF employ statistical modeling to uncover thematic patterns within a text collection, as Egger and Yu indicated in their 2022 study. Nevertheless, there is a notable distinction between the two. LDA is categorized as a generative statistical model, while NMF takes a decompositional, non-probabilistic approach rooted in matrix factorization, belonging to linear algebraic algorithms. Non-negative Matrix Factorization (NMF), introduced by Lee and Seung in 2000, is a widely employed tool for analyzing high-dimensional data. It excels at automatically extracting sparse, meaningful features from a set of non-negative data vectors. NMF serves as an unsupervised technique for reducing the dimensionality of non-negative matrices. A key advantage of NMF compared to LDA is its computational efficiency and scalability, as highlighted by Egger and Yu (2022). NMF is more inclined to produce higher-quality topics than LDA with the same experimental settings. Learning with NMF-based schemes is another effective method in short text topic mining in addition to the popular LDA-based paradigms (Chen et al., 2019).

2.2.3. Bidirectional encoder representations from transformers (BERT)

BERTopic is an unsupervised clustering-based technique for topic modeling. It utilizes Bidirectional Encoder Representations from Transformers (BERT) to create contextual sentence vector representations. These vector representations capture semantic information, labeling topics based on their contextual meaning. BERTopic operates as a topic modeling algorithm by following a three-step process. First, it converts each document into an embedding representation using a pre-trained language model. Afterward, it reduces the dimensionality of these embeddings to improve the clustering process. Finally, it extracts topic representations from the document clusters using a customized class-based variation of TF-IDF, as introduced by Grootendorst (2022). The main advantage of BERTopic is that it allocates clusters precisely and gives topic name suggestions based on clusters. Topic modeling based on BERT does not require the number of topics to be specified in advance (Egger & Yu, 2022).

3. Research methodology

The research objective is to utilize NLP and Topic modeling methods in research papers within the systems thinking field. The proposed approach consists of stages for identifying topical interests, depicted in Figure 2. These stages are executed step-by-step, encompassing data preparation, pre-processing, and feature extraction. Subsequently, three distinct topic modeling techniques are introduced: LDA, NMF, and BERTopic. Finally, the model's performance is evaluated using topic evaluation metrics and validating their coherence. The proposed approach is elaborated in the following sections.

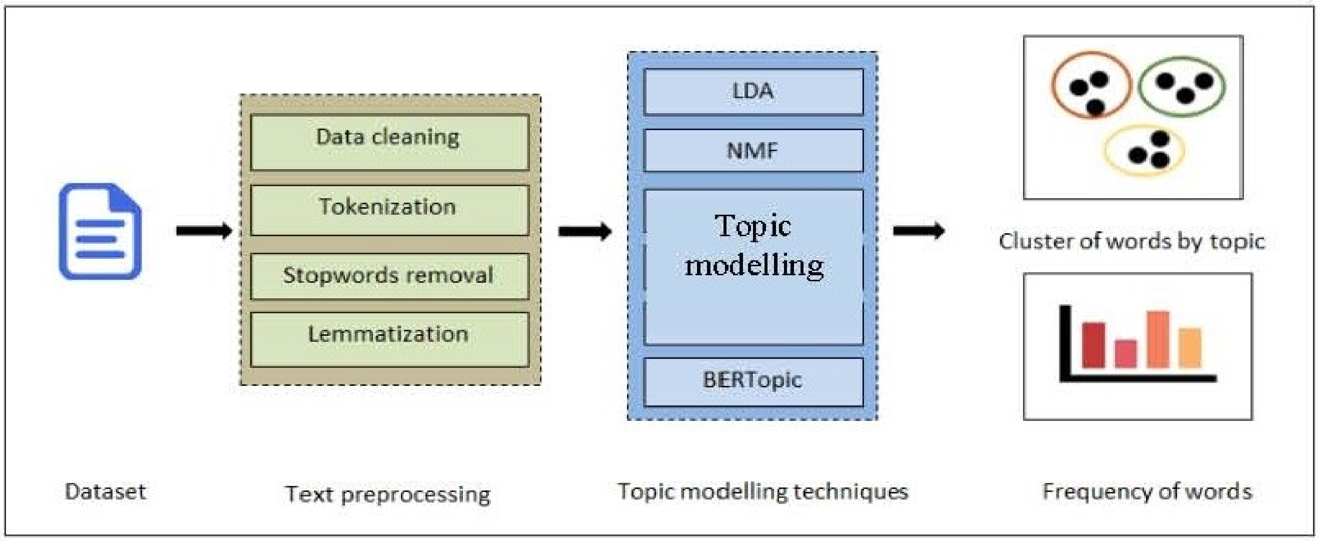


Figure 26. Overview of topic modelling schema using LDA, NMF, and BERTopic (Krishnan, 2023)

3.1. Data collection

About the database, a total of 1,400 documents encompassing articles, conference papers, and book chapters from the Scopus database are obtained. The search criteria were based on identifying the terms 'systems thinking' and 'ST' within the papers' metadata. Specifically, information such as the abstract, keywords, year, source, country/territory, document type, subject area, open-access status, and the language of the document, which is English, is focused. Articles from the Scopus database are filtered and extracted based on their document type (article), document language (English), and document topic (systems thinking).

The topic modeling algorithm is applied for these documents, including LDA, NMF, and BERTopic. This algorithm was executed using the Python version 3.9.

3.2. Data pre-processing

Before conducting frequency analysis and topic modeling algorithms, the data was ready by performing actions such as eliminating stop words, tokenizing, lemmatizing, and stemming terms. This preparatory phase aims to remove less meaningful terms and prevent the counting of similar words in different verb forms more than once (Blum & Raviv, 2023). Data pre-processing is important in enhancing and purifying the raw data, ensuring that it includes only essential attributes for the topic modeling task (Krishnan, 2023).

As shown in Figure 2, different stages of text pre-processing include Tokenization, Lowercasing, Stop Words removal, stemming, and lemmatization. These text pre-processing steps were widely used for dimensionality reduction (Mursi et al., 2023).

Normalization of the case: This pre-processing technique involves converting all the text of the articles to lowercase or uppercase letters and merging exact words to reduce dimensions.

Stop Words Removal: Stop words are common words in a language often considered unnecessary in text mining programs. These words include pronouns, prepositions, articles, and auxiliary verbs that were removed from the text of the articles. Removing stop words, stemming, and term frequency can significantly affect the classification output (Mursi et al., 2023).

Tokenization: This pre-processing technique involves dividing the text of the articles into discrete and recognizable elements, such as words, phrases, symbols, or complete sentences, to work more effectively on the text. Depending on the domain and language, tokenization can significantly improve classification accuracy.

Stemming: In the stemming process, all suffixes and prefixes are removed from the words, reducing different word forms that convey the same meaning to their root or stem. The quality of a model depends on how well stemming can correctly match different forms of a word to the same root (Mursi et al., 2023).

Lemmatization: In the Lemmatization technique, parts of speech are identified, and inflectional forms are associated with their corresponding lemmas. The lemmatization process involves replacing a given token with its corresponding lemma (Mursi et al., 2023).

4. Descriptive analysis findings

The graph in Figure 3 illustrates the distribution and proportions of publications related to the field of ST over different years. Figure 2 1400 articles are included in this category, comprising 1326 research articles and 74 review articles published across 121 journals. Initially, there was no clear pattern in the earlier years. However, it is noteworthy that there has been a substantial annual growth in the number of articles, particularly after 2016, indicating a consistent linear increase over time.

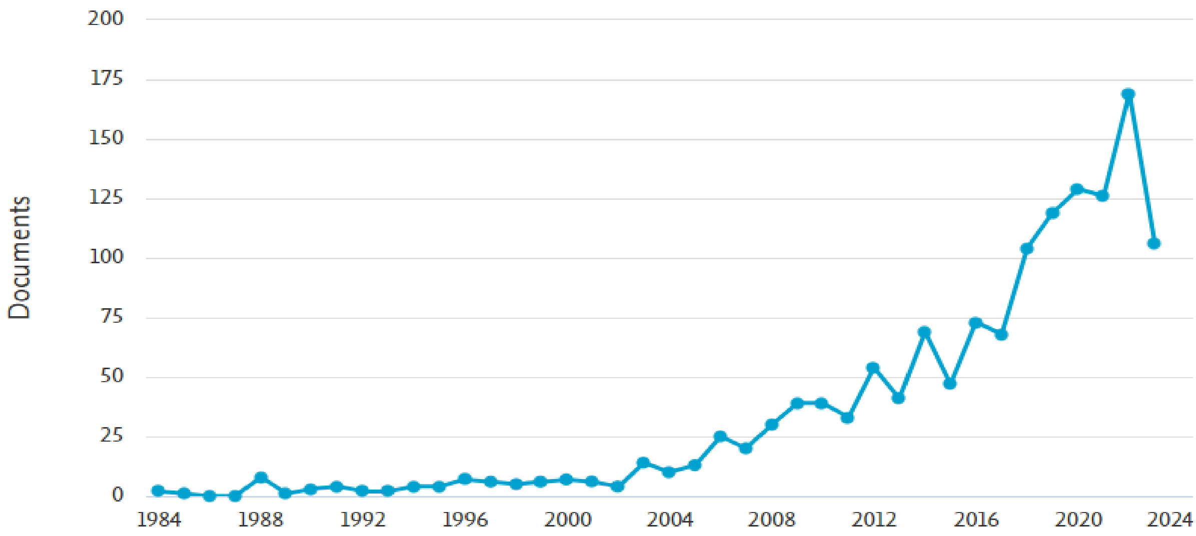


Figure 27. Distribution of articles in the field of ST by years

Considering the sources of publication, it is observed that the top 10 countries with the highest publication rates contribute to 84% of the total publications. In simpler terms, nearly four-fifths of the 1400 publications are generated by these ten countries, with the "United States," "United Kingdom," and "Australia" leading the way in this domain (refer to Figure 4).

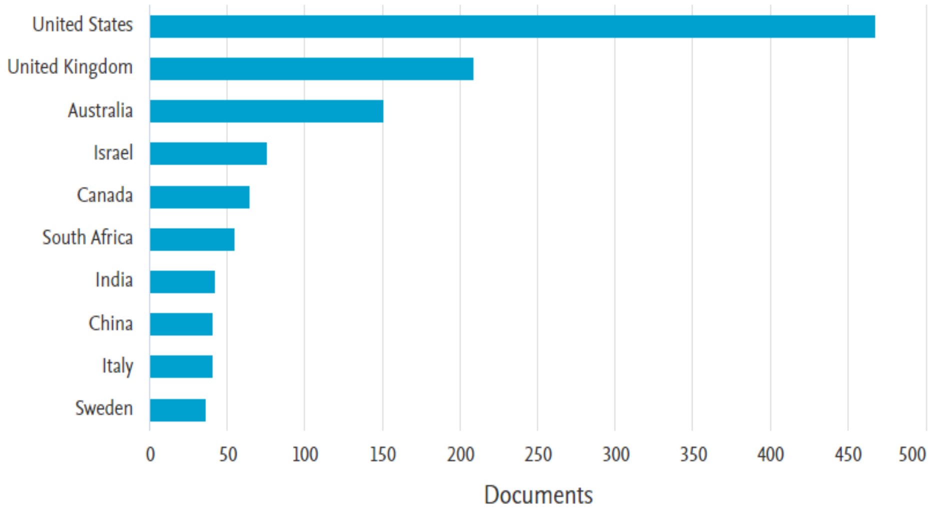


Figure 28. Prominent countries in articles in the field of ST

The findings regarding prominent areas of study in the context of systems thinking (ST) articles are presented in Figure 5, which illustrates the primary topic areas featuring the most articles. The majority of these articles are concentrated in the field of social sciences.

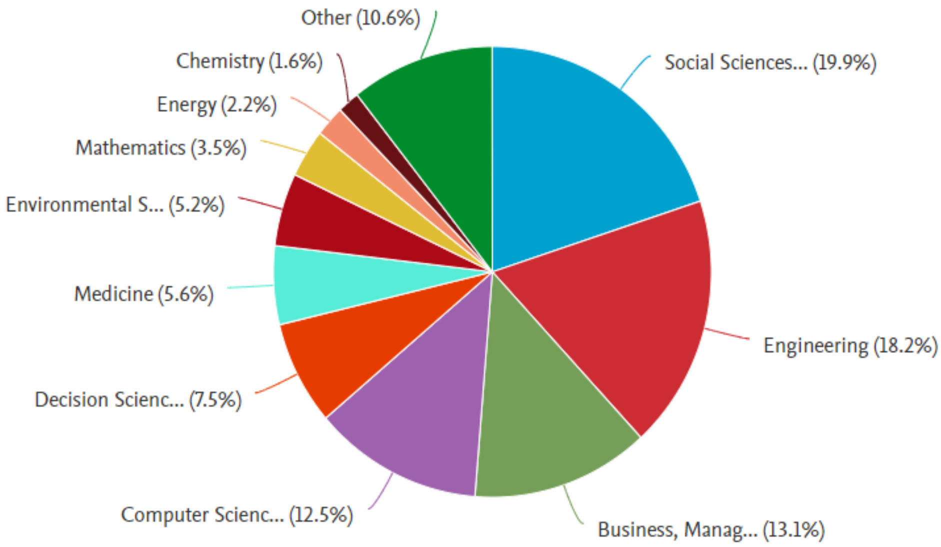


Figure 29. Top most-published subject areas and percent of publications

5. Implementation of topic models

5.1. Results of LDA topic modeling

LDA-based topic models typically require a predetermined selection of the number of topics as input to the model. For evaluating the effectiveness of an LDA topic model, a coherence score estimates how effectively the aggregate set of words can characterize a given topic it comprises (Chen et al., 2019). The LDA model employs the collapsed Bayes sampling method in Gensim. As shown in Figure 6, our LDA topic model with four topics achieves a significant coherence score exceeding 0.36.

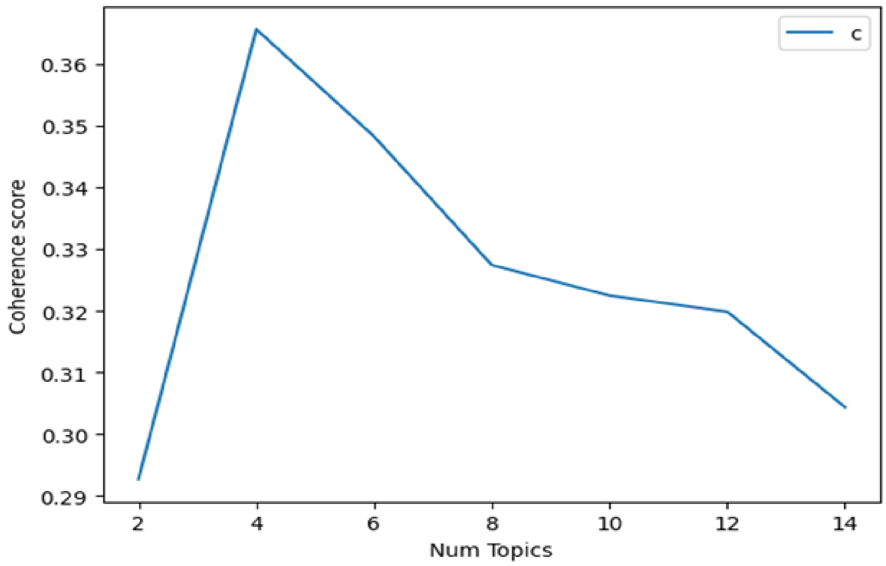


Figure 30. Coherence score of the LDA topic model for numbers of topics.

This section presents findings derived from an analysis of published research on Systems Thinking (ST). The main goal of using topic modeling is to identify the most commonly discussed themes within a body of literature rather than conducting a comprehensive literature review, as highlighted by Gurcan et al. in 2021. Of the web-based interactive visualization tools, pyLDAvis by Genism is the most commonly used tool for depicting the information embedded within a topic model, as noted by Islam (2019). This tool enables the visualization of topic distributions across a given text corpus and helps establish connections between the topics and the associated documents (research papers).

The present study employs an LDA model to ascertain four distinct topics and their distribution across the documents. In Figure 7, each bubble in the left-hand plot represents a specific topic, with the size of the bubble indicating its prevalence. An effective topic model is characterized by having reasonably large, non-overlapping bubbles distributed across the chart rather than clustering in a single area. On the right-hand side, words represent the most significant keywords. Placing the cursor over one of the bubbles updates the words and bars on the right-hand side to show the top 30 salient keywords that form the selected topic, along with their estimated term frequencies, as described by Islam (2019). These words are closely linked to research in the field of Systems Thinking and enable us to identify four distinct topics based on their semantic content, effectively outlining subfields of research in the domain of Systems

Thinking. Additionally, Table 1 presents the keywords generated by the LDA analysis for a selection of 1400 articles focusing on the application of systems thinking.

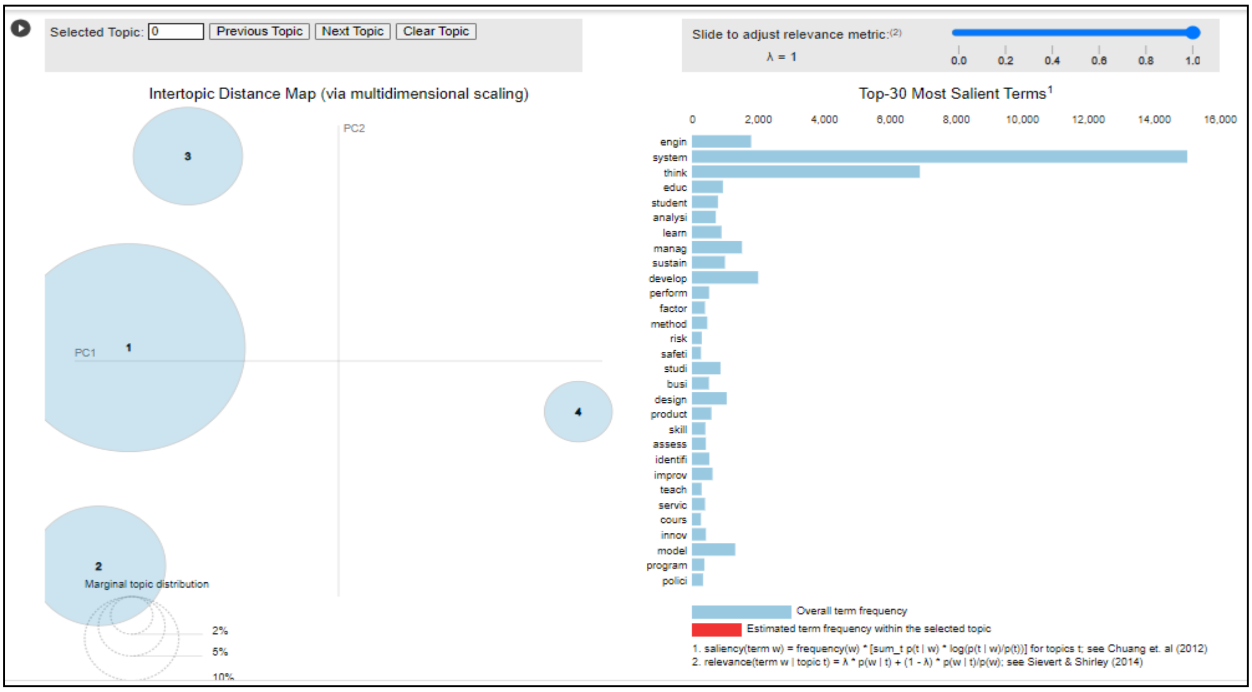


Figure 31. Visual inspection of LDA

Table 5. Sample topics generated by LDA

Topic classification	Keywords	Articles (N=1400), n (%)
Topic 1: understanding and modeling complex systems	System, think, complex, approach, develop, model, understand ,research, critic, practice, theory, paper, inform, process, manag, problem, organ, methodology, design, knowledge, concept, work, analysis, differ, social, , appli, provid, applic, human, dynam	855 (61.1%)
Topic 2: business sustainability	Sustain, manag, system, develop, approach, product, busi, service, innov, polici, industri, model, environment, implement, think, process, improve, oper, effect, chang, casual- loop, impact, public, stakehold, plan, research, dynam, strategi, project, identifi	283 (20.2%)
Topic 3: interdisciplinary learning and problem-solving in education	engine, system, think, educ, student, learn, develop, skill, design, teach, course, program, studi, profession, project, assess, scienc,tool, univers, technolog, abil, Particip, knowledge, sustain, teacher, need, active, experi, train, integr	189 (13.5%)
Topic 4: improve healthcare delivery	System, safeti, risk, analysis, think, factor, accid, measur, nurs, assess, method, studi, identifi, manag, simul, improve, event, paitent, hospital, model, control, report, level, result, survey, associ, medic, standard, construct	73 (5.2%)

Undoubtedly, the most prominent and widely discussed subject is "comprehending and modeling intricate systems". This theme is the focus of approximately 61.1% of the studies. This area of focus delves into the challenges associated with understanding and modeling intricate and ever-changing systems, such as conceptual models, soft systems methodology, ecological systems, social systems, and economic systems. The second most prevalent theme, which appears in 20.2% of the selected papers, is 'business sustainability". This subject is instrumental in fostering the creation of sustainable products and services, enabling businesses to grasp the intricate interactions among various components of the system and their contributions to environmental issues. It also aids businesses in identifying innovation opportunities and designing approaches for system-level transformation. The subsequent theme, "interdisciplinary learning and problem-solving in education," constitutes 13.5% of the papers. This topic explores how systems thinking can be harnessed to teach critical thinking, instructional leadership, problem-solving, and interdisciplinary learning. Finally, "enhancing healthcare delivery" is the subject of 5.2% of the selected papers. This topic examines how systems thinking can be utilized to enhance healthcare delivery, manage safety, improve patient outcomes, and enhance population health. Figure 8 presents a visual representation of the distribution of these topics over the years and shows the relative changes in their popularity over time, as determined by Latent Dirichlet Allocation (LDA).

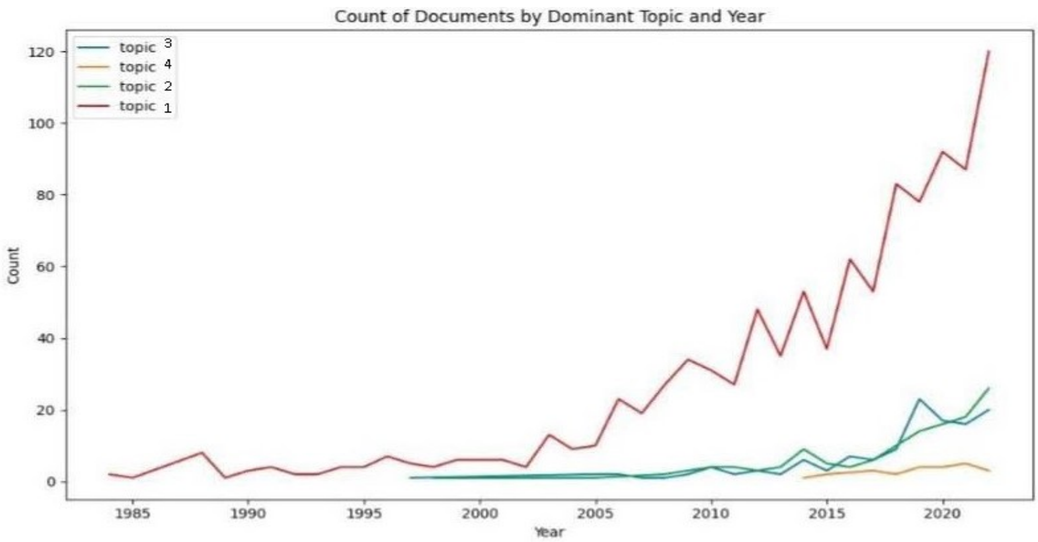


Figure 32. Topic distribution over time with LDA.

5.2. Results of NMF topic modeling

LDA is a widely used approach for identifying and monitoring relevant topics in extensive text collections (Jelodar et al., 2019). Nevertheless, alternative techniques exist, such as BERTopic and NMF, which are also commonly employed. These two approaches have been incorporated to evaluate the robustness of our findings and gain insights from alternative methods. NMF breaks down the term-document matrix into term-feature and feature-document matrices, revealing the words contributing to each topic and the topics found in each document. Unlike LDA, a probabilistic model, NMF employs matrix factorization while enforcing non-negativity constraints (Blum & Raviv, 2023).

Figure 9 illustrates the relationship between the Optimal Number of Topics and the Coherence Score in NMF. NMF achieves the highest coherence score of 0.36, indicating identifying 10 distinct topics. As a result, NMF outperforms LDA, mainly due to its reliance on TF-IDF weighting instead of raw word frequencies (Egger & Yu, 2022). NMF aims to reduce dimensionality without sacrificing vital information and extract essential features for modeling purposes (Preetham et al., 2022). Table 2 displays the keywords generated by NMF, focusing on 1400 articles that canter around the application of systems thinking.

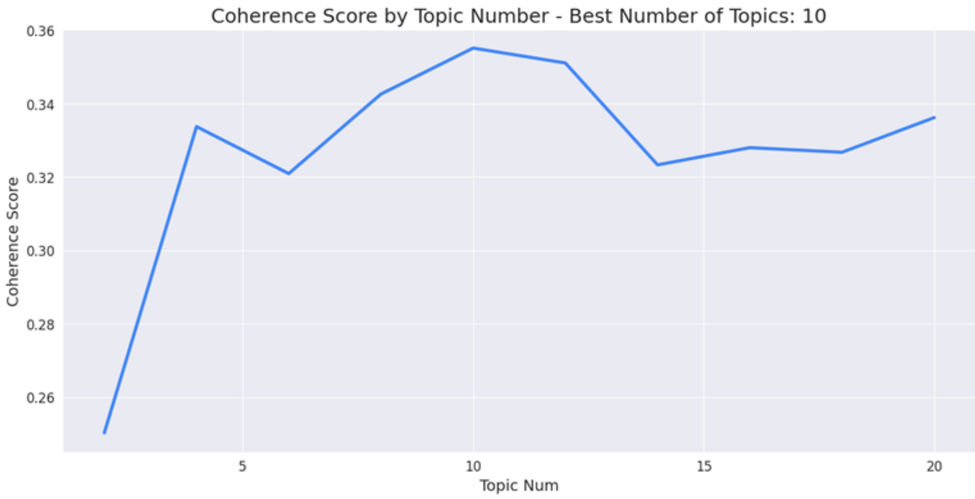


Figure 33. Coherence score of the NMF topic model for numbers of topics.

Table 6. Sample topics generated by NMF

Topic classification	Keywords	Articles (N=1400), n (%)
Topic 1: system dynamics modeling	model, dynam, causal, loop, diagram, chain, causal loop, suppli chain	181 (12.92%)
Topic 2: engineering education	engineering, cest, capacity, education, engineering think, think engineering, engineering education, capacity engineering	104 (7.42%)
Topic 3: Chemistry education	Chemistry, education, green, chemical, division, green Chemistry, Chemistry education, chemical education	49 (3.5%)
Topic 4: improve healthcare delivery	Health, care, public, public health, healthcare, policy, service, human	130 (9.28%)
Topic 5: interdisciplinary learning and problem-solving in education	Student, education, learn, school, skill, teacher, teach, think skill,	224 (31.36%)
Topic 6: improve patient outcomes	Safety, accident, risk, analysis, factor, nurse, safety culture, safety management	90 (6.42%)
Topic 7: understanding and modeling complex systems	Critical think, cest, methodology, practical, theory, research, social	193 (13.78%)
Topic 8: environmental sustainability	Sustainable, Sustainable develop, develop, environment, social, economy, integration, education Sustainable	132 (9.42%)
Topic 9: business sustainability	design, design thinking, product, process, design process, service, innovation, technology	112 (8%)
Topic 10: improve organizational performance	Management, project, knowledge, knowledge management, project management, business, organization, quality	184 (13.14%)

Upon visualizing the data, it was observed that several instances of topic overlap affect the performance of the NMF model, as documented by Preetham et al. in 2022. The intersecting themes were combined into one topic to overcome this problem. Specifically, topics 1 and 7 were merged, 2, 3, and 5 were combined, 4 and 6 were unified, and 8 and 9 were fused. As a result of this reduction, the total topic count decreased from 10 to 5, making it quite similar to the LDA model. The comparison found similarities in how both models categorized these topics. For instance, topics 1 in LDA and 1 and 7 in NMF shared common terms, representing research papers focused on "understanding and modeling complex systems".

Similarly, topics 2 in LDA and 8 and 9 in NMF pertained to documents related to "business sustainability." Topic 3 in LDA and topics 2, 3, and 5 in NMF exhibited similarities, indicating an emphasis on educational topics. Lastly, topics 4 in LDA and 4 and 6 in NMF delved into research papers concerning "improving healthcare delivery". Figure 10 illustrates the distribution of these topics over the years, demonstrating how their popularity has changed relative to each other.

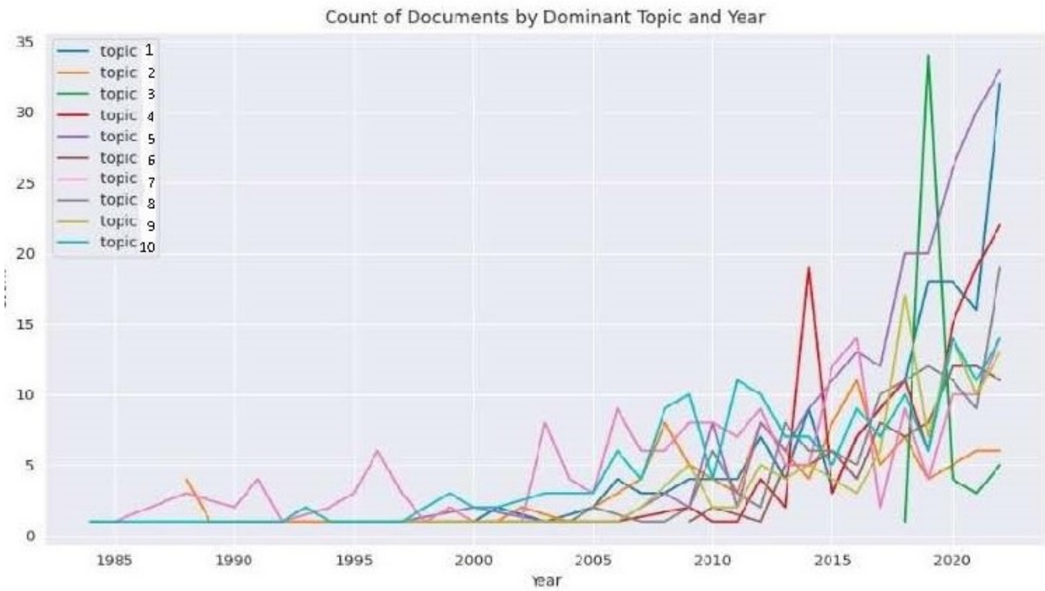


Figure 34. Topic distribution over time with NMF.

Consequently, the key topics in systems thinking research are as follows: "system dynamics modeling" (topic 1), "improve healthcare delivery" (topic 4), "interdisciplinary learning and problem-solving in education" (topic 5), "understanding and modeling complex systems" (topic 7), "environmental sustainability" (topic 8), and "improve organizational performance" (topic 10), which are commonly recognized as significant subjects in this field.

5.3. Results of BER topic modeling

BERTopic utilizes a class-based term frequency-inverse document frequency (c-TF-IDF) algorithm to evaluate term significance within a cluster and create term representations (Sánchez-Franco & Rey-Moreno, 2022). In simpler terms, it assigns higher values to terms more representative of their respective topics. Unlike LDA, BERTopic offers continuous modeling instead of discrete topics (Alcoforado et al., 2022). This model's stochastic nature leads to varied outcomes with repeated runs.

Once the model is calculated, researchers can extract the most significant topics. It is important to note that Topic 0, with a count of -1, consistently represents outliers and should be disregarded. Researchers can also search for keywords and receive the most relevant topics based on similarity scores. They can further delve into individual topics based on their keywords. To facilitate a more comprehensive analysis of the potentially extensive list of topics, BERTopic provides an interactive map of intertopic distances for examining individual topics (Grootendorst, 2022).

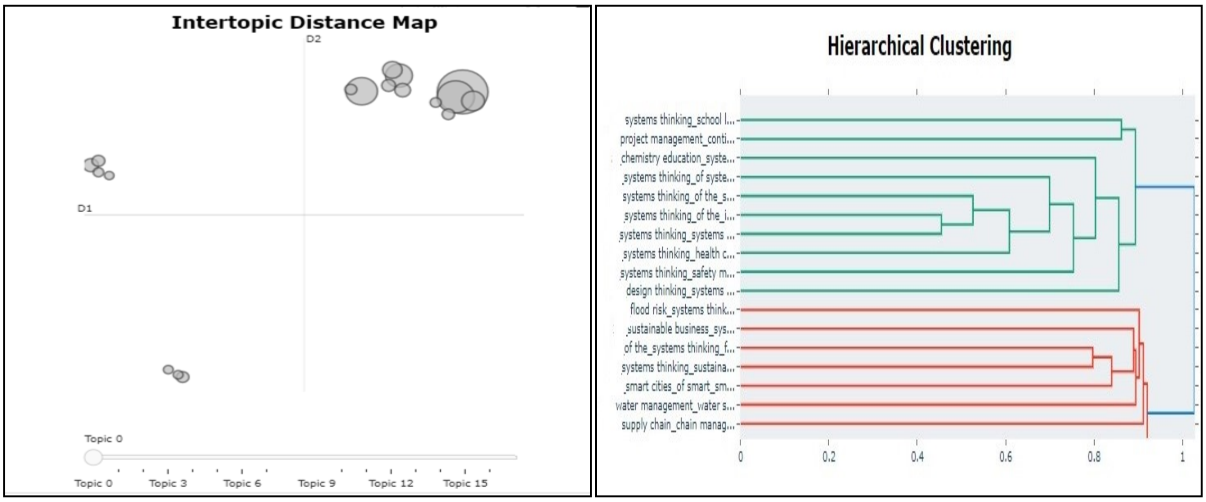
BERTopic enables the hierarchical reduction of topics, especially when closely related topics are evident in the intertropical distance map (Figure 11a). To achieve this reduction, hierarchical clustering is performed using the cosine distance matrix between topic embeddings. Similar topics are grouped (Figure 11b). For instance, Topic 13 (Six Sigma) and Topic 16 (continuous improvement) are clustered together due to their proximity. Similarly, Topics 3 and 9 (sustainable development), Topic 2 and Topic 23 (systems engineering), and Topics 12 and Topic 14 (education) are treated as part of the same cluster. This visualization aids researchers in understanding how the algorithm organizes topics.

After reviewing the proposed topic structure, researchers can interactively determine the appropriate number of topics in an interactive manner. However, it is worth noting that determining an optimal number of topics can be challenging due to topic overlap and the blending of two to three different aspects. For example, this study selected 8 topics from the 24 extracted topics (Table 3) to demonstrate how topics can be reduced (Figure 12).

Table 7. Topics generated by BERTopic

Topic	Representation	Articles (N=1400), n (%)
0 (-1)	systems thinking, of the, in the, of systems	332 (23.71%)
1	systems thinking, health care, public health, ...	202 (14.42%)
2	Systems thinking, systems engineering, engine...	129 (9.21%)

Topic	Representation	Articles (N=1400), n (%)
3	Systems thinking, of the, sustainable developm...	114 (8.14%)
4	Systems thinking, safety management, risk mana...	76 (5.42%)
5	chemistry education, green chemistry, systems ...	56 (4%)
6	Critical systems, systems thinking, of critica...	40 (2.85%)
7	systems thinking, in the, of the, system thinking	36 (2.57%)
8	systems thinking, water management, in the, ...	35 (2.5%)
9	Sustainable development, systems thinking, bio...	34 (2.42%)
10	systems thinking , quality management, ...	32 (2.28%)
11	systems thinking , social entrepreneur, ...	31 (2.21%)
12	systems thinking , higher education, ...	30 (2.14%)
13	Six sigma, systems thinking, asset management...	29 (2.07%)
14	Systems thinking, school leadership, school p...	26 (1.85%)
15	Information systems, systems thinking, soft s...	25 (1.78%)
16	project management, continuous improvement, ...	24 (1.71%)
17	Systems thinking, family farmers, food...	22 (1.57%)
18	systems thinking , cyber security, traffic man, ...	21 (1.5%)
19	electric vehicles, energy consumption, sustain, ...	20 (1.42%)
20	systems thinking , neurological position, ...	20 (1.42%)
21	Supply chain, chain management, supply chains...	19 (1.35%)
22	design thinking, design systems, systems thin...	18 (1.28%)
23	systems engineering, systems thinking, ...	18 (1.28%)
24	knowledge management, knowledge assets, criti.	11 (0.78%)



(a) (b)

Figure 35. (a) BERTopic interactive intertopic distance map; (**b**) Hierarchical clustering of topics

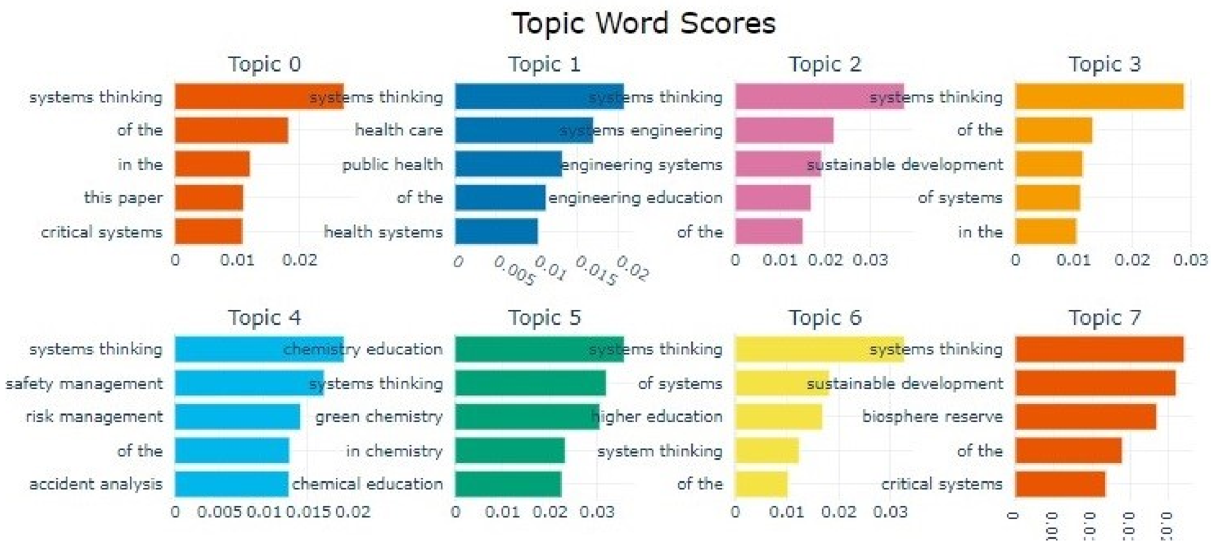


Figure 36. Extracted topics with BERTopic

Discussion and conclusions

This section presents the study's implications, the field's current state, and future inferences based on the results and discussion. The study aimed to examine articles related to system thinking (ST) in the Scopus database from 1984 to 2023. The bibliometric characteristics of the field were analyzed using descriptive analysis. The results showed increased interest in ST over the years, with a linear increase in articles published annually, particularly after 2016. Social science subject areas were the most prevalent in the interdisciplinary field, and the United States, the United Kingdom, and Australia were the leading countries in publications.

The study also focused on the applications of systems thinking. It used keyword analysis and topic modeling techniques such as LDA, NMF, and BERTopic to identify trends in different domains and identified the most extensively covered areas in the literature The voluminous topics were “understanding and modeling complex systems”, “business sustainability” and “interdisciplinary learning and problem-solving in education”, "improving healthcare delivery", "system dynamics modeling", "engineering education", "chemistry education", "improve patient outcomes", "environmental sustainability" and "improve organizational performance. These topics have seen an increase in publications over time and are expected to continue to be studied in the future.

The study on topic modeling of system thinking themes has provided valuable insights into the multidimensional nature of system thinking. The study effectively discovered and categorized the key themes and concepts supporting system thinking through topic modeling approaches. The study's most innovative aspect is the inclusion of topic modeling analysis, which provided a summarized overview of the literature by grouping articles into logical topics characterized by key relevant terms.

The primary contribution of this study lies in developing a comprehensive understanding of the trends and themes of research in the field of systems thinking. The study's use of multiple topic modeling techniques, such as LDA, NMF, and BERTopic, can inspire further research on applying these techniques in other fields.

However, the study's exclusive focus on journal articles may be a limitation; future research could include different documents. Similar studies conducted at intervals over the years could be analyzed.

The comparison of evolving trends and deeper semantic analyses could explore specific subtopics within the ST domain.

Overall, the study provides valuable insights into the ST field's current state and future trends. The research findings are valuable to researchers and practitioners in the field, providing insights into the field's current state, research interests, and evolving trends. Also, the study's findings have practical implications for practitioners and researchers in diverse fields, highlighting the relevance of system thinking in addressing complex and dynamic challenges. The identified themes can serve as a foundation for further research, as well as for policy development and practical applications aimed at fostering a systems-oriented approach to problem-solving and decision-making.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Abdelrazek, A., Medhat, W., Gawish, E., and Hassan, A., 2022. November. Topic Modeling on Arabic Language Dataset: Comparative Study. *In International Conference on Model and Data Engineering* ,pp. 61-71. Springer, Cham. https://doi.org/10.1007/978-3-031-23119-3_5.

Ackoff, R. L., 1971. Towards a system of systems concepts. *Management science*, *17*(11), pp. 661-671. https://doi.org/10.1287/mnsc.17.11.661

Ackoff, R. L., 1973. Science in the systems age: Beyond IE, OR, and MS. *Operations Research*, *21*(3), pp. 661-671. https://doi.org/10.1287/opre.21.3.661

Adams, K. M., and Keating, C. B., 2011. Overview of the systems of systems engineering methodology. *International Journal of Systm of Systems Engineering*, 2(2-3), p. 112-119. https://doi.org/10.1504/IJSSE.2011.040549

Alami, N., Meknassi, M., En-nahnahi, N., El Adlouni, Y., and Ammor, O., 2021. Unsupervised neural networks for automatic Arabic text summarization using document clustering and topic modeling. *Expert Systems with Applications*, *172*, p. 114652. https://doi.org/10.1016/j.eswa.2021.114652

Alcoforado, A., Ferraz, T. P., Gerber, R., Bustos, E., Oliveira, A. S., Veloso, B. M. ... and Costa, A. H. R., 2022, March. ZeroBERTo: Leveraging zero-shot text classification by topic modeling. In *International Conference on Computational Processing of the Portuguese Language*. pp. 125-136. Springer, Cham. https://doi.org/10.1007/978-3-030-98305-5_12

Assaraf, O. B. Z., and Orion, N., 2005. Development of system thinking skills in the context of earth system education. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *42*(5), pp. 518-560. https://doi.org/10.1002/tea.20061

Boardman, J., & Sauser, B., 2008. *Systems thinking: Coping with 21st century problems*. CRC Press.

Barde, B. V., and Bainwad, A. M., 2017. An overview of topic modeling methods and tools. In *2017 International Conference on Intelligent Computing and Control Systems (ICICCS)* .pp. 745-750. IEEE. https://doi.org/10.1109/ICCONS.2017.8250563

Beer, S., 1972. Brain of the Firm. Harmondsworth: *Allan Lane*.

Beer, S., 1979. The Hart of Enterprise. Chichester: *John Wiley.*

Bertalanffy, L. V., 1968. *General system theory: Foundations, development, applications*. G. Braziller. http://repository.vnu.edu.vn/handle/VNU_123/90608.

Bloom, B. S., 1956. Taxonomy of. *Educational Objectives*. doi: 10.1007/978-1-4419-1428-6_141.

Blum, A., and Raviv, A., 2023. The effects of the financial crisis and Basel III on banks' risk disclosure: A textual analysis. *Finance Research Letters*, *53*, p. 103680. https://doi.org/10.1016/j.frl.2023.103680

Checkland, P., 1981. Systems thinking, systems practice: includes a 30-year retrospective. *Journal-Operational Research Society*, 51(5), pp.647-647.

Checkland, P. B., 1989. Soft systems methodology. *Human systems management*, *8*(4), pp. 273-289.

Chen, Y., Zhang, H., Liu, R., Ye, Z., and Lin, J., 2019. Experimental explorations on short text topic mining between LDA and NMF based Schemes. *Knowledge-Based Systems*, *163*, pp.1-13.

https://doi.org/10.1016/j.knosys.2018.08.011

Chowdhury, R., 2023a. Methodological flexibility in systems thinking: Musings from the standpoint of a systems consultant. *Systemic Practice and Action Research*, *36*(1), pp. 59-86. https://doi.org/10.1007/s11213-022-09597-w

Chowdhury, R., 2023b. Holistic flexibility for deploying systems thinking as a cognitive skill. *Systemic Practice and Action Research*, pp.1-23. https://doi.org/10.1007/s11213-022-09626-8

Churchman, C. W., Ackoff, R. L., and Arnoff, E. L., 1957. Introduction to operations research.

Clemson, B., 1991. *Cybernetics: A new management tool* (Vol. 4). CRC Press.

Deming, W. E., 1982. Quality, productivity, and competitive position. *(No Title)*. URL: https://cir.nii.ac.jp/crid/1130000797039430528

De Souza, D. E., 2022. A critical realist approach to systems thinking in evaluation. *Evaluation*, *28*(1), pp. 72-90. https://doi.org/10.1177/13563890211064639

Dolansky, M. A., and Moore, S. M., 2013. Quality and Safety Education for Nurses (QSEN): The Key is Systems Thinking. *Online Journal of Issues in Nursing*, *18*(3). URL: https://pubmed.ncbi.nlm.nih.gov/26812094/

Drucker, P.F., 1954. The Practice of Management. New York: *Harper & Row*.

Egger, R., and Yu, J., 2022. A topic modeling comparison between lda, nmf, top2vec, and bertopic to demystify twitter posts. Frontiers in sociology, 7, p. 886498. https://doi.org/10.3389/fsoc.2022.886498

Frank, M., 2000. Engineering systems thinking and systems thinking. INCOSE Journal of Systems Engineering, vol. 3, no. 3, pp. 163-168. https://doi.org/10.1002/1520-6858

Frank, M., 2002. Characteristics of engineering systems thinking – A 3-D approach for curriculum content. IEEE Transaction on System, Man, and Cybernetics, vol. 32, no. 3, Part C, pp. 203-214. https://doi.org/10.1109/TSMCC.2002.804450

Flood, R. L., and Jackson, M. C., 1991. *Critical systems thinking*. Chichester: Wiley.

Flood, R. L., and Carson, E. R., 2013. *Dealing with complexity: an introduction to the theory and application of systems science*. Springer Science & Business Media.

Forrester, J. W., 1958. Industrial dynamics: a major breakthrough for decision makers. *Harvard business review*, *36*(4), pp. 37-66.

Grohs, J. R., Kirk, G. R., Soledad, M. M., and Knight, D. B., 2018. Assessing systems thinking: A tool to measure complex reasoning through ill-structured problems. *Thinking Skills and Creativity*, *28*, pp. 110-130. https://doi.org/10.1016/j.tsc.2018.03.003

Grootendorst, M. 2022., BERTopic: Neural topic modeling with a class-based TF-IDF procedure. *ArXiv preprint arXiv*: p. 2203.05794. https://doi.org/10.48550/arXiv.2203.05794

Gurcan, F., Cagiltay, N. E., and Cagiltay, K., 2021. Mapping Human-Computer Interaction Research Themes and Trends from Its Existence to Today: A Topic Modeling-Based Review of past 60 Years. *International Journal of Human-Computer Interaction*, 37(3), pp.1–14, https://doi.org/10.1080/10447318.2020.1819668

Hossain, N. U. I., Dayarathna, V. L., Nagahi, M., and Jaradat, R., 2020. Systems thinking: A review and bibliometric analysis. *Systems*, *8*(3), p.23. https://doi.org/10.3390/systems8030023

Hitchins, D. K. 2003. *Advanced systems thinking, engineering, and management*. Artech House.

Islam, T., 2019. Yoga-veganism: Correlation mining of twitter health data. *ArXiv preprint arXiv: p.1906.07668*. https://doi.org/10.48550/arXiv.1906.07668

Jackson, M. C. 2019. Critical systems thinking and the management of complexity. *John Wiley & Sons.*

Jaradat, R. M., 2015. Complex system governance requires systems thinking-how to find systems thinkers. *International Journal of System of Systems Engineering*, *6*(1-2), pp.53-70.

Jelodar, H., Wang, Y., Yuan, C., Feng, X., Jiang, X., Li, Y., and Zhao, L., 2019. Latent Dirichlet allocation (LDA) and topic modeling: models, applications, a survey. *Multimedia Tools and Applications*, *78*, pp.15169-15211. https://doi.org/10.1007/s11042-018-6894-4

Keating, C. B., 2008. Emergence in system of systems. *System of systems engineering: Innovations for the 21st century*, pp. 169-190. https://doi.org/10.1002/9780470403501.ch7

Krishnan, A., 2023. Exploring the Power of Topic Modeling Techniques in Analyzing Customer Reviews: A Comparative Analysis. *ArXiv preprint arXiv, p. 2308.11520*. https://doi.org/10.48550/arXiv.2308.11520

Lee, D., and Seung, H. S., 2000. Algorithms for non-negative matrix factorization. *Advances in neural information processing systems*, 13.

Maani, K. E., and Maharaj, V., 2004. Links between systems thinking and complex decision making. *System Dynamics Review: The Journal of the System Dynamics Society*, *20*(1), pp. 21-48. https://doi.org/10.1002/sdr.281

Miller, J. G., 1978. Living Systems,‖ McGraw Hill. *New York*.

Mursi, J. K. A., Subramaniam, P. R., and Govender, I. 2023. Exploring the Influence of Pre-Processing Techniques in Obtaining Labelled Data from Twitter Data. In *2023 IEEE AFRICON* .pp. 1-6. IEEE. https://doi.org/10.1109/AFRICON55910.2023.10293408

Nagahi, M., Hossain, N. U. I., Jaradat, R., Goerger, S. R., Abutabenjeh, S., and Kerr, C., 2020. August. Do the practitioners' level of systems-thinking skills differ across sector types? *In 2020 IEEE International Systems Conference (SysCon)* .pp. 1-5. IEEE. https://doi.org/10.1109/SysCon47679.2020.9275917

National Research Council., 2012. A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. *National Academies Press*. URL: https://nap.nationalacademies.org/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts

Preetham, S., Reddy, B. R., Reddy, D. S. T., and Gupta, D., 2022, November. Comparative Analysis of Research Papers Categorization using LDA and NMF Approaches. In *2022 IEEE North Karnataka Subsection Flagship International Conference (NKCon)* .pp. 1-7. IEEE. https://doi.org/10.1109/NKCon56289.2022.10127059

Principe, V. A., de Souza Vale, R. G., de Castro, J. B. P., Carvano, L. M., Henriques, R. A. P., de Almeida e Sousa Lobo, V., and de Alkmim Moreira Nunes, R., 2021. A computational literature review of football performance analysis through probabilistic topic modeling. *Artificial Intelligence Review*, pp.1-21. https://doi.org/10.1007/s10462-021-09998-8

Ratter, B. M., 2012. Complexity and Emergence. Human-nature interactions in the Anthropocene: Potentials of social-ecological systems analysis, p. 90.

Richmond, B., 1993. Systems thinking: critical thinking skills for the 1990s and beyond. *System dynamics review*, *9*(2), pp. 113-133. https://doi.org/10.1002/sdr.4260090203

Sánchez-Franco, M. J., and Rey-Moreno, M., 2022. Do travelers' reviews depend on the destination? An analysis in coastal and urban peer-to-peer lodgings. Psychology & marketing, 39(2), pp. 441-459. https://doi.org/10.1002/mar.21608

Senge, P. M., 2006. The fifth discipline: The art and practice of the learning organization. Broadway Business.

Senge, P., 1991. The learning organization made plain. *Training & Development*, *45*(10), pp. 37-44.

Sharma, A., Rana, N. P., and Nunkoo, R., 2021. Fifty years of information management research: A conceptual structure analysis using structural topic modeling. *International Journal of Information Management*, *58*, p. 102316. https://doi.org/10.1016/j.ijinfomgt.2021.102316

Shin, N., Bowers, J., Roderick, S., McIntyre, C., Stephens, A. L., Eidin, E. ... and Damelin, D., 2022. A framework for supporting systems thinking and computational thinking through constructing models. *Instructional Science*, *50*(6), pp. 933-960. https://doi.org/10.1007/s11251-022-09590-9.

Skyttner, L., 2005. *General systems theory: Problems, perspectives, practice*. World scientific.

Steward, D. V., 1981. The design structure system: A method for managing the design of complex systems. *IEEE transactions on Engineering Management*, (3), pp. 71-74.

Sweeny, L. B., and Sterman, J. D., 2000, August. Bathtub dynamics: Preliminary results of a systems thinking inventory. In *International System Dynamics Conference, Bergen, Norway*. pp.2-67

Ulrich, W., 2005. A brief introduction to critical systems heuristics (CSH). *ECOSENSUS project site*.

Journal of Systems Thinking in Practice
JSTINP, *QUARTERLY*
Homepage: jstinp.um.ac.ir
Online ISSN: 2821-1669, Print ISSN: 2980-9460
Research Article
DOI: 10.22067/JSTINP.2023.85639.1080
JSTINP 2023; Vol. 2, No. 4

Prioritizing of the Internet of Manufacturing Things (IoMT) Challenges in Automotive Industry by Using Interpretive Structural Modeling (ISM)

Sahar Valipour Parkouhi[a*], Abdolhamid Safaei Ghadikolaei[a], Hamidreza Fallah Lajimi[a]

[a] *Department of Industrial Management, Faculty of Economics and Administrative Sciences, University of Mazandaran, Mazandaran. Iran.*

How to cite this article

Valipour Parkouhi, S., Safaei Ghadikolaei, A., Fallah Lajimi, H., 2023. Prioritizing of The Internet of Manufacturing Things (IoMT) Challenges in Automotive Industry by using Interpretive Structural Modeling (ISM), *Journal of Systems Thinking in Practice*, 2(4), pp.57-77. doi: 10.22067/jstinp.2023.85639.1080
URL: https://jstinp.um.ac.ir/article_44692.html

A B S T R A C T

Smart manufacturing can be referred to as an important consequence of the Fourth Industrial Revolution. With the advent of this revolution, manufacturing companies must use numerous new technologies to become smart. Companies face multifaceted challenges because of these new technologies. The Internet of Things (IoT) technology is one of the achievements of Industry 4.0, which plays an important role in implementing smart manufacturing. IoT used in smart manufacturing is called the Internet of Manufacturing Things (IoMT Like other technologies, IoMT has its challenges. Therefore, manufacturing organizations must be able to identify these challenges and concentrate on them based on their priority. This study identified the challenges of using the Internet of Things in smart manufacturing were identified by reviewing the literature. The Interpretive Structural Modeling (ISM) technique was used to prioritize challenges in the automotive industry. Based on the research findings, the challenges were classified into three levels. This leveling provides a suitable model for automotive industry managers prioritize their strategies and actions accordingly.

Keywords

Smart manufacturing, Internet of things, Internet of Manufacturing Things, Challenges, Interpretive Structural Modeling.

Article history

Received: 2023-11-30
Revised: 2023-12-19
Accepted: 2023-12-22
Published (Online): 2023-12-28

Number of Figures: 5 **Number of Tables: 7** **Number of Pages: 21** **Number of References: 44**

****Corresponding author***
Email: s.valipour@stu.umz.ac.ir

1. Introduction

In recent years, in wireless communications and networking, a new paradigm called the Internet of Things (IoT) has attracted the attention of many researchers and industrialists. The Internet of Things can be defined as a network of physical objects that are digitally connected so that they can sense, monitor, and influence each other (Xu et al., 2023). A supply chain is also a network that requires monitoring and controlling relationships between components. Therefore, using IoMT in different parts of the supply chain can facilitate communication and cooperation between partners and processes. Smart manufacturing is formed by using the Internet of Things in manufacturing (as part of supply chain processes). According to the definition presented by the Smart Manufacturing Leadership Coalition (SMLC), smart manufacturing is "the right data in the right form, the right people with the right knowledge, the right technology, and the right operations, whenever and wherever the production needed throughout the manufacturing enterprise" (Edgar and Pistikopoulos, 2018). Another definition was provided by the National Institute of Standard and Technology (NIST), based on which smart manufacturing is "fully integrated, collaborative manufacturing systems that respond in real-time to meet changing demands and conditions in the factory in the supply network, and customer needs".

As with previous manufacturing parameters, smart manufacturing has also developed in the automotive industry. The automotive industry is regarded as a key industry in terms of its extensive relationship with a chain of industries before and after. It has a high potential for economic development. As stated in the philosophy of production paradigms, concepts such as mass production, lean production, and world-class manufacturing, which have revolutionized various industries, were first introduced and implemented in the automotive industry (mass production at Ford Motor Company, lean production and world-class manufacturing at Toyota) (Ebrahimi et al., 2019). Consequently, the present study examines the Internet of Things challenges in smart manufacturing as a new production paradigm in the automotive industry.

In addition to the dramatic change in the automotive industry, the Internet of Manufacturing Things has affected the performance of auto manufacturers and the software they use, thus trying to maximize values (Krasniqi and Hajrizi, 2016). Smartening the automotive industry will bring lower costs, energy savings, environmental protection, and efficient after-sales services (Liu et al., 2012). There are serious challenges in smartening and implementing IoMT to achieve these goals. In the last decade, these challenges have been introduced in conducted research in the field of smart manufacturing and the Internet of Things (Afzal et al., 2019; Chen et al., 2014; Cooper and James, 2009; Farahani et al., 2018; Werlinger et al., 2009; Kumar and

Mallick, 2018; Lee and Lee, 2015; Lim et al., 2018; Makhdoom et al., 2019; Reyna et al., 2018). However, it is impossible to consider and address all challenges simultaneously. Therefore, it must be determined at which level each challenge is and which are prioritized. Using the ISM technique to level the challenges and, consequently, their management in IoMT deployment is also considered a contribution of the innovation in the present study. In conclusion, this study addresses these two primary questions: What difficulties does the Internet of Manufacturing Things present? Given the restricted resources, which issues ought to be managers' top priorities?

This paper is organized as follows. In section 2, the IoMT implementation challenges were extracted by reviewing the IoMT literature and its application in smart manufacturing. Section 3 describes the steps of research and the ISM technique. Section 4 includes the leveling of the challenges introduced in this research. Finally, section 5 presents the results of the research.

2. Literature and research background

2.1. Internet of things (IoT) and internet of manufacturing things (IoMT)

Chinese Premier Li Keqiang has developed the Internet Plus initiative to accelerate China's slowing economy. This initiative aims to link the Internet and related information technology to current industries to increase productivity and economic growth. Cloud computing, mobile Internet, big data utilization, and the Internet of Things are the pillars of Internet Plus (Hristov, 2017). The Internet of Things was first introduced by Kevin Ashton in 1999 through the Auto-ID Center at MIT. For Ashton, "Internet of Things" means all objects and people equipped with computers, sensors, and the Internet that can be managed. He also introduced Radio-Frequency Identification (RFID) as a prerequisite (Dhumale, et al., 2017). The Internet of Things has features such as connectivity to remote data collection, analysis, and management capabilities that minimize human intervention in producing, transmitting, and using data (Rose et al., 2015).

There are two different aspects to the Internet of Things (See Figure (1)): Information Technology (IT) and Operational Technology (OT) (Khan et al., 2020) .. IT is the “objects” such as servers, databases, and applications. Networks run these objects while IT controls them. IT ensures that the connections between data in a company are safe and reliable. OT is mainly concerned with industrial interactions. This aspect consists of sensors, systems connected to machines, and other types of equipment that control the performance of physical systems. Before IoT, the two concepts of IT and OT were two different poles that worked separately and did not need to interact with each other. However, IoT is here to combine these two concepts as they are based on a world of interrelated objects (Khan et al., 2020).

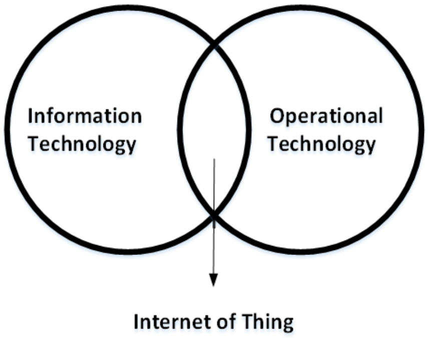


Figure 37. Venn diagram of IoT (Khan et al. 2020)

According to research conducted in this area, several researchers have proposed some definitions for IoT (Table 1), although there is an overlap in these definitions.

Table 8. Definition of IoT

References	Definitions
(Satyavolu et al., 2015)	The Internet of Things includes objects or 'things' with sensors embedded to enable them to communicate their state with other objects and automated systems in the environment.
(Dorsemaine et al., 2015).	IoT "connects a group of interconnected infrastructures and objects and allows their management to extract and analyze data. In IoT, connected objects are sensors that create a specific function and communicate with other equipment".
(Rose et al., 2015)	IoT refers to extending network connectivity and the capability to compute objects, devices, and sensors that are generally not considered computers. These smart objects require minimal human intervention in producing, exchanging, and consuming data. They often include features that can be used to connect connectivity to remote data collection, analysis, and management capabilities.

The objects mentioned in the above definitions represent a node in a virtual network that continuously transmits a large volume of data about itself and other network components (Satyavolu et al., 2015). Things that are deployed in IoT are (i) RFID tags for unique identification, (ii) sensors for detecting physical changes in the environment, and (iii) actuators for transmitting information to the environment (Lanotte and Merro, 2018).

In IoT, objects are generally objects of physical things or virtual things that can be identified and integrated into communication networks. Physical objects exist in the physical world and can be sensed and/or acted upon and/or connected. The sensors of surrounding environments, industrial robots, goods, and electrical equipment are examples of physical objects. Virtual objects exist in the virtual world and can be stored, processed, and accessed. Examples of virtual objects include multimedia content, application software, and service representations of physical things (Lee et al., 2013).

The endpoint of communication in IoT can be humans or objects (devices/machines). Consequently, two categories of communication are considered for IoT (Lee et al., 2013). Human-to-Object (Thing) Communication: Humans communicate with a device to obtain specific information, which includes remote access to objects by humans. Object-to-Object (Thing-to-Thing) Communication: An Object delivers information to another object that may or may not be human.

Before industrialization, most of the work had to be done by the workforce. After the first industrial revolution, machines and human resources started a corroboration by which the manufacturing time was reduced, the quality of the products was increased, and the general productivity was ameliorated. Even now, in the era of the Fourth Industrial Revolution, Technologies like IoT are used to improve productivity, reliability, and accessibility of financial resources to open new doors to how products are made and introduced to the market. Internet of Manufacturing Technology (IoMT) is the application of IoT in Manufacturing. IoT systems are introduced in the previous section. Before defining IoMT, it is better to define Manufacturing Things. Manufacturing Things are all the essential instruments and physical equipment a factory needs to turn raw material into the finished product. Workforce, machines, work-in-progress items, and many other company objects are considered manufacturing things (Zhang et al., 2014). IoMT is an optimized system for managing and driving manufacturing data that optimally controls manufacturing processes, from placing orders to manufacturing and selling the finished product(Zhang et al., 2014). In another sense, IoMT is all the manufacturing steps, processes, and generally the whole manufacturing cycle in a factory. IoMT is an open network system that combines advanced manufacturing, IoT, information, and modern management (Li et al., 2018). IoM has two parts: software and hardware. Hardware is all Auto-ID systems that hold manufacturing data, while software is several application services responsible for backing up the decision-making process (Zhang et al., 2014).

2.2. The application of the internet of things in smart manufacturing

The application of IoT in various fields is increasing rapidly. The Internet of Things can be used in various areas, including smart manufacturing, smart grid, smart healthcare, smart home, and smart city.

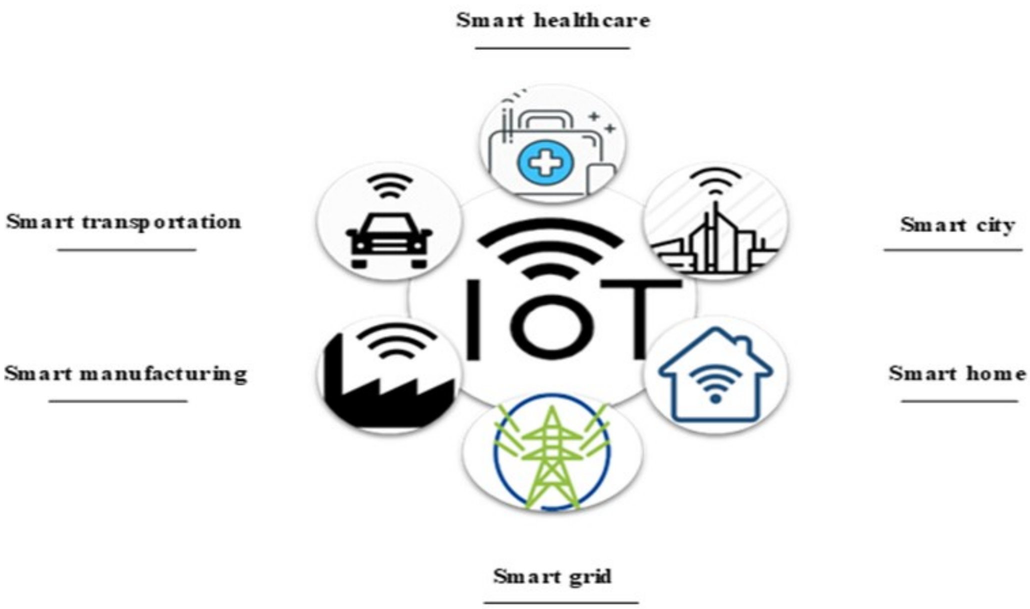


Figure 38. IoT application

As shown in Figure (2), one of the Internet of Things applications is smart manufacturing. Smart manufacturing aims to improve final product productivity, efficiency, reliability, and control(Kouicem et al., 2018). Smart manufacturing includes new technologies such as machine-to-machine (M2M) communication, wireless sensor networks (WSNs), automation technologies, big data, and the Internet of Things.

The IoT approach is an ideal solution for automating and controlling the manufacturing process and plays an important role in creating a communication infrastructure for information acquisition and sharing. Real-time data of actuators is not limited and resilient to changes, but RFID and WSN are effective tools in supporting the distribution and decentralization of production resources. The dynamic IoT architecture facilitates information integration by combining the host company and other virtual companies to conduct projects throughout the company. Dynamic relationships are created for specific projects. After the completion of the project, this combination can be changed, and the company is ready to do another project. To conduct manufacturing projects, some human-to-human, human-to-object, and object-to-object interactions take place. With the development of the Internet of Things, these interactions can be integrated. This way, partners can focus on multiple decisions requiring integrated and compact information and high computing power rather than worrying about interactions. Manufacturing companies use multiple computer resources such as servers, databases, and decision units. It leads to waste investment, failure in utilizing production resources, low productivity, and improper information exchange among servers. Cloud computing provides a vital solution to these problems. All data is stored on public or private cloud servers, and complex decisions can be supported using cloud computing (Bi et al., 2014). According to the stated cases above, IoT affects all parts of the production chain (communications, information, decision-making). Therefore, examining the challenges of implementing IoT in manufacturing companies can identify critical points and take necessary action measures.

2.3. Challenges of using IoMT in manufacturing

The development and application of IoMT affect various aspects of human life (such as security, healthcare, productivity, energy, and environmental sustainability). A literature review revealed that IoMT challenges were introduced in various fields, such as healthcare and treatment (Farahani et al., 2018) and blockchain (Kumar and Mallick, 2018; Makhdoom et al., 2019). Many studies have examined the conceptual study of this field (Afzal et al., 2019; Chen et al., 2014; Cooper and James, 2009; Farahani et al., 2018; Werlinger et al., 2009; Khan and Salah, 2018; Kumar and Mallick, 2018; Makhdoom et al., 2019; Reyna et al., 2018). Some studies have identified security challenges (Khan and Salah, 2018; Kumar and Mallick, 2018) and data management challenges (Cooper and James, 2009). The gap seen in the literature is the study of the challenges of the Internet of Things in the manufacturing industry. IoMT implementation and deployment in the manufacturing industry requires infrastructure associated with organizational, hardware, and software issues and challenges. By reviewing the literature on the application of IoMT in smart manufacturing, the challenges of Table (2) were identified.

Table 9. Challenges of using IoMT

Challenges		Definitions	References
Data management and integrity	C_1	Applying the IoMT approach creates a large amount of homogeneous and heterogeneous data; data analysis in different periods can produce practical results for the organization. Most data centers cannot process, integrate, and store this data on individual or organizational dimensions.	(Cooper and James, 2009; Farahani et al., 2018; Mohammadzadeh et al., 2018; Lee and Lee, 2015; Lim et al., 2018; Nasrollahi and Ramezani, 2020)
Sensitive data access control	C_2	With the deployment of the IoMT approach and the wide variety of data types, the level of user access to important and sensitive data is critical for the organization, and the lack of a coherent strategy for how users access disrupts the security of the information system.	(Werlinger et al. 2009; Mazhar et al., 2023)
Storage capacity and scalability	C_3	In IoMT, data and equipment integration is critical; therefore, all processes and devices need to be considered at maximum capacity so that in case of their development, there will be no disruption to their speed and utilization for stakeholders. It is possible by using tools such as smartphones.	(Farahani et al., 2018; Reyna et al., 2018)
User privacy	C_4	IoMT integrates and manages many issues related to individuals, including health and welfare services. All the information about people in one software package can affect user privacy.	(Afzal et al., 2019; Chen et al., 2014; Khan and Salah, 2018; Lee and Lee, 2015; Lim et al., 2018; Reyna et al., 2018)
Lack of security and trust management	C_5	The available hardware and software on the IoMT platform are extremely vulnerable due to a lack of encryption, insecure web interface, and other security issues, and consequently, hackers can access all the information on the platform, which creates insecurity for organizations and distrust for individuals.	(Afzal et al., 2019; Farahani et al., 2018; Mohammadzadeh et al., 2018; Khan and Salah, 2018; Khan and Turowski, 2016; Kumar and Mallick, 2018; Lee and Lee, 2015; Makhdoom et al., 2019; Nasrollahi and Ramezani, 2020; Reyna et al., 2018); Kaur et al., 2023)
Intra-organizational resistance (Labor)	C_6	The predominance of traditional approaches to processes, the feeling of job insecurity, and the organization's lack of acceptance of technology-based approaches cause their high resistance and challenge the dominance of the IoMT platform over the organization.	(Werlinger et al., 2009)
Integration of information system of external partners	C_7	Business cooperation of organizations together to achieve sustainable competitive advantage requires integration between their information systems. Business partners have information systems with different processes since data integration from different information systems with different programming languages requires an integrated data system.	(Cooper and James, 2009; Werlinger et al., 2009); Mazhar et al., 2023)

DOI: 10.22067/JSTINP.2023.85639.1080

Cost	C_8	Implementing IoMT is a costly project that companies are reluctant to invest in due to the lack of transparency in the results and cost-benefit analysis.	(Afzal et al., 2019; Werlinger et al., 2009; Kumar and Mallick, 2018)
Technical and empirical knowledge of management and staff	C_9	Since IoMT is an emerging and novel phenomenon, management and staff may not have mastered the relevant technical knowledge, leading to disruption and sometimes resistance. Therefore, technical training of individuals is vital for the implementation of IoMT.	(Werlinger et al., 2009; Mohammadzadeh et al., 2018)
Top management Support	C_{10}	For organizations to participate in the implementation of IoMT, there is a need for support and understanding of IoMT and its applications by senior management to make the necessary changes to implement it.	(Werlinger et al., 2009; Luthra and Mangla, 2018)
Standardization	C_{11}	The IoMT is a network with many heterogeneous devices that meet different standards and must interact with each other. Standardization can improve interoperability and allow products and services to compete at higher levels. However, the rapid growth of the Internet of Things has made it difficult to establish standards, including interoperability, accessibility, and security.	(Choudhary et al., 2020; Mohammadzadeh et al., 2018; Kumar and Mallick, 2018; Kumar et al., 2021; Luthra and Mangla, 2018)
Legal Issue	C_{12}	In IoMT, there are no rules on how to use its data or fight against crimes that occur while using the data; therefore, the security of data and information and the investigation of crimes from a legal point of view must be considered.	(Kumar and Mallick, 2018; Luthra and Mangla, 2018; Reyna et al., 2018)
The rapid growth of device technology	C_{13}	With the rapid growth of technology, devices and equipment in the IoMT network are becoming more advanced and powerful daily. Therefore, it is necessary that these devices have high flexibility in development or updating so that their replacement and relocation do not impose much cost and time on the organization.	(Luthra and Mangla, 2018; Mazhar et al., 2023)

DOI: 10.22067/JSTINP.2023.85639.1080

3. Research methodology

The present research is applied in terms of purpose and a descriptive survey regarding data collection. This study used existing literature studies to identify the challenges of IoMT implementation in smart manufacturing. On the other hand, field studies were conducted to complete the questionnaire. Experts of the present study are manufacturing managers and consultants active in the automotive industry who have work experience in manufacturing and research and applied experience in the field of the Internet of Things. The questionnaires were sent to the experts by e-mail, and 6 questionnaires were completed and returned by the respondents.

In this study, to achieve the relationship between the challenges of IoMT and creating a hierarchical structure, after reviewing the literature in this area, the challenges were identified, and then, through a questionnaire, the opinions of experts were collected. The ISM technique was used to create a hierarchical structure. Finally, MICMAC analysis was conducted to investigate the challenges of driving and dependence on power (See Figure (3)).

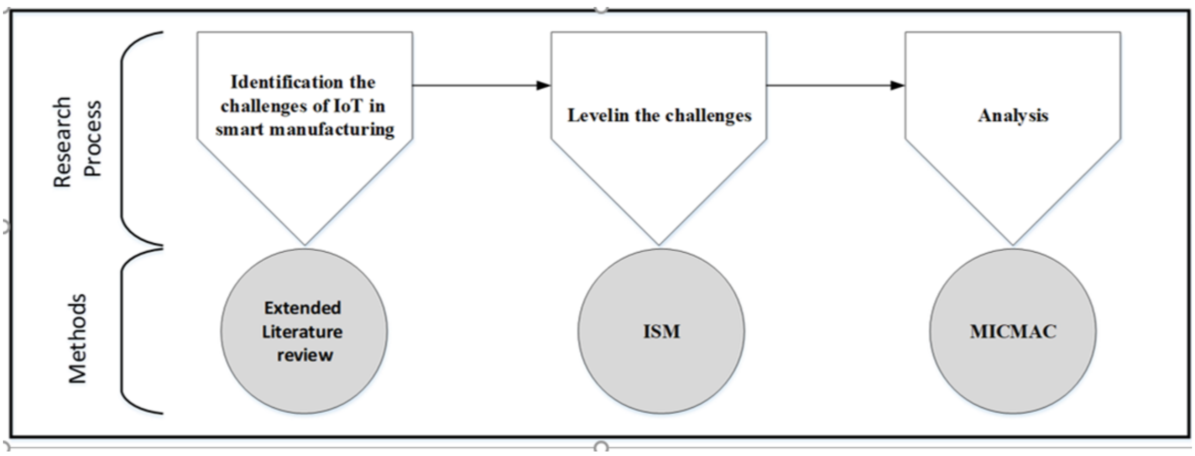


Figure 39. Research framework

3.1. Interpretive structural modeling (ISM)

Interpretive structural modeling is a systematic and structured method introduced by Warfield (1974). ISM is a powerful technique that breaks down a complex system into several subsystems and transforms it into a hierarchical model. This methodology combines three demonstrating languages of words, diagraphs, and discrete mathematics (Kaswan and Rathi, 2019). ISM is used to determine the interaction between factors and the impact of factors (Ali et al., 2022; Yang and Lin, 2020). One of the logics of this method is that the factors that have a greater impact on a system than other factors are more important. This technique helps to establish order in the complex relationships between the elements of the system (Agarwal et al., 2007). It can also prioritize and level the elements of a system, which helps managers better execute the designed model. ISM technique in various fields such as lean Six Sigma enablers (Kaswan and Rathi, 2019), green building project risks (Guan et al. 2020), the study of supply chain sustainability (Chand et al., 2020), effective factors in green innovation performance (Yang and Lin, 2020) has been used.

Six stages must be taken to apply interpretive structural modeling techniques and determine the priorities and internal linkages of the system's constituents. First, the elements/dimensions are determined, and then a structural self-interaction matrix is obtained. The initial reachability matrix is then extracted, and in the next step, the reachability matrix is adapted. Leveling the elements of the reachability matrix is the next step, and finally, the model is drawn.

Step 1. Formation of structural self-interaction matrix

In this step, a pairwise comparison of the research elements is conducted. For this purpose, the scale presented by Bolaños et al. in 2005 is used, as shown in Table (3).

Table 10. The proposed scale for the structural self-interaction matrix formation (Bolaños et al. 2005)

Linguistic variables	**Number**
High influence	3
Meduim influence	2
Very low influence	1
No influence	0

Step 2. Creation of initial reachability matrix

At this point, the structural self-interaction matrix becomes a binary matrix. The reachability matrix is obtained by determining the relationships as zero and one from the matrix obtained from the total opinions of the respondents in two steps:

Sub-Step 1: First, a unit numerical scale (m) is considered, and the self-interaction matrix numbers are compared with it. Bolanos et al. (year?) Defined these relationships as follows:

$$M = \begin{cases} a_{ij} = 1 & if \quad a_{ij} \geq m \\ a_{ij} = 0 & if \quad a_{ij} < m \end{cases}$$

$$m = 2 \times n$$

Where n represents the number of respondents and m represents the scale value.

Sub-Step 2: In this step, the initial reachability matrix is obtained by adding the results of the first step to the unit matrix.

Step 3. Creation of the final reachability matrix

The final reachability matrix is formed by applying transitivity relations among the variables in the next step.

Step 4. Determining relationships and leveling factors

The reachability matrix in Step 3 becomes a matrix with a standard framework by placing elements on its levels. In this step, the reachability matrix is categorized into different levels.

An antecedent set and a reachability set are identified for every variable to establish the variables' priority and level. The reachability set of each variable includes the variables that can be reached through this variable, and the antecedent set of each variable includes the variables through which this variable can be reached. It is conducted using the reachability matrix. After determining each variable reachability and antecedent sets, the intersection set, which includes the shared challenges between the reachability and the antecedent sets, is identified for each variable.

The level of variables is determined after determining reachability, antecedent, and intersection sets. In the first table, the variable with the same reachability set and intersection set occupies the highest level of the table. After determining these variables, they will be removed from the table, and the next table with the rest of the variables will be formed. In the second table, as in the first table, the second-level variable is specified, and this process is continued until the level of all variables is determined.

Step 5. Drawing the initial and final interpretive structural model

A structural model is formed using the final reachability matrix. If there is a relationship between factors i and j, this relationship is indicated by an arrow going from *i* to *j*, and the ISM model diagram is formed. Finally, after eliminating transferability, the diagram becomes a model based on interpretive structural modeling.

Finally, interpretive structural modeling is created by placing factors according to their level in a directional graph. Factors classified in level one are placed in the lowest hierarchy of the interpretive structural modeling model, and higher-level factors are placed in the higher hierarchy of the model.

3.2. MICMAC Analysis

MICMAC has integrated with the ISM method to help analyze the findings. It is an analysis method that classifies factors into four categories according to their driving power and dependence power. Driving power and dependence power are determined using the ISM method. The driving power of a factor is the total number of other factors that are influenced by it, whereas the dependence power of a factor includes the total number of factors that affect it. All factors can be classified into 4 categories (Xu and Zou, 2020):

Group 1. Autonomous factors: These factors have weak driving and dependence power. They need links to the system in which they are located. They cannot affect others or be affected by other factors.

Group 2. Dependent factors: These factors have weak driving and strong dependence power. These factors are deeply influenced by linkage and driving factors and are less likely to affect others.

Group 3. **Linkage factors:** These factors have intense driving and dependence power, and any change in them will significantly cause the reaction of other factors. In addition, system feedback affects these linkage factors.

Group 4. Driving factors: These factors have strong driving but weak dependence power. These factors greatly affect other factors.

4. Result

In the present study, by reviewing the literature in the field of using the Internet of Things in smart manufacturing, the challenges facing this new manufacturing system have been identified in Table (2). Due to the importance of examining the mentioned challenges in deploying smart manufacturing and determining the priority of the challenges to take appropriate measures, their leveling was conducted using ISM.

Based on the defined steps, from the aggregation of experts' opinions, the Structural Self-Interaction Matrix (SSIM) was formed and presented in Table (4).

Table 11. Structural self-interaction matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
C_1	0	1	16	3	2	3	3	16	2	1	2	18	3
C_2	18	0	0	16	3	1	2	3	0	0	1	2	1
C_3	17	17	0	2	1	3	2	17	1	2	1	1	1
C_4	17	2	0	0	17	2	1	1	1	2	2	1	2
C_5	0	1	3	3	0	16	1	1	0	1	1	1	3
C_6	2	3	1	1	16	0	2	0	18	16	0	15	1
C_7	3	2	3	0	2	1	0	18	1	3	13	18	2
C_8	14	1	13	0	0	0	1	0	0	18	0	0	1
C_9	0	1	0	2	1	18	3	0	0	17	2	2	1
C_{10}	2	0	3	1	1	17	1	1	1	0	2	1	1
C_{11}	18	2	1	1	2	0	18	1	1	0	0	2	14
C_{12}	1	2	1	0	17	1	3	3	0	18	3	0	0
C_{13}	3	17	17	2	2	16	1	2	17	0	16	1	0

According to the structural self-interaction matrix and the scale number (m = 12), the initial reachability matrix was calculated (Table (5)).

Table 12. Initial reachability matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	1	1	1	0	1	0	0	1	0	1	0	1	0
C2	1	1	1	1	1	0	0	1	0	0	0	1	0
C3	1	1	1	1	0	0	0	1	0	1	0	1	0
C4	1	0	1	1	1	1	0	1	0	0	0	1	0
C5	0	0	0	0	1	1	0	0	1	1	0	1	0
C6	0	0	0	0	1	1	0	0	1	1	0	1	0
C7	1	0	1	0	1	0	1	1	0	1	1	1	1
C8	1	1	1	0	0	1	0	1	0	1	0	1	0
C9	0	0	0	0	1	1	0	0	1	1	0	1	0
C10	0	0	0	0	1	1	0	0	1	1	0	1	0
C11	1	1	1	0	0	1	1	1	1	0	1	1	1
C12	0	0	0	0	1	1	0	0	0	1	0	1	0
C13	1	1	1	1	1	1	1	1	1	1	1	1	1

The final reachability matrix was formed by applying transitivity relations among the challenges in the next step. The final reachability matrix is demonstrated in Table (6).

Table 13. The final reachability matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	Driving Power
C1	1	1	1	1	1	1	0	1	1	1	0	1	0	10
C2	1	1	1	1	1	1	0	1	1	1	0	1	0	10
C3	1	1	1	1	1	1	0	1	1	1	0	1	0	10
C4	1	1	1	1	1	1	0	1	1	1	0	1	0	10
C5	0	0	0	0	1	1	0	0	1	1	0	1	0	5
C6	0	0	0	0	1	1	0	0	1	1	0	1	0	5
C7	1	1	1	1	1	1	1	1	1	1	1	1	1	13
C8	1	1	1	1	1	1	0	1	1	1	0	1	0	10
C9	0	0	0	0	1	1	0	0	1	1	0	1	0	5
C10	0	0	0	0	1	1	0	0	1	1	0	1	0	5
C11	1	1	1	1	1	1	1	1	1	1	1	1	1	13
C12	0	0	0	0	1	1	0	0	1	1	0	1	0	5
C13	1	1	1	1	1	1	1	1	1	1	1	1	1	13
Dependence Power	8	8	8	8	13	13	3	8	13	13	3	13	3	

As mentioned, each level is identified when the intersection of the reachability set and the antecedent set equals the reachability set. Then, the leveled factors are removed, the intersections are re-examined, and the next-level factors are determined. This algorithm continues until the leveling is conducted completely. Table (7) provides the reachability set, antecedent set, and intersection set and the level related to each challenge.

Table 14. Level partitioning of drivers

Challenge	Reachability set	Antecedent set	Intersection set	Level
C_1	2,3,4,5,6,8,9,10,12	2,3,4,7,8,11,13	2,3,4,8	2
C_2	1,3,4,5,6,8,9,10,12	1,3,4,7,8,11,13	1,3,4,8	2
C_3	2,4,5,6,8,9,10,12	1,2,4,7,8,11,13	2,4,8	2
C_4	1,2, 5,6,8,9,10,12	1,2,3,7,8,11,13	1,2,8	2
C_5	6,9,10,12	1,2,3,4,6,7,8,9,10,11,12,13	6,9,10,11	1
C_6	5,9,10,12	1,2,3,4,5,7,8,9,10,11,12,13	6,9,10,11	1
C_7	1,2,3,4,5,6,8,9,10,11,12,13	11,13	11,13	3
C_8	1,2,3,4,5,6,9,10,12	1,2,3,4,7,11,13	1,2,3,4,	2
C_9	5,6,10,12	1,2,3,4,5,6,7,8,10,11,12,13	5,6,9,10,12	1
C_{10}	5,6,9,12	1,2,3,4,5,6,7,8,9, 11,12,13	5,6,9,12	1
C_{11}	1,2,3,4,5,6,7,8,9,10 ,12,13	7,13	7,13	3
C_{12}	5,6,9,10	1,2,3,4,5,6,7,8,9,10,11,13	5,6,9,10,12	2
C_{13}	1,2,3,4,5,6,7,8,9,10,11,12	7,11	7,11	3

According to the leveling performed in the previous step, a graph was formed as shown in figure (4).

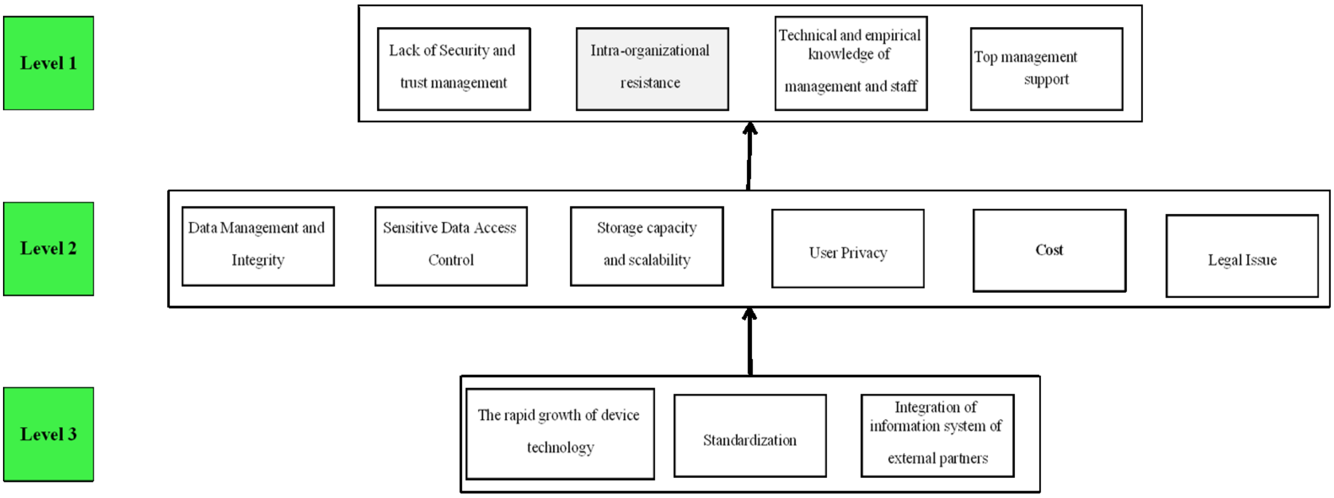


Figure 40. ISM model for challenges of internet of thing in smart manufacturing

Conducting MICMAC analysis requires calculating each factor's driving power and dependence power, which should be obtained from each row's summation and each column's summation in the final reachability matrix. After calculating these values given in Table (7), the coordinate figure is illustrated in Figure (5), where the position of the factors is specified.

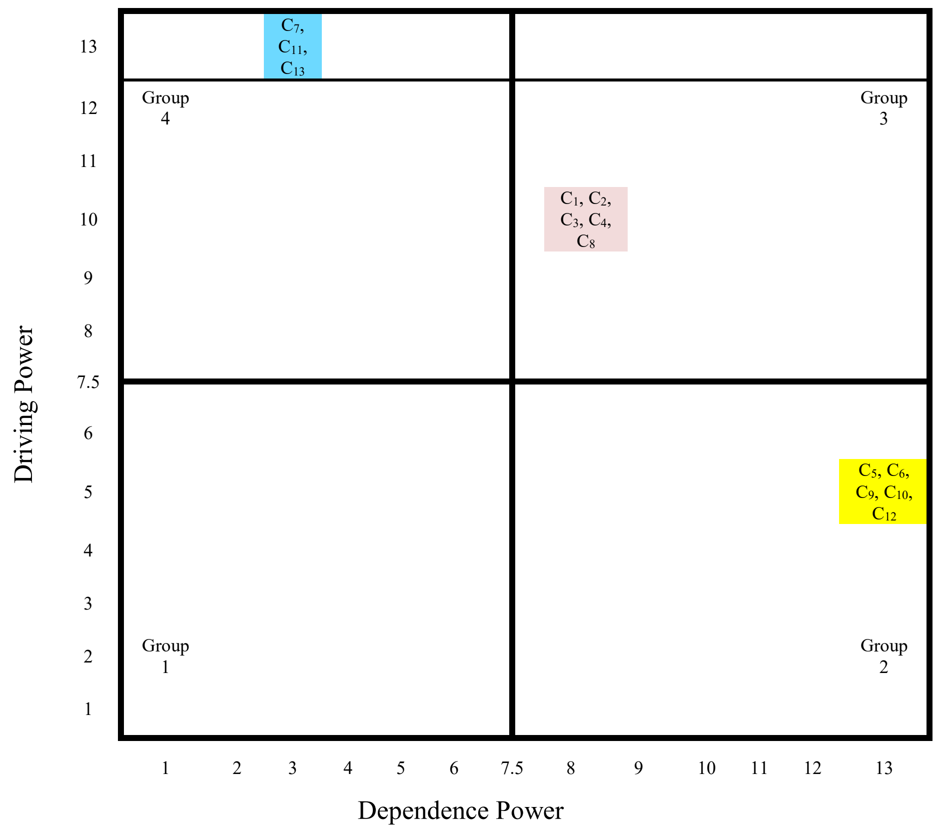


Figure 41. MICMAC analysis

According to the MICMAC analysis, none of the identified challenges are placed in the group of autonomous factors (group 1), which means that all the challenges introduced are related to the system and affect it. Challenges categorized in Group 2 include lack of security and trust management, Intra-organizational resistance, Technical and empirical knowledge of management and staff, top management support, and legal issues, which have the potential to be highly influenced (are being influenced). In group 3, there are challenges with data management and integrity, lack of sensitive data access control, storage capacity and scalability, control of access to sensitive data, storage capacity and scalability, privacy, and cost, which highly interact with the system. These challenges are highly influential and highly influenced; consequently, much more attention should be focused on them. Integration of information systems of external partners, standardization, and rapid growth of technology are challenges that have strong driving power located in the group of linkage factors (group 4).

5. Discussion

Business relationships with other organizations are recognized as a challenge when they do not have similar information and security systems. In addition, this challenge can occur when multiple organizations with different security and information systems merge (Werlinger et al., 2009). Given this challenge, developing IoMT in smart manufacturing requires a common platform for global standardization. Common standards worldwide can enable relationships between organizations and other organizations and the integration of organizations. Addressing these two challenges can help remove the next-level challenges, including data management and integration. Another challenge at the third level is that technology is evolving rapidly, which is too costly. Therefore, this issue will lead to a cost challenge, which will be addressed later.

The data collected in the system are different, which makes them difficult to manage and integrate. On the other hand, due to the sharing of sensitive data related to inventories, bottlenecks, and various incidents, implementing IoMT requires updated approaches in the ethical, technical, and legal fields. Considering these issues is essential in preventing cyber criminalities because companies are responsible for not only their data but also the data security of supply chain partners (Luthra and Mangla, 2018). Another challenge at the second level, privacy, will be addressed mainly by considering legal issues. Another critical issue in implementing IoMT is that all new systems cost money due to the transformation of all aspects of existing systems. Therefore, investing in new projects requires the acceptance and support given by top management, and this is a challenge that will be addressed at level one.

In implementing and deploying any new system, top management support is one of the primary key factors, and not addressing this organizational factor will create a major challenge in its acceptance and implementation (Luthra and Mangla, 2018) because other factors required to implement a new project such as capital, human resource, and equipment are under the control of senior management in the organization. Since people can share their expertise and experience with others, the technical and empirical knowledge of management and staff will help them win support for accepting the deployment of a smart system. However, this will reinforce the implementation process (Werlinger et al., 2009). Since human resources play an essential role in implementing and advancing a new project in the organization, addressing this factor in using IoMT is vital as it can prevent other challenges. Perhaps the lack of a culture of using new information systems can be considered one of the main reasons for intra-organizational resistance within the organization. Using the same user account is unacceptable for employees (Werlinger et al., 2009) and will lead to mistrust, another level-one challenge. The resulting insecurity and mistrust prevent employees from cooperating in implementing IoMT in production systems (Afzal et al., 2019).

 DOI: 10.22067/JSTINP.2023.85639.1080

6. Conclusion

In recent years, the Internet of Things in various aspects of business has attracted the attention of many researchers and industrialists. One of the applications of the Internet of Things is in smart manufacturing. Implementing IoT in manufacturing, like all new and emerging technologies, will be associated with challenges that are critical to be identified. Furthermore, knowing which challenges come first and have the most significantimpact on implementing the smart manufacturing system is important. In other words, due to companies' limited resources and capabilities, it is impossible to overcome all these challenges simultaneously.

Therefore, in this study, by reviewing the literature, the challenges of IoMT were identified, and the ISM technique was used to determine their importance and level in the automotive industry. According to the opinions of experts in the automotive industry and ISM, the challenges were classified into three levels. Afterward, using MICMAC analysis, it was found that among the challenges introduced, the integration of information systems of external partners, standardization, and the rapid growth of technology has strong driving power, and on the other hand, lack of security and trust management and top management support are highly influenced compared with other challenges.

After identifying and prioritizing IoMT implementation challenges, the next step is to decide whether to remove them. Doing this step requires preparing and analyzing two fields. The former is determining the relevant component of technology with each challenge. The latter is identifying the related stakeholders for each challenge. These points help managers choose the most effective actions to overcome these challenges. Therefore, it can be suggested to researchers to analyze them.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Afzal, B., Umair, M., Shah, G.A. and Ahmed, E., 2019. Enabling IoT platforms for social IoT applications: Vision, feature mapping, and challenges. *Future Generation Computer Systems*, *92*, pp.718-731. https://doi.org/10.1016/j.future.2017.12.002.

Agarwal, A., Shankar, R. and Tiwari, M.K., 2007. Modeling agility of supply chain. *Industrial marketing management*, *36*(4), pp.443-457. https://doi.org/10.1016/j.indmarman.2005.12.004.

Ali, S., Baseer, S., Abbasi, I.A., Alouffi, B., Alosaimi, W. and Huang, J., 2022. Analyzing the interactions among factors affecting cloud adoption for software testing: a two-stage ISM-ANN approach. *Soft Computing*, *26*(16), pp.8047-8075. https://doi.org/10.1007/s00500-022-07062-3.

Bi, Z., Da Xu, L. and Wang, C., 2014. Internet of things for enterprise systems of modern manufacturing. *IEEE Transactions on industrial informatics*, *10*(2), pp.1537-1546. https://doi.org/10.1109/TII.2014.2300338.

Bolaños, R., Fontela, E., Nenclares, A. and Pastor, P., 2005. Using interpretive structural modelling in strategic decision-making groups. *Management Decision*, *43*(6), pp.877-895. https://doi.org/10.1108/00251740510603619.

Chand, P., Thakkar, J.J. and Ghosh, K.K., 2020. Analysis of supply chain sustainability with supply chain complexity, inter-relationship study using delphi and interpretive structural modeling for Indian mining and earthmoving machinery industry. *Resources Policy*, *68*, p.101726. https://doi.org/10.1016/j.resourpol.2020.101726.

Chen, S., Xu, H., Liu, D., Hu, B. and Wang, H., 2014. A vision of IoT: Applications, challenges, and opportunities with china perspective. *IEEE Internet of Things journal*, *1*(4), pp.349-359. https://doi.org/10.1109/JIOT.2014.2337336.

Choudhary, T., Virmani, C. and Juneja, D., 2020. Convergence of Blockchain and IoT: An Edge Over Technologies. *Toward Social Internet of Things (SIoT): Enabling Technologies, Architectures and Applications: Emerging Technologies for Connected and Smart Social Objects*, pp.299-316. https://doi.org/10.1007/978-3-030-24513-9_17.

Cooper, J. and James, A., 2009. Challenges for database management in the internet of things. *IETE Technical Review*, *26*(5), pp.320-329. https://doi.org/10.4103/0256-4602.55275.

Dorsemaine, B., Gaulier, J.P., Wary, J.P., Kheir, N. and Urien, P., 2015, September. Internet of things: a definition & taxonomy. In *2015 9th International Conference on Next Generation Mobile Applications, Services and Technologies* (pp. 72-77). IEEE. 10.1109/NGMAST.2015.71.

Dhumale, R.B., Thombare, N.D. and Bangare, P.M., 2017. Supply Chain Management using Internet of Things.

Ebrahimi, M., Baboli, A. and Rother, E., 2019. The evolution of world class manufacturing toward Industry 4.0: A case study in the automotive industry. *Ifac-Papersonline*, *52*(10), pp.188-194. https://doi.org/10.1016/j.ifacol.2019.10.021.

Edgar, T.F. and Pistikopoulos, E.N., 2018. Smart manufacturing and energy systems. *Computers & Chemical Engineering*, *114*, pp.130-144. https://doi.org/10.1016/j.compchemeng.2017.10.027.

Farahani, B., Firouzi, F., Chang, V., Badaroglu, M., Constant, N. and Mankodiya, K., 2018. Towards fog-driven IoT eHealth: Promises and challenges of IoT in medicine and healthcare. *Future generation computer systems*, *78*, pp.659-676. https://doi.org/10.1016/j.future.2017.04.036.

Guan, L., Abbasi, A. and Ryan, M.J., 2020. Analyzing green building project risk interdependencies using Interpretive Structural Modeling. *Journal of cleaner production*, *256*, p.120372. https://doi.org/10.1016/j.jclepro.2020.120372.

Hristov, K., 2017. Internet plus policy: A study on how China can achieve economic growth through the internet of things. *Journal of Science and Technology Policy Management*, *8*(3), pp.375-386. https://doi.org/10.1108/JSTPM-03-2017-0007.

Kaswan, M.S. and Rathi, R., 2019. Analysis and modeling the enablers of green lean six sigma implementation using interpretive structural modeling. *Journal of cleaner production*, *231*, pp.1182-1191. https://doi.org/10.1016/j.jclepro.2019.05.253.

Kaur, B., Dadkhah, S., Shoeleh, F., Neto, E.C.P., Xiong, P., Iqbal, S., Lamontagne, P., Ray, S. and Ghorbani, A.A., 2023. Internet of things (IoT) security dataset evolution: Challenges and future directions. *Internet of Things*, p.100780. https://doi.org/10.1016/j.iot.2023.100780.

Khan, A. and Turowski, K., 2016. A survey of current challenges in manufacturing industry and preparation for industry 4.0. In *Proceedings of the First International Scientific Conference "Intelligent Information Technologies for Industry"(IITI'16) Volume 1* (pp. 15-26). Springer International Publishing. https://doi.org/10.1007/978-3-319-33609-1_2.

Khan, M.A. and Salah, K., 2018. IoT security: Review, blockchain solutions, and open challenges. *Future generation computer systems*, *82*, pp.395-411. https://doi.org/10.1016/j.future.2017.11.022.

Khan, S., Khan, M.I. and Haleem, A., 2020. Prioritisation of challenges towards development of smart manufacturing using bwm method. *Internet of Things (IoT) Concepts and Applications*, pp.409-426. https://doi.org/10.1007/978-3-030-37468-6_22.

Kouicem, D.E., Bouabdallah, A. and Lakhlef, H., 2018. Internet of things security: A top-down survey. *Computer Networks*, *141*, pp.199-221. https://doi.org/10.1016/j.comnet.2018.03.012.

Krasniqi, X. and Hajrizi, E., 2016. Use of IoT technology to drive the automotive industry from connected to full autonomous vehicles. *IFAC-PapersOnLine*, *49*(29), pp.269-274. https://doi.org/10.1016/j.ifacol.2016.11.078.

Kumar, N.M. and Mallick, P.K., 2018. Blockchain technology for security issues and challenges in IoT. *Procedia computer science*, *132*, pp.1815-1823. https://doi.org/10.1016/j.procs.2018.05.140.

Kumar, V., Vrat, P. and Shankar, R., 2021. Prioritization of strategies to overcome the barriers in Industry 4.0: a hybrid MCDM approach. *Opsearch*, pp.1-40. https://doi.org/10.1007/s12597-020-00505-1.

Lanotte, R. and Merro, M., 2018. A semantic theory of the Internet of Things. *Information and Computation*, *259*, pp.72-101. https://doi.org/10.1016/j.ic.2018.01.001.

Lee, G.M., Crespi, N., Choi, J.K. and Boussard, M., 2013. Internet of things. *Evolution of Telecommunication Services: The Convergence of Telecom and Internet: Technologies and Ecosystems*, pp.257-282. https://doi.org/10.1007/978-3-642-41569-2_13.

Lee, I. and Lee, K., 2015. The Internet of Things (IoT): Applications, investments, and challenges for enterprises. *Business horizons*, *58*(4), pp.431-440. https://doi.org/10.1016/j.bushor.2015.03.008.

Li, S., Chen, W., Hu, J. and Hu, J., 2018. ASPIE: a framework for active sensing and processing of complex events in the internet of manufacturing things. *Sustainability*, *10*(3), p.692. https://doi.org/10.3390/su10030692.

Lim, C., Kim, K.J. and Maglio, P.P., 2018. Smart cities with big data: Reference models, challenges, and considerations. *Cities*, *82*, pp.86-99. https://doi.org/10.1016/j.cities.2018.04.011.

Liu, J., Xiao, Y., Li, S., Liang, W. and Chen, C.P., 2012. Cyber security and privacy issues in smart grids. *IEEE Communications surveys & tutorials*, *14*(4), pp.981-997. https://doi.org/10.1109/SURV.2011.122111.00145.

Luthra, S. and Mangla, S.K., 2018. Evaluating challenges to Industry 4.0 initiatives for supply chain sustainability in emerging economies. *Process Safety and Environmental Protection*, *117*, pp.168-179. https://doi.org/10.1016/j.psep.2018.04.018.

Makhdoom, I., Abolhasan, M., Abbas, H. and Ni, W., 2019. Blockchain's adoption in IoT: The challenges, and a way forward. *Journal of Network and Computer Applications*, *125*, pp.251-279. https://doi.org/10.1016/j.jnca.2018.10.019.

Mazhar, T., Irfan, H.M., Haq, I., Ullah, I., Ashraf, M., Shloul, T.A., Ghadi, Y.Y., Imran and Elkamchouchi, D.H., 2023. Analysis of Challenges and Solutions of IoT in Smart Grids Using AI and Machine Learning Techniques: A Review. *Electronics*, *12*(1), p.242. https://doi.org/10.3390/electronics12010242.

Mohammadzadeh, A.K., Ghafoori, S., Mohammadian, A., Mohammadkazemi, R., Mahbanooei, B. and Ghasemi, R., 2018. A Fuzzy Analytic Network Process (FANP) approach for prioritizing internet of things challenges in Iran. *Technology in Society*, *53*, pp.124-134. https://doi.org/10.1016/j.techsoc.2018.01.007.

Nasrollahi, M. and Ramezani, J., 2020. A model to evaluate the organizational readiness for big data adoption. *International Journal of Computers, Communications and Control*, *15*(3). https://doi.org/10.15837/IJCCC.2020.3.3874.

Reyna, A., Martín, C., Chen, J., Soler, E. and Díaz, M., 2018. On blockchain and its integration with IoT. Challenges and opportunities. *Future generation computer systems*, *88*, pp.173-190. https://doi.org/10.1016/j.future.2018.05.046.

Rose, K.A., Sable, S., DeAngelis, D.L., Yurek, S., Trexler, J.C., Graf, W. and Reed, D.J., 2015. Proposed best modeling practices for assessing the effects of ecosystem restoration on fish. *Ecological Modelling*, *300*, pp.12-29. https://doi.org/10.1016/j.ecolmodel.2014.12.020.

Satyavolu, P., Setlur, B., Thomas, P. and Iyer, G., 2015. Designing for manufacturing's 'internet of things'. *Technology solutions*, pp.4-14.

Werlinger, R., Hawkey, K. and Beznosov, K., 2009. An integrated view of human, organizational, and technological challenges of IT security management. *Information Management & Computer Security*, *17*(1), pp.4-19. https://doi.org/10.1108/09685220910944722.

Xu, X. and Zou, P.X., 2020. Analysis of factors and their hierarchical relationships influencing building energy performance using interpretive structural modelling (ISM) approach. *Journal of Cleaner Production*, *272*, p.122650. https://doi.org/10.1016/j.jclepro.2020.122650.

Xu, Y., de Souza, R.W., Medeiros, E.P., Jain, N., Zhang, L., Passos, L.A. and de Albuquerque, V.H.C., 2023. Intelligent IoT security monitoring based on fuzzy optimum-path forest classifier. *Soft Computing*, *27*(7), pp.4279-4288. https://doi.org/10.1007/s00500-022-07350-y.

Yang, Z. and Lin, Y., 2020. The effects of supply chain collaboration on green innovation performance: An interpretive structural modeling analysis. *Sustainable Production and Consumption*, *23*, pp.1-10. https://doi.org/10.1016/j.spc.2020.03.010.

Zhang, Y., Wang, W., Liu, S. and Xie, G., 2014. Real-time shop-floor production performance analysis method for the internet of manufacturing things. *Advances in Mechanical Engineering*, *6*, p.270749.https://doi.org/10.1155/2014/270749.

Journal of Systems Thinking in Practice
JSTINP, *QUARTERLY*
Homepage: jstinp.um.ac.ir
Online ISSN: 2821-1669, Print ISSN: 2980-9460
Research Article
DOI: 10.22067/JSTINP.2023.85842.1084
JSTINP 2023; Vol. 2, No. 4

Ferdowsi University of Mashhad

Evaluating the Implementation Cost of Blockchain in Organizations through System Dynamics

Azam Modares[a], Nasser Motahari Farimani[a]*, Kimia Abdari[a]

[a] *Department of Management, Faculty of Economics and Administrative, Ferdowsi University of Mashhad, Mashhad, Iran.*

How to cite this article

Modares, A., Motahari Farimani, N., Abdari, K.,2023. Evaluating Implementation Cost of Blockchain in Organizations through System Dynamics, *Journal of Systems Thinking in Practice*, 2(4), pp.78-104. doi: 10.22067/jstinp.2023.85842.1084.

URL: https://jstinp.um.ac.ir/article_44718.html.

ABSTRACT

One of the main obstacles to the adoption of blockchain is the cost of its adoption. The application of this technology in an organization requires the costs of development, design, maintenance, hardware, software, and energy consumption according to its adoption rate. This study uses system dynamics (SD) and machine learning (ML) methods to predict the final cost of blockchain implementation. Compared to mathematical programming, simulation techniques for estimating costs are scarce. However, SD modeling is suitable to account for the complexity and dynamic of systems and support long-term, strategic decision-making. To better understand the system behavior, it is necessary to formulate the relationships between the variables and simulate the values of the variables over time. The relationship between these variables is analyzed using the qualitative SD modeling method with stakeholders through questionnaires and 15 interviews. After identifying the variables, their effect on each other and the implementation cost are investigated. Since the charts obtained from the SD give us the behavior of state and flow variables for time, linear regression applying cross-validation, as one of the ML methods, is used to get a graph showing the system's state as a rate function. Thus, this research provides a reasonable basis for estimating the cost function of blockchain implementation. The validity of the suggested method's results is investigated through sensitivity analysis. The results demonstrate the effectiveness of the proposed model. Simulation results indicate that implementing scenarios such as changes in the average block creation time significantly enhances transaction cost, hardware cost, and software cost, leading to increased implementation cost of blockchain for organizations. The results of this research can significantly help decision-makers develop and apply blockchain technology in organizations.

Keywords

System dynamics, Blockchain, Cost management, Transaction.

Article history

Received: 2023-12-12
Revised: 2023-12-20
Accepted: 2023-12-28
Published (Online): 2023-12-28

Number of Figures: 10 **Number of Tables: 8** **Number of Pages: 27** **Number of References: 36**

***Corresponding author**
Email: n.motahari@um.ac.ir

1. Introduction

Blockchain technology is a relatively new concept initially introduced by Haber and Stornetta in 1991 (Haber & Stornetta, 1991). It reached its peak of prominence with the introduction of Bitcoin. Blockchain is a decentralized digital ledger database composed of informational blocks that are all interlinked. Each block is connected to the previous one in this structure, creating a chain-like data structure (Rajabi et al., 2022). In blockchain-based tracking systems, every transaction and action is recorded and observable, and they can be tracked and retrieved by multiple parties at any given time (Dasaklis & Casino, 2019). Traditional supply chain systems rely on centralized information systems like enterprise resource planning, which typically store all data in a central location. These information systems have several limitations, including a lack of trust among supply chain members. They use centralized databases susceptible to attacks, corruption, and hacking (Roozkhosh et al., 2023b). In traditional database systems, records are usually maintained in a single location within an organization. A central authority controls the database, ensuring transaction integrity and managing user access. Six key features distinguishing blockchain technology from traditional information systems are decentralization, immutability, security, auditability, accessibility, and smart contracts.

Blockchain is, by its nature, a decentralized platform, eliminating the need for third-party validation, regardless of the activities conducted on the platform. No strong central entity exists in blockchain to establish rules, centralize accounting, and maintain a general ledger. The most essential part of blockchain technology is the consensus algorithms used to determine how network participants agree on adding information blocks to the blockchain. Blockchain supports advanced concepts like smart contracts and assets (Moosavi et al., 2021). Smart contracts are a significant technology that enables valid transactions without third-party involvement. Smart contracts are agreements between companies in a supply chain process (e.g., senders and carriers in a transportation chain) encoded in code and automatically executed by computers after specific conditions are met (e.g., the arrival of a product at a telecommunications company). The code is stored and replicated in a blockchain. The benefits of smart contracts include increased accuracy, speed, security, trust, transparency, traceability, and efficiency (Khan et al., 2021).

Different blockchain architecture configurations make it possible for various use cases in the business sector. Blockchain comes with challenges and limitations that need to be considered before its adoption and implementation. One of the primary challenges associated with blockchain is its scalability. Scalability refers to the network's ability to process many transactions and meet demand (Durach et al., 2021). This issue concerns the network's computational and operational capacity in processing operations and transactions. In other words, the higher the scalability of blockchain, the more influential the network is in supporting transactions. As the use of blockchain expands and the number of blockchain networks increases, computational power for solving more complex algorithms also increases, leading to improved scalability. It means that more transactions can be processed simultaneously, resulting in a substantial increase in the amount of data that can be shared (Kamble et al., 2020).

Before implementing a blockchain system, how much of the information can be shared among participants should be determined. It can vary based on the advantages and limitations associated with blockchain implementation. For instance, increasing the adoption rate of blockchain may lead to increased costs for an organization, but it can also reduce costs in other aspects (Bafandegan et al., 2023). Therefore, one of the main obstacles to implementing blockchain is the cost associated with its execution. Fixed and variable costs play a significant role in using blockchain. One of the primary costs of implementing blockchain pertains to the initial development and maintenance expenses. Implementing blockchain requires a high level of capital investment. Additionally, additional costs will be incurred if companies need to change their systems and train their employees to acquire blockchain knowledge.

One of the main disadvantages of blockchain is its high energy consumption and the associated costs. The more complex smart contracts are, the more they use more sophisticated consensus algorithms, which require higher computational power (Golosova & Romanovs, 2018). Therefore, they need more time and incur higher costs for coding, which necessitates individuals with advanced programming skills, further increasing the cost of creating a blockchain. Organizations that use more complex smart contracts also require the development of more extensive databases and hardware. More complex consensus algorithms require more powerful hardware.

Additionally, higher computational power consumes more energy, leading to increased energy costs. Another significant issue that increases the cost of blockchain, particularly with the use of extensive smart contracts, is the cost of code inspection and testing and human error in the coding phase. It is evident that as the complexity of smart contracts increases, human error also rises.

Due to the complex nature of blockchain technology development, experts within organizations often struggle to predict costs accurately, considering varying adoption rates (Roozkhosh et al., 2023a). Predicting costs and establishing a relationship between costs and adoption rates is unsuitable for mathematical modeling and analytical methods, as numerous factors and variables influence adoption rates and their associated costs (Modares et al., 2024; Modares et al., 2023b). Additionally, the relationship between influential variables and feedback mechanisms is complex and dynamic (Modares et al., 2023). In this research, the behaviors of various variables are identified using an SD approach, considering all factors related to adoption rates and their associated feedback mechanisms within the study's time frame. All variables that impact blockchain adoption are identified by employing an SD approach. After identifying these variables, their impact on each other and the adoption rate is examined. Hence, utilizing the SD approach, the behavior of variables is displayed concerning each other over time, and the effect of variables on each other is well-reflected in simulating the behavior. After implementing this approach and validating the model, the behavior of model variables is simulated for future intervals. Since the chart derived from systems dynamics shows the states and flows as functions of time, machine learning-based validation methods are used to obtain a chart representing the system's state as a function of the net rate. In essence, because the changes in the state variables over time are determined as the sum of input rates positively and output rates negatively, relationships between state variables and flows are maintained at each moment, and variable values can be expressed in terms of each other.

By adopting a comprehensive approach that integrates statistical analysis and systemic modeling, this research endeavors to fill critical gaps in existing literature. Through its detailed exploration of the influence of adoption rate on the cost of blockchain implementation, this study seeks to provide a robust framework for understanding and optimizing the intricate dynamics at play within blockchain. In this research, the cost function of blockchain implementation has been estimated, and its relationships with other related costs have been obtained. These relationships have been estimated using the method of SD and regression, which has yet to be addressed in any research so far. The relationship between the costs of blockchain implementation has yet to be explored in the literature. Therefore, this motivates us to examine them in the organizations. Based on conducted studies, three factors will be highlighted that are the main contribution and motivation in this study:

(8) Examining the relationship between the influencing variables on the cost of blockchain implementation is surprisingly unsettled in the literate.
(9) Estimating the cost of blockchain implementation functions could be more compelling to the literate.
(10) To our knowledge, system dynamics, and regression techniques are simultaneously considered in blockchain implementation for the first time in this paper.

The remainder of the paper is organized as follows. The literature review is presented in section 2. Section 3 discusses the method. The model and data analysis are presented in section 4. The conclusion is given in section 5.

2. Literature review

Previous studies have presented that most blockchain studies focus on the benefit of BT, how it works, and its potential benefits (Kamble et al., 2021). In recent years, many studies have examined the application facilities of BT in any organization from the perspective of the supply chain due to its lack of knowledge and immaturity (Kamble et al., 2020; Kamble et al., 2021). Yadav et al. (2020) proposed the adoption of BT in the supply chain. In this work, the main component of the adoption of BT related to the supply chain was identified. These components were examined and used to model the efficient supply chain using component analysis. The designed supply chain produced a more efficient result than traditional supply chain management. Li et al. (2018) analyzed the current state of BT by analyzing the various areas in the organization with the key objective of maximizing the coherent adoption of this technology. They emphasized the need for a coherent adoption of BT in the organization rather than a diverse adoption. Olawumi et al. (2021) considered the complex causal interrelationship of the main factors affecting the adoption of BT using the system dynamics method in the construction industry. The findings presented that users' awareness and satisfaction, standard development, and top management support are solutions that would improve adopting BT in construction companies and the construction industry. Tipmontian et al. (2019) examined the impact of the adoption of BT for safe food supply chain management through the SD method. The preliminary discussion and survey were carried out with the participants from food expert companies, and causal loop charts and stock and flow charts were validated. The opportunities, challenges, and trade-offs of applying BT to the global food supply chain have been examined throughout the system dynamics model.

Tian (2018) considered a supply chain traceability system for real-time food tracing according to the Internet of Things, Hazard Analysis and Critical Control Points (HACCP), and BT. They also consider the challenges of the future adoption of BT in food supply chain systems. Chang (2019) proposed a blockchain-enabled newsvendor model to maximize total profit. The authors presented a newsvendor problem to study how adopting BT affects inventory decisions and how to obtain optimal adoption. The cost and demand functions in their model depend on the adoption rate. However, they did not obtain the cost and demand functions and

 DOI: 10.22067/JSTINP.2023.85842.1084

defined them based on some assumptions. Chang et al. (2021) considered adopting technology for the newsvendor problem, as exemplified by BT. Their goal was to determine how adopting BT impresses the optimal profit and the corresponding optimal ordering decisions. Also, the authors considered the optimal technology adoption for profit maximization while examining the cost of adoption. Like Chang (2019), the cost and demand functions depend on the adoption rate, while the cost and demand functions are considered a priori known based on some assumptions.

Keskín et al. (2023) have examined the newspaper vending problem in which a retailer and a seller are connected through blockchain technology. In this scenario, the retailer receives information about the status and quality of products from the seller moment by moment. The authors have analyzed and compared the model under two conditions: in one case, the retailer uses blockchain for information sharing, while in the other, they use a traditional supply chain without blockchain. The results indicate that costs are significantly reduced when the retailer and the seller are connected via blockchain.

Kouhizadeh and Sarkis (2018) examined the obstacles to blockchain adoption from technology-environment-organization perspectives. They provided an overview of the barriers to implementing blockchain for supply chain control based on existing literature in organizational methods, technology, and sustainability. After collecting data, they used the DEMATEL technique to analyze and identify the most significant factors. Omar et al. (2020) explored a blockchain-based supply chain with inventory management policies by sellers using smart contracts. The results of this study suggest that considering blockchain for supply chain operations increases the profitability of the case study and provides a secure, transparent, reliable, and efficient communication channel among various stakeholders. Garg et al. (2021) proposed a solution for system designers to predict the successful adoption of blockchain technology in organizations using machine learning methods. In this research, factors affecting blockchain adoption were considered within the framework of technology-organization-environment, and a decision support system was designed using Bayesian network analysis with important criteria that managers can use to predict the likelihood of blockchain adoption in their company. De Giovanni (2020) designed a blockchain-based supply chain with two members: a seller and a retailer. This supply chain can be managed through the adoption of blockchain technology. The results show that blockchain eliminates all potential risks and uncertainties in the supply chain, significantly reducing order costs. The authors used game theory to analyze the expected profits generated by retailers and suppliers from blockchain adoption.

2.1. Blockchain

Blockchain possesses essential features such as decentralization, traceability, and tampering prevention. The blockchain tracking system is built on a secure database and a reliable monitoring system. With the capability to use smart contracts, blockchain is a comprehensive information system that can be easily shared among participants (Ahmadi et al., 2021). The process of registering, transferring, and tracking products is executed through the collaboration of smart contracts. Tracking systems, enabled by smart contracts, can share information related to material specifications for predicting final products, environmental conditions, product maintenance, and information about the entire production and distribution processes. Product quality requirements must be met per predetermined conditions through smart contracts, and these standards will be automatically enforced. Conditions encompass all the requirements that suppliers must fulfill to ensure product quality. Since data in this network is transparent and visible to all without intermediaries, both parties in the contract can have confidence in its reliability. The agreements between the two parties are automatically executed in each of these contracts. When a specified condition is met, the contract execution process begins automatically. In this way, contracts are executed via automation (Gurtu & Johny, 2019). Smart contracts provide the necessary infrastructure for real-time tracking and transparency in the supply chain of goods. These contracts can take various forms, such as production product processing, sales, transportation, and quality contracts. Figure 1 shows the types of Contracts in exchanges.

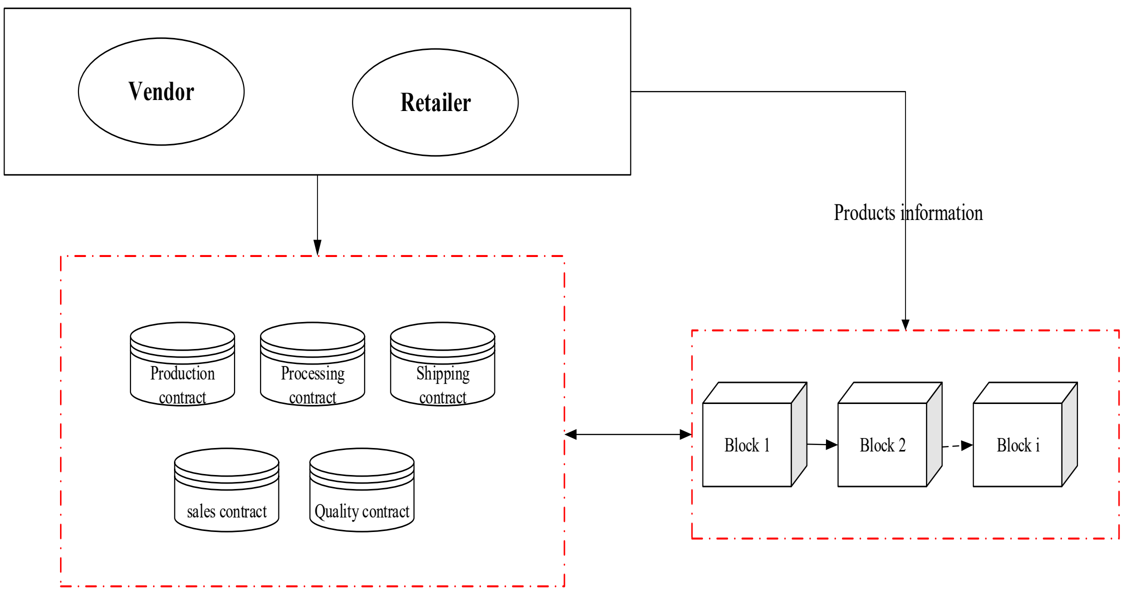


Figure 1. Types of contracts in exchanges

3. Research method

In this paper method, the costs of implementing the blockchain are using the SD. For this purpose, technical variables influencing blockchain implementation are first identified. Then, their relationships and feedback are determined, and cause and effect and stock charts are drawn. After that, the relationship between the blockchain implementation costs and the variables affecting it is investigated using machine learning. Figure 2 shows the steps related to the research method.

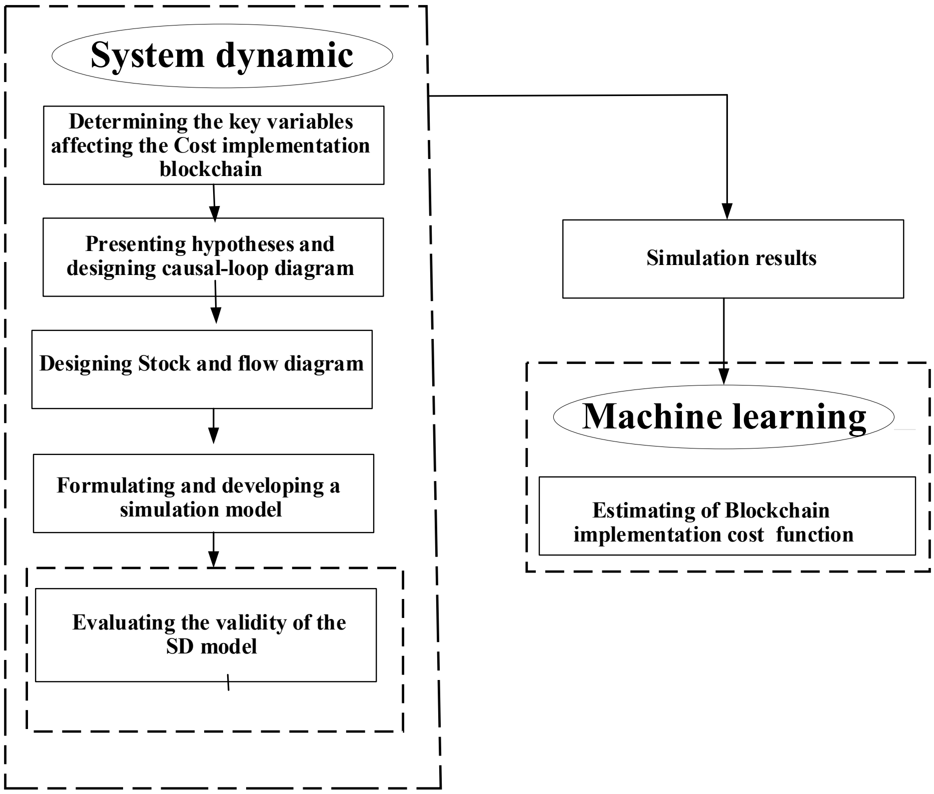


Figure 2. General steps of research

3.1. System dynamics (SD)

The simulation technique is efficient for predicting system behavior. Imitating the operation in a real-world system over time is called simulation. Simulation is the re-enactment of real-world scenarios for different reasons, including education, preparing for a predicated event, or troubleshooting an issue (Durach et al., 2021). One of the essential simulation methods is system dynamics simulation. SD aims to aid people in finding out about dynamic and complex systems and help them make better decisions. SD provides methods to analyze dynamic systems (Emroozi et al., 2022). The main character of the SD models is to consider the system behavior.

SD modeling is used to model non-linear dependencies in the real world. The use of feedback, scenario-making, and considering the sensitivity of parameters are essential reasons for the efficiency of these techniques (Modares et al., 2021). Non-linear and complex relationships and the uncertainty of system behavior are usually specified as feedback loops. Forrester initially introduced the SD technique concerning supply chain management (Roozkhosh & Pooya, 2023). The supply chain contains different factors, including the flow of goods and materials with information sharing available in the system (Modares et al., 2023c; Modares et al., 2023d). The supply chain processes have a complicated structure; the system's behavior is also dynamic. A comprehensive understanding of the relationships between system components by providing a holistic attitude of entire systems is provided using SD by modeling real-world problems (Modares et al., 2023e; Emroozi et al., 2024). System dynamics methods are built by connecting the adequate components of a system structure and simulating the behavior obtained from that system structure (Roozkhosh, 2023b). The system structure consists of feedback, flows, and stock. Feedback loops are used to analyze the relationship between variables (Kamble et al., 2020). Stocks and flows impact each other using feedback loops and causal relationships. Also, they produce effects and show system characteristics. SD based on causal relationships and feedback examines system dynamics behavior. SD modeling with emphasis on the relationships among the system components is applied to consider the system's dynamic behavior. Analyzing system behavior using various hypotheses gives policymakers feedback to make policies effective.

3.1.1. Identifying the key variables and their relationships

After identifying the problem's key variables, the dynamic nature of the problem is presented in the form of feedback loops by identifying the relationships of the variables. Then, feedback is generated in each subsystem. Finally, dynamic hypotheses are developed by utilizing a causal–loop chart. To better understand the system behavior, it is necessary to formulate the relationships between the variables and simulate the values of the variables over time. The relationships between these variables were analyzed using the qualitative SD modeling method with stakeholders through questionnaires and 15 interviews. Figure 3 shows the causal-loop chart of the model. The causal–loop diagram related to the present study is shown in Figure 3 to illustrate the hypotheses and describe the dynamic nature of the problem. Feedback loops can be of two varied kinds, either negative or positive. The values related to the two nodes within the related change in the positive feedback loop are in the same direction. In the negative

 DOI: 10.22067/JSTINP.2023.85842.1084

causal loop, the two nodes change in opposite directions, so if the node where the link starts decreases, the other node increases conversely (Sterman, 2002). The dynamic hypotheses of the model are stated as follows**:**

Loop R1: As the number of transactions increases, the transactions per capita increase. The increase in transactions per capita reduces the cost of transactions. Then, reducing the transaction cost increases the number of transactions.

Loop R2: As the number of transactions increases, communication increases and creates more trust between the members involved in the blockchain. Then, trust increases participation, and participation increases the retailer's demand from the seller. It also increases the number of transactions.

Loop R3: As the number of transactions increases, the number of blocks increases, and the increase in blocks increases the size of the blockchain. Then, increasing the size of the blockchain increases the number of transactions.

Loop B1: The more transactions are used in the blockchain, the more specialized human resources are needed. Therefore, with the increase in workforce costs, the costs of implementing the blockchain will increase, and as a result, the number of transactions will decrease.

Loop B2: Loop B2 is contrary to expectation, so the more transactions are used in the blockchain, the more the need for more advanced hardware increases. Therefore, the cost of setting up the hardware increases, which leads to an increase in the cost of blockchain operations, and as a result, the number of transactions decreases.

Loop B3: The size of the blocks used in the blockchain increases, the speed of transactions reduces, and as a result, the numbers of transactions decrease. Then, decreasing the number of transactions leads to a decrease in the size of the blockchain.

 DOI: 10.22067/JSTINP.2023.85842.1084

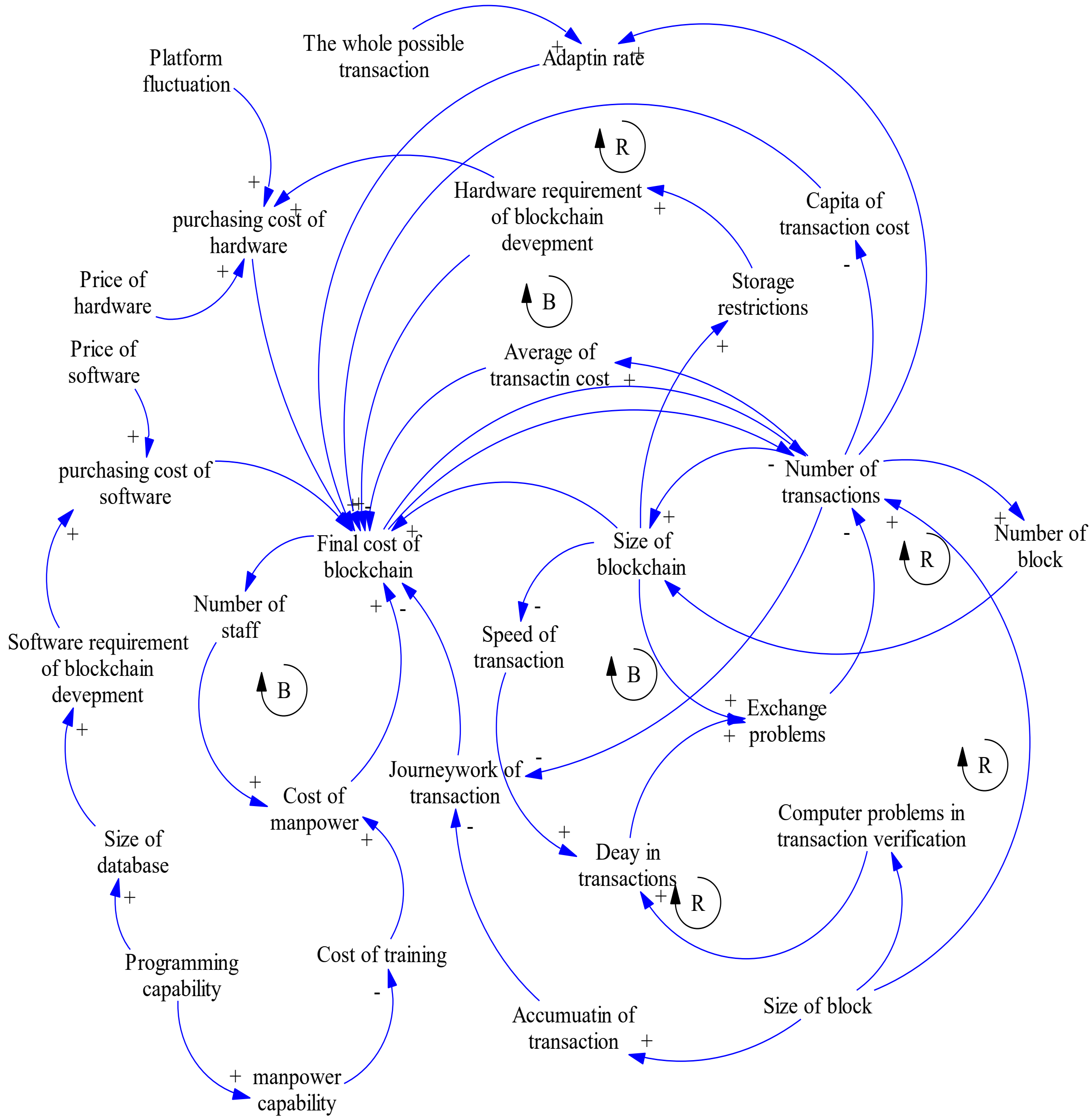


Figure 3. Causal-loop chart

In this phase, through data collection, mathematical relationships between variables and initial values are formulated using the VENSIM simulation software. A Stock and flow model helps managers and system designers quantitatively analyze the system. Stocks and flows are the foundation of SD modeling. Stocks can accumulate information, materials, or energy over time. Stock shows a part of a system whose value in time at a given instant depends on the system's past behavior. The stock's value in time at a particular instance cannot be specified by measuring the value of the other variables of the system in time at that instant. It has been obtained by measuring how it changes every instant and adding up all these changes. Flows, on the other hand, are entities that make stocks decrease or increase. Flows show the rate at any given instant when the stock changes. The stock variables are defined by equation (1).

$$\text{Stock}\left(t\right)=S\left(t_0\right)+\int \text{inflow}\left(t\right)-\text{outflow}\left(t\right)d\left(t\right) \quad (1)$$

Stock (t) is the accumulation value of stock variables at t moment, illustrated by stocks in feedback charts. Inflow (t) or outflow (t) are flow variables. Also, S (t0) is the initial value of the stock variables. As it turns out, flow variables are derived from the instantaneous changes of the stock variables. Stock variables in the present study include the number of transactions, the implementation cost of blockchain, and the number of blocks. The stock and flow chart related to the present study is shown in Figure 4. By completing the model simulation and also entering the relationship between the variables in the VENSIM software, the model outputs are obtained by simulation. This simulation was performed over 100 days.

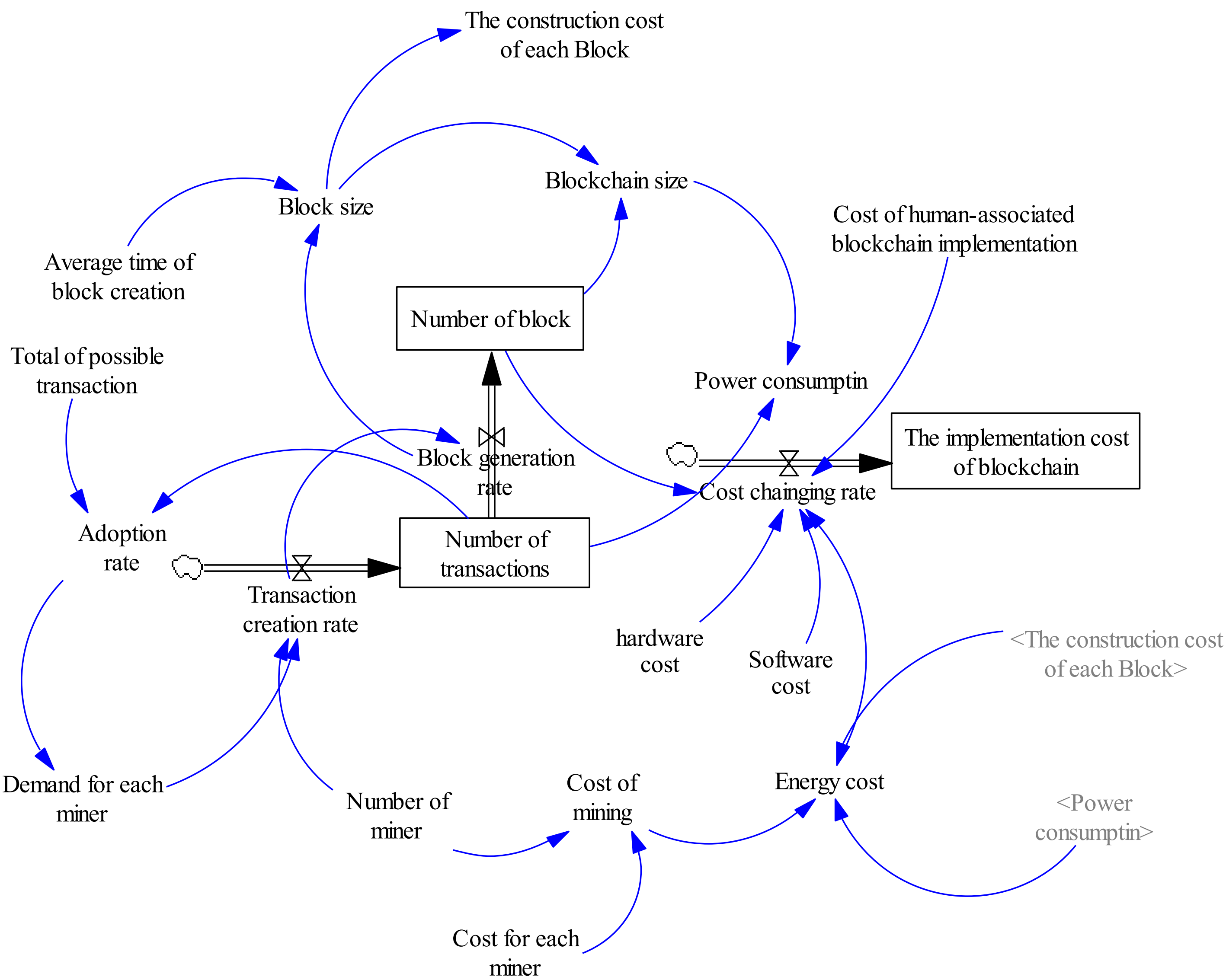


Figure 4. Stock and flow chart design for evaluating key factors affecting the cost of blockchain

3.1.2. Formulating and developing a simulation model

All the studied variables in the proposed model are formulated based on the relationships between them. It can describe the behavior of stock and flow variables using mathematical functions; if the graph of changes in the behavior of the flow variable is available, the behavior of stock variables can be inferred using it. The formula for some of the most critical variables is given in Tables 1 and 2.

Table 15. Formulas and values used for stock variables in the simulation

Variable	Formula	Type of variable
The implementation cost of blockchain	$\mathrm{Fc}(t_1) = Fc(t_0) + \int \text{cost changing rate}$	Stock variable
Number of blocks	$\mathrm{SBT}(t_1) = \mathrm{SBT}(t_0) + \int \text{block generation rate}(t)$	Stock variable
Number of transactions	$NT\ (t_1) = \int NT\ (t_0) + \text{Transaction creation rate}(\mathrm{dt})$	Stock variable

Table 16. Formulas and values used for flow and auxiliary variables in the simulation

Variable	Formula	Type of variable
Cost of mining	$\text{Number of miner} \times \text{cost for each miner}$	Flow variable
Cost changing rate	hardware cost+software cost+energy cost +cost of human-assosiated blockchain implementation	Flow variable
Block generation rate	$\text{transaction creation rate} \times \text{cofficient of transaction creation rate}$	Flow variable
Adaption rate	$\text{Number of transaction} / \text{Total of possible transactions}$	Flow variable
Power consumption	Blockchain size×number of transactions	Flow variable
Rate of increase in blocks	$\dfrac{\text{Number of blocks} \times \text{Rate of increase in demand}}{\text{Average time of block creation}}$	Flow variable
blockchain size	(Block size*Number of block)	Flow variable
Block size	Number of transactions/Blockchain size	Flow variable

Table 3 shows the initial value of some variables. These values have been obtained from expert specialists in the field of blockchain who have been working on its implementation for years.

Table 17. Values used for stock and constant parameters in the simulation

Variable	Type of variable	Initial value
Cost of human associated blockchain implementation	Constant	500000
Software cost	Constant	150000
Energy cost	Constant	21000000
Hardware cost	Constant	450000
software cost	Constant	6743200
Cost of miner	Constant	300
Constructing cost of each block	Constant	7654
Total possible of transaction	Constant	76543207

3.1.3. Estimating the relationships between costs of blockchain implementation and other variables

In this study, the behavior of variables over time is first estimated using a dynamic approach. Given that this method is time-dependent and considers the system's dynamics, it can be said that the behavior of variables during similar times is the same. Since varied variables in SD and their effect on system behavior are investigated, the status of each variable under the effect of other variables is shown at any point in time. In fact, at any given moment, all variables are expressed in terms of other variables and their effects on system dynamics. It means that the state variable changes are specified in terms of time (a derivative of the state variable) from the sum of the input rate variables as positive and the output rate variables as negative. So, at any given time, the connections between the variables are established, and the values of the variables are expressed in terms of each other. Therefore, since the SD approach only gives the process of graphing variables and points, a method that can perform the estimated function of the dynamics approach. The regression technique is used to evaluate the functions using the data provided by the dynamics approach is required.

Regression algorithms approximate a mapping function from input variables to continuous output variables. Some error metrics are used to evaluate the performance of the model. Mean squared error (MSE) is the most common method. In MSE, the error is obtained by squaring the difference between the actual value (y_i) and the predicted value and averaging it across the dataset. The cost function using this method in the regression is as follows:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - f\left(x_i;\omega\right)\right)^2 \quad (2)$$

This method aims to find the best regression function ($f\left(x_i;\omega\right)$) that is equivalent to the best ω. Where ω are the optimal linear parameters of the regression function.

4. Results

4.1. Simulation results

Based on the simulation model presented in the present study, the simulation of the proposed variables is followed in Figures 5 and 6. The results show that the implementation cost of blockchain will reach 800M currencies from the beginning to the end of the simulation period and will increase the implementation cost of blockchain at different times. Because the number of transactions increases during the simulation period, the number of blocks also increases.

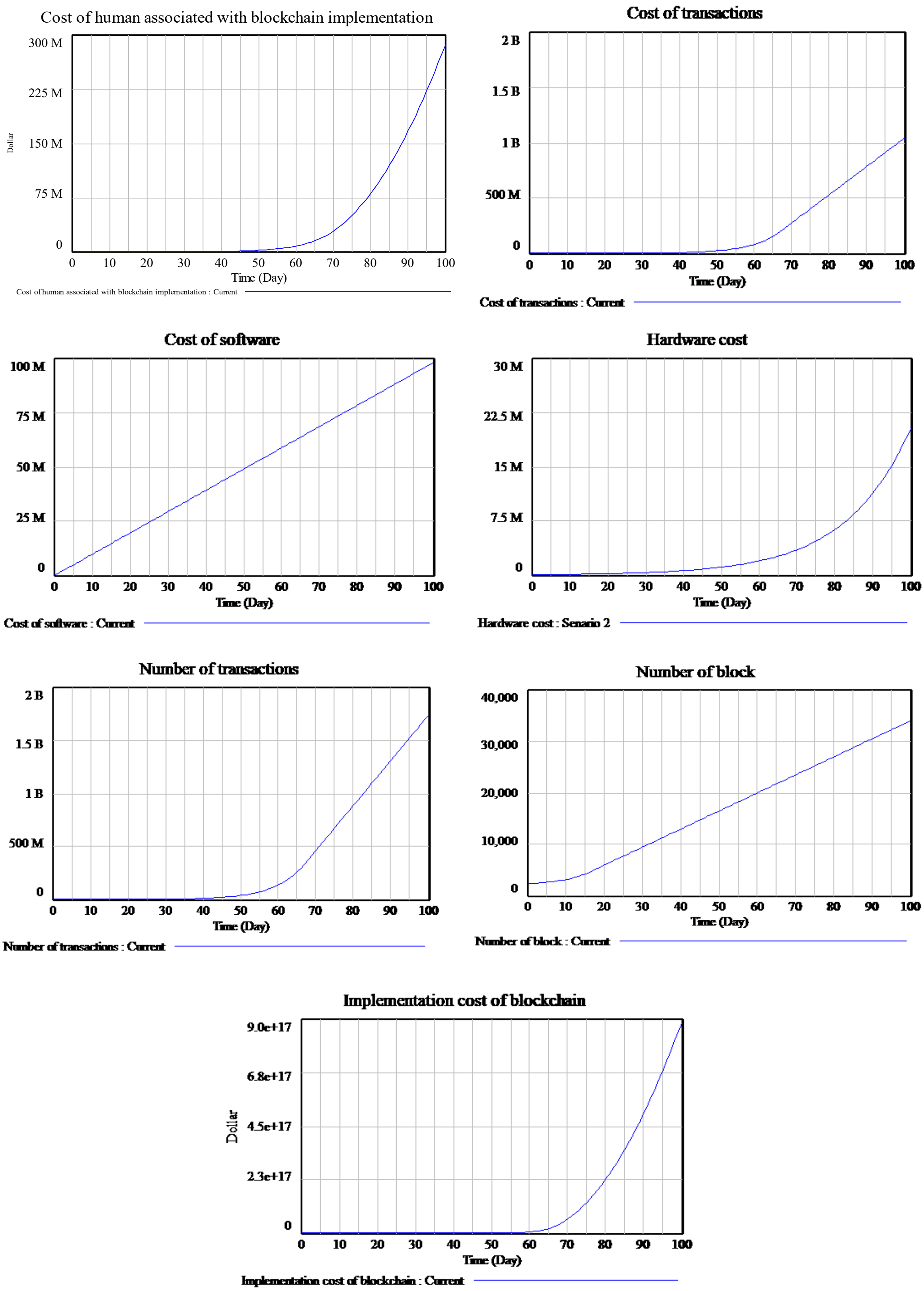


Figure 5. Simulation results

DOI: 10.22067/JSTINP.2023.85842.1084

From Figure 5, it can be seen that over time, as the number of transactions increases due to greater participation, the number of blocks also increases, and this causes the cost of implementing the blockchain to increase over time.

Figure 5 encapsulates a comprehensive portrayal of the model's execution spanning a substantial 100-day timeline, offering insights into the evolving dynamics within the studied system. The ensuing findings shed light on the multifaceted outcomes of this extensive simulation. The discernible correlation observed between the increasing adoption rate and its parallel influence on the implementation cost of blockchain is of particular significance. The depicted trends underscore the exponential cost growth, signifying robust development. With the increase in the adoption rate, it can be seen that the software cost increases linearly, and the rest of the costs increase non-linearly. As a result, the total cost of blockchain implementation increases non-linearly.

4.1.1. Different scenarios

Scenario design goes beyond changing parameter values; scenario design involves decision-making strategies, structures, and rules. Because real systems are highly nonlinear, the effect of scenario combinations is usually not equal to the sum of the effects of each scenario alone. Most policies overlap, sometimes reinforcing each other and significantly increasing and decreasing each other (Sterman, 2002). System behavior in the past reflects the reality of the system structure, but different scenarios can be assumed for the future. Changes strongly influence the system's future behavior in model variables, constants, system rules, relationships between variables, and model leverage points. Product quality requirements must be met per predetermined conditions through smart contracts, and these standards will be automatically enforced. According to the structure and perceived behavior of the model, in this study, the constants are changed to provide new scenarios. In this study, two different scenarios have been stated that these scenarios lead to improved system behavior. In other words, by simultaneously making the changes mentioned in the three scenarios, a structure can be created that leads to improved system behavior.

In other words, an optimal scenario should be implemented to improve the studied variables in the model. The simulated model can be used to design and evaluate policies for improvement. Scenario design involves the creation of entirely new strategies, structures, and decision rules. Policies' strength and sensitivity to parameter uncertainties should be evaluated in a wide range of scenarios. To simulate a dynamic model, one must first select several main variables to study and then evaluate their results based on scenarios.

The differences in the variables are shown in Table 4. The diagrams related to the comparison of the variables in different scenarios are shown in Figure 6. In the main scenario, based on the available data at the community level, the coefficient of block generation is equal to 10%. Also, the average time of block creation is 50%. By creating special infrastructures and instructions, it is possible to improve the two variables mentioned more than the other variables. Therefore, the focus is on these two variables to analyze different scenarios. In the first scenario, the average time of block creation variable increased by 60%, and the coefficient of block generation increased by 20%. In the second scenario, the coefficient of block generation has increased by 3%, and the average time of block creation has increased by 70%. This change has enhanced the cost of implementing blockchains.

Figures 6 illustrate that changes in each variable have improved system behavior. A change in any of the variables is expected to improve the system behavior. However, since the system dynamics examines nonlinear relationships and the effect and variability of variables on each other, it is not obvious without providing a suitable model to examine the relationships and their effect on system behavior. Therefore, by running these scenarios, the influence of the block's creation time on the costs of implementing blockchain can be seen.

Table 18. Values of variables based on different scenarios

Type of scenario	**Coefficient of block generation**	**Average time of block creation**
The main scenario	0.1	0.5
The first scenario	0.2	0.6
The second scenario	0.3	0.7

 DOI: 10.22067/JSTINP.2023.85842.1084

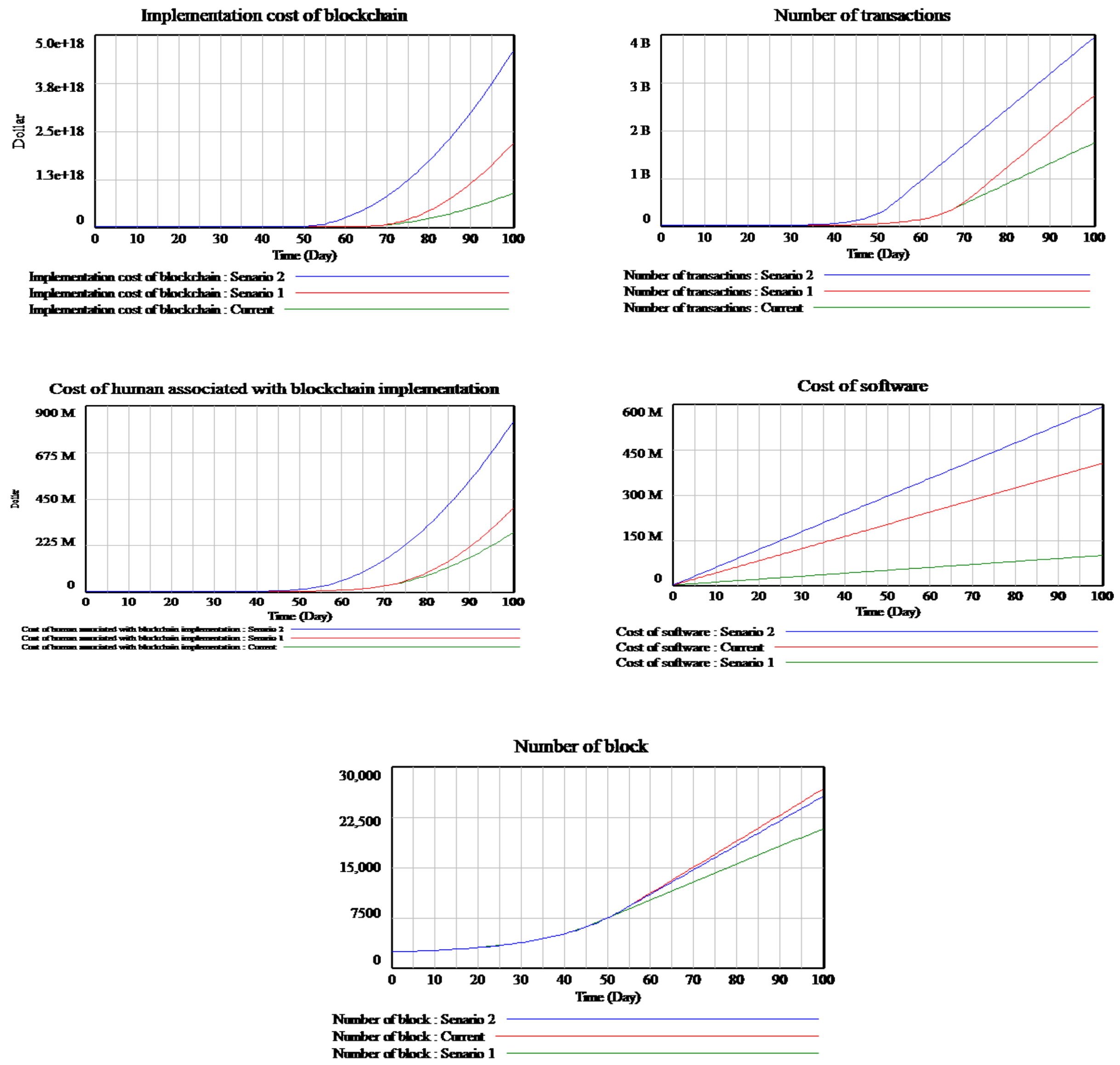


Figure 6. Scenario design and evaluations

4.2. Regression results

Figure 7 shows the relationship between blockchain implementation and human costs.

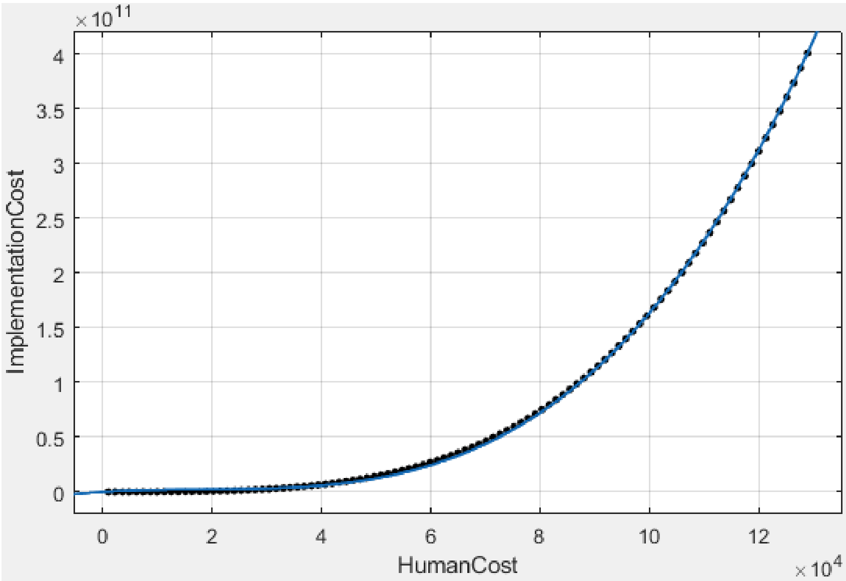


Figure 7. The relationship between human cost and blockchain implementation cost

The value of the coefficient and intercept of the cubic function is given in Table 5.

Table 19. Coefficients of the quadratic function
(The relationship between the implementation cost of BT and human cost)

Coefficients	Coefficient of α_1^3	Coefficient of α_1^2	Coefficient of α_1	Intercept
Value	-3015	3.28e+05	-16.33	0.0002939

According to the results obtained from Table 4, the final cost terms of human cost are as follows:

$$FC_{\alpha_1} = -3015\alpha_1^3 + 3.28e + 05\alpha_1^2 + -16.33\alpha_1 + 0.0002939 \quad (3)$$

Figure 8 shows the relationship between hardware and blockchain implementation costs using the quadratic function.

Modares et al., JSTINP 2023; Vol. 2. No. 4 DOI: 10.22067/JSTINP.2023.85842.1084

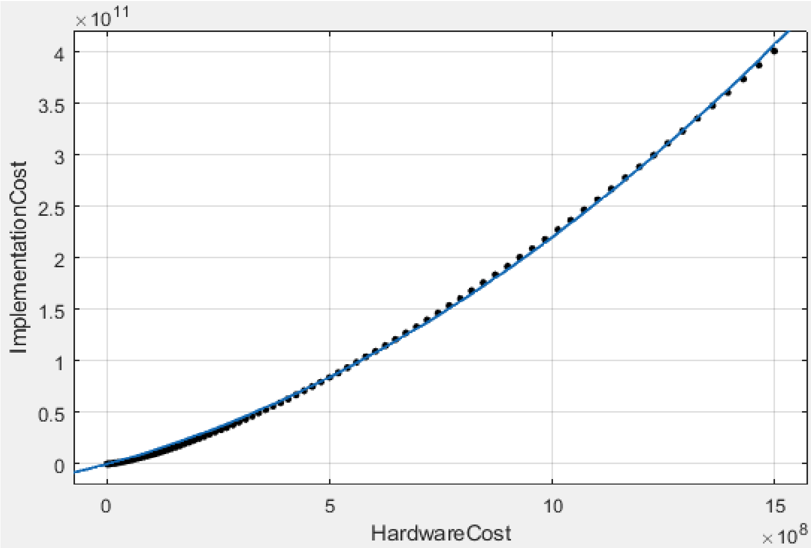


Figure 8. The relationship between hardware cost and blockchain implementation cost

The value of the coefficient and intercept of the quadratic function is given in Table 6.

Table 20. Coefficients of the quadratic function
(The relationship between the implementation cost of BT and hardware cost)

Coefficients	**Coefficient of α_2^2**	**Coefficient of α_2**	**Intercept**
Value	0.452	117.7	1.026e-07

According to the results obtained from Table 5, the final cost terms of hardware cost are as follows:

$$FC_{\alpha_2} = 30.452\alpha_2^2 + 117.7\alpha_2 + 1.026e - 07 \quad (4)$$

Figure 9 shows a relationship between software and blockchain implementation costs using the quadratic function.

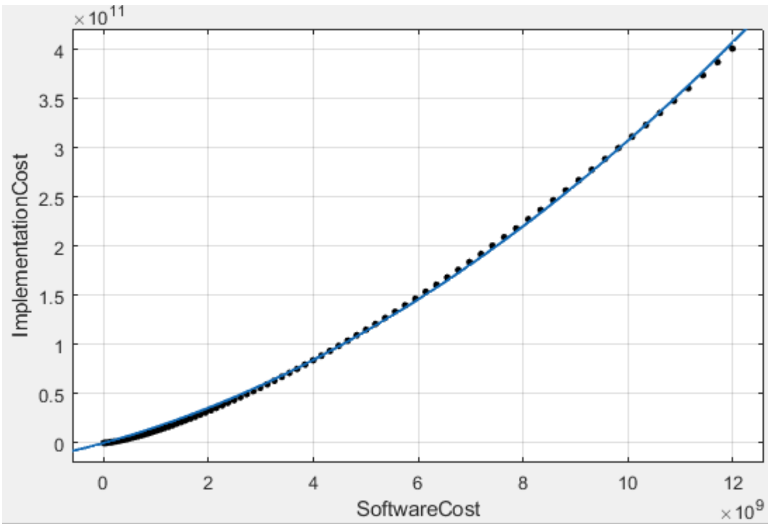


Figure 9. The relationship between software cost and blockchain implementation cost

The value of the coefficient and intercept of the quadratic function is given in Table 6.

Table 21. Coefficients of the quadratic function

(The relationship between the implementation cost of BT and human cost)

Coefficients	Coefficient of α_3^2	Coefficient of α_3	Intercept
Value	0.9157	14.72	1.603e-09

According to the results obtained from Table 7, the final cost terms of software cost are as follows:

$$FC_{\alpha_3} = 0.9157\alpha_3^2 + 14.72\alpha_3 + 1.603e - 09 \quad (5)$$

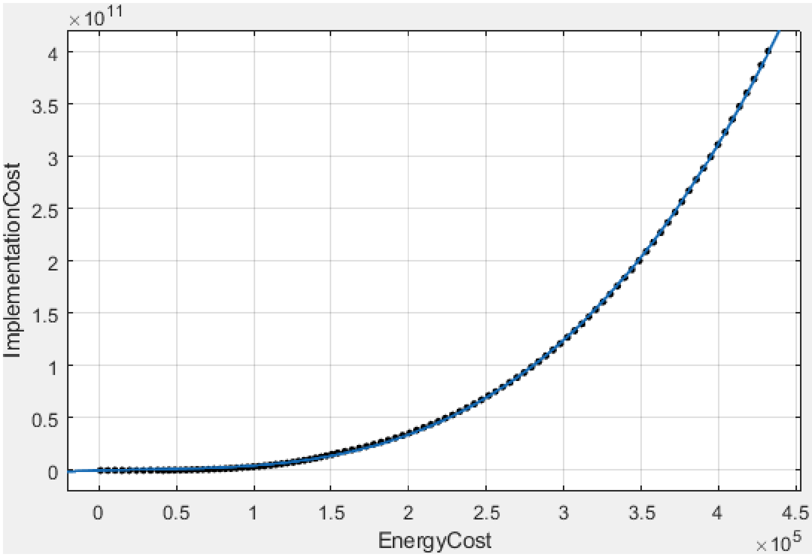


Figure 10. The relationship between energy cost and blockchain implementation cost

Figure 10 shows a relationship between energy cost and blockchain implementation cost using the quadratic function. The value of the coefficient and intercept of the cubic function is given in Table 8.

Table 22. Coefficients of the quadratic function
(The relationship between the energy cost and blockchain implementation cost)

Coefficients	Coefficient of α_4^3	Coefficient of α_4^2	Coefficient of α_4	Intercept
Value	8.268	4.111e+04	-0.5576	6.018e-06

5.

According to the results obtained from Table 7, the final cost terms of cost are as follows:

$$FC_{\alpha_4} = 4.111e + 04\alpha_4^3 + 3.28e + 05\alpha_4^2 + -0.5576\alpha_4 + 6.018e - 06 \quad (6)$$

After obtaining the cost functions in terms of blockchain implementation cost, the cost function is obtained, which depends on the cost of hardware, software, hardware, and energy costs, which is given in equation (7).

$$FC\left(\alpha_1,\alpha_2,\alpha_3,\alpha_4\right)=-3015\alpha_1^3+3.28e+05\alpha_1^2+-16.33\alpha_1 +30.452\alpha_2^2+117.7\alpha_2+0.9157\alpha_3^2+14.72\alpha_3+1.603e-09 +4.111e+04\alpha_4^3+3.28e+05\alpha_4^2+-0.5576\alpha_4+4532676 \quad (7)$$

Given the significance of blockchain implementation, this study specifically examines the relationship between human cost, software cost, hardware cost, and implementation cost of blockchain. The results indicate that a quadratic function provides a more accurate estimate of this relationship. These findings are valuable for managers as they can utilize simulation and function estimation techniques in various industries, taking into account the specific conditions of their organization. It enables managers to make informed decisions regarding the optimal level of reliability based on the prevailing human error factors. After estimating the cost function, the cost can be obtained in different amounts of hardware, software, energy, and human costs. This paper provides a solution to predict the cost of blockchain implementation.

This study is becoming increasingly important for managers and system designers to develop efficient solutions for applying blockchain. This research helps organizational planners predict the cost of blockchain implementation at any level of adoption rate and find the optimal cost according to the benefits and organizational conditions.

As observed, with the expansion of blockchain networks, computational power for solving more complex algorithms increases, and thus, the scalability of sharing information also increases. Therefore, this study determined the percentage of information that can be shared among participants before implementing blockchain, considering the advantages and obstacles in blockchain implementation. Thus, the relationship between the cost of blockchain implementation and the order cost with the blockchain acceptance rate was examined to obtain the optimal acceptance rate. Therefore, in this research, by estimating the cost function based on the acceptance rate, organizations can be helped to understand what types of smart contracts to use and with what complexities. Depending on different acceptance rates, managers can predict the cost of blockchain implementation and choose the best possible scenario for their organization. Therefore, the results can help managers select the optimal adoption rate for applying blockchain. More retailer-vendor communication leads to more transactions in the organization. However, scalability problems make it impossible to do more transactions per unit of time in the blockchain network. The results of this research examine the rate of adoption of the blockchain according to the degree of scalability of the blockchain. Using the obtained results from this study, every manager can analyze the relationship between the adoption rate and the factors affecting it and find the optimal rate for the organization where the costs are at their lowest. Therefore, organizations can analyze the effects of different rates on costs and other factors and know at what adoption rate blockchain can be used according to the issues in the organization. One of the main advantages of this designed model is that in this research, at any optimal rate that is obtained, the system planners can analyze and adjust according to the number of transactions that can be done in the organizations; they can choose the type of blockchain used in their company. It means they know whether they should use a smart contract in the blockchain they are using. Decision-makers can understand what type of smart contract and at what level of complexity they can use due to scalability. Therefore, the results of this research can significantly help planners in the development and application of blockchain technology in organizations.

5. Discussion and conclusion

It is essential to address the issue of increasing the blockchain implementation cost in various industries because it contributes to financial risks. Therefore, accurate and correct prediction of the implementation cost amount is significant. In this research the SD technique was used to calculate the implementation cost. Using the SD technique to examine the problem dynamically has provided the possibility of a better and more complete examination of the conditions of the factors according to the costs, the number of blocks, the number of transactions, and other factors. In this research, all elements were extracted according to the opinion of experts and research backgrounds. This research uses the system dynamics method to calculate the blockchain implementation cost after identifying the key variables. The systems dynamic approach can estimate the state of the desired variables and their dependent variables on the chosen horizon by examining and detecting the behavior of variables. The research horizon is 100 periods. The system behavior is reconstructed. As a result, the dynamic relationships of factors were identified, and the system's behavior was predicted favorably. By identifying the system's behavior and the obtained results from the SD method, the system's future behavior is predicted. In addition, the investigation of indirect relationships is also important in calculating blockchain implementation costs. This research uses the system dynamics method to calculate the blockchain implementation cost after identifying the key variables. As a result, using the SD technique, due to the simultaneous examination of the degree of communication between the factors and the dynamics of the probability system, the blockchain implementation cost has been calculated more optimally according to the conditions and dynamically.

Based on this 100-day horizon, the system's behavior was simulated for future periods. The study demonstrates that the implementation cost of blockchain can be significantly increased by altering variables that affect the implementation cost of blockchain, such as hardware cost, human cost, hardware cost, transaction cost, and number of blocks and transactions. At the end of the simulation period, the total cost reaches approximately 9×10^{17}, indicating a high cost level. The regression method is utilized to estimate figures, revealing that increasing the number of transactions is crucial in increasing cost.

Although the technique used in the present research is valuable and has improved blockchain implementation costs, it still faces limitations. The presented model is a hypothetical model formed by reviewing the research background and experts' opinions. Decision-making based on experts' opinions is formed based on the mental framework, the nature of the judge, and perceptual errors based on the expert's experience and skill, and therefore, the results may be different in the same conditions (of course, to some extent, this violation can be resolved by checking the inconsistency rate). In the future, an extensive survey can be conducted to validate the findings of this study. In addition, experts' opinions have been definitively collected in this research, and verb expressions and linguistic variables have not been used in the form of fuzzy methods. It is suggested that in future research, the preparation of questionnaires and the way of data collection should be closer to real-world conditions. Since in this research, the factors affecting costs based on the research background are not complete, and there may be more factors in the scope of the problem, it is suggested that in future research, in addition to collecting factors based on the research background and opinion Industrial experts, the documents of the investigated organization and the opinions of academic and industrial experts should be used simultaneously. Collecting factors in this way will lead to a complete list of elements. The spatial scope investigated in this research is limited to the study, and it is suggested that this issue be investigated more widely in future research. One of the limitations of the research was that there was no reference data for some variables, and the researcher had to survey experts to model.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Ahmadi, E., Khaturia, R., Sahraei, P., Niyayesh, M. and Fatahi, O., 2021. Using blockchain technology to extend the vendor managed inventory for sustainability. *Journal of Construction Materials*, 3, pp.1-5. https://doi.org/10.36756/JCM.v3.1.5.

Bafandegan Emroozi, V., Roozkhosh, P., Modares, A. and Roozkhosh, F., 2023. Selecting green suppliers by considering the internet of things and CMCDM approach. *Process Integration and Optimization for Sustainability*, pp.1-23. https://doi.org/10.1007/s41660-023-00336-9.

Chang, J.A., Katehakis, M.N., Shi, J.J. and Yan, Z., 2021. Blockchain-empowered Newsvendor optimization. *International Journal of Production Economics*, 238, p.108144. https://doi.org/10.1016/j.ijpe.2021.108144.

Chang, A.C., 2019. *Blockchain adoption and design for supply chain management* (Doctoral dissertation, Rutgers University-Graduate School-Newark). https://doi.org/doi:10.7282/t3-wxwf-xj62.

Dasaklis, T. and Casino, F., 2019, May. Improving vendor-managed inventory strategy based on Internet of Things (IoT) applications and blockchain technology. In *2019 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)* (pp. 50-55). https://doi.org/10.1109/BLOC.2019.8751478.

De Giovanni, P., 2020. Blockchain and smart contracts in supply chain management: A game theoretic model. *International Journal of Production Economics*, 228, p.107855. https://doi.org/10.1016/j.ijpe.2020.107855.

Durach, C.F., Blesik, T., von Düring, M. and Bick, M., 2021. Blockchain applications in supply chain transactions. *Journal of Business Logistics*, 42(1), pp.7-24. https://doi.org/10.1111/jbl.12238.

Emroozi, V.B., Modares, A. and Roozkhosh, P., 2022. Presenting an efficient scenario to deal with the prevalence of COVID-19 disease using a system dynamics approach in Iran. *International Journal of Simulation and Process Modelling*, 19(3-4), pp.122-137. https://doi.org/10.1504/IJSPM.2022.131555.

Emroozi, V.B., Kazemi, M., Modares, A. and Roozkhosh, P., 2024. Improving quality and reducing costs in supply chain: The developing VIKOR method and optimization. *Journal of Industrial and Management Optimization*, pp.0-0. https://doi.org/10.3934/jimo.2023088.

Garg, P., Gupta, B., Chauhan, A. K., Sivarajah, U., Gupta, S., & Modgil, S. (2021). Measuring the perceived benefits of implementing blockchain technology in the banking sector. *Technological forecasting and social change*, *163*, 120407. https://doi.org/10.1016/j.techfore.2020.120407.

Golosova, J. and Romanovs, A., 2018, November. The advantages and disadvantages of the blockchain technology. In *2018 IEEE 6th workshop on advances in information, electronic and electrical engineering (AIEEE)* (pp. 1-6). IEEE. https://doi.org/10.1109/AIEEE.2018.8592253.

Gurtu, A. and Johny, J., 2019. Potential of blockchain technology in supply chain management: a literature review. *International Journal of Physical Distribution & Logistics Management*, 49(9), pp.881-900. https://doi.org/10.1108/IJPDLM-11-2018-0371.

Haber, S. and Stornetta, W.S., 1991. How to time-stamp a digital document (pp. 437-455).

Kamble, S.S., Gunasekaran, A., Kumar, V., Belhadi, A. and Foropon, C., 2021. A machine learning based approach for predicting blockchain adoption in supply Chain. *Technological Forecasting and Social Change*, 163, p.120465. https://doi.org/10.1016/j.techfore.2020.120465.

Kamble, S.S., Gunasekaran, A. and Sharma, R., 2020. Modeling the blockchain enabled traceability in agriculture supply chain. *International Journal of Information Management*, 52, p.101967. https://doi.org/10.1016/j.ijinfomgt.2019.05.023.

Khan, S.N., Loukil, F., Ghedira-Guegan, C., Benkhelifa, E. and Bani-Hani, A., 2021. Blockchain smart contracts: Applications, challenges, and future trends. Peer-to-peer Networking and Applications, 14, pp.2901-2925. https://doi.org/10.1007/s12083-021-01127-0.

Kouhizadeh, M. and Sarkis, J., 2018. Blockchain practices, potentials, and perspectives in greening supply chains. *Sustainability*, 10(10), p.3652. https://doi.org/10.3390/su10103652.

Li, Y., Marier-Bienvenue, T., Perron-Brault, A., Wang, X. and Paré, G., 2018. Blockchain technology in business organizations: A scoping review. http://hdl.handle.net/10125/50454.

Modares, A., Bafandegan Emroozi, V. and Mohemmi, Z., 2021. Evaluate and control the factors affecting the equipment reliability with the approach Dynamic systems simulation, Case study: Ghaen Cement Factory. Journal of Quality Engineering and Management, 11(2), pp.89-106. [In Persian]. https://dorl.net/dor/20.1001.1.23221305.1400.11.2.1.6.

Modares, A., Motahari Farimani, N. and Bafandegan Emroozi, V., 2023b. Applying a multi-criteria group decision-making method in a probabilistic environment for supplier selection (Case study: Urban railway in Iran). *Journal of Optimization in Industrial Engineering*, 16(1), pp.129-140. https://doi.org/10.22094/joie.2023.1950386.1929.

Modares, A., Farimani, N.M. and Emroozi, V.B., 2023c. A vendor-managed inventory model based on optimal retailers selection and reliability of supply chain. *Journal of Industrial and Management Optimization*, 19(5), pp.3075-3106. https://doi.org/10.3934/jimo.2022078.

Modares, A., Farimani, N.M. and Emroozi, V.B., 2023d. A new model to design the suppliers portfolio in newsvendor problem based on product reliability. *Journal of Industrial and Management optimization,* 19(6), pp.4112-4151. https://doi.org/10.3934/jimo.2022124.

Modares, A., Farimani, N.M. and Dehghanian, F., 2023a. A New Vendor-Managed Inventory Model by Applying Blockchain Technology and Considering Environmental Problems. *Process Integration and Optimization for Sustainability,* pp.1-29. https://doi.org/10.1007/s41660-023-00338-7.

Modares, A., Farimani, N.M. and Dehghanian, F., 2024. A new vendor-managed inventory four-tier model based on reducing environmental impacts and optimal suppliers selection under uncertainty. *Journal of Industrial and Management Optimizatio*n, 20(1), pp.188-220. https://doi.org/10.3934/jimo.2023074.

Modares, A., Kazemi, M., Emroozi, V.B. and Roozkhosh, P., 2023e. A new supply chain design to solve supplier selection based on internet of things and delivery reliability. *Journal of Industrial and Management Optimization*, 19(11), pp.7993-8028. https://doi.org/10.3934/jimo.2023028.

Moosavi, J., Naeni, L.M., Fathollahi-Fard, A.M. and Fiore, U., 2021. Blockchain in supply chain management: A review, bibliometric, and network analysis. *Environmental Science and Pollution Research*, pp.1-15. https://doi.org/10.1007/s11356-021-13094-3.

Olawumi, T.O., Ojo, S., Chan, D.W. and Yam, M.C., 2021. Factors influencing the adoption of blockchain technology in the construction industry: A system dynamics approach. In *Proceedings of the 25th International Symposium on Advancement of Construction Management and Real Estate* (pp. 1235-1249). Springer Singapore. https://doi.org/10.1007/978-981-16-3587-8_84.

Omar, I.A., Jayaraman, R., Salah, K., Debe, M. and Omar, M., 2020. Enhancing vendor managed inventory supply chain operations using blockchain smart contracts. *IEEE Access*, 8, pp.182704-182719. https://doi.org/10.1109/ACCESS.2020.3028031.

Rajabi, S., Roozkhosh, P. and Farimani, N.M., 2022. MLP-based Learnable Window Size for Bitcoin price prediction. *Applied Soft Computing*, 129, p.109584. https://doi.org/10.1016/j.asoc.2022.109584.

Roozkhosh, P., Pooya, A. and Agarwal, R., 2023a. Blockchain acceptance rate prediction in the resilient supply chain with hybrid system dynamics and machine learning approach. *Operations Management Research*, 16(2), pp.705-725. https://doi.org/10.1007/s12063-022-00336-x.

Roozkhosh, P. and Pooya, A., 2023. Dynamic Analysis of Bitcoin Price Under Market News and Sentiments and Government Support Policies. *Computational Economics*, pp.1-36. https://doi.org/10.1007/s10614-023-10477-1.

Roozkhosh, P., Pooya, A., Soleimani Fard, O. and Bagheri, R., 2023b. Revolutionizing Supply Chain Sustainability: an Additive Manufacturing-Enabled Optimization Model for Minimizing Waste and Costs. *Process Integration and Optimization for Sustainability,* pp.1-16. https://doi.org/10.1007/s41660-023-00368-1.

Sterman, J. D. (2002). All models are wrong: reflections on becoming a systems scientist. *System Dynamics Review: The Journal of the System Dynamics Society*, *18*(4), 501-531.

Tian, F., 2018. An information system for food safety monitoring in supply chains based on HACCP, blockchain and internet of things.

Tipmontian, J., Alcover, J.C. and Rajmohan, M., 2020. Impact of blockchain adoption for safe food supply chain management through system dynamics approach from management perspectives in thailand. *Multidisciplinary Digital Publishing Institute Proceedings*, 39(1), p.14. https://doi.org/10.3390/proceedings2019039014.

Yadav, S. and Singh, S.P., 2020. Blockchain critical success factors for sustainable supply chain. Resources, Conservation and Recycling, 152, p.104505. https://doi.org/10.1016/j.resconrec.2019.104505.

Journal of Systems Thinking in Practice
JSTINP, *QUARTERLY*
Homepage: jstinp.um.ac.ir
Online ISSN: 2821-1669, Print ISSN: 2980-9460
Research Article
DOI: 10.22067/JSTINP.2023.84398.1075
JSTINP 2023; Vol. 2, No. 4

Barriers and Solutions to Implementing Iran's Human Resource Ecosystem: A Mixed Methodology based on Total Systems Intervention

Mohammad Mahdi Ranjbar Fordoei[a], Ali Davari[b]*, Hasan Boudlaie[a]

[a] *Department of Social and Behavioral Sciences, University of Tehran, International Campus Unit Kish, Kish, Iran.*
[b] Management *Department,Faculty of Entrepreneurship University of Tehran, Tehran, Iran.*

How to cite this article

Ranjbar Fordoei, M. M., Davari, A., Boudlaie, H., 2023. Barriers and Solutions to Implementing Iran's Human Resource Ecosystem: A Mixed Methodology based on Total Systems Intervention, *Journal of Systems Thinking in Practice*, 2(4), pp.105-131. doi: 10.22067/jstinp.2023.84398.1075.
URL: https://jstinp.um.ac.ir/article_44715.html

A B S T R A C T

Implementing the human resources ecosystem poses a significant challenge for large private and public organizations. This challenge is exacerbated by the comprehensive nature of its concepts and its dependence on the availability of rich and abundant resources. The primary objective of this research is to scrutinize the barriers hindering the implementation of the human resources ecosystem in Iran, considering the prevailing environmental conditions. The secondary goal is to propose viable steps for resolving these problems and overcoming the barriers through a comprehensive understanding of the challenges associated with implementing this ecosystem. The Total Systems Intervention (TSI) meta-methodology system was selected to achieve a holistic understanding of the system. Deploying the Total Systems Intervention framework, a systematic process was initiated to identify the system's principal challenges and pinpoint applicable methods. Nine main challenges were identified, leading to the selection of two methods—namely, the Importance-Performance Approach (IPA) and the Soft Systems Methodology (SSM)—for categorization and the development of implementation solutions. The findings, based on the perspectives of seven experts in the field of human resources, revealed that non-compliance with strategic plans with the human resource ecosystem and environmental dynamism and uncertainty are the most crucial and impactful barriers. Consequently, issues such as the lack of executive flexibility and insufficient stakeholder participation were identified as additional problems of high importance but lower effectiveness. Subsequently, the research delved into discussing methods for implementing and monitoring the ecosystem, resulting in the design of a comprehensive framework for implementation. The research underscores that successfully implementing the human resources ecosystem necessitates internal system integration and alignment among managers, stakeholders, programs, and resources. This alignment accelerates and streamlines the implementation process, highlighting the importance of a cohesive approach to realizing the system's potential.

Keywords

Human resources ecosystem, Problem solving, Systems thinking, Soft systems methodology, Total systems interventions.

Article history

Received: 2023-09-11
Revised: 2023-12-21
Accepted: 2023-12-27
Published (Online): 2023-12-28

Number of Figures: 7 **Number of Tables: 4** **Number of Pages: 27** **Number of References: 48**

****Corresponding author***
Email: ali_davari@ut.ac.ir

1. Introduction

The Human Resources (HR) ecosystem creates a living and dynamic environment consisting of people, processes, technologies, and other stakeholders active in human resources activities that interact and exchange with each other and affect the surrounding environment (Garavan et al., 2019). The HR ecosystem is divided into seven parts: recruitment and selection, performance management, learning and development, succession planning, compensation and benefits, human resources information systems, and human resources data analysis; each of these parts should interact constructively and dynamically with each other and improve the human resource management system in organizations (Donnelly and Hughes, 2022). The environmental changes in organizations, such as the development of technologies, knowledge-centered organizations, and evolution in the concept of work and specialization, have caused traditional human resource management to no longer meet the organization's needs. By not considering and adapting to these developments, it cannot be believed that human resource management can have a suitable function for the organization in the current and future conditions (Amelia, 2018), and the concept of human resource management needs to be changed and recreated towards the human resource management ecosystem. So that resource management can perform its tasks while adapting to traditional and environmental changes and take the necessary measures to improve the current human resources system (Dharmasiri, 2015).

Regarding the current state of the human resources ecosystem in the country, it can be said that now those involved in management issues have realized, with the help of existing knowledge and experience, that most of the difficulties of organizations and their managers are directly or indirectly related to human resources issues (Asadi et al., 2022). In fact, in developing and underdeveloped countries, although they have sufficient and sometimes abundant physical and natural capital, they face countless problems due to the lack of attention to human capital and the lack of development of their human resources. The correct use of human resources also requires workforce planning, efficient organizational structure, and matching of jobs and employees so that the organization does not suffer from slowness, mismanagement, incomplete employment, lack of motivation, and incompetence of employees (Fuller et al., 2019).

In terms of achieving the desired state of human resources management through the human resources ecosystem in organizations, it is possible to plan strategic human resources at the national level and coordinate the human resources structure of the organizations with it, significantly reducing the unemployment rate, modernizing the classification and evaluation structure (Donnelly and Hughes, 2022; Wieland et al., 2023). Clear job descriptions and certification requirements are necessary for specific jobs. Concurrently there is a growing trend in employee education levels and organizational structure revisions that favor unique structures, work groups, decentralization, and integration of unit responsibilities, particularly in the human resources management unit (Malik et al., 2022). Also, creating a salary structure based on the performance and effort of individuals and also based on the labor market situation in order to attract capable job seekers, creating flexibility in working hours and the workplace in order to make better use of specialists, strengthening the culture of participation and democracy for attracting the support of employees from the organization and finally paying attention to the individual motivations of employees in career success through the establishment of a career growth path to provide future managers of organizations are other suggestions (Yalenios and d'Armagnac, 2022).

In this regard, the World Economic Forum emphasized the latest official report on the state of human capital in different countries, published in 2017 (Figure 1). Despite technological advancements, a significant portion of the global human capital reserve remains underutilized, with only 62% being effectively harnessed. The report allocates Iran 54.97 points out of 100, ranking it 104th out of the 130 countries surveyed on the Human Capital Index. This score places Iran below several lower-income countries, including Tajikistan, the Philippines, Ghana, and Cameroon. In the context of the Middle East, Iran ranks 11th out of the 12 countries examined.

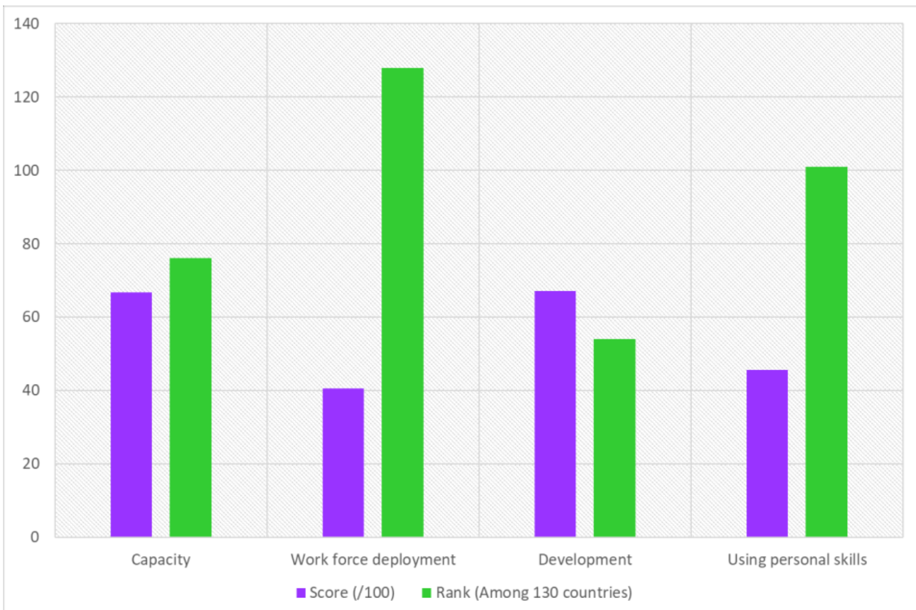


Figure 42. Iran's score and ranking, according to human capital sub-indices (source: Fraumeni and Liu, 2021).

A general look at the hiring process in companies in Iran's industries shows that no process has been defined for the entry of human resources into companies (Nafari and Rezaei, 2022), which is considered one of the main factors of the human resource challenge throughout the world (Sawan et al., 2021). The fundamental definition of the recruitment process depends on the entry of ineffective people into the organization. Providing human resources and recruiting forces requires scientific and principled research and needs assessment (Martinez, 2016). Recruiting forces without a proper needs assessment will cause the entry of inefficient forces or placement of efficient forces in the wrong position and, as a result, waste the forces' strength and the company's potential. Iran's industries, as one of the custodians of industrial development, play an essential role in this field, which can help the growth of industries by implementing the human resource ecosystem (Khoshmaram et al., 2020).

In addressing the complexities of the human resources (HR) ecosystem in the context of Iranian organizations, our research seeks to delve into crucial questions surrounding the design and assumptions underpinning this ecosystem for stakeholders. Specifically, it aims to identify the primary beneficiaries of the system and unravel the key assumptions essential for its optimal design and implementation. In order to adequately address these questions, the study will critically review the body of literature, identifying gaps in authors' knowledge of HR ecosystems and highlighting new perspectives. Subsequently, this study will explore the methodologies employed to answer our research questions, implementing selected methods to gather pertinent data. The analysis of results will provide valuable insights into the intricate landscape of the HR ecosystem in Iran, shedding light on essential assumptions, beneficiaries, and practical implementation strategies.

2. Literature review

The term "ecosystem" was coined in 1930 by Roy Clapham to denote the physical and biological components of the environment and their relationship with each other. English ecologist Arthur Tansley described the term ecosystem as a system of interactions between binoculars (a group of living organisms) and their biotope (the environment in which they live). Tansley directly emphasized the link between biotic and abiotic components (Burke and Morley, 2022). Therefore, the word ecosystem is derived from the science of biology, combining the two words ecology and system (De Stefano et al., 2018). Therefore, the ecosystem is a concept that integrates plant and animal environments, population dynamics, behavior, and evolution (Sawan et al., 2021). The ecosystem approach studies the hypotheses of human behavior in the framework of interactions between people and their environments (Hu et al., 2022). There are differences among the definitions of the ecosystem, and branches have also been inferred from these differences. However, all definitions generally have three common characteristics: 1. living elements, 2. inanimate elements, and 3. their interaction. The European Quality Management Foundation states that organizations must adequately understand their ecosystem and its place in it (Zaharov and Lobacheva, 2020).

The human resource ecosystem has become popular since the 1980s with the introduction of two models under the titles of the adaptive model and the Harvard model, which focused on integrating strategy and human capital (Tajpour and Hosseini, 2019). Creating a human resource ecosystem ensures the organization has skilled, committed, and motivated employees to strive for sustainable competitive advantage (Mauro and Borges-Andrade, 2020). The logic of the human resources ecosystem is based on presenting and agreeing on the design of methods for managing employees in the long term. This logic forms the basis of achieving a competitive advantage through the human resources ecosystem. In this way, it defines the goals and plans of the organization on how to achieve business goals through employees (Ma and Zhang, 2020).

The human resource ecosystem is a network of actors whose success and survival depend on each other. This concept states that organizations should not be considered separate actors but part of an ecosystem (Meijerink and Keegan, 2019). Ecosystem refers to elements, people, organizations, or institutions that can act as a stimulus or obstacle for companies to enter international markets. Such an ecosystem includes hundreds of elements grouped in different domains (Stone et al., 2020). The human resource ecosystem is a new way of thinking and acting for developing human resources and their successful entry into industries. All necessary systems are considered in their development and how they interact with each other (Melisa et al., 2013). To understand its ecosystem, an organization must know and understand the following components:

Organization: The organization itself is at the center of an organization's ecosystem. In an organization, important components must be defined correctly: A: Organizational leadership, B: Foundation/existential philosophy of the organization, C: Organizational strategy, D: Organizational culture, e: management structure of the organization, and: promotion of organizational performance and transformation (Zakharov et al., 2021).

Stakeholders: Stakeholders are individuals, groups, or organizations that directly or indirectly have a role or benefit in that organization because they either affect or are affected by the organization. External stakeholders are partners and suppliers (Khazaei et al., 2023), society, shareholders (Taghipour et al., 2023a), employees, customers, and government institutions (Nayeri et al., 2022). Some challenges and opportunities are obtained through interaction with the stakeholders (Ang et al., 2011).

Market/competition scene: The market is a collection of actual and potential customers, which practically becomes a competition scene due to the presence of competitors and other actors. Actors such as competitors, potential customers, new entrants, media and social networks, innovations, laws, human resources, special interest groups, and intermediaries are usually present in this scene. Some challenges and opportunities are created in the market and competition scene. Organizations must continuously create sustainable value to survive and grow in the market (Alfes et al., 2021).

Global environment Supertrends: The global environment is a relatively distant and macro environment in which organizations are more affected by its components, and these components, in turn, can determine a part of the opportunities and challenges of an organization (Taghipour et al., 2023; Ehsanifar et al., 2023). The changes that occur in the global environment have long-term effects. The time they can have is also called supertrends (Lim et al., 2020).

Based on the stated content, the previous research in this field will be reviewed, and during this review, it will be determined how the existing gap in the literature is in Table 1.

Table 23. Research background.

	Reference	Research objectives	The result of the research
1	Zakharov et al., 2021	Investigating ecosystems in personnel management in the digital economy	The results showed that it is an ecosystem formed and developed in large Russian banking organizations. Organizations must use partner companies' services to form and develop the human resources ecosystem.
2	Wang and Zhu, 2017	Investigating the impact of green human resource management on the entrepreneurial ecosystem, investigating the impact of green human resource management on green thinking, investigating the impact of green human resource management on sustainable development, investigating the impact of green human resource management on globalization	The characteristics of the zero-sum game in traditional models were analyzed, and the health of ecosystems was used to evaluate the competitiveness of species and the advantages of harmonious coexistence in order to evaluate companies and marine workers. The evaluation model is created throughout the ecosystem based on the evaluation of maritime companies and employees.
3	Ma and Zhang, 2020	Evaluating and regulating the health of the human resource ecosystem	The perspective of the human resource ecosystem helps organizations pay attention to the human resource management system as a dynamic system, and this dynamic should be created between human resource management processes such as recruitment, recruitment, training, and maintenance with the external environment.
4	Snell and Morris, 2021	Determining the processes of the human resources ecosystem, determining the operational strategies of the human resources ecosystem	The research findings show 18 dimensions for the deployment model of the human resource management ecosystem. Research results indicate the influence of green human resources management on the ecosystem of

	Reference	Research objectives	The result of the research
			entrepreneurship, green thinking, sustainable development, and globalization.
5	Meijerink and Keegan, 2019	Regulating human resource ecosystems through alignment of exchanges; Determining the landscape in human resource ecosystems of the gig economy	The perspective of the human resource ecosystem helps organizations pay attention to the human resource management system as a dynamic system, and this dynamic should be created between human resource management processes such as recruitment, recruitment, training, and maintenance with the external environment.
6	Garavan et al., 2019	An ecosystem perspective on international human resource development, providing a framework for implementing the human resource ecosystem	They have provided a framework in this area that includes interdependence, power center, bargaining power, and relationships between employees and managers, which will develop human resources at the international level.
7	Sawan et al., 2021	Determining the environmental factors affecting the determination of strategies, those in charge of recruiting and providing human resources, and human resource planning based on industry job competencies	Determining the right number of people, technical knowledge, group orientation, evaluation of professional competencies, legal requirements, implementation of the recruitment process, employee empowerment and fairness in attracting human resources and the factor of competition in each of the dimensions affecting employment have been given the highest priority.
8	Amelia, 2018	Determining competency criteria, matching competencies with jobs, human resource recruitment measures, human resource supply measures, and internal and external consequences, prioritizing these factors	Digital Human Resources presents case studies and detailed interviews with HR managers of large multinational companies and provides comprehensive empirical evidence for academics and students interested in human resource development in today's digital environment. This book will also be valuable for managers who want to adapt to the role of human resources in their companies or organizations.
9	Martinez, 2016	Developing human resources in the digital space, adapting the ecosystem of human resources to e-commerce	Human resource management functions positively and significantly affect the ecosystem for the companies studied. Also, the function of providing human resources, the function of training human resources, the function of improving the quality of relationships, the function of creating value, and the function of performance evaluation have a positive and significant effect on the human resources ecosystem.
10	Dharmasiri, 2015	Determining the functions of human resources management on the ecosystem, the function of improving the quality of relationships, the function of creating value, and the function of evaluating performance in the human resources ecosystem.	This research includes 10 main components in the human resources ecosystem: targeting, attraction, training, growth, career path, maintenance, talent management, reward, succession, and employee satisfaction, which organizations should consider.
11	Malik et al., 2022	Examining the ecosystem of human resources in the electronics industry; Identifying the components of the human resources ecosystem	It should be noted that the ecosystem approach is an obstacle in the way of other management and protection methods such as Biosphere reserves, protected areas, and single species protection programs or other methods that are carried out under national policies and legal frameworks are not. Instead, this approach can integrate all other approaches and methods to deal with complex situations.

Examining existing literature reveals a wealth of research dedicated to the human (HR) resources ecosystem, providing valuable insights into its various dimensions and applications. However, a notable gap exists in the precise elucidation of the ecosystem's structure concerning the specific groups of stakeholders under investigation. Many studies have overlooked the involvement of diverse layers within the system, resulting in a theoretical vacuum regarding the clarity and inclusivity of the designed ecosystem. To address this gap, our research endeavors to conduct a meticulous and in-depth analysis, delving into the nuanced perspectives of different stakeholders. By doing so, it aims to uncover hidden opinions and perspectives across various layers of the HR ecosystem. Through this comprehensive exploration, our research seeks to make informed decisions about the requisite assumptions for designing a legitimate and inclusive HR ecosystem, thereby contributing to enhancing and refining existing .theoretical frameworks in this field

3. Methodology

In line with the central research question focusing on the assumptions in the design of the human resources ecosystem in Iran, this section delineates the research methodology, data collection method, and other pertinent details. Two distinct approaches are adopted for comprehensive data collection and analysis. The primary approach employs the Total Systems Intervention (TSI) methodology. Simultaneously, a complementary method is employed to grade and identify the significance of various indicators. This secondary approach leverages the Importance-Performance Approach (IPA), as Bi et al. (2019) outlined. The forthcoming sections will expound upon the specifics of the research design, interview seven experts (from a statistical population of all HR experts and managers in Tehran), and obtain data gathering procedures, providing a comprehensive overview of the methodological framework guiding this study.

3.1. Total systems intervention (TSI)

The purpose of TSI is to implement the requirements of critical systems (Tayebnia et al., 2023). In short, it sees the conditions of the issues as full of disturbances that cannot be understood and analyzed based on only one point of view; that is why it believes that they should be looked at from different points of view. Perhaps, like what is summarized in the metaphors, when the facilitators and the participants have agreed on the topics and issues of progress, it is time to choose a methodology or a set of systematic methodologies to manage the disorder and face the issues (Zare Mehrjerdi and Bakhshandeh, 2023). This choice should be made with the knowledge of the strengths and weaknesses of the methodologies at hand, which are revealed by critical systems. It is important to consider pluralism when choosing a methodology. Different methodologies can be used to examine different aspects of the problem and ensure that all interests are considered technically critical and emancipatory. In addition, the initial choice of methodology should be subject to continuous review and may change as the nature of the disorder changes. This way, TSI leads to an intervention continuously examining and addressing the main issues. According to the explanations, it is clear that because TSI uses all system methodologies, it should be described as a meta-methodology. The following six principles form the basis of this meta-methodology (Dehghan Nayeri et al., 2020):

(11) The conditions of the issues are too complex to be understood from one point of view, and the consequences they create are too complex to be dealt with by immediate solutions;
(12) Therefore, the situation of issues and concerns, the consequences and problems they contain must be evaluated from different perspectives;
(13) After the main issues and topics are identified, an appropriate choice of methodology(s) should be made to guide the interventions;
(14) It is necessary to gain a complete understanding of the strengths and weaknesses of systematic methodologies and use this knowledge along with understanding the main issues and issues to choose appropriate methodologies;
(15) Different systems perspectives and methodologies should be used to define and examine different aspects of organizations and their issues in a complementary way; TSI follows systematic cycles during its three phases.
(16) Facilitators and participants are involved in all stages of the TSI process.

In this research, using the TSI approach, two methodologies have been selected and used for evaluation, the schematic of which can be seen in Figure 2:

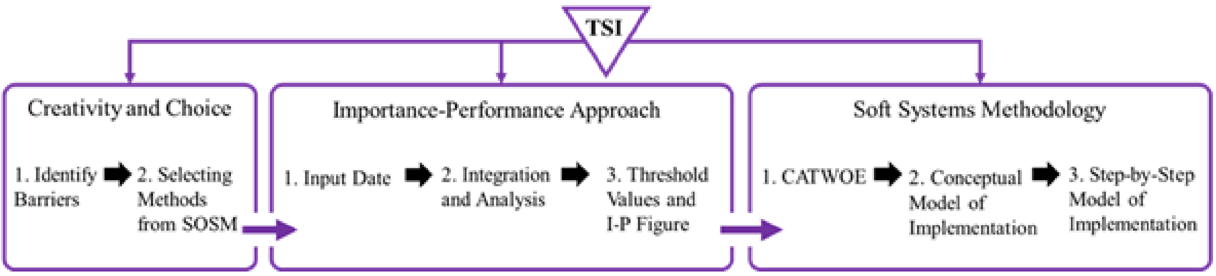


Figure 43. Schematic of the modelling stages and investigation of the problem under the TSI framework.

After presenting the method and methodology of the work, according to the steps of the action research method (Pashaa et al., 2023), it is time to use the idea and meta-methodology in the target organization, which is discussed below. As stated in the introduction, TSI has three main stages of creativity: selection of dominant methodologies and implementation. This section describes how to deal with each of these stages (Mirhosseini et al., 2021). After identifying the problems and barriers of ecosystem implementation in the previous phase, dominant methodologies should be selected to solve them in the second phase. At this stage, the appropriate methodologies to solve the issues raised have been selected based on the framework of ideas understanding the context of the issues in the SOSM (Checkland and Poulter, 2020).

The challenge lies in determining high-performance task subsystems amidst the complexity and pluralism of the ecosystem. The intricacy arises from numerous controllable and uncontrollable factors influencing the process of breaking down subsystems into an executable operational plan. The organizational culture further contributes to the complexity of the issue's conditions. Participants adopt a pluralistic mindset, acknowledging that multiple stakeholders may propose various solutions, each viewing the problem from a unique perspective. The ultimate goal is to reach a consensus among these diverse viewpoints. Therefore, according to the research conducted in the methodologies suitable for these conditions and according to the position of the problem in the SOSM table, the SSM methodology (Checkland and Poulter, 2020) has been chosen as the dominant methodology, but considering that one of the stages of TSI is to recognize the Barriers and root problems. This step deals with structuring the obtained options using the IPA approach (Bi et al., 2019).

These methodologies are right at the opposite point of complex methods, and this method focuses on recognizing the problematic situation. According to Checkland and Poulter (2020), the list of instructions for improvement is worthless, and only practice and learning are valuable and lasting (Checkland & Poulter, 2020; Faezirad & Khoshnevisan, 2023). This methodology adopts an action research approach to address problems, emphasizing a knowledge-based foundation for generating solutions and improving conditions. Following Checkland's seven-stage model for SSM, the process begins with an unstructured problem situation (Step 1) and progresses to a structured state through analysis and creating a rich picture (Step 2). The third step involves using CATWOE elements (Customer, Actor, Transform, World view, Owner, Environment) to formulate root definitions for the system. Subsequently, a model of targeted activities or a conceptual model is developed in Step 4. Step 5 entails comparing the existing situation with the conceptual model, identifying improvement measures and potential changes in Step 6.

For the implementation of TSI, its modified version was used, which, according to what Jackson (2020) says, the three phases of creativity, selection, and implementation should be repeated in this phase. Therefore, meetings were held with the relevant human resources ecosystem planning group for the creativity stage to update the ecosystem indicators (Dehghan Nayeri et al., 2020). The organization's challenges in progressing toward ecosystem implementation were documented during brainstorming sessions. Key issues included identifying necessary steps and formulating an operational plan to ensure successful implementation. Analysis of discussions and diverse proposals posed a challenge, necessitating a consensus among group members. To address this, researchers recommended employing methods from the pluralism approach. Given the group's familiarity with IPA and SSM, these methodologies were chosen to navigate and resolve challenges during the implementation phase in the organization.

3.2. IPA technique

The performance-importance analysis (Bi et al., 2019) is a multi-indicator model (Taghipour et al., 2023 b). The effectiveness of this model strongly depends on its analytical indicators. In the IPA model, each index is evaluated from the perspective of two dimensions: "importance (ideal situation)" and "performance (current situation of factors)". This model uses essential criteria to determine where resource allocation is most critical. A performance-importance analysis matrix structures the IPA technique. This matrix consists of two axes, the X-axis showing the performance and the Y-axis of its importance.

This matrix is shown in Figure 3, which is divided into four quadrants, and each quadrant has a specific strategy that helps the decision-making process. This matrix determines the degree of priority of indicators for improvement (Bi et al., 2019).

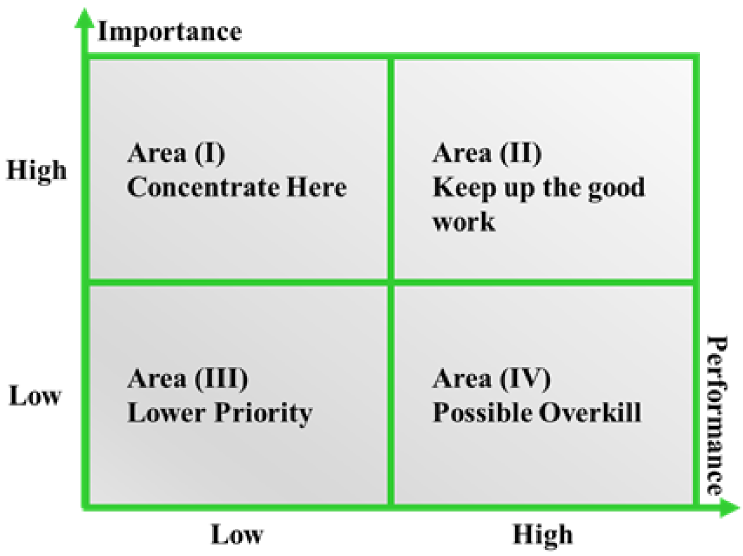


Figure 44. Performance-importance analysis matrix and quadratic model (Bi et al., 2019).

Importance shows the relative value of indicators in quality. Since the separate analysis of the performance dimensions and importance dimension data, especially when both sets of data are studied simultaneously, may not be meaningful. Therefore, the data related to the importance level and the performance of indicators on the 2D network are displayed in the above figure. This two-dimensional network is called the importance/performance matrix or IP matrix. The role of the matrix, which consists of four parts or quadrants, and there is a specific strategy in each quadrant, is to help the decision-making process. In the IPA model, indicators can be measured on a scale of 5, 7, or 9 degrees, and data related to their importance and performance level is collected using a questionnaire. For this purpose, customers are asked two questions about each index, the importance of the desired index, and the level of performance in that index.

First Area: In this area, the process importance of the process is very high, but the process performance is weak, so the processes in this sector are vulnerable and should be prioritized for improvement. Perceived characteristics are important for people, but the organization's performance level in those characteristics is low. This quadrant shows the weakness of the organization or company. The basic point is that the inability to identify the characteristics in this quadrant causes low customer satisfaction. Efforts to improve should be given the highest priority because the main weakness is in this area (Bi et al., 2019).

Second Area: This quadrant is considered to be the main strength of the organization, which should be continued. The importance of the process is very high, and the performance of the process is strong, so the processes of this sector are maintained and given more attention as competitive advantages.

Third Area: In this quadrant, the specified factors are unimportant. The organization is also weak in those criteria. On the other hand, since they are not very important, the company should not focus too much on this sector and waste its resources. Only limited resources should be used (Ramezani et al., 2021).

Fourth Area: In this quarter, the criteria are of low importance, but the company's performance in this sector is high. In this section, resources are wasted. In other words, the resources allocated to these features are more than necessary and should be spent elsewhere. This model is known as the quadratic model. It is an area where the importance of the process is low. However, the performance of the process is very strong, so the processes of this department cause waste in the organization and should be eliminated or properly exploited. The steps of IPA are as follows: First step: First, effective indicators should be extracted based on the goal of the problem. Second step: Determine the importance of the influencing factors. b_{jp} and c_{jp} represent the importance and performance values, respectively, which are determined for the j_{th} attribute by the p_{th} decision maker or customer. A Likert scale can characterize these values. In this method, a 5-point Likert scale is used. Step 3: Use the geometric mean and integrate the opinions of all decision-makers or customers. Saati suggests that using the geometric mean is a more effective way to express the collective opinion of several decision-makers. Thus, b_j is the final importance value, and c_j is the final performance value of the j_{th} characteristic, which results from the collective opinion of p customers or experts. In order to study more closely, the steps of this method in the research Bi et al. (2019) can be examined.

3.3. Soft systems methodology (SSM)

SSM soft systems methodology was proposed for the first time in 1972 by Checkland at Lancaster University, and the first article about SSM titled (Towards a System-Oriented Methodology for Solving Real World Problems) was published in Systems Engineering Journal by Peter Checkland in 1972. Print the receipt. SSM is an action research method that creates learning through research into problem conditions (Checkland and Poulter, 2020). In other words, since this method is an action research method, it not only causes intervention in problematic situations but also causes learning from this intervention by creating feedback loops; the methods used to implement SSM are extensive. However, the conceptual basis used is permanently fixed. In SSM, targeted conceptual models, each of which can be interpreted in several ways, are a means that provides a structure and framework through which discussions between people are guided and an agreement is reached between people with different and sometimes conflicting views (Cabrera et al., 2023; Wieland et al., 2023). The most famous and common research method in soft operations is the soft systems methodology (SSM), an action research method that creates learning through research in problem conditions. This methodology uses a seven-step process, according to Figure 4.

In the first stage, the problem in the real world is discovered, and its location is considered; in this stage, it has been specified what exactly is looked for, and the general space of the problem is drawn (Checkland and Poulter, 2020). In the second step, the situation of the problem, the people involved, and the structure of the problem are drawn in the form of illustrative images. These are simple images of those things that people feel are the most important aspects of the situation under investigation. These images show the problems related to the situation with the rapid modeling of the systems and help to provide a tool for initial recognition by comparing the model with real actions. The third step: In this step, the real world enters the conceptual and systemic world, and the fundamental definition of the problem is presented.

Fundamental definition: It is a sentence that describes the ideal system, its goals, the people involved in the situation, the people affected, and the influencer. A basic definition is derived from the first and second steps using a CATWOE technique. Therefore, it is possible to create a set of fundamental definitions, which group discussions will help to reach an agreement on a fundamental definition (Checkland and Poulter, 2020).

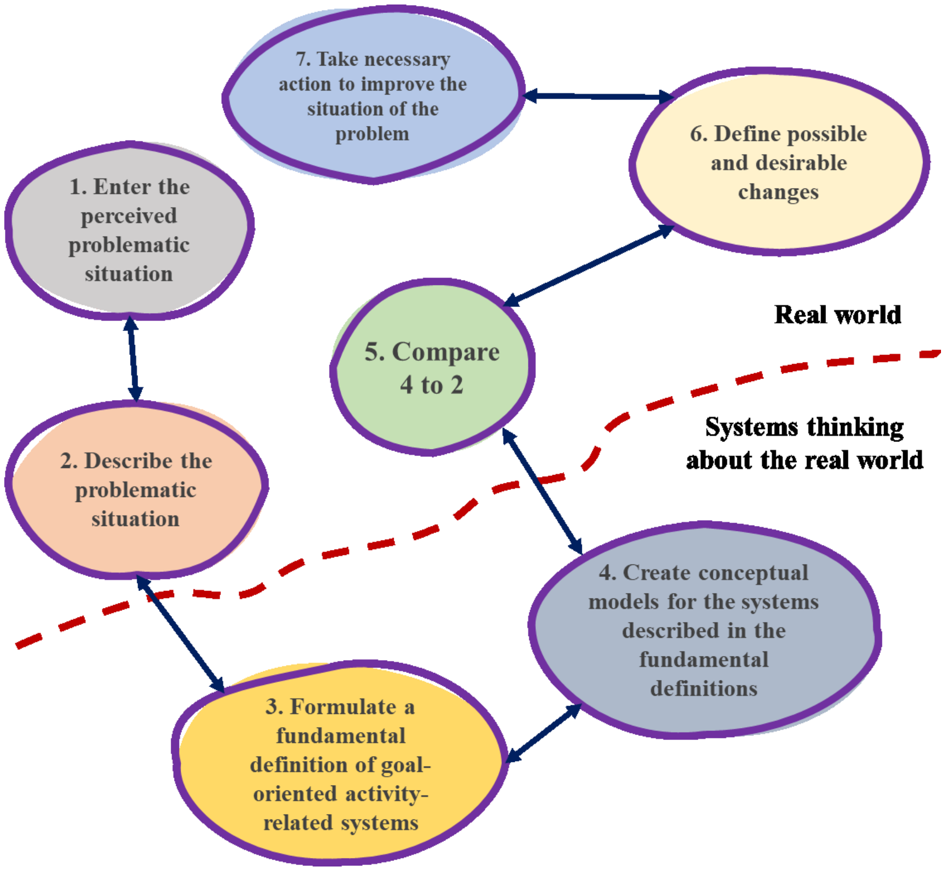


Figure 45. Seven main stages of soft systems methodology.

Fourth stage: Creating a conceptual model: A conceptual model, which represents activities with relevant relationships, is created using the basic definition. The model process consists of the following:

Using imperative verbs, express the necessary activities that must be performed

(17) Choose activities that can be performed alone
(18) Put these activities in one row and put other activities that are related to these activities in the next rows.
(19) Show the dependence between activities using vectors
(20) Move the arrangement of activities to avoid overlapping vectors as much as possible.
(21) Finally, check if your model has system features.

System features: 1- A goal in progress 2- A means to evaluate performance 3- Decision making process 4- System components 5- Components that have mutual effect 6- Environment 7- Boundary between systems and environment 8- Resources 9- Continuity. The model should have five to nine activities that are related to each other based on logical dependencies.

Fifth stage: Comparing the conceptual model with the real world: This step compares steps 2 and 4. In this step, the model built in the previous step is compared with what is in the world and shown in step 2. This work changes the conceptual model to the real world. The result of this step may lead to repeating steps 3 and 4. Sixth stage: Determining possible and desirable changes: In this step, whether the methods proposed in the previous steps will improve the system is determined. In other words, possible and desirable changes are identified in the sixth stage. After discussion and exchange of opinions between analysts and people involved in the issue of changes, they are approved. Structural, procedural, and behavioral changes show all kinds of changes in this stage. Seventh stage: Improving the situation of the problem: In this step, it is determined how the changes of the previous step will be implemented. In the seventh stage, the changes mentioned in the sixth stage are implemented, and a new iteration can be started. Based on what was discussed in the methodology section, the research steps were generally described, and it was determined what methods were used for analysis. Based on this, the various steps claimed will be implemented in the next part.

4. Implementation and results

4.1. The first stage: creativity

Based on TSI steps in the first phase, creativity is needed to understand issues and concerns related to the human resources ecosystem, with the help of tools such as social paradigms and organizational metaphors (Mingers & Rosenhead, 2004; Sydelko et al., 2024). At this stage, in the beginning, the Barriers to the implementation of the human resources ecosystem have been identified, and then, according to the literature review and studies conducted by the researchers in the case of science and technology parks in Iran, some of the Barriers to the implementation of the human resources ecosystem, which are: the lack of appropriate culture for the implementation Ecosystem, procedural order and lack of executive flexibility, Barriers related to the formation of subsystems and specific functional units, structural and cultural Barriers to the implementation of new procedures, environmental uncertainty, and organizational dynamics, external policies and laws. Accepted, the weak participation of the stakeholders in establishing the ecosystem, the lack of connection between the goals of the ecosystem and the organizational resources, and the lack of skills of managers in using management tools for the optimal allocation of resources were introduced as important concerns. In the end, among them, two main challenges are "the lack of clear strategies for the implementation of the human resources ecosystem and the lack of satisfaction and cooperation of the employees for its proper implementation" and "the lack of trust of the executive managers in the results obtained from the implementation of the human resources ecosystem and not having the necessary expertise in the field Allocation of resources and the absence of a clear connection between the resources of the organization and the needs of the ecosystem, which is a kind of environment over other factors and of course can be solved by the researchers, were chosen. According to them, the dominant issues identified are:

(22) How to form specific sub-systems and functional units so that they have an executive guarantee and involve the participation of the organization's employees.
(23) Simulating the results of implementing the human resources ecosystem and its prioritization, as well as how to allocate resources for its implementation optimally.

According to the review of the literature and the prevailing conditions of public organizations, including in the organization in question, if the procedures related to the designed ecosystem are derived from the opinions of their executives in the organizations and their compilation is done from the bottom up, it can be optimally Attract the participation of these people for the implementation of the ecosystem and in this way give a suitable answer to the first problem. Also, one way to gain managers' trust is to use methods to predict the future. The results of the forecast should be a source for managers to make decisions, so their process should be undeniable and logical in the eyes of the relevant managers so that it can make them believe in the implementation of the ecosystem in the future so that the second problem can also be answered appropriately.

4.2. The second stage: selection

In the continuation of the process of choosing the dominant methodology, because the initial agreements have been made in the selection of ecosystem indicators for their prioritization and the allocation of resources, this study faced a unifying and still complex problem, which, according to the positions of that problem in the SOSM table, from the IPA and SSM methodologies It has been taken as one of the most used methods in the field of policy making and decision making, which will be after TSI steps.

4.3. The third stage: implementation of TSI

First, the IPA method was implemented, and its contents were presented. Here, the IPA method is customized according to the nature of the problem. In this matter, importance, and performance are the main criteria; in this context, performance is a word with a positive meaning. Therefore, the performance of barriers has been considered negative (the greatest amount of destruction/inhibition for implementing the human resources ecosystem). In the following, the input Table 2 is presented, which was obtained from the point of view of seven experts in the field of human resources. These seven experts have at least 5 years of experience in human resources and are working in the headquarters and regional units of the mentioned government organization.

Table 24. Barriers and input data of 7 experts

Code	Barriers	I1	I2	I3	I4	I5	I6	I7	P1	P2	P3	P4	P5	P6	P7
A1	Absence of proper culture for the implementation of the ecosystem	5	1	5	3	2	2	2	5	3	1	4	2	5	5
A2	Prescriptive procedures and lack of executive flexibility	3	2	5	4	5	2	2	2	2	2	4	2	2	5
A3	Barriers related to the formation of specific sub-systems and functional units	3	3	3	4	1	4	1	1	4	2	3	1	5	2
A4	Structural and cultural barriers to the implementation of new procedures	5	1	1	2	4	4	1	4	4	2	4	3	3	2
A5	environmental uncertainty and organizational dynamics,	3	5	4	4	3	1	4	1	2	1	4	4	1	4
A6	Foreign policies and approved laws	1	3	1	4	4	1	4	1	2	3	2	4	1	4
A7	Little participation of stakeholders in establishing the ecosystem	1	5	4	4	1	5	4	2	4	5	4	2	2	4
A8	Ecosystem objectives are not related to organizational resources	4	3	3	3	3	1	4	1	1	5	4	2	4	1
A9	Lack of managers' skills in using management tools to allocate optimal resources	1	1	5	1	3	1	3	1	2	4	1	3	3	3

After collecting the experts' data using a 5-point Likert scale, these data are aggregated by geometric mean and converted into a single value for each obstacle. A threshold value is also considered for both criteria. The examination of Barriers and the average obtained are specified in Table 3.

Table 25. The result of the analysis of the IPA method and the obtained threshold limit.

Barriers	P(Avg)	I(Avg)
A1	3.1386	2.4939
A2	2.5170	3.0401
A3	2.1879	2.3796
A4	3.0224	2.0648
A5	2.0000	3.1203
A6	2.1193	2.1193
A7	3.0683	2.8690
A8	2.0648	2.7839
A9	2.1552	1.7226
Threshold Value	2.4748	2.5104

Based on the obtained threshold, whose lines are red, it can be seen that Barriers 5 and 8 have the highest level of deterrence and importance. Also, barriers 2 and 7, despite their high importance, have a low deterrence rate is low. Likewise, the criteria below the red horizontal line are less critical.

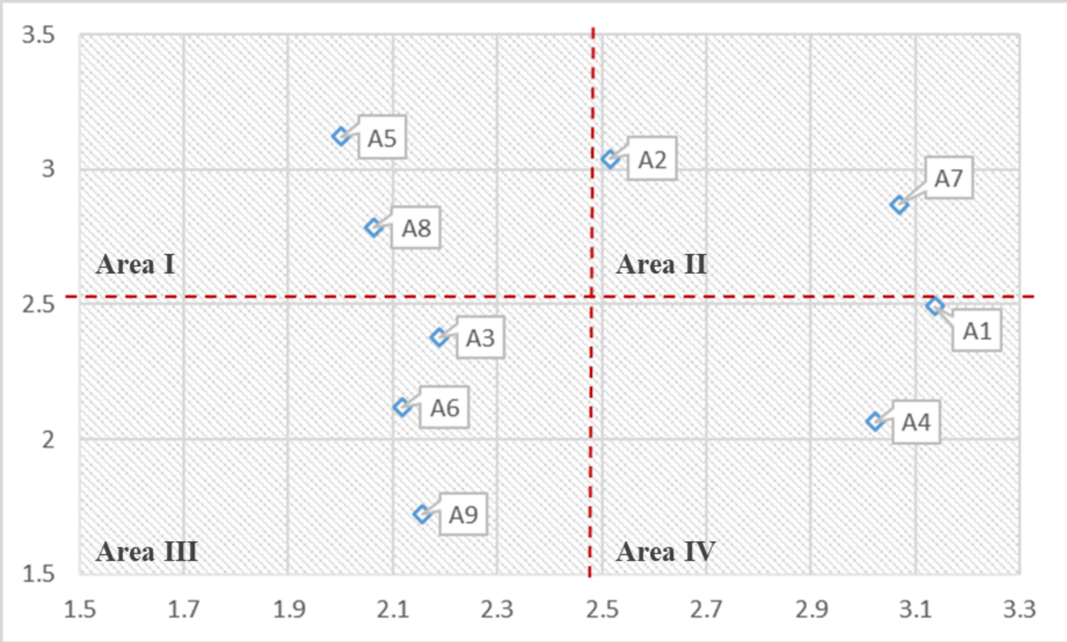


Figure 46. Location of barriers in performance-importance chart

Based on Figure 5, it is clear that more focus should be placed on the issue of aligning goals and planning, stakeholder participation, robust planning to face uncertainty, and executive flexibility. In the same way, according to the opinion of the experts, it became clear that in order to remove these barriers and solutions by the SSM method and with a precise definition of the system and its main actors, a solution should be found for the implementation of the human resources ecosystem.

For this purpose, following steps one and two of the SSM method during the formation of the meetings, in the third step, the definition of the roots with the help of CATWOE elements in Table 4 and according to the principles presented by Mingers and Rosenhead (2004), for the ecosystem executive system in the organization was explained as follows: "A system owned by the primary stakeholders of the company, and jointly managed with the human resources department and other department representatives, has effectively translated strategic human resource plans into actionable steps to achieve our planning objectives. However, this system is currently constrained by financial, time-related, cultural, and structural limitations."

Table 26. CATWOE elements

C	**Customers**	The head of the organization / main owners and shareholders / employees of the organization's departments
A	Actors	Strategic planning department / elected representatives from other departments
T	Transformation	Transforming strategies into operational measures with high performance guarantee
W	World view	A system that leads to access to strategic goals in the organization
O	Owner	Head of the organization
E	Environmental constraints	Lack of proper culture and structure for implementation, time and financial limitation

After explaining the root defenitions, the conceptual model of the activity was extracted based on it in step 4. According to group discussions in numerous meetings and research conducted in similar organizations, such as existing models in the human resource ecosystems of different countries and companies, especially in public organizations, a conceptual model related to the next stage was drawn.

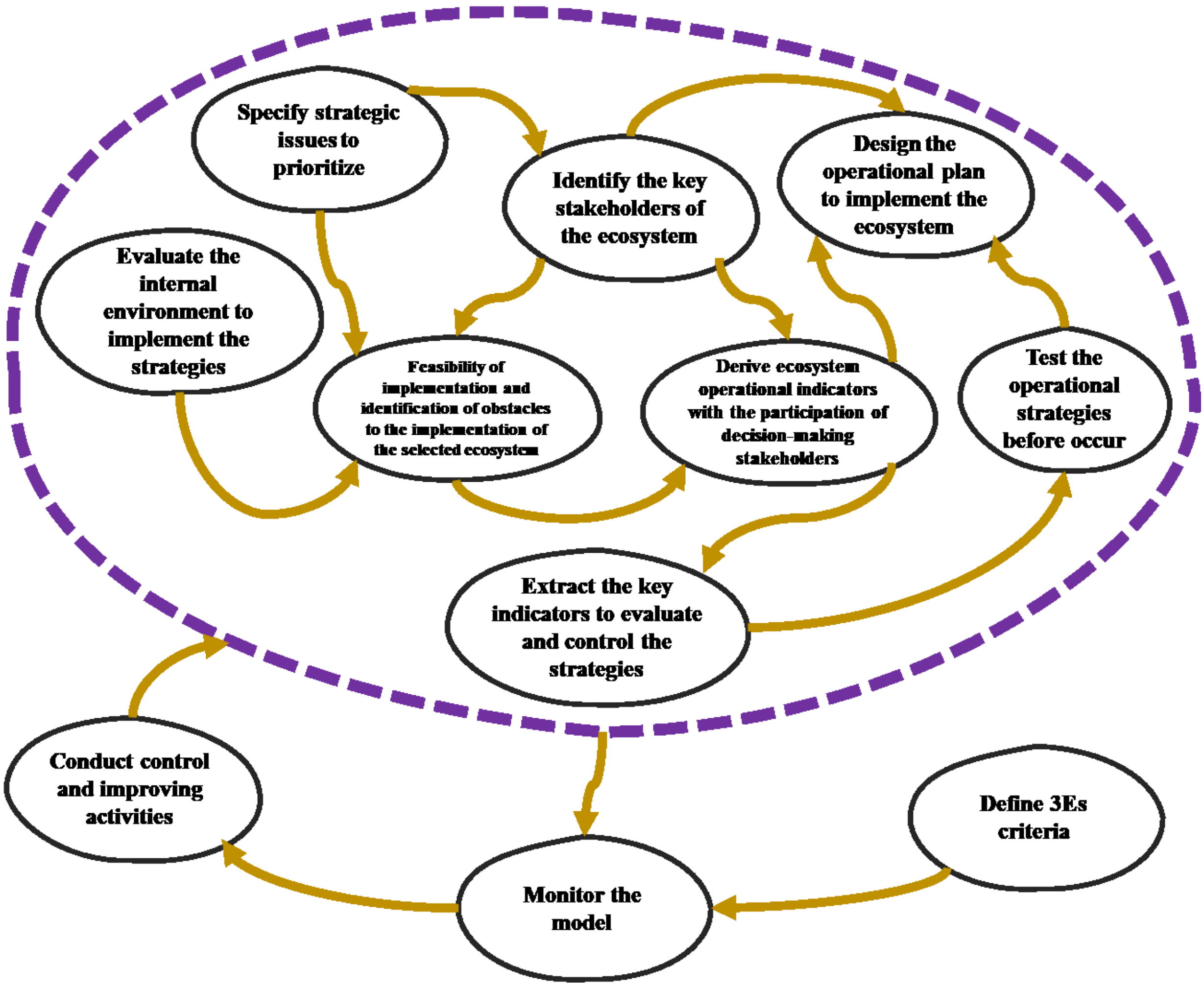


Figure 47. The conceptual model of the human resources ecosystem implementation system in a public organization

As can be seen in the conceptual model, in order to measure the validity of the model according to the three criteria (3E) of adequacy, efficiency, and effectiveness9, appropriate measures have been defined, and these three criteria are, respectively:

A. Adequacy: Does the conversion process work properly?
B. Efficiency: Is the conversion process done with minimal resources?
C. Effectiveness: Does the conversion process lead us to the main goals?

All three defined criteria were examined during group meetings. In this way, the adequacy of the model was obtained by attracting the opinion of experts so that each person admitted that the model and the activities defined in it are sufficient to implement the human resources ecosystem and, further, about the efficiency standard through comparison, which was carried out with the previous process to implement human resources management in the organization in question. Its efficiency was confirmed, and finally, the subject owners confirmed the model's effectiveness, considering that the extracted activities were based on the goal of implementing the human resources ecosystem.

In the fifth stage, the comparison of the conceptual model with what is happening in practice in the target organization was discussed, and improvement proposals were presented in the form of necessary steps to implement strategies in organizations similar to the target organization, as has been seen in Figure 7. and thus, the sixth stage was implemented.

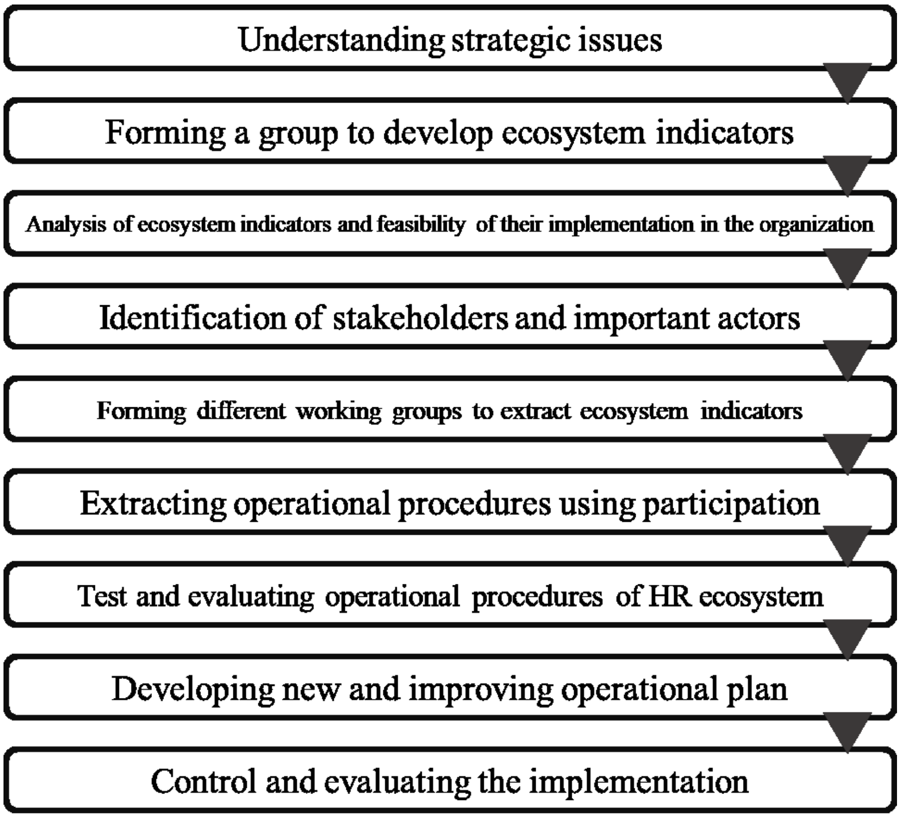


Figure 48. The steps of implementing the human resources ecosystem in a public organization.

The steps in Figure 7 were extracted to implement the strategy in a government organization using an action research method. They were implemented in practice, so the seventh stage of SSM was also completed. Thus, TSI meta-methodology was used in the organization in question, and the themes were used. The research led to developing a roadmap for implementing the human resources ecosystem in similar organizations, which is introduced in the next section.

Before stating the benefits of implementing the ecosystem in this section, the necessary guidelines are given as fully operational recommendations to the human resource planning group for implementing selected ecosystem indicators (which in public organizations are usually determined by those in power or the government). For the proposed model, due to the benefit of systemic methodologies, several advantages can be mentioned, among the most important of which are combined methods of extracting and evaluating human resources ecosystem indicators and also reducing the distance between the planning and operational layers by attracting the participation of stakeholders and executives. The strategy is to prepare the operational plan for the human resources ecosystem. Below are the advantages and other points of the presented model:

• Ease of implementation steps and high adaptability to special conditions in each organization.
• The pragmatic and action-oriented aspect of the model makes it attractive to implement.
• Learning strategy and paying attention to culture are the basic principles for implementing strategies.
• Reducing the risk and costs of strategy implementation by simulating them in a virtual environment.
• Having the flexibility to face environmental changes and uncertainties in the organization.
• Preventing the interference of individual emotions in the formulation of strategies due to the commitment to the results of group work.
• Economic efficiency of the model for implementation due to the use of the power of people within the organization.

Of course, in the beginning, it may take much time to implement. However, in the future, every time the roadmap is used, the learning will lead to its completion, increasing the strategic knowledge of people and reducing costs, and things like this, all of which are somehow the result of using the methodology. - It is a system in the human resources ecosystem that has been approved by the people in the organization's human resources department.

5. Discussions and managerial insights

The human resources ecosystem can positively contribute to the innovative activities of the organization. The human resources ecosystem also positively affects employee engagement, leadership, managers' motivation to learn, promotion of learning culture, and development of social capital (Sheehan et al., 2014). Emerging technologies, in particular, play a key role in helping to find innovative ways to help people of all ages develop knowledge and skills (Molvey, 2021). During this research and in the stages of implementation of IPA and especially SSM methodologies, in the framework of TSI, information about the benefits and importance

 DOI: 10.22067/JSTINP.2023.84398.1075

of the human resources ecosystem and its implementation in the studied organization and in general in Iran was obtained. Also, with field surveys, it is possible to provide the context for implementing such systems in organizations and be a starting point for organizations to move their view from the traditional approach to human resource management to newer paradigms such as the human resource ecosystem. This issue becomes doubly important because municipalities are one of the custodians of the growth and development of the urban economy. According to the mentioned materials, it can be said that what will happen if the focus is on the ecosystem of human resources:

(1) Recognizing and consciously focusing on the strengths and areas of human resources that can be improved, which leads to the compilation of accurate and local resources in this area.
(2) By focusing on this ecosystem, human resources planning can be improved in different horizons (short-term, medium-term, and long-term).
(3) By paying more attention to the ecosystem, it is possible to help improve or redesign human resources’ structure, processes, activities, and systems.
(4) Using different criteria leads to an increase in the share of human resources in realizing business goals and strategies.
(5) Using different performance indicators better describes human resources’ contribution to organizational performance.
(6) Detailed investigation and analysis of the human resources ecosystem will increase the effectiveness of this ecosystem and its seven subsystems.
(7) Addressing the fundamentals of the human resources ecosystem will strengthen the efficiency of the seven parts of the ecosystem, leading to a better interaction of the subsystems.
(8) One of the emphases of the human resources ecosystem is to create a learning environment for employees. Creating such an environment in the ecosystem is necessary to promote learning from experiences in the entire ecosystem.
(9) Considering that this issue of the human resources ecosystem has been raised as one of the new trends in human resources management, its investigation in Persian sources is essential, which will lead to improving the scientific level in this field.

6. Conclusion

Iran's industries, which, despite technological growth, still have a high dependence on human power, and in other words, with the introduction of technology and machinery into the field of activity of these industries, contrary to expectations and contrary to what is seen in the world, human power still has the main say. Even though technology is a substitute for human power in many industries, production lines hire less but more expert human power due to technological development. Unfortunately, this issue has not happened in Iran's industries, and this study shows a reverse procedure in this rule. Considering that there are major challenges in the country's human resources field today, this problem has doubled the problems of Iranian industries. Moreover, this issue has created severe challenges for Iran's industries since today's generation is looking for mechanized and more leisurely activities and is interested in something other than hard work. Also, with the investigations carried out in the empirical literature, it has been established that the concept of the human resource ecosystem is a new and innovative topic that has been neglected by researchers in domestic research and has received less attention in foreign research. By conducting more extensive research in this field, it is possible to help develop the theoretical foundations and concepts of the human resources ecosystem and the development of industries.

Therefore, this research aimed to design and implement a framework for analyzing the barriers to creating a human resources ecosystem, relying on deep systemic views and critical thinking. This research's main question was, what barriers slow down or fail to implement this ecosystem in public sector organizations in Iran? The second question that challenged us in this field was how, knowing these barriers, have barriers solved and overcome them. Therefore, in order to solve this problem, a series of approaches were chosen. At the beginning of facing the problem, the system was discussed with comprehensive systems interventions. Then, using the TSI framework, the main barriers to implementing the human resources ecosystem were identified, and barriers in terms of their importance and effectiveness should have been understood. By examining the framework of TSI and the tools it provided, the IPA approach was chosen for this purpose. This approach, based on the opinions of 7 experts, examined the barriers. Then, it identifies the most important barriers that impact the system (negative performance) most. After this stage, the experts' views were focused on stakeholders, flexibility, environmental uncertainties, and, most importantly, the non-compliance of strategic plans. At this point, the issue is investigated and recognized using the soft systems technique, workable solutions are organized to be implemented, and the obstacles to the human resources ecosystem are eliminated. Ultimately, the procedure for its implementation was determined step by step.

The present study opens avenues for future research in several critical areas within human resource ecosystem management. Firstly, there is a promising avenue for research to delve into identifying and exploring human resource ecosystem enablers and understanding the factors that facilitate the successful implementation and functioning of such ecosystems within organizational contexts. Additionally, the emergence of Human Resource 4.0 presents an intriguing area for investigation, exploring the integration of advanced technologies, artificial intelligence, and data analytics in shaping the future landscape of human resource management. Future research can benefit from employing a mixed-methods approach, combining hard and soft operations research techniques to understand the intricate dynamics within the human resource ecosystem comprehensively. Moreover, employing innovative Multiple Attribute Decision Making (MADM) methods such as COCOSO (Comprehensive Compromise Solution) and WASPAS (Weighted Aggregated Sum Product Assessment) can offer a quantitative framework to assess and quantify the outcomes of this research, providing a more nuanced understanding of the complex interplay of factors involved in effective human resource ecosystem management.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Alfes, K., Veld, M. and Fürstenberg, N., 2021. The relationship between perceived high-performance work systems, combinations of human resource well-being and human resource performance attributions and engagement. *Human Resource Management Journal*, *31*(3), pp.729-752. https://doi.org/10.1111/1748-8583.12310.

Amelia, P., 2018. Digital HR: A Critical Management Approach to the Digitalization of Organizations. *SSRU Journal of Management Science*, *5*(2).

Ang, J.B., Madsen, J.B. and Islam, M.R., 2011. The effects of human capital composition on technological convergence. *Journal of Macroeconomics*, *33*(3), pp.465-476. https://doi.org/10.1016/j.jmacro.2011.03.001.

Asadi, H., Barati, O., Garavand, A., Joyani, Y., Kahkesh, M.B., Afsarimanesh, N., Seifi, M. and Shokri, A., 2022. Challenges facing hospital human resources during the COVID-19 pandemic: a qualitative study in Iran. *International Journal of Human Rights in Healthcare*, *15*(5), pp.489-498. https://doi.org/10.1108/IJHRH-03-2022-0016.

Bi, J.W., Liu, Y., Fan, Z.P. and Zhang, J., 2019. Wisdom of crowds: Conducting importance-performance analysis (IPA) through online reviews. *Tourism Management*, *70*, pp.460-478. https://doi.org/10.1016/j.tourman.2018.09.010.

Burke, C.M. and Morley, M.J., 2023. Toward a non-organizational theory of human resource management? A complex adaptive systems perspective on the human resource management ecosystem in (con) temporary organizing. *Human Resource Management*, *62*(1), pp.31-53. https://doi.org/10.1002/hrm.22132.

Cabrera, D., Cabrera, L.L. and Midgley, G., 2023. The four waves of systems thinking. *Journal of Systems Thinking*, pp.1-51. https://doi.org/10.54120/jost.000051.

Checkland, P. and Poulter, J., 2020. Soft systems methodology. *Systems approaches to making change: A practical guide*, pp.201-253. https://doi.org/10.1007/978-1-4471-7472-1_5.

De Stefano, F., Bagdadli, S. and Camuffo, A., 2018. The HR role in corporate social responsibility and sustainability: A boundary-shifting literature review. *Human Resource Management*, *57*(2), pp.549-566. https://doi.org/10.1002/hrm.21870.

Dehghan Nayeri, M., Khazaei, M. and Alinasab-Imani, F., 2020. The critical heuristics of iranian banking credit system: analysis of the antithetical opinions of the beneficiaries. *Systemic Practice and Action Research*, *33*, pp.363-392. https://doi.org/10.1007/s11213-020-09524-x.

Dharmasiri, A.S., 2015. Exploring an HR Ecosystem: A Glimpse through Ten Gs. http://repository.kln.ac.lk/handle/123456789/16119.

Donnelly, R. and Hughes, E., 2023. The HR ecosystem framework: Examining strategic HRM tensions in knowledge-intensive organizations with boundary-crossing professionals. *Human Resource Management*, *62*(1), pp.79-95. https://doi.org/10.1002/hrm.22115.

Ehsanifar, M., Dekamini, F., Spulbar, C., Birau, R., Khazaei, M. and Bărbăcioru, I.C., 2023. A Sustainable Pattern of Waste Management and Energy Efficiency in Smart Homes Using the Internet of Things (IoT). *Sustainability*, *15*(6), p.5081. https://doi.org/10.3390/su15065081.

Faezirad, M. and Khoshnevisan, A., 2023. Leveraging the Potential of Soft Systems Methodology to Trigger Data Governance Policy-Making in the Banking Industry. *Journal of Systems Thinking in Practice*, *2*(1), pp.56-70. 0.22067/jstinp.2023.81196.1038.

Fraumeni, B.M. and Liu, G., 2021. Summary of World Economic Forum,"The Global Human Capital Report 2017—Preparing people for the future of work". In *Measuring Human Capital* (pp. 125-138). Academic Press. https://doi.org/10.1016/B978-0-12-819057-9.00008-1.

Fuller, J., Jacobides, M.G. and Reeves, M., 2019. The myths and realities of business ecosystems. *MIT Sloan Management Review*, *60*(3), pp.1-9.

Garavan, T.N., McCarthy, A. and Carbery, R., 2019. An ecosystems perspective on international human resource development: A meta-synthesis of the literature. *Human Resource Development Review*, *18*(2), pp.248-288. https://doi/abs/10.1177/1534484319828865.

Hu, B., McCune Stein, A., Mao, Y. and Yan, A., 2022. The influence of human resource management systems on employee job crafting: An integrated content and process approach. *Human Resource Management Journal*, *32*(1), pp.117-132. https://doi.org/10.1111/1748-8583.12392.

Jackson, M.C., 2020. Critical systems practice 1: Explore—Starting a multimethodological intervention. *Systems Research and Behavioral Science*, *37*(5), pp.839-858. https://doi.org/10.1002/sres.2746.

Khazaei, M., Hajiaghaei-Keshteli, M., Rajabzadeh Ghatari, A., Ramezani, M., Fooladvand, A. and Azar, A., 2023. A multi-criteria supplier evaluation and selection model without reducing the level of optimality. *Soft Computing*, *27*(22), pp.17175-17188. https://doi.org/10.1007/s00500-023-08954-8.

Khoshmaram, M., Shiri, N., Shinnar, R.S. and Savari, M., 2020. Environmental support and entrepreneurial behavior among Iranian farmers: The mediating roles of social and human capital. *Journal of Small Business Management*, *58*(5), pp.1064-1088. https://doi.org/10.1111/jsbm.12501.

Lim, D.H., Hur, H., Ho, Y., Yoo, S. and Yoon, S.W., 2020. Workforce resilience: Integrative review for human resource development. *Performance improvement quarterly*, *33*(1), pp.77-101. https://doi.org/10.1002/piq.21318.

Ma, R. and Zhang, J., 2020. Human Resource Ecosystem Health Assessment and Regulation of Marine Enterprises Based on Niche Measurement. *Journal of Coastal Research*, *115*(SI), pp.317-321. https://doi.org/10.2112/JCR-SI115-098.1.

Malik, A., Budhwar, P., Mohan, H. and NR, S., 2023. Employee experience–the missing link for engaging employees: Insights from an MNE's AI-based HR ecosystem. *Human Resource Management*, *62*(1), pp.97-115. https://doi/abs/10.1002/hrm.22133.

Martinez, E., 2016. The HR Ecosystem. *NHRD Network Journal*, *9*(1), pp.45-48. https://doi/pdf/10.1177/0974173920160112.

Mauro, T.G. and Borges-Andrade, J.E., 2020. Human resource system as innovation for organisations. *Innovation & Management Review*, *17*(2), pp.197-214. https://doi.org/10.1108/INMR-03-2019-0037.

Meijerink, J. and Keegan, A., 2019. Conceptualizing human resource management in the gig economy: Toward a platform ecosystem perspective. *Journal of managerial psychology*, *34*(4), pp.214-232. https://doi.org/10.1108/JMP-07-2018-0277.

Mingers, J. and Rosenhead, J., 2004. Problem structuring methods in action. *European journal of operational research*, *152*(3), pp.530-554. https://doi.org/10.1016/S0377-2217(03)00056-0.

Mirhosseini, S.S., Ramezani, M., Khazaei, M. and Azar, A., 2021. Exploring and analysing the risks and challenges of implementing ERP systems: Critical system thinking. *International Journal of Information Systems and Change Management*, *12*(3), pp.234-258. https://doi.org/10.1504/IJISCM.2021.120325.

Nafari, E. and Rezaei, B., 2022. Relationship between human resources strategies and organizational performance based on the balanced scorecard in a public hospital in Iran: a cross-sectional study. *BMC Health Services Research*, *22*(1), p.363. https://doi.org/10.1186/s12913-022-07767-z.

Nayeri, M.D., Khazaei, M. and Abdolahbeigi, D., 2022. The drivers of success in new-service development: Rough set theory approach. *International Journal of Services and Operations Management*, *43*(4), pp.421-439. https://doi.org/10.1504/IJSOM.2022.127465.

Pashaa, N., Rabieh, M., Eslamifarc, G. and Hajiaghad, S.H.R., 2023. Analyzing the Manual and Automated Assembly Line Using System Dynamics (SD) Approach. *Journal of Systems Thinking in Practice*, *2*(1), pp.1-27. https://doi.org/10.22067/jstinp.2023.78113.1017.

Ramezani, M., Azar, A. and Khazaei, M., 2021, June. Gap analysis through a hybrid method: Critical systems heuristics and best worst method. In *The International Workshop on Best-Worst Method* (pp. 272-286). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-89795-6_19.

Sawan, M., O'Donnell, L.K., Reeve, E., Gnjidic, D., Chen, T.F., Kelly, P.J., Bell, J.S. and Hilmer, S.N., 2021. The utility of a computerised clinical decision support system intervention in home medicines review: a mixed-methods process evaluation. *Research in Social and Administrative Pharmacy*, *17*(4), pp.715-722. https://doi.org/10.1016/j.sapharm.2020.06.010.

Snell, S.A. and Morris, S.S., 2021. Time for realignment: The HR ecosystem. *Academy of Management Perspectives*, *35*(2), pp.219-236. https://doi.org/10.5465/amp.2018.0069.

Stone, R.J., Cox, A., Gavin, M. and Carpini, J., 2023. *Human resource management*. John Wiley & Sons.

Sydelko, P., Espinosa, A. and Midgley, G., 2024. Designing interagency responses to wicked problems: A viable system model board game. *European Journal of Operational Research*, *312*(2), pp.746-764. https://doi.org/10.1016/j.ejor.2023.06.040.

Taghipour, A., Ramezani, M., Khazaei, M., Roohparvar, V. and Hassannayebi, E., 2023. Smart Transportation Behavior through the COVID-19 Pandemic: A Ride-Hailing System in Iran. *Sustainability*, *15*(5), p.4178. https://doi.org/10.3390/su15054178.

Taghipour, A., Sohrabi, A., Ghaedi, M. and Khazaei, M., 2023a. A robust vaccine supply chain model in pandemics: Case of Covid-19 in Iran. *Computers & Industrial Engineering*, *183*, p.109465. https://doi.org/10.1016/j.cie.2023.109465.

Taghipour, A., Fooladvand, A., Khazaei, M. and Ramezani, M., 2023b. Criteria Clustering and Supplier Segmentation Based on Sustainable Shared Value Using BWM and PROMETHEE. *Sustainability*, *15*(11), p.8670. https://doi.org/10.3390/su15118670.

Tajpour, M. and Hosseini, E., 2019. The effect of human and social capital on entrepreneurial activities: A case study of Iran and implications. *Entrepreneurship and Sustainability Issues*, *6*(3). Available at SSRN: https://ssrn.com/abstract=3682545.

Tayebnia, M., Karimi, A., Padash, H. and Yazdani, H., 2023. Developing the Framework of Entrepreneurship Education Ecosystem in Iranian Schools Using Soft System Methodology. *Journal of Systems Thinking in Practice*, *2*(2), pp.1-32. https://doi.org/10.22067/JSTINP.2023.81499.1052.

Wang, Y.D. and Zhu, L., 2017. Logical structure of enterprise human resource ecosystem based on self-organization theory. *Advanced Management Science*, *6*(1), pp.37-41. https://doi.org/10.7508/ams.2017.01.009.

Wieland, A., Stevenson, M., Melnyk, S.A., Davoudi, S. and Schultz, L., 2023. Thinking differently about supply chain resilience: what we can learn from social-ecological systems thinking. *International Journal of Operations & Production Management*, *43*(1), pp.1-21. https://doi.org/10.1108/IJOPM-10-2022-0645.

Yalenios, J. and d'Armagnac, S., 2023. Work transformation and the HR ecosystem dynamics: A longitudinal case study of HRM disruption in the era of the 4th industrial revolution. *Human Resource Management*, *62*(1), pp.55-77. https://doi.org/10.1002/hrm.22114.

Zaharov, D. & Lobacheva, A., 2020. Organization HR-Ecosystem Formation and Development. *Management*, pp.23-26.

Zakharov, D.K., Ivanovskaya, L.V. and Pritoliuk, A.V., 2021. Ecosystems in Personnel Management in the Digital Economy. In *Socio-economic Systems: Paradigms for the Future* (pp. 1347-1354). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-56433-9_140.

Zare Mehrjerdi, Y. and Bakhshandeh, M., 2023. Evaluation Model of the Systems Thinking Level of the Organization (Case Study: an Iranian Oil Company). *Journal of Systems Thinking in Practice*, *2*(2), pp.56-77. https://doi.org/10.22067/JSTINP.2023.81262.1040.

Guide for Authors

Manuscriprt submission and useful files

Manuscripts should be submitted by the corresponding authors through only our online manuscript tracking systems (MTS) via https://jstinp.um.ac.ir/contacts. Submissions by anyone other than one of the authors will not be accepted. The corresponding author takes responsibility for the paper during submission and peer review. If you have any problem in submission through the MTS for technical reason or etc. please feel free to contact us via https://jstinp.um.ac.ir/journal/contact.us

Please read the remainder of these instructions to authors and then click https://jstinp.um.ac.ir/contacts to navigate to JSTINP online submission page.

All papers must be submitted online

For reviewing purposes you should upload either a .doc file with the figures and tables integrated within the text of the main document.

Submission of a manuscript will be held to imply that it contains original unpublished work and is not being submitted for publication elsewhere at the same time.

Peer Review

All manuscripts are assessed in accordance with the peer review principle. An editor will assess a submitted manuscript initially for its suitability in general terms. If a manuscript is evaluated suitable, it is forwarded to two or more peer reviewers. The editor cannot designate himself as a peer reviewer. You can see peer review process section for more information via https://jstinp.um.ac.ir/journal/process

Proof of acceptance

After acceptance, we will email a PDF of the proofs to the corresponding author.

Manuscriprt style

The language of the journal is English. The journal operates a double-blind review process whereby Reviewers' names and Authors' names are screened from each other. **Word template** is available for this journal. Please save the template to your hard drive, ready for use. Please pay close attention to the instructions below.

Title Page

Title page includes title of article, author's name and affiliation, abstract and keywords.

- Names and affiliations of all authors must be provided in a separate document and uploaded using the file designation – "Author Title Page Only".
- If any of the named co-authors moves affiliation during the peer review process, the new affiliation can be given as a footnote. Please note that no changes to affiliation can be made after the manuscript is accepted.
- Do NOT incorporate into your main document.
- Give the full address, including email, telephone and fax, of the author who is to check the proofs.

Please supply all details required by any funding and grant-awarding bodies as an Acknowledgement on the title page of the manuscript, in a separate paragraph, as follows:

- *For single agency grants:*"This work was supported by the [Funding Agency] under Grant [number xxxx]."
- *For multiple agency grants:*"This work was supported by the [Funding Agency 1] under Grant [number xxxx]; [Funding Agency 2] under Grant [number xxxx]; and [Funding Agency 3] under Grant [number xxxx]."

Main document

A typical manuscript will be between **4000** and **10000** words including tables, references, captions, footnotes, and endnotes. The text should be 1.5 line spacing throughout and with 2.5 cm page margins. Manuscripts that greatly exceed this will be critically reviewed with respect to length. The manuscript contains nothing that is abusive, defamatory, libelous, obscene, fraudulent, or illegal.

Any consistent spelling and punctuation styles may be used. Please use double quotation marks, except where “a quotation is ‘within’ a quotation”. Long quotations of 40 words or more should be indented without quotation marks.

- **Font size:**
  - In text: Times New Roman 12
  - Level I headings: bold font, Times New Roman 12
  - Level II headings: bold and Italic font, Times New Roman 12
  - Level III headings: Italic font, Times New Roman 12

The first page

- **Title:** as short as possible, with no abbreviations or acronyms.
- **Abstract:** A brief abstract (150 and 300 words) should be included with all Manuscript types. An abstract is a concise summary of the whole paper, not just the conclusions, and is understandable without reference to the rest of the paper. It should contain no citation to other published work.
- **Keywords**: Right after the abstract, provide 3 to 6 keywords.

Structure of second page until the end of manuscript

The structure of the manuscript can be as follows:

- **Introduction**
- **Literature review**
- **method**
- **Results**
- **Discussion and Conclusion**

- **Limitations and suggestions**
- **Acknowledgements**
  Disclosure statement: No potential conflict of interest was reported by the author(s).
- **References**
- **Appendices (as appropriate).**

Reference style

All references should be formatted according with the Harvard referencing style. References should be quoted in the text as name and year within brackets and listed at the end of the paper alphabetically. Where reference is made to more than one work by the same author published in the same year, identify each citation in the text as follows: (Collins, 1998a), (Collins, 1998b). Where three or more authors are listed in the reference list, please cite in the text as (Collins et al., 1998). Provide page number(s) for direct quotations: (Collins, 1998, p.36).

All references must be complete and accurate. Online citations should include date of access. If necessary, cite unpublished or personal work in the text but do not include it in the reference list.

- Eberlein RL. 1984. Simplifying dynamic models by retaining selected behavior modes. PhD Thesis, Massachusetts Institute of Technology, Cambridge, MA.
- Forrester, JW. 1991. Longer-term economic changes. D-4207-1, MIT System Dynamics Group Literature Collection. Available from the System Dynamics Society: https://www.systemdynamics.org/mit-sdgroup-literature-collection.
- Graham AK. 1980. Parameter estimation in system dynamics modeling. In Randers J. (ed.) *Elements of the System Dynamics Method*. Productivity Press, Cambridge MA, 143-161.
- Homer JB. 1983. Partial-model testing as a validation tool for system dynamics. In *Proceedings of the 1983 International System Dynamics Conference*. Chestnut Hill, MA, System Dynamics Society.
- Naumov S, Oliva R. 2018. Structural Dominance Analysis Toolset. Retrieved September 17, 2019, from http://people.tamu.edu/~roliva/research/sd/sda/.
- Sterman JD. 2000. *Business Dynamics: Systems Thinking and Modeling for a Complex World.* Irwin/McGraw-Hill, Boston.
- Tan B, Anderson EG, Dyer JS, Parker GG. 2010. Evaluating system dynamics models of risky projects using decision trees: Alternative energy projects as an illustrative example. *System Dynamics Review*26(1): 1-17.

Figures, Tables and Formulas

Figures' title should be writhen below the figure, and tables' title at the top of the table in Times New Roman 10. Figures and tables render within the text and immediately place after the explaining paragraph. The content of tables in Times New Roman 10.

- Tables and Figures number from No. (1) To refer to the content of the Figures and diagrams in the text, use the number and appropriate referral.
- Inserting decimal numbers, instead of using slash (/), and show negative numbers by using the minus sign.
- Formulas represent centered in Times New Roman11 and render in a two column table with no border and number with figure in parentheses.

Conflict of interest declaration and author agreement form

Submission of an article implies that the work described has not been published previously, nor is it under consideration for publication elsewhere. Authors also certify that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere, including electronically in the same form, in English or in any other language, without the written consent of the copyright-holder.

Copyright assignment form

Accepted manuscripts become the permanent property of the JSTINP and may not be reproduced, in whole or in part, without the written permission of the Editor. The Copyright assignment form must be completed and sent to Journal of Systems Thinking in Practice (JSTINP) editorial office.

Free article access

Journal of Systems Thinking in Practice quickly and easily gives anyone free access to the electronic version of the articles for free.

Further information

Any correspondence, queries or additional requests for information on the Manuscript Submission process should be sent to the Editorial Office as follows: **E-mail: jstinp.um.ac.ir**

Response to Reviewer (Submit revision and response letter)

You will be unable to make your revisions on the originally submitted version of the manuscript. Instead, revise your manuscript using a word processing program and save it on your computer. Please also highlight the changes to your manuscript within the document by using the track changes mode in MS Word or by using bold or coloured text. Once the revised manuscript is prepared, you can upload it and submit it through https://jstinp.um.ac.ir/contacts.

When submitting your revised manuscript, please respond to the comments made by the reviewer(s) in the response letter. You can use this letter to document any changes you make to the original manuscript. In order to expedite the processing of the revised manuscript, please be as specific as possible in your response to the reviewer(s). You can use the following letter template.

Because we are trying to facilitate timely publication of manuscripts submitted to the Journal of Systems Thinking in Practice, your revised manuscript should be uploaded as soon as possible. If it is not possible for you to submit your revision in a reasonable amount of time, we may have to consider your paper as a new submission.

Instructions before submission

Short checklist

Please make sure all the following files have been prepared before submission:

1. Assignment of Copyright Form
2. Conflict of interest declaration and author agreement Form
3. Title page: MS Word template of Title page based on Guide for Authors
4. Main manuscript: MS Word template of Main manuscript based on Guide for Authors
5. Supplementary files (if applicable)
6. Contact information for all authors (including First and last names, name of institutions with complete addresses, university or organizational e-mail addresses, ORCID IDs for authors, the corresponding author's full affiliation and phone number
7. Key words
8. References in Harvard style