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From Conflict to Cooperation: A Multi-Methodological Approach to Managing the Solid Waste Crisis in Lebanon

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ABSTRACT

The management of solid waste in Lebanon has evolved into a complex issue, marked by its deleterious environmental, economic, and public health ramifications for both civilians and the state exchequer. Despite the longstanding nature of Lebanon's municipal waste predicament, it escalated to catastrophic proportions in 2015 following the closure of Naameh, the nation's largest landfill. The persisting crisis from 2015 endures due to the government's inadequate and poorly conceived solutions, with the potential to rekindle at any juncture. This paper addresses two fundamental concerns. Initially, a comprehensive portrayal of the municipal solid waste scenario in Lebanon is provided, encompassing its diverse facets. Subsequently, the researchers advocate an integrative approach amalgamating centralized and decentralized systems. Pioneering a strategic proposal to address Lebanon's solid waste predicament, the researchers employ a Journey-Making (JM) methodology to discern direct and indirect actors. Subsequently, a game theory approach, facilitated by the Graph Model for Conflict Resolution (GMCR+) software, is utilized to derive solutions that cater to the satisfaction of all involved parties. The selection of the optimal scenario is contingent upon the available options for the primary stakeholders, factoring in the political, sectarian, economic, and environmental landscape of Lebanon.

Keywords

Lebanon, Strategy, Decentralization, JM, SWM.

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1. Introduction

With advancements in solid waste treatment technology, treatment methods have been categorized into thermal processes (including incineration, high thermal dissociation, medium thermal dissociation, moderate thermal dissociation, carbonization, etc.) and biological processes (comprising composting, anaerobic fermentation, landfill, calcining, etc.). Each of these methods presents distinct advantages and is applicable under specific conditions (Awasthi, 2022). Governments are urged to conduct comprehensive research and assessments of these technologies, considering factors such as investment, operational and maintenance costs, geographical requirements, material recovery rates, quality, and adherence to environmental regulations. Subsequently, based on the unique demands of their nation, authorities should embrace the technology or combination of technologies that comprehensively address all facets of integrated treatment.

In the context of Lebanon, characterized by limited open spaces and a substantial organic content (60-70%) in household waste (Abou Jaoude et al., 2022), coupled with financial constraints necessitating judicious choices, there is a call for the adoption and implementation of an integrated technology roadmap in all sanctioned service areas. This strategy should exclude costly and unsuitable technical options.

Lebanon allocates approximately $420 million annually to solid waste management (Sweid, 2021), excluding associated health costs, amounting to roughly $150 per ton. In contrast, other nations achieve superior outcomes with significantly lower expenditures. The absence of a comprehensive and efficacious waste management strategy, coupled with a dearth of tangible outcomes, has precipitated a deteriorating situation. Approximately 6,000 tons of waste are generated daily, with a majority being either landfilled (51%) or haphazardly dumped (32%) across more than 1,000 landfills nationwide (Ajeeb, 2017; Sbeih, 2023). Notably, key landfills are approaching maximum capacity, portending severe environmental, health, social, and political crises.

The Lebanese populace contends daily with many economic, social, health, and political challenges, compounded by the collapse of their banking system resulting from years of conflict and corruption. Amid these adversities, the waste management crisis, rooted in the post-civil war era, persists. Subsequent to that period, Lebanese legislators have not accorded adequate attention to the solid waste issue, and no comprehensive plan has been devised, leading to a series of crises (Baumann, 2023). The most conspicuous of these crises unfolded in 2015 when the Naameh landfill reached its saturation point, causing refuse accumulation on the streets of

the capital, Beirut, and its environs. The ensuing health deterioration, direct impact on tourism, and public protests were noteworthy (Menhall and Joseph, 2017). Subsequently, the government attempted to address the crisis through an emergency plan involving a vertical expansion of the landfill, one of the two main landfills serving Beirut and its vicinity. However, this interim measure proved unsuccessful due to a lack of scientific implementation (Boswall, 2019).

Considering the unique standards in Lebanon, influenced by a considerable degree of political, sectarian, and partisan diversity, resolving the waste predicament necessitates a comprehensive plan. Such a plan should consider both environmental and economic standards while garnering acceptance from the populace and the ruling parties in Lebanon.

The cost associated with the collection and treatment of a ton of waste exhibits variability contingent upon factors such as the waste type, national geography, population income, waste collection technology, dietary practices, and the rural or urban nature of the region. In Lebanon, the elevated cost of waste collection is influenced by factors including mismanagement, governmental weaknesses, the absence of a waste-handling culture—such as inadequate household sorting—and the prevalence of a "throwing in the street" mindset. Environmental experts in Lebanon universally assert that the expense incurred by the Lebanese government for collecting and treating a ton of waste stands as the highest globally (Khalil, 2022). The toll of inadequate waste management in Lebanon is approximated at $15 million annually. Specifically, the public treasury bears an approximate cost of $155 per ton for waste disposal, ranking as the highest globally. By comparison, in Canada, the cost per ton ranges between $58 and $75; in Italy, it varies from $16 to $78, and in Syria, it stands at $2.5 (El Richani, 2017).

2. Methodological background

This section provides a concise literature review encompassing GMCR, Soft OR, and multimethodology intervention. The objective is to delineate the research gap, ultimately guiding the formulation of a solution.

2.1. Graph model for conflict resolution (GMCR)

In challenging circumstances, the GMCR model serves as a decision-making methodology for resolving intricate disputes. The approach involves constructing a graphical model to depict the decision problem and the interconnections among pivotal variables. The model is formulated by identifying these critical variables, delineating their interactions, and subsequently mapping

them onto a graph structure (Xu et al., 2018). Nodes within the graph symbolize decision variables, and edges signify relationships, with nodes and edges assigned weights based on their respective significance and the strength of their connections. Mathematical optimization techniques are employed to solve the model, seeking the optimal solution that maximizes overall benefits and minimizes conflicts. The GMCR model has proven effective across diverse domains, including environmental management, natural resource management, transportation planning, and public policy decision-making (Aghmashhadi et al., 2022). The development and analysis of the GMCR model incorporate algorithms that forecast potential outcomes and facilitate their examination. This encompasses considerations such as decision-makers, potential states, reachability, equilibria, foresight, and stability (Hipel & Fang, 2020). Recognizing the key components of conflicts occurs during the modeling phase. After the user inputs the list of Decision Makers (DMs) and their preferences, the software generates numerous potential configurations of options or states. Given that not all mathematically contemplated scenarios align with agreeable or feasible states in real conflicts, the model excludes infeasible combinations of tactics, thereby reducing the number of considered states (Kinsara et al., 2015).

2.2. Problem structuring methods

The problem structuring methods (PSM) phase in the resolution of operations research (OR) challenges is widely regarded as the most intricate (Smith & Shaw, 2019). Precision and diligence are imperative for a comprehensive understanding of intricate issues, and researchers have proffered diverse methods, each varying in complexity, to facilitate the identification of decision-makers, available options, potential scenarios, and other pertinent aspects. One such method is Soda, subsequently refined into Journey Making (JM), which proves beneficial for aiding decision-making in complex problem domains. Nonetheless, the efficacy of JM experiences a notable decline with an escalation in the number of decision-makers and available options (Eden and Ackermann, 2018). In this investigation, researchers intend to employ JM to ascertain primary and secondary players based on their power and interest levels. This determination will be made through the distribution of questionnaires to experts within the Lebanese domain, focusing on the reality of the waste issue. Following this, the Generalized Multiplicative Choquet Integral (GMCR) method will be implemented to identify the most suitable option (Nassereddine et al., 2021). The selection will prioritize scenarios closely aligned with implementation while considering the political, economic, and environmental

realities in Lebanon pertaining to the final disposal of solid waste.

2.3. Multimethodology intervention

Paucar-Caceres (2010) posits that employing diverse approaches in Operations Research/Management Science (OR/MS) research signifies a notable advancement. Kotiadis and Mingers (2006) contends that adopting multiple methodologies is a beneficial strategy for problem-solving and decision-making. This approach involves the integration of various OR/MS techniques along with the concurrent utilization of various problem-structuring techniques (PSM) (Zhu, 2011; Ormerod, 2014). However, Howick and Ackermann (2011) caution that amalgamating methodologies in case studies may result in a lack of generalizable lessons within literature. Ormerod 2014) underscores that the selection of intervention design is contingent upon the specific problem, emphasizing that there is no singular "best way" to combine approaches. Despite the ongoing interest in integrating multiple PSM models, recent literature explores the amalgamation of PSM with non-PSM methodologies, such as hard-OR and decision analysis (Ackermann, 2012).

2.4. Research gap

The identified research lacuna in solid waste management in Lebanon revolves around the absence of comprehensive studies delving into the social, political, and behavioral dimensions of waste management practices. While there has been research on the technical and environmental facets of waste management, there is a notable dearth of attention to comprehending the attitudes, perceptions, and behaviors of diverse stakeholders, encompassing households, businesses, and local communities.

The formulation of effective and sustainable waste management strategies stands to gain significant benefits from an in-depth understanding of the Lebanese political landscape, which encompasses diverse political parties, sects, and currents, along with the ongoing economic crisis. Additionally, sociocultural factors influencing waste generation, disposal practices, and recycling behaviors should not be overlooked.

To obtain a more holistic comprehension of the challenges and opportunities in addressing the waste crisis and achieving sustainable waste management in the nation, there is a call for research that scrutinizes the political, social, and behavioral aspects alongside the existing technical and economic studies. In pursuit of this objective, researchers have adopted a multi-methodological approach, integrating journey-making (JM) and game theory. Initially, the

distribution of questionnaires to experts and researchers in the fields of environment, economics, and politics, all with an interest in the issue of solid waste in Lebanon, facilitated a comprehensive understanding of the problem from diverse dimensions and identified both direct and indirect influential players. Subsequently, applying the Generalized Multiplicative Choquet Integral (GMCR+) software allowed researchers to determine options for direct players, laying the groundwork for presenting and discussing feasible consensus states with the principal decision-makers.

3. Research methodology

A notable deficiency exists in the remodeling and modeling process, a gap that Journey Making (JM) proves capable of bridging. While JM effectively addresses this weakness, its applicability in analyzing social interventions, such as conflict resolution, is particularly fruitful for comprehending the situation, developing options, and predicting scenarios. However, it is imperative to note that JM encounters limitations in handling complex scenarios as the number of players, options, and scenarios increases, making it less suitable as a negotiation method.

In summary, this paper concentrates on developing and implementing multimethodological intervention, capitalizing on the merits of soft Operational Research (OR) and game theory to navigate the intricate nature of real-world problems.

The five fundamental steps of this research involve delineating the circle of impact on Lebanon's solid waste issue through the Journey Making (JM) approach. Subsequently, primary participants are selected and distinguished from secondary players. The second stage employs a SWOT analysis to contrast centralization and decentralization in waste management. The third step proposes a synthesis of centralization and decentralization as a recommended solution, aligning with the political, demographic, and economic circumstances in Lebanon. The GMCR program is then employed to select the most optimal options for the main actors identified in the initial phase. The conclusion involves the players endorsing the proposed strategy.

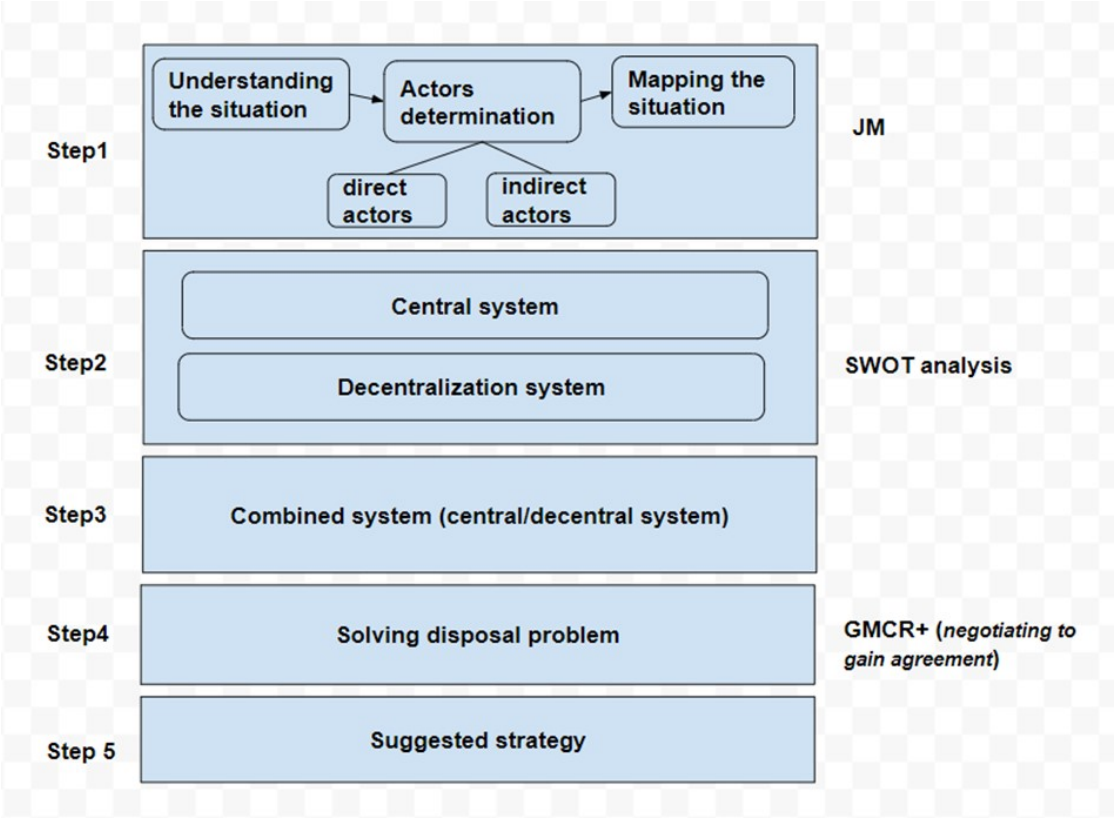

Figure 1. The study framework

3.1. Actors classification

The conflict in solid waste management (SWM) in Lebanon involves multiple parties, both directly and indirectly. The research initiation encompassed a survey targeting experts in the field. A decision team was assembled comprising ten experts representing influential political parties, municipal members, academic researchers, and officials from environmental associations and non-governmental organizations.

The preliminary phase involved a comprehensive examination of the historical context of SWM, coupled with the collection of experts' opinions. Based on this information, nine actors were initially selected. In the subsequent round, the most pivotal actors were identified.

Despite utilizing a causal map structure that primarily centers on individual players in this conflict, experts incorporate an assessment of the underlying causes of the conflict when choosing decision-makers (players), determining their available options, assigning participant roles, and mapping the overall situation. In consideration of the initial phase, which involves becoming acquainted with the situation in the Journey Making (JM) process, the table below outlines the involvement of nine players.

Table 1. Lebanon's SWM conflict actors

1	Relevant ministries	MoE[1], MoIM[2], MoA[3], MoPH[4], MoPWT[5], MoET[6], MoF[7], MoEW[8], MoI[9])
2	Municipal councils	Independent or union municipalities
3	Lebanese parties	Each party influences its affiliates or supporters
4	NGOs, CBOs	Organizations concerned mainly with the environment, Health, and Social awareness sectors
5	Private sector	Recycling industry, Agriculture sector, Energy sectors, Street scavengers, Companies
6	Academics	Universities, Research institutions, Professors, and Published articles.
7	Service users	Households, Companies, Hospitals...
8	Financing organizations	International and National institutions, Regional funds, Donors
9	Lobby	Media, Influential politicians…

MOE[1] Ministry of Environment, MOIM [2]Ministry of Interior and Municipalities, MoA[3] Ministry of Agriculture, MOPH [4]Ministry of Public Health, MOPWT [5]Ministry of Public Works and Transport, MOET[6] Ministry of Economy and Trade, MoEW [7]Ministry of Energy and Water, MoF [8]Ministry of Finance, MoI[9] Ministry of Industry.

In the context of solid waste management (SWM) in Lebanon, there exist numerous direct players or decision-makers alongside indirect players whose role is integral to the success of any developed strategy aimed at resolving the waste predicament. The distinction between direct and indirect players hinges on their capacity as active individuals or institutions to either accept or reject any proposed strategy. In negotiations involving multiple parties, whether internal or international, attaining a specific agreement that satisfies all parties necessitates maximal support and endorsement from entities not directly engaged in decision-making. This is particularly noteworthy in the intricate case of Lebanon, characterized by sectarian distribution and cultural differences. Pressure groups assume a pivotal role in influencing public opinion to accept decisions emanating from the central authority. Beyond that, pressure groups, or lobbies, play a crucial role in shaping a coherent narrative and enhancing the understanding of a scientific and practical foundation for politicians who may not have reached decision-making positions based on specialized scientific backgrounds.

Table 2. Power/interest

No	**Actors**	**Power**	**Interest**
1	Relevant ministries	3.2	2.7
2	Lebanese parties	3.5	2.8
3	Municipal councils	3	3.5
4	NGOs, CBOs	1.5	3.7
5	Private sector	1.4	3.2
6	Academics	1.3	4
7	Financing organizations	2	2.4
8	Service users	1.5	2
9	Lobby	2.2	3

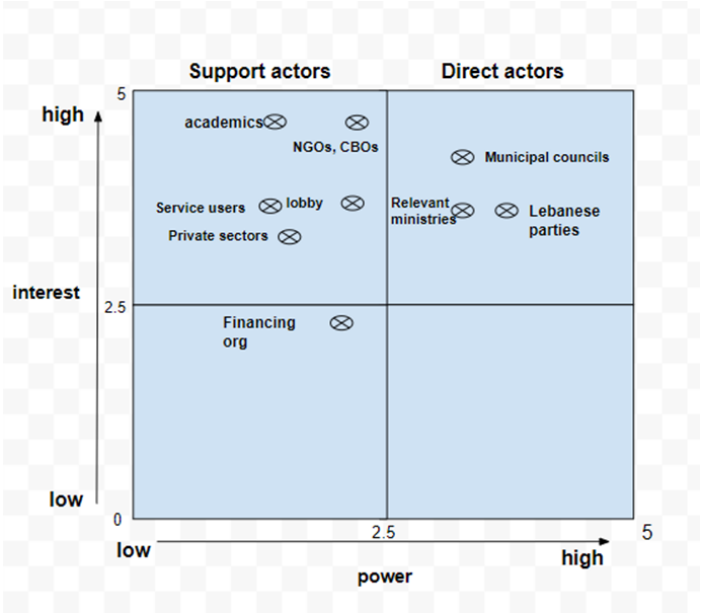

Figure 2. The Power/interest grid of the actors

As illustrated in Figure 2, three primary actors will progress to the subsequent phase, namely the GMCR+ program, to examine the available options for resolving the conflict and formulating a strategy that garners acceptance from all involved parties.

4. SWOT analysis (centralization vs decentralization)

Certain individuals may posit that solid waste management (SWM) in a nation like Lebanon should be straightforward, given the predominantly organic nature of the waste, the modest size of its territory, and the geographical diversity enabling the establishment of sanitary landfills across various locations. However, the intricate sectarian structure of Lebanon, which significantly influences political dynamics and decision-making processes, stands as the nation's fundamental challenge.

The collection and disposal of waste from a centralized location, such as a landfill or incinerator, falls under the purview of centralized waste management. In contrast, decentralized waste management involves waste collection and processing at smaller, more regional facilities, including composting or recycling facilities. The following outlines key distinctions between centralized and decentralized waste management systems in Lebanon:

1. Cost: Centralized waste management systems, requiring extensive infrastructure and incurring higher operating costs, may be more expensive to establish and maintain compared to decentralized systems. Decentralized systems, particularly those leveraging local labor and resources, could present a more cost-effective alternative.

2. Effectiveness: Centralized systems, capable of processing larger quantities of waste simultaneously, may excel in terms of waste collection and disposal. Conversely, decentralized systems tailored to specific waste streams and regional conditions may exhibit superior efficiency in resource recovery and recycling.

3. Environmental Impact: The environmental repercussions of both centralized and decentralized waste management systems depend on the technology and procedures employed. Decentralized systems often embody greater sustainability, promoting the principles of the circular economy. In contrast, centralized systems may contribute to increased greenhouse gas emissions, air pollution, and soil contamination.

4. Community Involvement: Decentralized waste management systems, often operated by local businesses or cooperatives, offer opportunities for community engagement in waste reduction and recycling efforts. In contrast, centralized systems managed by larger governmental or commercial entities may be less responsive to community demands and preferences.

In summary, there is no singular approach to waste management in Lebanon. Depending on priorities and environmental considerations, a combination of centralized and decentralized systems may constitute a viable and effective strategy.

Central system

Strengths:	Weaknesses
- Long distance collection and controlled landfilling - Ease of assigning responsibilities	- persistence corruption - weaken the role of society - Low treatment quality
Opportunities	**Threats**
- Reduce the cost to the government - Direct monitoring	- Repetition of crisis - Direct influence on political changes - Lack of change

Decentralized system

Strengths	Weaknesses
- Participation of non-governmental organizations - Increase the sense of responsibility of the households - Quality treatment	- less government monitoring - Poor experience and training - Difficulty assigning responsibilities framework
Opportunities	**Threats**
- Activating the industrial sector - Flexibility in treatment solutions - Local jobs	- Inequalities of service - Handling and disposal of residual and toxic wastes

Figure 3. SWOT analysis of the centralized vs decentralized system

4.1. Combined system

According to a SWOT analysis, the optimal approach for managing solid waste in Lebanon involves integrating both centralized and decentralized systems. The centralized system would entail the implementation of legislation, establishing precise regulations for solid waste disposal, and overseeing the activities of municipalities and nongovernmental organizations. To avert potential environmental crises, an imperative for Lebanon given its existing challenges, the ultimate waste disposal option, whether it be incineration, landfilling, exporting, or a combination, must be subjected to explicit and stringent environmental restrictions. Facilitated by nongovernmental organizations, the decentralized system, represented by governorates and municipalities, is empowered to engage in waste collection, sorting, operation of recycling plants, or the licensing of specialized facilities under its supervision. This fosters community involvement in diverse environmental initiatives by enhancing public awareness. The decentralized system is capable of receiving support and grants from amicable municipalities and donor nations in various forms, encompassing financial assistance, administrative training, public awareness campaigns, and specialized waste sorting and pressing machinery.

5. Decision-makers and their options

As previously elucidated, in accordance with the outcomes derived from the application of the JM method for player identification, the principal actors in this context are the Lebanese government, municipal councils, and Lebanese political entities. Each entity harbors distinct rationales guiding its preference for a particular waste disposal methodology over another. Given the prevailing financial crisis in Lebanon, the government endeavors to ascertain an economically viable solution that is both cost-effective and expeditious in implementation. This pursuit is motivated by the imperative of securing public support, especially amidst the time-sensitive scenario posed by the impending saturation of existing waste disposal sites. Moreover, the relatively transient tenures of Lebanese governments foster a proclivity for expeditious, albeit less enduring, accomplishments, as opposed to the formulation of long-term strategic resolutions.

Municipal councils, being most directly impacted by the environmental consequences within their purview, exhibit a heightened aspiration for expeditious waste elimination. The immediacy of this concern stems from the direct repercussions on residents' perceptions and evaluations of municipal councils should a failure to address the crisis transpire. Consequently, there exists a

pressing need for a rational and verifiable solution. Municipal councils, located in close proximity to residents, grapple with mounting pressures arising from the escalating waste disposal predicament and a concomitant dearth of financial support from the central government. Concurrently, these councils contend with external pressures from civil society groups, non-governmental organizations, and academic institutions, all actively engaging with them to influence their perspectives and proffer solutions for crisis mitigation. Given the often-representative nature of municipal councils vis-à-vis political parties, even with changes in membership, the councils consistently revert to representing the dominant parties in their regions. This temporal advantage empowers them to formulate strategic programs for waste crisis resolution alongside expeditious measures for waste removal.

Lebanese political entities exhibit substantial convergence in their perspectives with municipal councils. Each party, whether confined to a specific region or spanning multiple regions, nominates candidates from its adherents to contest municipal council elections, resulting in alignment between municipal decisions and the positions of dominant parties in a given locale (Parreira, 2020). In this instance, the competitive atmosphere among Lebanese political entities may act as a positive catalyst, prompting the provision of optimal solutions to the waste disposal predicament. Consequently, political entities actively seek consultations with experts in the field, alongside engagement with non-governmental organizations and donors for the financing of waste disposal initiatives. Furthermore, it is noteworthy that political entities, within their spheres of influence, place emphasis on generating employment opportunities for loyal citizens, thereby stimulating contemplation on productive projects achievable through waste recycling.

The Lebanese government possesses several alternatives for addressing the waste issue in Lebanon, as indicated by Verdeil (2018). One avenue involves substantial investments in enhancing the existing waste management infrastructure, encompassing the establishment of new landfills and waste treatment facilities. Another approach entails the implementation of programs aimed at waste reduction and recycling, such as composting and plastic recycling, to diminish the volume of generated waste and mitigate its environmental impact. Furthermore, the government may contemplate waste-to-energy solutions, including incineration and gasification, as mechanisms for generating electricity from waste. Additionally, there exists the possibility of importing waste for processing and disposal within Lebanon or exporting waste from Lebanon to other nations under specific conditions. However, this latter option is frequently contentious and may encounter resistance from local communities. Ultimately, a comprehensive and sustainable resolution to the waste predicament in Lebanon may necessitate

a synergistic application of these alternatives, coupled with effective governance and public involvement.

It is imperative to acknowledge that the interplay among the government, political parties, and municipalities is characterized by a dynamic and cyclical nature rather than a linear progression. Within the framework of the Lebanese political landscape, decision-making in the government is intricate and may involve voting on proposed resolutions that ministers scrutinize and subsequently vote on following consultations with their affiliated political parties. Conversely, proposed legislation may emanate from the requests of municipalities and political parties, which submit these propositions to ministers for endorsement and voting, thereby facilitating their transformation into enforceable laws. This elucidation underscores the primary objective of this article, which aims to formulate solutions attaining a relative or complete consensus among diverse political entities, even those espousing disparate political ideologies. This is because political accord and consensus represent the sole avenue for devising sustainable environmental and technological solutions to the quandary of waste and environmental pollution in Lebanon.

From a technical perspective, the stakeholders are confronted with three viable alternatives that necessitate judicious decision-making, each entailing environmental and financial advantages and disadvantages.

5.1. Incineration

Waste incineration is a process wherein waste materials undergo combustion, resulting in the conversion of these materials into ash, gas, and heat. This method is frequently employed for the management of waste that proves challenging to recycle, compost, or dispose of in a landfill (Zhuang et al., 2022).

The incineration process entails loading waste into a furnace or incinerator, typically equipped with a high-temperature burner and air pollution control devices. Subsequently, the waste is subjected to combustion at elevated temperatures, typically within the range of 800 to 1000 degrees Celsius. This process serves to reduce the volume of waste and transform it into ash and gases. Gases generated during incineration are typically subjected to treatment to eliminate pollutants before their release into the atmosphere.

The utilization of waste incineration as a waste management strategy carries both advantages and disadvantages. On the positive side, it can diminish the quantity of waste destined for landfills, generate heat or power, and offer a secure means of disposing of hazardous waste.

Conversely, potential drawbacks include the emission of air pollutants during incineration, with consequent adverse effects on the environment and human health. In comparison to alternative waste management strategies, the construction and operation of incinerators can be costly, and there exists a risk of producing harmful ash residue during the combustion process. In sum, while waste incineration can prove effective in certain scenarios, meticulous management and regulation are imperative to mitigate its adverse impacts on human health and the environment.

In the context of Lebanon, waste management has persistently presented challenges, prompting the consideration of waste incineration as a prospective solution to the nation's waste crisis. Nevertheless, this proposal has encountered substantial controversy and opposition within Lebanon, primarily stemming from apprehensions regarding its environmental and health implications.

The closure of Lebanon's largest landfill in Naameh in 2015 led to a significant waste management crisis, with refuse accumulating in the streets of Beirut and other major cities. In response, the Lebanese government advocated for waste incineration as a resolution to the crisis but encountered substantial resistance from local communities and environmental activists.

Opponents of waste incineration in Lebanon have voiced concerns regarding the potential release of toxic pollutants into the air and its impact on public health. Moreover, there have been reservations about the perceived lack of transparency and public consultation in the decision-making process (Chalhoub, 2018).

Despite these concerns, there have been endeavors to advance waste incineration in Lebanon. In 2018, a waste-to-energy plant was proposed in the city of Sidon, although it encountered significant opposition from residents and environmental groups. As of 2021, the future trajectory of waste incineration in Lebanon remains uncertain, with ongoing debates and controversies surrounding the issue.

5.2. Landfilling

The United States Environmental Protection Agency (U.S. EPA) recognizes that the integrity of all landfill liners tends to degrade within a span of 20 years, if not sooner, thereby warranting a nominal lifespan guarantee of approximately two decades (Barlaz et al., 2002). Furthermore, the detection of leakage, whether subterranean or airborne, poses a non-trivial challenge, often exacerbated by inadequacies in testing methodologies.

Landfilling represents a waste management approach entailing the burial of waste in a demarcated land area (Singh, 2019). Typically, the waste is enveloped in layers of soil or

alternative materials, serving the dual purpose of mitigating odors, preventing disease dissemination, and minimizing contamination risks.

Various landfilling methods are deployed contingent upon the nature of the waste and its geographical location. Noteworthy examples encompass:

1. Sanitary landfills: These facilities are engineered for the management of municipal solid waste (MSW) and are conventionally equipped with impermeable linings to forestall the dissemination of contaminants into the contiguous soil and groundwater (Nanda & Berruti, 2021).

2. Industrial landfills: These sites are configured for the disposal of waste generated through industrial processes and may be subject to distinct regulatory frameworks and requisites compared to sanitary landfills.

3. Hazardous waste landfills: Tailored for the management of hazardous waste materials, such as chemicals, solvents, and medical waste, these landfills adhere to stringent regulations ensuring the safety of both workers and the environment.

4. Bioreactor landfills: Crafted to augment the natural decomposition of waste, bioreactor landfills introduce liquid or air into the landfill environment to foster the proliferation of microorganisms facilitating waste breakdown.

The selection of a landfilling method hinges on the characteristics, composition, and location of the waste in question. While landfilling is generally regarded as a less favored waste management strategy compared to recycling, composting, or waste-to-energy alternatives, as it does not align with resource conservation or energy recovery principles, it nonetheless persists as a prevalent method due to its cost-effectiveness and straightforward implementation.

5.3. Waste exportation

Waste exportation denotes the practice of conveying waste materials from one country to another for disposal or recycling purposes (Marbury, 1995). This practice has been the subject of extensive debate due to its potential adverse effects on the environment, public health, and social justice. On the one hand, countries exporting waste may derive benefits from diminished waste disposal costs and increased revenue through recycling. Conversely, importing nations may encounter heightened environmental pollution, health hazards, social disparities, and the risk of illicit dumping and trafficking.

In recent years, the matter of waste exportation has garnered heightened attention in academic research, policy formulation, and public discourse. Scholars have scrutinized diverse

facets of waste exportation, encompassing its economic, environmental, and social ramifications, the legal and regulatory frameworks governing the practice, and the determinants influencing waste trade flows and patterns.

In its entirety, the issue of waste exportation remains intricate and contentious, necessitating a judicious examination of myriad factors and perspectives. Consequently, further research and dialogue are imperative to formulate effective and equitable policies and practices that can ensure sustainable waste management and mitigate the adverse impact of waste on the environment and public health.

In the context of Lebanon, one proposed solution involves exporting waste to other countries for treatment and disposal, a strategy successfully implemented in countries facing comparable waste management challenges, such as Sweden and Denmark, where waste is exported to Germany for treatment (Behzad et al., 2020). However, the viability of waste exportation as a solution for Lebanon is not devoid of challenges. Considerations include logistical and financial factors such as transportation costs, customs fees, and the expenses associated with treatment and disposal in the receiving country. Additionally, it is recognized that waste exportation may not constitute a sustainable long-term solution, as it fails to address the root causes of the waste management crisis in Lebanon, such as deficient infrastructure and a lack of political will to implement effective waste management policies.

5.4. DMs' preference ranking over the feasible states

Inferences regarding players' preferences regarding the states are drawn from the conflict background and expert opinions, as outlined in Table 3. Divergence in preference among decision-makers (DMs) was noted concerning experts. Consequently, the Borda count method was employed to delineate the ultimate preference. Further details on the Borda Count method can be found in Zahid and De Swart (2015).

	Ordered		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Decimal	Filter	699	747	750	751	763	767	2491	2523	2525	2527	2555	2559	2747	2795	2798	2799	2811	2815	3259	3293	3295	3310	3311	3327
1 - lebanese parties	incineration	-	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y
	export abroad	-	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
	building new landfil	-	N	N	Y	Y	N	Y	N	N	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	Y	Y	Y	Y
	Expansion existing l	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2 - municipalities	incineration	-	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	N	N	Y
	export abroad	-	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y
	building new landfil	-	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
	expansion existing l	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
3 - relevant ministr	incineration	-	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
	export abroad	-	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N
	building new landfil	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
	expansion existing l	-	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Payoff For:	lebanese parties	-	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Payoff For:	municipalities	-	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Payoff For:	relevant ministries	-	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	Nash	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	GMR	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	SEQ	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	SIM	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	SEQ & SIM	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	SMR	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Figure 4. Feasible states

```
lebanese parties:      [[22, 20, 21, 23, 24, 19, 7, 8, 9, 10, 11, 12, 1, 2, 3, 4, 5, 6, 13, 14, 15, 16, 17, 18]]
municipalities:        [[22, 23, 20, 21, 24, 19, 1, 2, 3, 4, 5, 6, 13, 14, 15, 16, 17, 18, 7, 9, 8, 11, 10, 12]]
relevant ministries:   [[12, 9, 7, 8, 11, 10, 1, 2, 5, 13, 6, 14, 17, 3, 4, 15, 16, 18, 22, 20, 21, 19, 23, 24]]
No Errors. Preference rankings are valid.
```

Figure 5. Preferences vector of the players

5.5. Stability analysis

If a player does not exhibit a tendency to transition from a specific state, that state is deemed the stable state for that player. When a state is stable for all players involved, it is termed "equilibrium." As previously delineated, diverse methodologies exist for ascertaining the equilibrium states of a conflict, contingent upon the players' attitudes and their decision-making horizon. In the context of Nash equilibria, players contemplate only one future state. A player characterized by Nash stability will abstain from making any moves if the prospective state fails to confer advantages surpassing those of the current state. In the overarching frameworks of general meta-rationality (GMR) and sequential stability (SEQ), a player's decision to move is contingent upon the consideration of the two ensuing steps.

The concordance among political parties and municipalities will reflect an internal consensus within the government, whose ministers are affiliated with these parties, as evidenced by GMCR+ outputs. Consequently, the practicable options (24 in total) outlined in the table are predominantly contingent upon political agreement, a characteristic uncommon in conflict research and analysis. Nevertheless, surveys and expert interviews posit that the optimal course of action involves formulating an environmental emergency plan encompassing the expansion

of existing temporary landfills in mutually agreed-upon locations by the parties and the establishment of new sanitary landfills adhering to safety requirements.

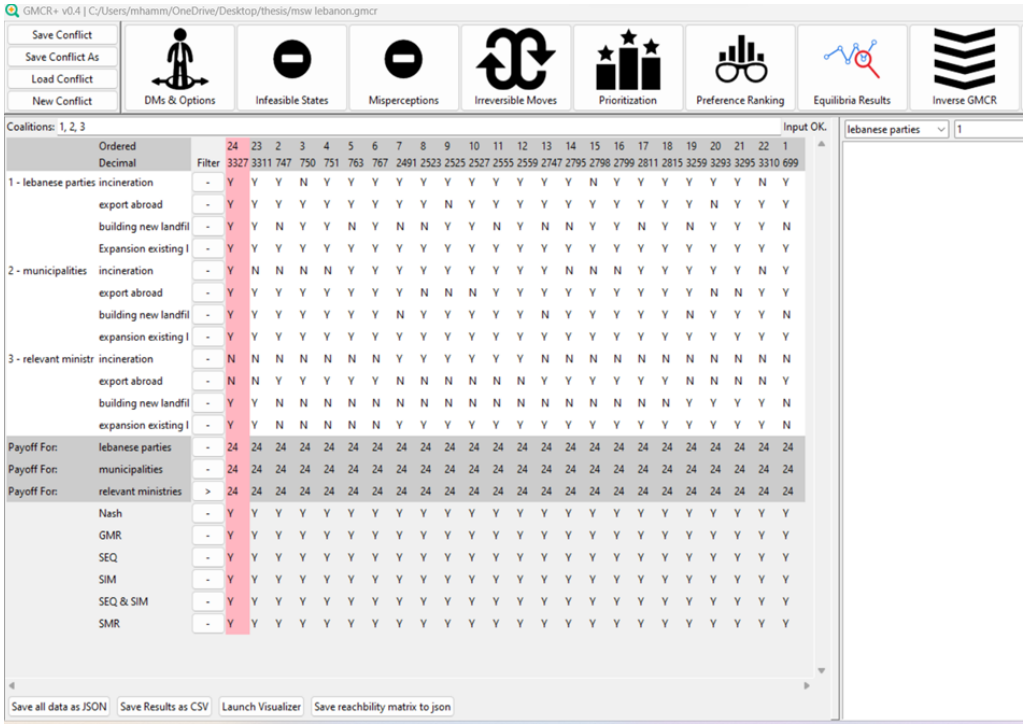

Figure 6. Equilibrium states

5.6. Equilibria

Throughout the GMCR+ outputs, it has been observed that the "payoffs" associated with all options (24 in total) are equivalent. This indicates that each option or decision in a conflict resolution scenario result in identical outcomes in terms of benefits or costs. In other words, there is no discernible variation in the consequences or rewards linked to each choice. This implies that all the options carry comparable environmental and financial impacts, and none of them offers a distinct advantage or disadvantage over the others.

Option No. 24 is regarded as the most favorable solution for the concerned ministries, as it secures technical agreement from municipalities and involved parties. This enables the government to broaden the range of technical options available for discussion. The state opts to avoid incineration due to its considerable environmental and health risks, particularly given Lebanon's lack of transparency in standards. Furthermore, incineration involves high operational and maintenance costs that the state is unable to afford amidst the current crisis.

6. Discussion and conclusion

Lebanon's waste predicament transcends mere technical concerns, fundamentally manifesting as a political issue. While the imperative for effective physical and technological waste

management solutions remains undeniable, the root challenges in Lebanon revolve around administrative inefficiencies, decision-making processes, and the absence of streamlined legislative frameworks. The dearth of a coherent waste management policy, coupled with political instability and pervasive corruption, collectively underpin the garbage crisis afflicting Lebanon. These political dynamics have impeded the implementation of efficient and sustainable waste management practices. Consequently, addressing Lebanon's waste crisis necessitates not only technical interventions but also a confluence of political resolve, transparent governance, and the establishment of effective regulations and laws.

Upon achieving a political consensus among influential factions and aligning with Lebanon's intricate political, sectarian, cultural, and economic context, a judicious initiation of the amalgamation of centralization and decentralization in Lebanon's solid waste management becomes imperative. The researchers underscore the exigency for decentralization owing to Lebanon's diverse cultural and social norms, as well as the prevalent socioeconomic disparities.

Waste incineration significantly reduces the volume of waste, reducing the need for landfill space. It is also possible to generate electricity or heat through waste-to-energy processes. However, due to concerns about air pollution, emissions of dioxins, furans, and other pollutants, and high initial investment and operating costs, this solution, although it may be acceptable to parties and municipalities, will not be accepted by the government as a solution.

Exporting waste can be a quick solution to the problem of waste accumulation, or it can be a temporary solution with the development of long-term waste management strategies, but the main problem lies in the unwillingness of any parties or countries to import solid waste from Lebanon, especially with the absence of a solid waste sorting policy.

Therefore, the Lebanese government remains faced with the option of landfilling waste, which is characterized by low initial investment compared to incineration and can be implemented relatively quickly. In addition, work must be done to build sanitary landfills on various Lebanese lands following the principle of decentralization in solid waste management, because Lebanon lacks such landfills that take appropriate environmental conditions into account. The proposed strategy advocates for the establishment of both decentralized sorting and recycling facilities managed by local cooperatives alongside centralized waste management facilities to handle substantial waste volumes efficiently. Public-private collaborations, educational initiatives, and active engagement of the business sector emerge as pivotal components of this approach. The formulation of a comprehensive waste management strategy is recommended, encompassing objectives related to waste minimization, recycling targets,

collection, sorting, treatment, and sanitary landfilling. To ensure progress tracking and adherence to environmental standards, continuous monitoring and evaluation are deemed indispensable.

The articulated strategy places significant emphasis on fostering a societal ethos that champions waste reduction, reuse, recycling, and composting while simultaneously endorsing industries rooted in recycling. The formulation of unequivocal policies delineating the roles of the state, municipalities, civil society organizations, and households is imperative. The integration of centralization and decentralization must unfold within the framework of an encompassing strategy garnering support across diverse regions, thereby averting the pitfalls encountered by previous initiatives.

6.1. Limitations

Given the intricate nature of the conflict, the research may encounter challenges pertaining to the accessibility and reliability of data concerning waste management in Lebanon. The findings and proposed strategy may exhibit specificity to the Lebanese context and may not readily lend themselves to broader application in regions or countries characterized by distinct socio-economic and political circumstances. The intricacies of waste management in Lebanon, entwined with political and social nuances, may pose difficulties in engaging a diverse array of stakeholders for the study. Furthermore, constraints related to time and finances may impede the practical implementation of the envisaged solution. A comprehensive evaluation of the technological viability of waste treatment methods is imperative, as certain technologies may prove nonviable or unsustainable within the framework of Lebanon's infrastructure.

Disclosure statement

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The Diffusion Model of NFC Technology in the Mobile Payment System in Iran

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ABSTRACT

This study aims to create a diffusion model for the diffusion of Near-Field Communication (NFC) technology in the mobile payment system in Iran. NFC technology is one of the technological applications that is spreading worldwide daily and being used in various industries. In recent years, the country's banking system has tried implementing it in electronic payments based on cell phones, but it has not yielded results. The study's statistical population is everyone over 18 who can use the banking system. It is an applied and mixed study (quantitative and qualitative) using a system dynamics approach. The results are summarized in four scenarios, with the fourth scenario providing the best results. By implementing this scenario, accompanied by an increase in contact rate, education and culture, and legal infrastructure, the growth of NFC technology among users of mobile phone-based payment systems in the country can be increased to an acceptable level.

Keywords

Technology diffusion, Near field communication technology, Mobile payment systems, System dynamics.

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1. Introduction

One of the technologies offered in mobile phones is Near-Field Communication (NFC). This technology has emerged in recent years and is growing and expanding. NFC technology is a communication standard for electronic equipment that can exchange data between two devices at a distance of less than 10 cm, with a bit rate of 106, 212, and 424 kbps and central frequency of 13.56 Mhz. The mobile payment system based on NFC is growing in many countries and can be used as an alternative to bank payment cards (Samouti and Fathy, 2020). This technology makes paying for goods or services possible by entering banking information into the installed software and bringing the mobile phone close to the card reader device equipped with an NFC chipset.

According to the statistics provided by the central bank and the "Shaparak" system, the growth of the use of the NFC system in Iran is very low, and the efforts made by the banks and electronic payment services providers have not resulted. In March 2015, the "Shaparak" published an instruction manual for the application of this system with the title "Introducing a payment model based on NFC technology in the country's payment network", but due to the lack of proper information, user training, and concerns of users about security and privacy, there is a long way to spread this technology in the country.

In this study, an effort will be made to pave the way for the diffusion of this technology by finding the effective indicators of the "NFC" technology, ranking them, and highlighting their most important.

The main question of this research is how to build the Near Field Communication technology diffusion model and the model validation method. This research can help improve electronic technologies in the payment system and grow the country's banking system.

2. Theoretical background and experimental background

2.1. Theoretical background

NFC technology is considered a communication standard for electronic equipment that can exchange data between two devices equipped with this technology at a distance of less than 10 cm. This feature can cause significant business growth in the consumer, producer, and seller sectors (Bojan et al., 2018). A significant advantage of NFC technology is that it prevents eavesdropping due to using short-range methods in interactions and transactions (Rahul et al., 2015).

Users of this technology can pay for goods or services by entering bank details into the mobile phone's software and bringing it close to the NFC-enabled device. The number of people choosing mobile payments based on NFC technology has also seen a huge jump in recent years. In 2017, 824 million people in the world used this payment method, and the number of users using this technology in mobile payment has increased to 1.3 billion people by 2020, which has grown by 13.5% compared to 2019 (NFC Forum, 2021).

In 2016, five banks, including Parsian Bank, Shahr Bank, Refah Bank, Mellat Bank, and Saderat Bank, unveiled NFC technology, which remained silent due to the lack of card readers equipped with this technology and the lack of widespread use of smartphones. In March 2020, despite the widespread use of smartphones equipped with NFC technology, the provision of POS devices equipped with this technology, and the issuance of a license for use by the Central Bank, it has yet to be well received. Non-establishment standards and unavailability of equipment, incompleteness of the necessary infrastructure, the reluctance of people to use NFC due to issues such as security, privacy and also the lack of necessary knowledge and awareness in this field caused the failure of the efforts made in Iran have been made to use this technology widely. By conducting this research, an effort will be made to remove barriers and provide a diffusion model based on the country's native culture.

2.1.1. Technology diffusion model

When the World Health Organization launched a global campaign to eradicate smallpox, it engaged in diffusion. When Apple launched the iPod, it released a new product (Dearing and Meyer, 2006). The diffusion process of new technologies has been studied for more than 30 years, and one of the most popular diffusion models is described by Rogers in the book Diffusion of Innovations (Sherry and Gibson, 2002). According to Rogers, "technology is an action plan, a tool that reduces uncertainty in causal loop relationships involved in achieving a desired result" and consists of two parts: hardware and software (Sahin, 2006).

Hardware is "a tool that embodies technology in the form of a material or physical object", and software is a "tool database" (Rogers, 2003). Since software (as a technological innovation) has a low level of observability, its adoption rate is very slow. According to Rogers (2003), acceptance is a decision about "full use of an innovation as the best available course of action" and rejection is a decision "not to adopt an innovation".

Rogers (2003) defined diffusion as a process in which technology is transferred through certain channels over time among the members of a social system.

2.1.2. Mobile phone payment systems

It refers to systems in which the process of paying for a product or service and financial transactions between the seller and the buyer can be done using a mobile phone and related software. "Mobile phone payment system" technology provides banking and financial facilities for all kinds of services and products through mobile phones (Sharma and Mathuria, 2018). Today, smartphones are used in various payments, such as online ticket purchases, online electronic transactions, transportation fares, bill payments and invoices for goods and services, and other similar cases. On the other hand, physical product purchases are possible through a "mobile payment system". Today, most electronic payment systems and payment tools can be used on mobile devices (Ometov et al., 2018).

"Mobile Payment System" is more than just a payment method. This system implements the processes of initiating, processing, and confirming financial transactions. Although different versions of mobile phone-based payment may have similar functions, their design and implementation are different due to methods and structures (Ahmed et al., 2021).

2.1.3. Near field communication technology

It is one of the latest short-range wireless communication technologies that provide secure communication between electronic devices and similar devices with this technology from a distance of approximately 10 cm (Rahul et al., 2015). NFC technology is an international interface and protocol standard for simple wireless communication between near-connected devices developed by "International Organization for Standardization". NFC devices communicate at bit rates of 106, 212, and 424 kbps. This International Standard defines communication modes for an NFC interface and protocol using inductively coupled devices operating at 13.56 MHz for connecting computer peripherals (Mohandas et al., 2015). In the electronic payment system by NFC, both the mobile phone and the card reader must be equipped with this technology.

2.1.4. System dynamics

System dynamics models are mathematical causal loop models whose basic assumption is simulation (Safaie et al., 2022). Results can predict a system's behavior accurately if its structure is presented accurately (Bastan et al., 2018). In system dynamics, Vensim software is used for simulation. System dynamics were presented in the mid-1950s by one of the professors of the Massachusetts Institute of Technology named Forrester as a new method for managing the

performance of companies. Experts believe that the human brain cannot correctly interpret the behavior of social systems using linear and one-way logic. Hence, multi-loop nonlinear feedback systems should be used to analyze various phenomena. By simulating the system's dynamics, the expertise was able to identify the root of the organizational problems of General Electric Company. By proving the effectiveness of system dynamics and technological progress, the use of computer software to implement this method was expanded (Vennix et al., 1997). In the early introduction of system dynamics, this approach was only used to solve organizational management problems. In 1970, the experts faced the challenge of using the system dynamics to analyse the problem of lack of resources caused by the growth of the human population. They created the first draft of the world's dynamic socio-economic system model and introduced it as a global dynamic model.

The system dynamics approach is based on concepts such as feedback loop and stock flow, and the authors will introduce these concepts and related definitions.

2.1.5. Causal loop diagram

Systems are interconnected nests in feedback loops whose connections cause the system's behavior. The feedback loop is a process in which system outputs are used as system inputs during a cycle (Angerhofer and Angelides, 2000). Feedback loops have two types, positive and negative, as shown in Figure 1.

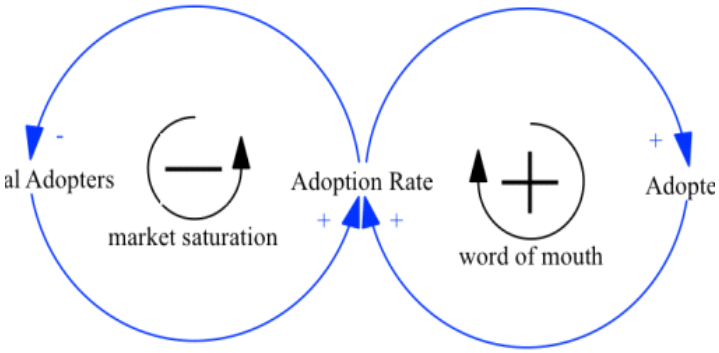

Figure 7. Positive and negative feedback loops (Angerhofer and Angelides, 2000)

2.1.6. Stock and flow diagram

The causal loop diagram visually displays the system's structure and qualitative analysis of the system. The stock and flow diagram (Figure 2) is a diagram that enables quantitative study and analysis of the system (Safaie et al., 2023). In system dynamics, anything whose value increases or decreases over time is called stock. Flow is the stock change rate (Sterman, 2000). Stock and flow models are usually simulated and analysed by computer software.

Figure 8. Stock - flow diagram in system dynamics (Sterman, 2000)

2.2. Experimental background

In this part of the research, studies on the diffusion of mobile payment systems using NFC technology have been investigated. The study conducted from 2007 to 2023 regarding mobile payment systems and NFC technology is given in Table 1. Various models have been used in this paper, such as fuzzy logic, the technology acceptance model, the integrated model of technology acceptance and use, the innovation diffusion model, and many others.

Most of the research has been done using various technology acceptance models, and only a few of these researches have used the technology diffusion model along with system dynamics. In cases where the system dynamics approach has been used, the issues of technology diffusion in electronic and mobile payment systems have been evaluated. The research done inside the country is in the field of similar technologies, and no research has been found on NFC technology in mobile payment.

According to the review of research (Table 1), severe weakness in this field has been observed, and the conducted investigations show the reluctance of the owners and internal researchers to use and diffusion of NFC technology in the mobile payment system. It is the first research conducted in the country in the field of spreading this technology in the mobile phone payment system based on NFC technology and with the approach of the country's system dynamics.

Table 3. Summary of studies

The author/authors	The research method	The variables
Chen and Chen (2007)	Bass diffusion model, system dynamics	Advertising and product price
Baran (2010)	Bass diffusion model and system dynamics	Word-of-mouth advertising, Advertising
Heydarieh and Shahabi (2012)	Technology acceptance and system dynamics	Perceived usefulness, perceived ease of use, user awareness, habit
Sarlak and Raustaei, Moghadasian (2013)	Technology acceptance model	Mental norms, ease of use, usefulness, attitude and security
Mousavi and Tajik (2013)	Bass diffusion, system dynamics	Word-of-mouth advertising, quality
Liébana-Cabanillas et al. (2013)	Technology acceptance model	Mental norms, ease of use, usefulness, attitude
Oh et al. (2014)	Technology acceptance model, innovation diffusion model	Service of usefulness, Ease of use, observability, testability, universality and expressed value, word-of-mouth advertising
Shin et al. (2014)	Technology acceptance model and technology	Perceived usefulness, perceived ease of use, innovation, optimism, responsibility, Intelligence,

The author/authors	The research method	The variables
	readiness model	Discomfort and insecurity
Longyara and Van (2015)	Technology diffusion model	Compatibility, Relative Advantage and perceived benefits, Complexity
Karsikko (2015)	Innovation diffusion model and technology acceptance model	Related benefits, Compatibility, Ease of use, Income, Influence of external networks, Use of payment cards, Cost, Security risks, Age, Income.
Oliveira et al. (2016)	An integrated model of technology adoption and use, Technology diffusion model of	Compatibility, Perceived technology security, Performance expectations, Innovation and social influence
Bastan et al. (2017)	Technology acceptance and system dynamics	Trust, Perceived usefulness, Ease of use, Satisfaction
Homayounfar and Nahavandi, Golbazzadeh (2017)	The spread of bass, System dynamics	Word-of-mouth advertising, The increase in advertising and research and development budgets.
Stanivuković et al. (2018)	Diffusion theory of innovation and fuzzy logic technology, Cost of migration, Innovation	Risk, Reliability, Compatibility, Multi-functionality, Applicability in the market, Limitations of existing technology, Cost of migration, Innovation.
Wang and Lai (2020)	Diffusion of innovation, System dynamics	Utility, User response time, Network interactions, Payment platform brand, Understanding user needs.
Shin and Lee (2021)	Technology acceptance model	Acceptability, Smart services and habit
MadadiNia, et al. (2023)	Bass diffusion model, System dynamic	Word-of-mouth advertising system, Mental norms, Technology image, User needs, Optimism, Insecurity, Productivity, Compatibility, Distrust complexity, Advertising effect.

3. Research methodology

This paper is applied research from an objective point of view. From the point of view of variable, quantitative, and qualitative research, as well as in terms of nature and method, it is classified as descriptive-analytical research. The data collection tools include questionnaires and interviews with experts who, due to the specialization of the subject, are experts with at least 18 years of work experience or university teaching in fields related to the research subject (information technology, electronic banking systems, and system dynamics). The Delphi method was used to extract the indicators. In this field, an exclusive interview was conducted with experts and senior managers of Mellat, Agriculture, and Resalat banks, as well as the Deputy of Mobile Communications of Khuzestan Province Telecommunication Company. Data analysis was done using the system dynamics approach and Vensim software.

4. Research findings

4.1. Causal loop model

The causal loop model for the diffusion of NFC technology is drawn based on the variables extracted in the research background section and their relationships in Figure 3.

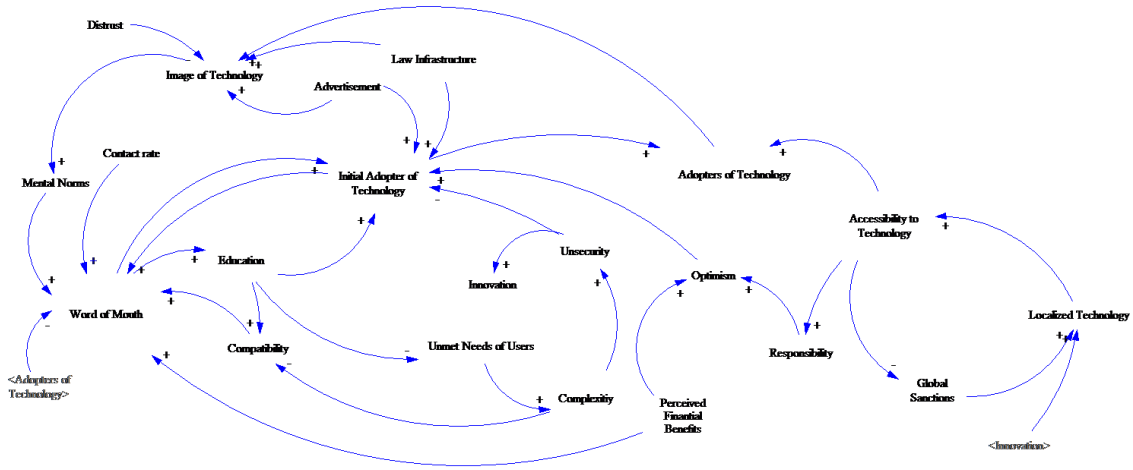

Figure 9. Causal loop model

4.2. The steps of system dynamics modelling

4.2.1. Dynamic hypothesis

The dynamic hypothesis describes the system's structure and explains what is happening dynamically (Koenig and Lewis., 2010). In the dynamic hypothesis, the authors have extracted the most important factors and ranked them according to their importance among all the factors in the research literature, using experts' opinions and the sensitivity analysis method. The dynamic hypothesis of this research is the explanation of the hypothesis as follows, which is tested by a simulated model:

Considering that the increase in the call rate increases word-of-mouth advertising, the improvement of word-of-mouth advertising will lead to the growth of potential adopters and the adoption rate of the technology. The technology rate variable's growth determines the changes in the actual number of technology adopters. With the increase in the growth rate of technology, the number of technology adopters has increased over time, which can give positive feedback to the word-of-mouth advertising variable. In the continuation of this cycle and the positive effect on the variable of stock of potential adopters and the variable of the growth rate of technology adopters, the authors will see an increase in the variable of technology adopters over time.

4.2.2. Stock-flow model

According to the causal loop model, the Stock-flow model was drawn, and the mathematical equations related to each variable were written using Vensim software. The Stock-flow diagram is shown in Figure 4.

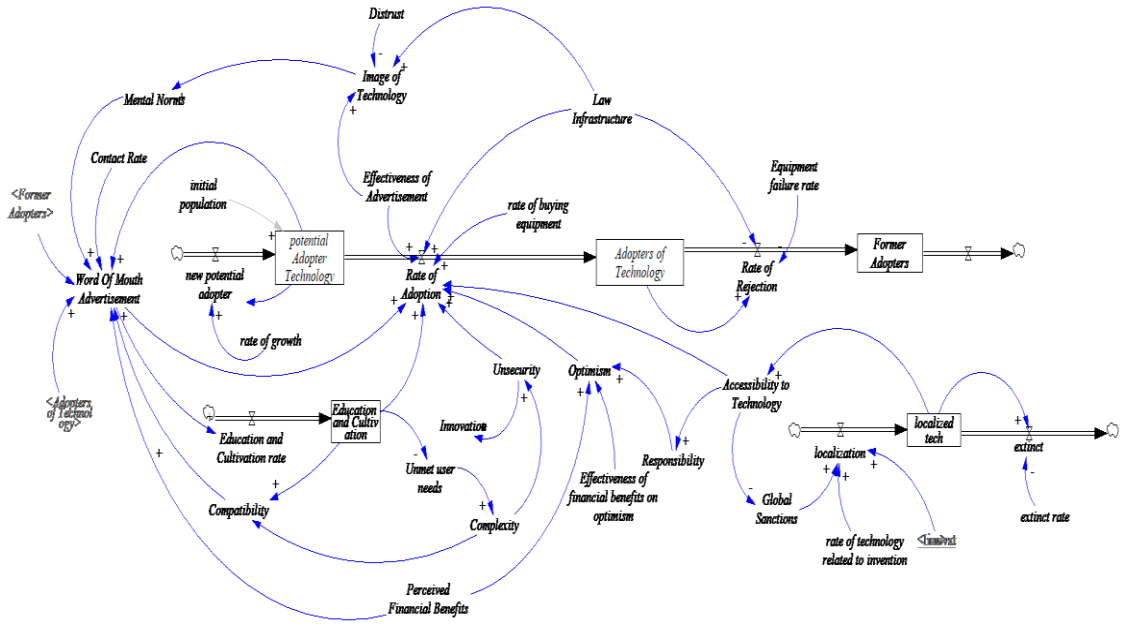

Figure 10. Stock-flow model diffusion model of NFC technology in mobile payment system

4.3. Model validation and simulation

After simulating the system dynamics model and before creating a scenario and relying on its results, validation should be done on the developed model. The most important step in determining the validity of the model designed in this research is judging its appropriateness. With the desired goal and after completing the stages of its design and implementation, the model was given to the expert group consisting of experts related to the subject and experienced senior managers in banking and economic institutions, information technology managers, and university professors to check the validity. Then, in order to confirm the validity of the presented model, since the NFC technology has not been seriously implemented in the country, first simulated the model for POS technology and issued bank cards; after confirming the validity of the model with various types of the methods, parameters of the model are set based on the NFC technology and the scenario analysis has been done regarding this type of technology.

4.3.1. Reference behavior reconstruction test

As seen in Figure (1), real data from 2015 to 2022 regarding the number of people who use bank cards have been compared with simulation results. The comparison of the results found that the model could reasonably simulate this reference variable's behavior to a reasonable extent.

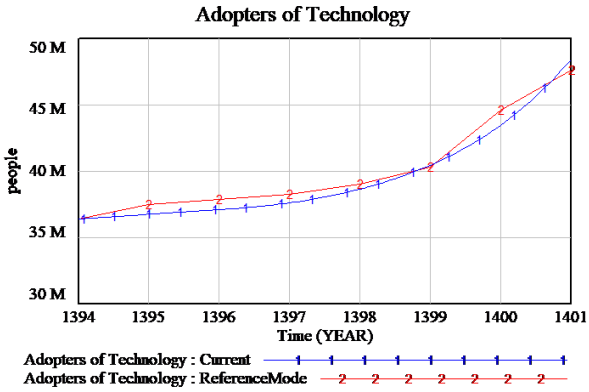

Figure 11. Comparing the real data and the variable simulation value of people that using bank cards

4.3.2. Structure verification test

The structure verification test evaluates the completeness and correctness of the model structure. The presented model's formulas for the variables are written and completed correctly, so the model can be implemented correctly. The implementation of the model shows that it is structurally free of defects, which has been confirmed using Vensim PLE software. The results presented in Figure 6 indicate the validity of the model.

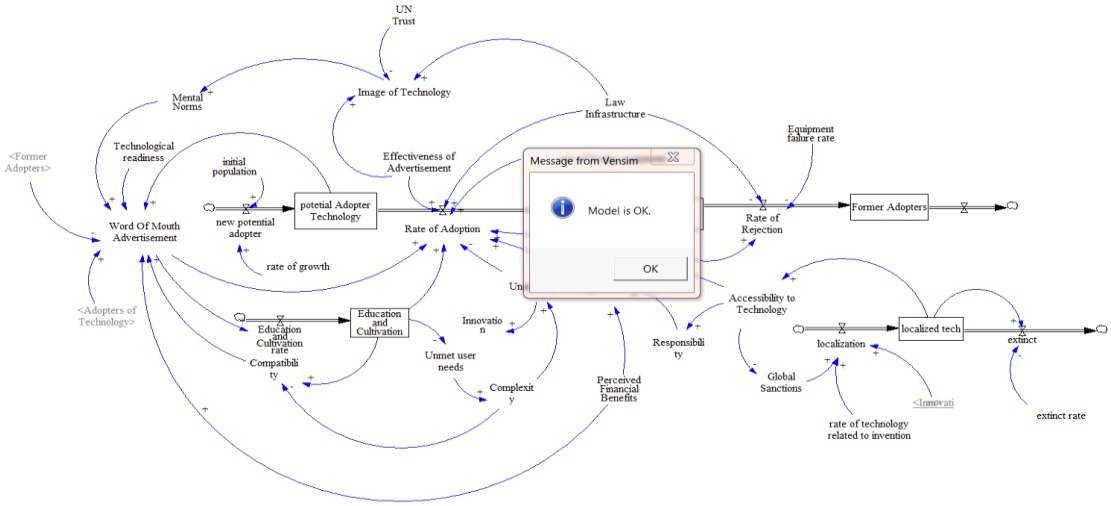

Figure 12. Checking of the model validity in the structural evaluation test with the Vensim software

4.3.3. Dimensional consistency test

The basic issue in this test is the equality and balance of the dimensions of the variables in all the equations used in the model. If all the selected units for the variables and fixed values in the model are correctly selected using the Vensim software, the correctness of the selected units can be evaluated by performing a dimensional verification test. If one of the selected units is not used correctly, it is impossible to confirm this test by the software, and incorrect units are shown as errors. According to the implementation of the designed model in Vensim software

and the results received, as seen in Figure 7, this model has been confirmed in terms of dimensional compatibility.

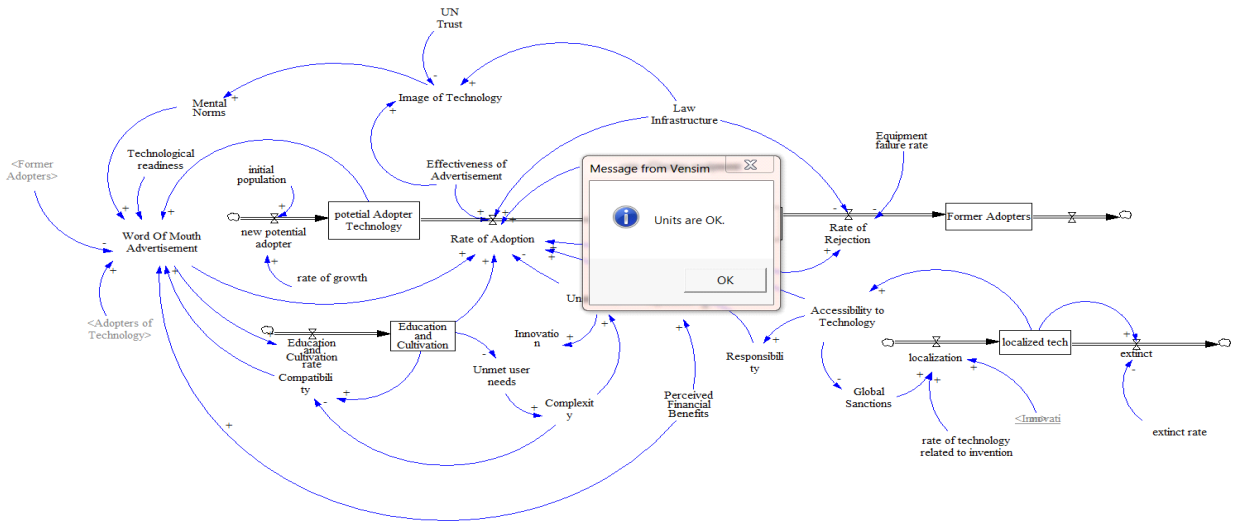

Figure 13. Examining the validity of the model in dimensional compatibility test with the vensim software

4.3.4. Limit condition test

In this part, the authors have examined the model's input variables under different values. The results showed that the model had reasonable behavior under certain conditions, and by observing the results of these changes in the input variables, practically no unreasonable behavior was observed. Therefore, the model's validity is confirmed in terms of this test. For example, by increasing the rate of technology growth by five times, as the authors expect, the number of potential adopters is greatly reduced, and the number of actual adopters is increased by the same amount (Figure 2&3). The model simulation results also indicated the same behavior, and no unreasonable behavior was observed regarding the model variables.

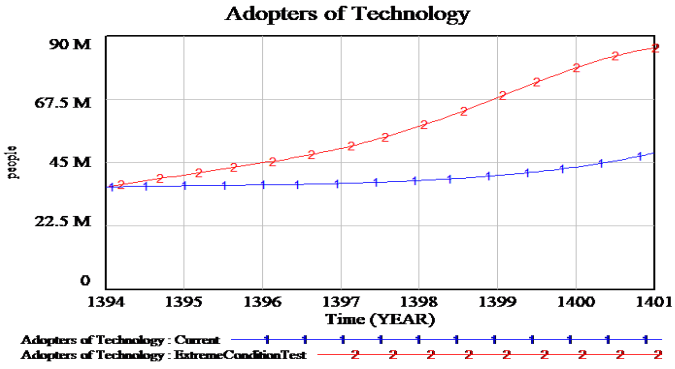

Figure 14. The results of the limit condition test of the simulated model

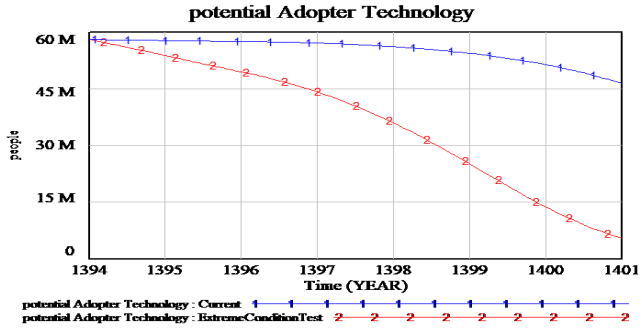

Figure 15. The results of the limit condition test of the simulated model

4.3.5. Boundary adequacy test

In this test, attention is paid to the structural relationships necessary to satisfy the purpose of the model, and this question must be answered: "Is the overall level of the model appropriate and all the related structures, including the variables and feedback effects that are necessary to investigate the problem?" Does it include the research objectives? Is it appropriate to the research objectives? Although it is almost impossible to deal with all the details and dimensions of the diffusion of NFC technology in the mobile phone payment system in Iran, and it requires building a model as big as human minds and the real world around them, the answer of the group of experts to this question, considering According to the dynamic hypothesis, the objectives of the research and the results of the implementation of the model were satisfactory.

4.3.6. Apparent validity test

This test examines the model's validity in terms of appearance so that the following questions can be answered in addition to compatibility with the real system: 1) Is the model structure similar to the real system? 2) Does the model provide a recognizable representation of the real system? 3) Is there a reasonable fit between the model's feedback structure and the real system's characteristics? The answers of the group of experts to all questions were positive, and the model's compliance with many previous researches on this matter and the effects of increasing the spread of NFC technology in the mobile payment system in Iran were quite evident.

4.4. Scenario planning

Identification of key parameters for scenario development: In this part, a sensitivity analysis was done on the parameters defined in the model to rank and identify the key factors. The impact of parameters on Technology Adopters is listed in Table No. 2.

Table 4. Ranking of the influence of different parameters on the variable of the technology adopters

NO	Variable
1	Contact rate
2	Early adopters
3	Legal infrastructure
4	Education and cultivation
5	Advertisement
6	Purchase of equipment
7	Lack of trust
8	Technology abandonment rate

4.4.1. First scenario: continuation of current conditions

After confirming the model's validity in terms of structure and behavior and setting the parameters related to bank payments based on NFC technology, the scenario analysis for the next ten years of this technology (1402 to 1412) will be done. According to Table 3, the parameters related to this technology are assumed to be similar to bank cards in the current conditions, and the scenario has been analyzed[1].

Table 5. Values of parameters affecting the diffusion of NFC

NO	Variable	Value in the first scenario
1	Contact rate	0.78
2	Early adopters	500,000
3	Legal Infrastructure	0.6
4	Education and cultivation rate	(0.05+Word of Mouth Advertisement/5.8e+007)
5	Advertisement	0.4
6	Purchase of equipment	0.5
7	Lack of trust	0.7
8	Technology abandonment rate	0.35

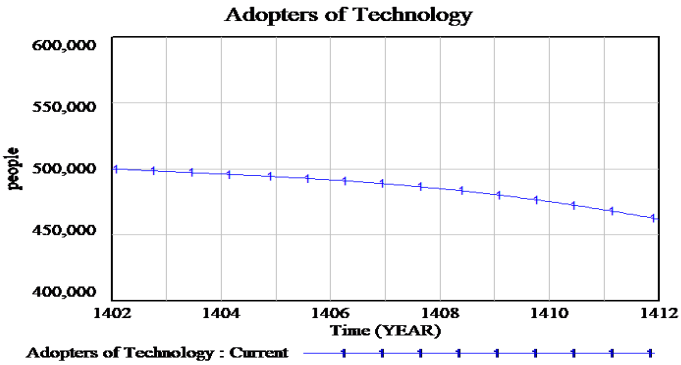

Figure 16. Reduction of technology adopters due to the implementation of the first scenario

As seen in the scenario of continuing current conditions, NFC technology, assuming stability in model simulation parameters in the past, will face a decline in diffusion, and the number of

1 Qualitative variables have been converted into quantitative values using a Likert-scale questionnaire or experts' opinions.

technology adopters will gradually decrease (Figure 6). Therefore, the following parameters were applied in the second scenario to expand the use of the mentioned technology.

4.4.2. The second scenario: improving the legal infrastructure, improving the effectiveness of advertising, and increasing trust

Due to the decline in the number of technology adopters in the first scenario, changes are made to the variables that influence the spread of technology. Therefore, to spread and expand the mentioned technology, the authors have improved legal infrastructure, advertising, and trust variables in the second scenario (according to Table 4).

Table 6. Parameters applied in the second scenario

NO	Variable	Value in the first scenario	Value in the second scenario
1	Contact rate	0.78	0.78
2	Early adopters	500,000	500,000
3	Legal infrastructure	0.6	0.9
4	Education and cultivation rate	(0.05+Word of Mouth Advertisement/5.8e+007)	(0.05+Word of Mouth Advertisement/5.8e+007)
5	Advertisement	0.4	0.6
6	Purchase of equipment	0.5	0.5
7	Lack of trust	0.7	0.35
8	Technology abandonment rate	0.35	0.35

As seen in Figure 11, the number of technology adopters is increasing compared to current conditions, and technology diffusion is significantly improving.

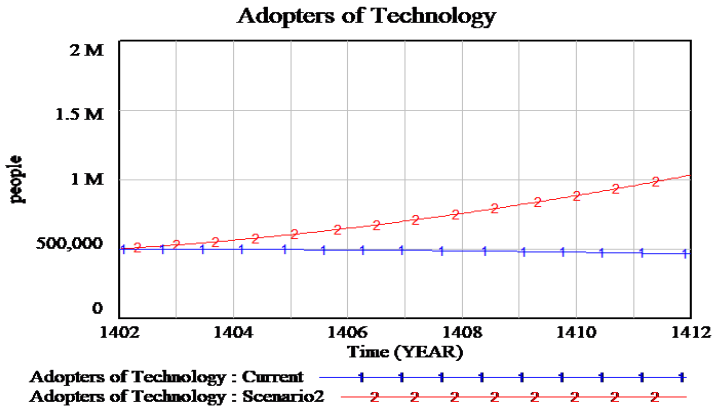

Figure 17. Increase of technology adopters up to 1,050,000 users in the second scenario

4.4.3. The third scenario: focusing on education and culture in addition to improving the parameters of the second scenario

In this scenario, all parameters of the second scenario have improved, and special attention has been paid to education and culture. According to Table 6, the number of technology adopters changes when the input rate for education and culture changes (Figure 12).

Table 7. Parameters applied in the third scenario

NO	Variable	Value in the first scenario	Value in the second scenario	Value in the third scenario
1	Contact rate	0.78	0.78	0.78
2	Early adopters	500,000	500,000	500,000
3	Legal infrastructure	0.6	0.9	0.9
4	Education and cultivation rate	(0.05+Word of Mouth Advertisement/5.8e+007)	(0.05+Word of Mouth Advertisement/5.8e+007)	2*(0.05+Word of Mouth Advertisement/5.8e+007)
5	Advertisement	0.4	0.6	0.6
6	Purchase of equipment	0.5	0.5	0.5
7	Lack of trust	0.7	0.35	0.35
8	Technology abandonment rate	0.35	0.35	0.35

After the changes made to the parameters in Table 5, the following results emerge regarding the behavior of the model variables: education and culture do not considerably influence the number of technology adopters.

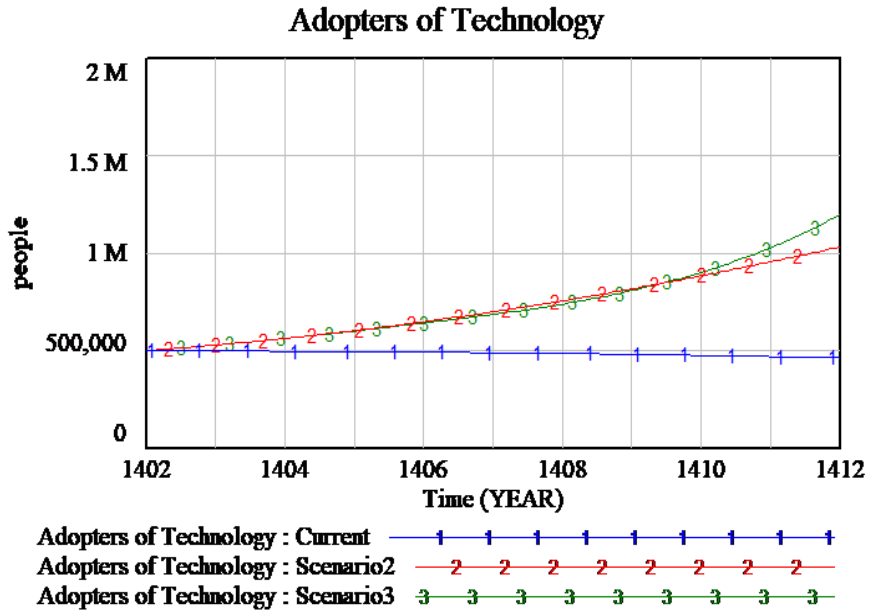

Figure 18. The increase of technology adopters 1.200.000 users in the third scenario

4.4.4. The fourth scenario: improving the early adopters in the fourth scenario

Assuming that the changes made to the parameters of the previous scenario are permanent, we assume that the authors will double the number of early adopters of the technology simulation, which was half a million in the previous scenario formulation (Table 6).

Table 8. Parameters applied in the fourth scenario

NO	Variable	Value in the first scenario	Value in the second scenario	Value in the third scenario	Value in the fourth scenario
1	Contact rate	0.78	0.78	0.78	0.78
2	Early adopters	500,000	500,000	500,000	1,000,000
3	Legal infrastructure	0.6	0.9	0.9	0.9
4	Education and cultivation rate	(0.05+Word of Mouth Advertisement/5 .8e+007)	(0.05+Word of Mouth Advertisement/5 .8e+007)	2*(0.05+Word of Mouth Advertisement/5 .8e+007)	2*(0.05+Word of Mouth Advertisement/5 .8e+007)
5	Advertisement	0.4	0.6	0.6	0.8
6	Purchase of equipment	0.5	0.5	0.5	0.5
7	Lack of trust	0.7	0.35	0.35	0.35
8	Technology abandonment rate	0.35	0.35	0.35	0.35

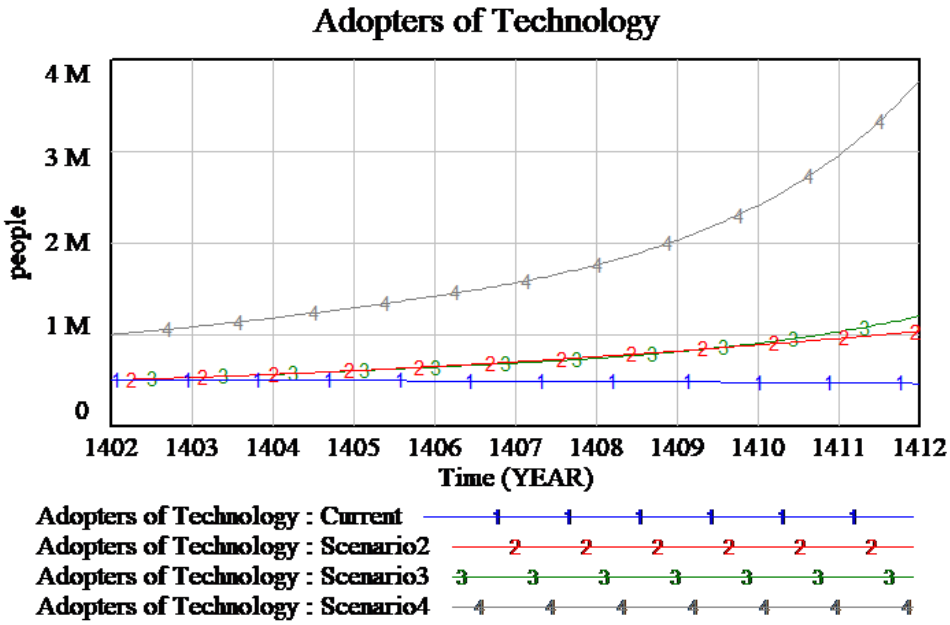

Figure 19. The increase of technology adopters up to 3.800.000 users in the fourth scenario

As shown in Figure 13, the initial number of people using NFC technology greatly impacts the growing trend of actual technology adopters. The results of the last scenario have also shown that the successful diffusion of NFC technology requires simultaneous actions in the four areas of advertising, reducing distrust of the technology, facilitating the legal infrastructure, and increasing the initial number of users of the technology. The summary of the scenarios can be found in Table 7.

Table 9. Definition of the four scenarios examined in the research

Scenario	Explanation of the scenario	The number of technology adopters in 1412
First	Continuation of the current process according to the bank card parameters	462,000
Second	Reducing lack of trust in technology, increasing advertising effectiveness, improving legal infrastructure	1,032,000
Third	Increasing the amount of education and culture	1,197,000
Fourth	Increasing the number of early technology adopters	3,774,000

4.5. Managerial insights.

According to the presented model, if the banks, financial and credit institutions, and other government institutions that influence the implementation of this technology are willing, in the not-so-distant years, the spread of this technology can be felt tangibly at the community level. The implementation and dissemination of this technology require a positive managerial attitude and perspective at the macro level of the country, the efforts of public and private institutions, as well as the implementation of laws and policies in order to ensure the security of users in the use of this technology by policymakers and legislators. The growth and spread of this technology depend on banking institutions, companies providing payment services, and customers. As the security provided in the provision of services increases, more customers will use this technology. With the increase in customers, banking institutions and service providers will be encouraged to install devices equipped with this technology more in society, and this cycle will continue as a self-reinforcing circle.

5. Conclusion and discussion

This study first presented the dynamic hypotheses as a causal progression diagram. Then, the stock variables of the model were identified, and the stock flow diagram was drawn. Subsequently, the mathematical relationships between the variables were entered into the model (Appendix 1), and the created model was evaluated and confirmed with validation tests. Next, the scenario analysis based on predicting the behavior of the model variables in the next ten years was performed, and the results were presented. As part of the reference behavior reconstruction test, the model simulated with an accuracy of over 98% the behavior of the number of card reader network operators from 2014 to 2022. After confirming the validity, a sensitivity analysis was performed to identify and rank the model's parameters. In the end, four scenarios were analyzed by adjusting the parameters for NFC technology.

The results of this study show that NFC technology will not only fail to develop but will also decline if it is developed according to the card banks' method. In order to successfully spread

this technology, the categories of advertising, legal infrastructure, education and culture, and early adoption of the technology must be considered simultaneously.

5.1. Limitations of the research

One of the limitations of most studies conducted using the system dynamics approach is the effects of variables and other parameters on the model making, which is limited according to the system boundary and its influence and the internal mechanism of the model. In this study, some parameters are assumed to be exogenous due to the large number of variables influencing the technology diffusion model.

Another limitation relates to some qualitative variables whose influence on the system under study is obvious. For example, legal infrastructure is a relatively defined variable for which an exact amount cannot be obtained.

Another limitation of the research is that we cannot use all the effective variables in technology diffusion. The increase in the number of influential variables in the diffusion of technology causes the expansion and complexity of the model. Therefore, it is suggested that in future research, in addition to the eight variables used for the scenario, new variables should be added to the model, and the model should be simulated again.

Disclosure statement

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

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Appendix 1:

Formulas written in the diffusion model of NFC technology in the mobile payment system

NO	Name of variables	Type of variable	Description	Initial value	Unit of variable	Equation of variable
1	Potential Adopter Technology	Level	Adopters who have the potential to use the technology.		People	new potential adopter-Rate of Adoption
2	Adopters of Technology	Level	Users who are using technology.		People	Rate of Adoption-Rate of Rejection
3	Former Adopters	Level	Users who were already using the technology.		People	Rate of Rejection
4	Initial population	Constant			People	58000000
5	New potential adopter	Auxiliary			People	initial population*rate of growth
6	Effectiveness of Advertisement	Constant	The passing of information by advertisement in social media, TV& …	0.4	Dmnl	0.4
7	Rate of Adoption	Auxiliary	The percentage of users who accept the technology and intend to use it.		people/ YEAR	0.5*(0.4* Accessibility to Technology+ 0.55* Effectiveness of Advertisement-.4*Unsecurity+ 0.5*Law Infrastructure +0.55* Education and Cultivation+ 0.5 *Optimism)* 0.55* Word Of Mouth Advertisement
8	Rate of Rejection	Auxiliary	The percentage of users who used technology until now, but no longer use it.		people/ YEAR	0.05* Adopters of Technology/Law Infrastructure
9	Rate of growth	Constant			Dmnl	0.08DELAY1({in} , {dtime})

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A Framework for Improving the Effectiveness of the E-Learning System in Hyper Famili Chain Stores

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ABSTRACT

Before the coronavirus pandemic, higher education centers and companies paid little attention to e-learning. The outbreak of the pandemic and the development of digital technologies have caused companies to pay much attention to e-learning. Therefore, companies are looking for the effective use of e-learning tools. The current research seeks to provide a framework to improve the effectiveness of the e-learning system in Hyper Famili chain stores. The current research is applied in terms of orientation and has a quantitative nature in terms of methodology. This study used two Fuzzy Delphi and Marcos methods for data analysis. The theoretical population of the research was managers, experts, and consultants in the field of education in Hyper Famili. Sampling was done as a judgment based on the expertise of experts in eLearning. The sample size was equal to 10 people. Interviews and questionnaires were used to collect data. The questionnaires used in this research were expert and priority questionnaires. In the first stage, 32 factors were obtained through literature review and interviews with eLearning experts. As a next step, these factors were screened by the distribution of expert questionnaires and the fuzzy Delphi method. Ten factors were selected for final prioritization with Marcos. The screened factors were prioritized by distributing priority questionnaires and Marcos. According to the scores, the most important factors have been found. Practical research proposals were developed based on the most prioritized factors. Some practical suggestions of the research were holding a training workshop on the benefits and applications of e-learning for senior managers, considering the appropriate budget for purchasing and preparing the necessary infrastructure in the field of e-learning, preparing strategic and operational documents based on future developments of new technologies in Iran and the world and the use of instructors with electronic teaching skills.

Keywords

Training, E-learning, System, Effectiveness, Marcos, Fuzzy delphi.

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1. Introduction

Rather than focusing on indicators such as wealth production and human power, today's global economy emphasizes human capital development. Meanwhile, education plays an undeniable role in the development of the human capital of societies, and educational activities should be developed. Education plays a key role in success and has a strategic value in business in today's competitive world. The World Bank says international investment in e-learning systems is growing rapidly. The e-learning system is used mainly because of its profitability, credibility, and marketability. More diverse and effective education methods are required due to the requirements and necessities of new businesses. As an effective tool, e-learning reduces the time and space between the learner and the teacher as much as possible, making education costs economical.

Operating systems based on new technologies are used in electronic learning, from computer-based learning to online collaborative learning. Learners are expected to make significant progress in their learning process using e-learning (Omar et al., 2011; Smith et al., 2008). E-learning is mainly used to increase flexibility in learning and efficiency and effectiveness. Many studies have considered e-learning their objective (Megahed and Mohammed, 2020; Pham et al., 2019; Ramírez-Correa et al., 2015; Shi et al., 2020). It can be generally argued that e-learning has developed a new paradigm and has provided the possibility of learning in any field for any person at any time and at any place.

In the e-learning environment, learners and teachers are separated from the point of view of time and place. Educational content is provided to learners through course management software, multimedia resources, and video conferencing. Learners interact with teachers, other learners, and other people or resources using computer communication facilities to perform individual and group learning activities.

Companies that allocate more of their dedicated budget for learning and development to e-learning are the most important drivers of e-learning development in the future (Tamm, 2020). The share of the global e-learning market will reach 50 billion dollars in 2026. 90% of companies now use e-learning, which was only 4% in 1995 (Tamm, 2020). The Dow Chemical Company saved $34 million and reduced training costs from $95 per human to $11 by shifting from physical classrooms to e-learning tools (Tamm, 2020).

Japan is one of the world's most successful countries in e-learning. E-learning is used in all Japanese universities and most companies. Most Japanese higher education institutions and companies use e-learning in their educational programs (Wang et al., 2018). Türkiye is one of

the most successful countries in the Middle East in e-learning. The e-learning market in Turkey is expected to reach more than $200 million by the end of 2023 (Çınar et al., 2021).

Health protocols focused on social distancing as the COVID-19 pandemic spread worldwide (Sajed and Amgain, 2020). In this regard, face-to-face training in schools, universities, and many companies was stopped in most countries, including Iran, to prevent the spread of COVID-19 (Viner et al., 2020). As Microsoft announced, the use of cloud services during the COVID-19 pandemic has grown by more than 700% (Singh, 2020). The COVID-19 pandemic made many companies feel the need to pay attention to the e-learning system. Nevertheless, the literature review shows that most of the studies in the field of e-learning have been conducted in higher education and universities. Instead of a systemic approach, these studies have examined a specific part of e-learning, for example, content or instructor, focusing on a sectorial perspective. Accordingly, the study seeks to identify and prioritize the factors affecting the effectiveness of the e-learning system in a non-academic environment (retail industry). The study questions are as follows:

1. What factors affect the effectiveness of the e-learning system in Hyper Famili chain stores?

2. What are the priority factors affecting the effectiveness of the e-learning system in Hyper Famili chain stores?

2. Literature review

Due to the development of ICT, progress has been made in many fields, such as finance and business, health, and education—E-learning results from the direct integration of education and technology (Al-Farihat et al., 2017). E-learning refers to the instructions digital devices provide for education (Clark & Mayer, 2016). E-learning provides access to educational resources and online learning through ICT (Perrin et al., 2014). E-learning is an information system that can transmit educational content to its audience through audio, video, and text media through e-mail, live chat sessions, discussions, forums, tests, and online assignments (Lee et al., 2011). E-learning at all educational levels enables learners to receive materials more quickly (Lee et al, 2011). Some researchers have mentioned the intervention of ICT in the education process concerning e-learning (Sun et al., 2008).

The educational paradigm has shifted from traditional education to electronic and virtual education. E-learning has many advantages for higher education, universities, companies, students, and learners. Some advantages include no need for physical presence and travel, lower

cost, adjustment of learning speed, visual and auditory features, up-to-date content, and improved learning quality. Learners need access to more learning resources in traditional education. However, various learning resources (text, image, audio, and video) are available to learners through the Internet and e-learning tools in electronic education (Al-Farihat et al., 2020). The development of ICT has caused many changes in various fields, including education. In this way, education and technology have been integrated, and e-learning has emerged as a powerful tool for teaching and learning. E-learning has been developed through various new smart technologies and has greatly affected teaching techniques (Al-Farihat et al., 2020). So, today's main educational paradigm shift is from traditional teacher-centered education to active learner-centered education (Son, 2016). Numerous studies have mentioned various factors such as e-learning content, tools, technologies, teachers, and evaluation processes as factors affecting the effectiveness of e-learning systems (Almaiah et al., 2020; Hammouri and Abu-Shanab, 2018; Kanwal and Rehman, 2017; Motaghian et al., 2013; Islam et al., 2010). Some studies on e-learning and the factors affecting it are given below.

In a study by Eli-Chukwu et al. (2023), the challenges facing e-learning in Nigerian higher education institutions were identified. The findings showed that Nigerian higher education institutions are still unprepared to adopt blended methods. There was no e-learning curriculum in Nigerian universities before the COVID-19 pandemic. Moreover, it was difficult for teachers and learners to adopt e-learning due to the lack of experience in using ICT and insufficient infrastructure to support e-learning. The results also showed that most universities in Nigeria only use traditional teaching methods despite the benefits of blended learning during the COVID-19 pandemic. In a study by Mastan et al. (2022), the models and development process of e-learning (learning management system) were evaluated. They derived e-learning development criteria using a systematic literature review and review of papers from three authoritative scientific databases from 2016 to 2021. E-learning development criteria were platform, evaluation model, evaluation, model, approach, problem, process, and challenge. The researchers suggested that these seven criteria could be used for future e-learning studies. The success of e-learning systems was evaluated by Al-Farihat et al. (2020). The findings indicated that the factors affecting the perceived satisfaction of e-learning were technical system quality, information quality, service quality, support system quality, learner quality, instructor quality, and perceived usefulness. Cidral et al. (2020) investigated the role of students' long-term attitudes towards electronic learning in its success. The study's main objective was to identify the drivers of e-learning success in Brazil. The study model suggested that students' long-term

orientation affects the positive relationship between using e-learning systems and perceived net benefits. The findings showed that the determinants of e-learning user satisfaction are information quality and the use of e-learning systems. In their study, Parusheva et al. (2018) examined the use of social media in higher education institutions. They sought to answer whether higher education institutions, which often operate in social, economic, and legal sciences, use the benefits of social media in learning management systems. The findings indicated that students use discussion forums, chats, and domestic messengers.

In a study by Ahmadi et al. (2021), a model was developed for the e-learning system of Iranian higher education institutions, and a conceptual model was designed at the level of components and indicators. The model had eight components: Knowledge transferability, interaction, teachers' attitude toward students, technical competence, content, attitude towards education, fluid experience, learning results, individual effects, and 28 indicators. According to the results, the highest rank belongs to learning results and individual effects, and the lowest rank belongs to interaction. Nazari Farrokhi et al. (2020) identified and ranked the components of e-learning technology in defense organizations. The findings suggested that attention should be paid to the components of using e-learning technology at Imam Ali Army Officer University.

Additionally, the value of information in the system is essential for users and plays a fundamental role. The information's quality, comprehensiveness, and up-to-dateness should be considered vital. Application software and software efficiency are other important components. Cloud computing technology and its capabilities to improve the quality of teaching and learning were investigated in a study by Kazem Pourian et al. (2017). They introduced cloud computing and its various services, examined its advantages and limitations in e-learning, and proposed solutions to improve the quality of higher education. Finally, the best model for using these services in e-learning and its success factors were presented after examining mobile cloud services in education. A fuzzy expert system to measure e-learner satisfaction was proposed in a study by Saeed and Azimi Hammat (2016). For this purpose, indicators such as learning interactions, feedback, quality, and usefulness of e-learning were extracted to measure learner satisfaction. The level of each indicator in the studied population was determined using fuzzy techniques, and the priority and contribution of each in learner satisfaction was obtained using the Analytic Hierarchy Process (AHP). The database of if-then rules was completed after obtaining these data and expert opinions, and the exact level of satisfaction was determined using Mamdani's fuzzy inference method. The study sample included 70 electronic master's students at Payam Noor University, whose satisfaction level was estimated to be high (equal to 0.75) after implementing the system with MATLAB. Arasti et al. (2015) explained the role of

individual, environmental, and system components in the success of entrepreneurship e-learning at the University of Tehran. According to the results, the factors affecting the success of entrepreneurship e-learning were individual factors, including teacher and student characteristics; environmental factors, including interactions and evaluation; and systemic factors, including the quality of education and content provided, the quality of the internet infrastructure and virtual education system, and the quality of university performance and services. The results of the quantitative analysis showed that the individual factor of student characteristics, the environmental factor of interactions, and the systemic factor of the quality of education and the content provided had the most significant effect on the success of entrepreneurship e-learning at the University of Tehran. Nazarpoori and Tabarsa (2014) investigated the factors affecting the acceptance of the e-learning system based on the technology acceptance model (TAM). They argued that the quality of content and the perception of network extent affect the acceptance of the e-learning system with an indirect effect on the perceived usefulness with an effect size of 0.28 and that the perception of network extent and computer self-efficacy affect the acceptance of e-learning system with an indirect effect on the perception of ease of use with an effect size of 0.20. Besides, learners with self-confidence in using computers believe in their ability to use the e-learning system to receive educational materials and have higher expectations of their abilities to use the system. So, they accept the system as a useful tool for learning.

There are many studies on e-learning. Some studies focus on the perception of e-learning quality, comparing e-learning with face-to-face learning and examining e-learning platforms (Ali et al., 2021; Natasia et al., 2022). Some studies have discussed the effects of satisfaction with e-learning on learning outcomes and the application of ontology in e-learning recommender systems (Rahayu et al., 2022).

Studies in Iran have addressed the key drivers of e-learning success, the effect of structural and cultural factors on e-learning, faculty members, and e-learning (Rajabi and Soltani, 2019; Gelard and Davarzani, 2018; Pourkarimi and Ramezanpour, 2019).

A literature review shows that most previous studies lack a systematic view of e-learning, have a partial view of e-learning, and only highlight specific aspects such as learners, tools, technologies, processes, or teaching methods. They also discuss higher education. This study systematically views e-learning and has been conducted in a context other than higher education. Table 1 shows the most important points related to previous research.

Table 10. Evaluation of previous studies

The main topics discussed	Important studies in this field	Summary of the research	Weakness of research
Studying the challenges of e-learning	Eli-Chukwu et al. (2023)	In these studies, various challenges facing e-learning, especially in higher education, have been considered.	Most of these studies have been conducted in higher education, and other organizations have been less investigated.
Evaluating of e-learning models	Mastan et al. (2022), Ahmadi et al. (2021)	These studies have investigated various types of e-learning models and their advantages and disadvantages in different organizations.	Despite evaluating different models, a method for prioritizing them has not been provided.
Identifying factors affecting the success of e-learning	Al-Farihat et al. (2020), Arasti et al. (2015)	In these studies, various factors affecting the success and effectiveness of e-learning have been considered.	In these studies, only a part of the factors is considered, and there is no systematic view.
Studying the role of new technologies in e-learning	Kazem Pourian et al. (2017)	In these studies, an attempt has been made to investigate the role of using different technologies, such as cloud computing, in e-learning.	Only the effects of some technologies, such as cloud computing, have been investigated in these studies. Technologies such as big data and blockchain in e-learning seem very important. However, these technologies have received less attention in the past.
Studying the satisfaction level of e-learning	Saeed and Azimi Hammat (2016)	In these studies, an attempt has been made to evaluate the level of satisfaction of e-learning learners.	In these studies, satisfaction has been considered only from the point of view of some stakeholders, for example, e-learners.

3. Methodology

The study is conducted to identify and analyze the factors affecting the effectiveness of the e-learning system in Hyper Famili chain stores. For this purpose, fuzzy Delphi and Markus techniques, which are quantitative and use quantitative data for analysis, were used to analyze the data. The fuzzy Delphi technique was used to screen the factors, and the MARCOS technique was used to analyze and rank them. The study has a quantitative and qualitative mixed methodology due to the quantitative methods used. It is also an applied study because of its benefits for education in the retail industry.

The data collection tools were interviews and questionnaires. The factors were extracted by reviewing the literature on organizational learning, e-learning, and e-learning systems. The fuzzy expert and MARCOS priority questionnaires were distributed among the experts to rank the factors. The expert questionnaires were evaluated using the Fuzzy Delphi technique, and the priority questionnaires were evaluated using the MARCOS technique. Both questionnaires were highly valid because the factors were extracted by reviewing authentic international and domestic articles in the fields of e-learning and the effectiveness of the e-learning system and interviewing e-learning experts, managers, and consultants in Hyper famili stores. Moreover, the priority questionnaires were highly reliable due to the appropriate size of the sample (10)

and the screening of the factors. The sample size was 10, which is favorable for expert judgment methods.

Also, the validity of the components of the expert assessment questionnaire was evaluated with two content validity coefficients, i.e., content validity ratio and content validity index. Since the content validity ratio of all factors was higher than 0.62, the research questionnaires had good validity. In addition, the content validity index of all factors was more than 0.79, indicating the reasonable validity of the research questionnaires. The value of the content validity index for the screened factors was above 0.9, which showed that the prioritization questionnaires had more validity than expert questionnaires.

The sample size in expert-oriented research based on multi-criteria decision-making techniques is based on the two critical rules of avoiding inconsistency and theoretical saturation. In these studies, the sample size between 5 and 20 experts is desirable and avoids inconsistency. The appropriate sample size and screening factors made the results more reliable in this research.

The study experts were e-learning managers (named experts) and consultants in Hyper Famili stores. The samples were selected using judgmental sampling based on their expertise in education, e-learning, and e-learning systems.

The study was conducted in three phases. Factors affecting the effectiveness of the e-learning system were extracted in the first phase through a literature review and interviews with managers and consultants. These factors were screened in the next phase using the fuzzy Delphi technique. Finally, the most important factors were identified using the MARCOS technique. The fuzzy Delphi technique was used in the study to screen the factors affecting the effectiveness of the e-learning system. In the fuzzy Delphi technique algorithm, a suitable fuzzy spectrum should be developed first to fuzzify the linguistic variables of the experts to screen the factors. In this regard, common phase spectra could be used. In this study, a five-point Likert scale was used, as shown in Table 2 (Habibi et al., 2015; Zare Bahnamiri et al., 2023):

Table 11. The fuzzy spectrum of the delphi technique

Triangular fuzzy number	Fuzzy value	Linguistic variable
(0, 0, 0.25)	$\tilde{1}$	Very low
(0, 0.25, 0.5)	$\tilde{2}$	Low
(o.25, 0.5, 0.75)	$\tilde{3}$	Moderate
(o.5, 0.75, 1)	$\tilde{4}$	High
(0.75, 1, 1)	$\tilde{5}$	Very high

The MARCOS technique (measurement alternatives and ranking according to compromise solution) is one of the new multi-criteria decision-making techniques introduced by Stanković

et al. (2020). In this study, the MARCOS technique was used to analyze and prioritize the factors affecting the effectiveness of the e-learning system. The experts commented on the importance of each factor on a 10-point scale. The steps of the MARCOS technique are as follows (Stanković et al., 2020; Arabi et al., 2023):

Step 1. Development of the decision matrix: This is the first step in all multi-criteria decision-making methods that aim at prioritization. In the MARCOS technique, m options are evaluated using n criteria. Thus, each option is assigned a score based on each criterion. The experts commented on each factor in this study on a 10-point scale.

Step 2. Determining ideal and anti-ideal alternatives: In this section, the values of ideal and anti-ideal alternatives are obtained based on the equations 1and 2.

$$AI = \max_i x_{ij} \ \ if\ j \in B \ and \ \min_i x_{ij} \ \ if\ j \ \in C \tag{1}$$

$$AAI = \min_i x_{ij} \ \ if\ j \in B \ and \ \max_i x_{ij} \ \ if\ j \ \in C \tag{2}$$

Step 3. Normalization: In this section, the values of the decision matrix are normalized linearly using the following equations. The normalization method is different for positive and negative indicators (Equations 3 and 4).

$$n_{ij} = \frac{x_{aj}}{x_{ij}} \ if\ j \in C \tag{3}$$

$$n_{ij} = \frac{x_{ij}}{x_{aj}} \ if\ j \in B \tag{4}$$

Step 4. Development of the weighted normal matrix: This matrix is extracted by multiplying the normal matrix by the weight of the indicators. In this study, the weight of the experts' opinions was considered the same due to the experts' expertise level closeness.

Step 5. Calculating the degree of utility of the alternatives (here, the factors): This section determines the ideal and anti-ideal utility of the alternatives according to the equations 5 and 6.

$$K_i^+ = \frac{S_i}{S_{ai}} \tag{5}$$

$$K_i^- = \frac{S_i}{S_{aai}} \tag{6}$$

Step 6. Determining the final performance and prioritizing the alternatives: In this section, the optimal performance of each alternative is determined using the equation 7.

$$f(k_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f(K_i^+)}{f(k_i^+)} + \frac{1 - f(K_i^-)}{f(k_i^-)}} \quad (7)$$

4. Findings

The factors affecting the effectiveness of the e-learning system were extracted through an analytical literature review and interviews with e-learning managers and consultants in Hyper Famili chain stores. In this way, 32 factors were obtained, 25 from the literature review and the rest from the interviews. The factors can be seen in Table 3. Studies on employee training and e-learning were reviewed to extract the factors.

Table 12. Factors affecting the effectiveness of the e-learning system

Factors	Sources
The support of the senior managers of Hyper Famili stores	Interviews
The use of competent and expert teachers	Kanwal and Rehman (2017), Motaghian et al. (2013), Islam et al. (2010)
The use of multimedia content in education	Ali et al. (2021), Natasia et al. (2022), Almaiah et al. (2020)
Methods of evaluating teacher performance	Kanwal and Rehman (2017), Motaghian et al. (2013), Islam et al. (2010), Saeed and Azimi Hammat (2016)
Methods of getting effective feedback	Saeed and Azimi Hammat (2016)
Methods of notifying employees about training courses	Motaghian et al. (2013), Islam et al. (2010),
Effective educational needs assessment methods	Interviews
The curriculum used for employee training	Hammouri and Abu-Shanab (2018), Kanwal and Rahmen (2017)
Effective tools for e-learning in the company	Hammouri and Abu-Shanab (2018), Kanwal and Rahmen (2017)
The time of holding training courses	Interviews
The ability of manpower in e-learning and its tools	Megahed and Mohammed (2020), Pham et al. (2019)
Methods of evaluating learners according to the type of education	Arasti et al. (2015)
The support level of e-learning tools and technologies	Megahed and Mohammed (2020), Pham et al. (2019), Ramírez et al. (2015)
The development of providing e-learning through smartphones	Ali et al. (2021), Natasia et al. (2022),
Network security	Interviews
Using appropriate models of e-learning	Mastan et al. (2022), Cidral et al. (2020)
The existence of suitable infrastructure for e-learning	Eli-Chukwu et al. (2023), Arasti et al. (2015)
Financing e-learning needs and requirements	Interviews
The extent of using experiences of higher education and companies in holding e-learning courses	Interviews
Supervision of the correct implementation of e-learning courses	Arasti et al. (2015)
The extent of access to online and offline resources by learners	Arasti et al. (2015)
Development of appropriate strategic and operational programs in e-learning	Interviews
Strengthening organizational culture according to new changes	Eli-Chukwu et al. (2023)
Diversity of e-learning models	Rajabi and Soltani (2018), Gelard and Davarzani (2018), Pourkarimi and Ramezanpour (2019)
Teaching method suitable for e-learning	Ahmadi et al. (2021)
Teachers' skill with e-learning teaching methods	Al-Farihat et al. (2020)

Factors	Sources
E-learning platforms	Mastan et al. (2022)
Perceived benefits of e-learning	Al-Farihat et al. (2020), Cidral et al. (2020)
Utilizing the capacity of social networks	Parusheva et al. (2018)
The Extent of using application software	Nazari Farrokhi et al. (2020)
Information quality of e-learning system	Nazari Farrokhi et al. (2020)
Ease of using e-learning tools and technologies	Nazarpoori and Tabarsa (2014)

Thirty-two factors extracted from the literature review and interviews with e-learning managers and consultants were screened using the fuzzy Delphi technique. Techniques such as MARCOS are highly sensitive to a large number of factors. In this step, 22 factors were removed from the calculations, and 10 were selected for the final ranking. The MARCOS technique selected those with a diffusion number greater than 0.7 (10 factors) for the final ranking. The number 0.7 was considered the threshold limit for screening factors. The threshold limit is between 0.5 and 0.7 in most studies and 0.7 in this study. The list of factors screened and their diffusion numbers are given in Table 4.

Table 13. The results of applying the fuzzy delphi technique on the factors screened

Factors	Average expert opinions			Defuzzied number
	Lower limit	Middle limit	Upper limit	
The ability of manpower in electronic education and its tools (A)	0.55	0.74	0.83	0.71
The support level of e-learning tools and technologies (B)	0.65	0.74	0.83	0.74
Using appropriate models of e-learning (C)	0.62	0.7	0.83	0.72
The existence of suitable infrastructure for e-learning (D)	0.71	0.83	0.94	0.83
The extent of using experiences of higher education and companies in holding e-learning courses (E)	0.67	0.73	0.85	0.75
The extent of access to online and offline resources by learners (F)	0.57	0.71	0.85	0.71
Development of appropriate strategic and operational programs in e-learning (G)	0.69	0.74	0.95	0.79
Teaching method suitable for e-learning (H)	0.63	0.8	0.85	0.76
Perceived benefits of e-learning (I)	0.75	0.83	0.96	0.85
Ease of using e-learning tools and technologies (J)	0.65	0.86	0.92	0.81

The content validity of the factors affecting the effectiveness of the e-learning system was measured using the content coefficient of the Lawshe model. A 10-member expert panel was formed to measure the content factor. Table 5 shows the minimum acceptable values for content validity coefficients for the number of different panels.

Table 14. Minimum appropriate content coefficients

Minimum acceptable values	The number of experts
0.99	5 to 7
0.78	8
0.75	9
0.62	10
0.59	11
0.56	12
0.54	13
0.51	14
0.49	15
0.42	20

The content factor values of each factor affecting the effectiveness of the e-learning system were calculated based on the equation 8.

$$CVR = \frac{n_e - \frac{N}{2}}{\frac{N}{2}} \quad (8)$$

n_e: the number of experts who evaluated the desired factor as necessary

N: the total number of experts

Table 6 shows the content factors of the factors screened.

Table 15. The list of the factors screened

Factors affecting the effectiveness of e-learning system	Definitions	Notation	Sources	Content factors
The ability of manpower in e-learning and its tools	This factor means the skills and expertise of employees regarding different methods and tools of e-learning.	A	Megahed and Mohammed (2020), Pham et al. (2019)	0.68
The support level of e-learning tools and technologies	In case of problems in the e-learning system, experts must fix these errors quickly and continuously.	B	Megahed and Mohammed (2020), Pham et al. (2019), Ramírez et al. (2015)	0.7
Using appropriate models of e-learning	There are different models in the field of e-learning. The model used should be compatible with the target audience, the intended industry, and the intended goals.	C	Mastan et al. (2022), Cidral et al. (2020)	0.71
The existence of suitable infrastructure for e-learning	This factor means the hardware and software infrastructure and required databases.	D	Eli-Chukwu et al. (2023), Arasti et al. (2015)	0.8
The extent of using experiences of higher education and companies in holding e-learning courses (E)	The purpose of this factor is to prepare documented reports about the lessons learned from the experiences of successful companies and universities in the field of e-learning.	E	Interviews	0.74
The extent of access to online and offline resources by learners	For each course, resources should be made available to employees to study the courses more effectively and accurately.	F	Arasti et al. (2015)	0.74
Development of appropriate strategic and operational programs in e-learning	Senior managers and officials in the training field should prepare long-term goals, perspectives, strategies, and a table of	G	Interviews	0.77

Factors affecting the effectiveness of e-learning system	Definitions	Notation	Sources	Content factors
	actions and indicators.			
Teaching method suitable for e-learning	It should be noted that electronic education teaching methods differ from traditional education.	H	Ahmadi et al. (2021)	0.75
Perceived benefits of e-learning	This factor represents the advantages and benefits of e-learning for the organization's performance and employees (in the opinion of the organization's senior managers).	I	Al-Farihat et al. (2020), Cidral et al. (2020)	0.82
Ease of using e-learning tools and technologies	This factor means user-friendliness and ease of learning methods and technologies.	J	Nazarpoori & Tabarsa (2014)	0.79

According to Table 5, the content coefficient of all screened factors for the 10-person panel is above 0.62, which shows the content validity of the screened factors. According to Table 5, the content factor for all screened factors for the 10-member panel is above 0.62, indicating the content validity of the screened factors. In the following, the screened factors were analyzed using the MARCOS technique.

In this section, the factors affecting the effectiveness of the e-learning system are ranked using the MARCOS technique. The decision matrix must first be formed. The experts commented on the importance of each factor on a 10-point scale. The values of the decision matrix were then normalized by the linear method. The weighted normal matrix was then obtained by multiplying the weight of the experts' opinions by the values of the normal matrix. In this study, the weight of the opinions of all experts was considered equal and 0.1 due to the slight difference in knowledge and position of the experts. The values of the weighted normal matrix are shown in Tables 7 and 8.

Table 16. The weighted normal matrix (the first five experts)

Factors	The first expert	The second expert	The third expert	The fourth expert	The fifth expert
A	0.03	0.022	0.044	0.04	0.056
B	0.04	0.056	0.056	0.06	0.067
C	0.03	0.044	0.044	0.05	0.056
D	0.09	0.1	0.089	0.09	0.078
E	0.05	0.044	0.067	0.05	0.056
F	0.04	0.056	0.056	0.06	0.067
G	0.07	0.067	0.067	0.07	0.056
H	0.06	0.056	0.078	0.06	0.056
I	0.1	0.1	0.1	0.1	0.1
J	0.07	0.089	0.1	0.07	0.078
Ideal alternative	0.1	0.1	0.1	0.1	0.1
Anti-ideal alternative	0.03	0.022	0.044	0.04	0.056

The values of the weighted normal matrix for the following five experts are given in Table 8. The results are given in two separate tables due to the high volume of calculations.

Table 17. The weighted normal matrix (the next five experts)

Factors	The sixth expert	The seventh expert	The eighth expert	The ninth expert	The tenth expert
A	0.04	0.03	0.033	0.02	0.02
B	0.05	0.04	0.033	0.03	0.04
C	0.05	0.06	0.044	0.03	0.04
D	0.07	0.08	0.1	0.09	0.08
E	0.07	0.06	0.056	0.06	0.05
F	0.08	0.07	0.044	0.03	0.04
G	0.07	0.08	0.078	0.07	0.07
H	0.07	0.07	0.089	0.05	0.06
I	0.1	0.1	0.1	0.1	0.1
J	0.08	0.08	0.1	0.07	0.06
Ideal alternative	0.1	0.1	0.1	0.1	0.1
Anti-ideal alternative	0.04	0.03	0.033	0.02	0.02

The four indices of the MARCOS technique, including Ki+, Ki-, f(Ki+), and f(Ki-), which are used for the final evaluation and analysis of the factors, were then obtained according to the weighted normal matrix data. The final scores of the factors can be seen in Table 9, which is the criterion for prioritization and final analysis.

Table 18. The final score of the factors affecting the effectiveness of the e-learning system

Factors	K_i^+	K_i^-	$f(K_i^+)$	$f(K_i^-)$	Final score	Ranking
A	0.335	1	0.74906	0.25094	0.309	10
B	0.472	1.409	0.74907	0.25093	0.435	8
C	0.448	1.337	0.74902	0.25098	0.413	9
D	0.868	2.588	0.74906	0.25094	0.8	2
E	0.563	1.682	0.74911	0.25089	0.519	6
F	0.543	1.621	0.74908	0.25092	0.501	7
G	0.698	2.084	0.7491	0.2509	0.644	4
H	0.649	1.937	0.74903	0.25097	0.599	5
I	1	2.985	0.74906	0.25094	0.922	1
J	0.798	2.379	0.74906	0.25094	0.735	3

As seen in Table 9, the perceived benefits of e-learning, the existence of suitable e-learning infrastructure, the ease of using e-learning tools and technologies, the development of appropriate strategic and operational plans in e-learning, and the teaching method suitable for e-learning have the highest priority, respectively. The Discussion and Conclusion section provides practical recommendations based on the priority factors. A seven-member panel interviewed the focus groups to strengthen the practical recommendations.

5. Managerial insights

The perceived benefits of e-learning can be said that the more senior managers of the organization understand and are aware of these concrete advantages and benefits, the more possible the use of these technologies will be. This study requires designing tools to measure

the benefits of this training for the organization, its processes, and performance.

Another problem for organizations implementing e-learning is the lack of required infrastructure. In this case, cooperation with reliable companies that support e-learning and using the experiences of universities can help organizations a lot. Without proper infrastructure, the e-learning system will be vulnerable.

Regarding strategic and operational plans, the organization's actions regarding e-learning will be scattered and inconsistent. In this case, cooperatively developing long-term and short-term goals, measures, and performance indicators will help the development of e-learning.

Another challenge for organizations in e-learning is not using appropriate models. Using traditional models in this system is incompatible with the e-learning goals and will cause dissatisfaction among learners.

6. Discussion and conclusion

This study aims to provide a framework for identifying and analyzing factors affecting the effectiveness of the e-learning system. For this purpose, 32 factors were extracted first through a literature review. Five e-learning experts at Hyper Famili stores were interviewed to strengthen the target list, and seven items were added. The distribution of expert questionnaires and the fuzzy Delphi technique screened the factors. Twenty-two factors with a defuzzified number less than 0.7 were excluded from the analysis. Ten selected factors were investigated by distributing priority questionnaires and the MARCOS technique. According to the calculations of the MARCOS technique, the perceived benefits of e-learning, the existence of suitable e-learning infrastructure, the ease of using e-learning tools and technologies, the development of appropriate strategic and operational plans in e-learning, and the teaching method suitable for e-learning have the highest priority, respectively.

This study differs from previous studies in two points. The first is its systematic approach to various factors involved in the effectiveness of e-learning. This study is not limited to a specific field or factor such as technology. The second is its focus on e-learning in a field other than higher education. Most of the studies on e-learning have been conducted in universities and higher education institutions.

For example, some studies have focused on system infrastructure. Some researchers have examined different models and methods of e-learning. There are other research studies for which the role of lesson plans and teachers has been important. Most of these research studies lack a systematic approach. In these studies, higher education and universities are mainly

considered, while there are many differences between the academic environment and economic enterprises.

The practical recommendations in the study are presented based on the priority factors, the first being the perceived benefits of e-learning. This factor is mentioned in the studies by Al-Farihat et al. (2020) and Cidral et al. (2020). Managers can adequately understand the benefits of implementing e-learning in the company by holding workshops and briefing classes on the advantages, disadvantages, challenges, and applications of e-learning. The content should be presented objectively and concretely based on statistics and figures and considering successful experiences in competing companies.

The lack of suitable infrastructure for e-learning is one of the main problems many companies operating in this field face. Some solutions for improving the infrastructure are considering the budget for providing the necessary hardware and software equipment, collaborating with some companies to hold joint training courses, and using the training services of some companies that provide e-learning services. This factor is focused on previous studies such as those by Eli-Chukwu et al. (2023) and Arasti et al. (2015).

The third factor is the ease of using e-learning tools and technologies. Fear of change and stress caused by new tools and technologies is one of the important obstacles to the development of e-learning in Iranian companies and businesses. New tools and technologies can be simplified by using teachers with high skills in e-learning, simple and effective course outlines, eliminating extra processes and activities, and using simple and practical software and applications. This factor is confirmed in the study by Nazarpoori and Tabarsa (2014).

The fourth factor is the development of appropriate strategic and operational plans for e-learning. The company's upstream documents cannot be indifferent to new technologies. The company's strategic plan should not be developed with a present-day approach but based on future trends and changes. Using the strategic foresight model in the company allows the consideration of future risks and drivers in various fields, especially training and learning, contributing to the effective training of employees. Metaverse, for example, is one of the new technologies that will completely transform corporate training. This factor was extracted from the interviews.

The last factor is the use of a teaching method suitable for e-learning. One of the reasons for the failure of e-learning systems in companies is the use of traditional methods in education. The teaching method can be improved by using teachers with high skills in e-learning, preparing a course outline suitable for e-learning, using new tools and technologies in education, paying

attention to new e-learning models, getting employee feedback, and evaluating teachers. This factor was confirmed by Ahmadi et al. (2021).

Recommendations include the future study of e-learning in the retail industry and the development of e-learning strategies. From a methodological point of view, scenarios for the future of e-learning in the retail industry should be designed with a systems dynamics approach.

Disclosure statement

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

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Estimating the Potential of Changes in Oil Price in IPCC Climate Scenarios: A System Dynamics Approach

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ABSTRACT

This paper uses the system dynamics approach to model the changes in oil price prospects in the framework of the shared socio-economic pathways (SSP) climate scenarios proposed by the Intergovernmental Panel on Climate Change (IPCC) until 2100. This theoretical structure connects the primary feedback mechanisms: supply, demand, and price. The determining factors of most tremendous significance in the supply sector are the Organisation of Petroleum Exporting Countries (OPEC) and non-OPEC production levels. The production targets set by OPEC are indicative of its market management policies and are significantly influenced by the actions of its key members. The oil price indicates a cyclical relationship with the oil supply of significant players. The determination of global oil demand in the demand section is based on various climate scenarios presented in the IPCC report. The fluctuation of Brent oil prices over time can be linked to the disparity between supply and demand. According to the model outcomes, the price of oil will be projected to decline to $20 per barrel by the year 2100 if the sustainability policies outlined in the SSP1 framework are implemented. However, in the alternative scenarios of SSP3, characterized by regional competition, and SSP4, characterized by heightened inequality and competition, oil prices are anticipated to rise to $100 per barrel. In the context of the SSP5 scenario, which posits a path of economic and social development reliant on the consumption of fossil fuels, the price of oil displays a declining pattern after a period of relatively higher prices. The peak oil prices within the Intergovernmental Panel on Climate Change (IPCC) scenarios exhibit significant variation based on their Representative Concentration Pathways (RCPs).

Keywords

Climatic change scenarios, Oil demand, Oil supply, Oil price, OPEC, System Dynamics.

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1. Introduction

Due to the concern of the world community about global warming, the efforts to adopt policies to manage the demand for fossil fuels, especially oil, have been expanded as one of the main factors of the aggravation of climate change (Meinshausen et al., 2009). A decrease in oil demand can cause a decrease in oil prices in a short time (Jaccard, 2005). As the prices of oil rise, the quantity of oil exploration operations leads to higher levels of greenhouse gas emissions (Harstad, 2012). Low oil prices are a barrier to production (Aghion et al., 2016). Many studies show that the transition from fossil fuel consumption to renewable energy is critical to reducing the impacts of climate change (Pörtner et al., 2022). The energy transition is predicted to lead to a long-term decline in oil demand, putting downward pressure on prices (Mercure et al., 2018).

The competitiveness and speed of adoption of alternative sustainable energy sources, such as electric vehicles, can be affected by oil prices. Rising costs associated with oil contribute to the increasing attractiveness of other clean energy sources. On the other hand, the decrease in the price of oil increases the continuous use of conventional fuels dependent on oil (Linn et al., 2014). If it has not happened yet, the peak of oil consumption may happen in the next two decades, subject to implementing policies to deal with climate change and sustainable energy developments (IEA, 2022). Finally, the relationship between oil prices and climate change influences the dynamics of supply, demand, and other oil market variables. (Pörtner et al., 2022).

In the international oil market, supply and demand are connected to determine the price while maintaining a state of equilibrium. Economic growth and development are the most influential forces behind increased demand for crude oil worldwide. According to studies, oil demand significantly correlates with GDP growth (Hamilton, 2014). Oil demand is more sensitive to oil price changes in the long run than in the short run because consumers need more time to react to changes in oil demand (Csereklyei et al., 2016). On the supply side, OPEC and key non-OPEC producers, such as Russia, have the market power to moderate global production and influence prices (Behar & Ritz, 2017). Finally, the imbalance between supply and demand causes oil price fluctuations. Faster demand growth than supply increases the price (Fagan, 2020). Overall, the interplay between changing supply and demand dynamics is a key determinant of global oil price changes, and understanding these fundamental market forces provides insight into the outlook for oil price changes (Baumeister and Kilian, 2016). This article uses the system dynamics approach to analyze the possibility of oil price changes in the

IPCC climate scenarios. System dynamics is a method for modeling and simulating complex systems and problems over time. It was developed in the 1950s by Jay Forster at the Massachusetts Institute of Technology. The key concept of this method is that systems can be modeled using feedback loops, state, and flow, which represent the non-linear dynamics of system (Forrester, 1968).

Because of the complexity of system dynamics models because of interdependencies, interactions, information feedback, and nonlinearity, testing different scenarios, policies, and decisions, the possibility of learning about complex systems through interactive simulations can be useful (Sterman, 2002). In system dynamics, a problem, such as oil price forecasting, is modeled as a system with state variables, flow, feedback loops, and nonlinearities. System dynamics is important for understanding oil price dynamics and making useful predictions.

Oil price changes under IPCC climate scenarios have been studied in this research. The Intergovernmental Panel on Climate Change published updated scenarios in the 2022 Sixth Assessment Report, Shared Socio-Economic Pathways. These scenarios provide frameworks for modeling different climate change mitigation pathways in this century (Pörtner et al., 2022).

Climate scenarios are divided into five categories in common social and economic path scenarios. In SSP1, sustainability policies support renewable energy, thus reducing oil demand. It puts pressure on the oil price. SSP2 reflects the middle path toward implementing climate policies and means a gradual reduction in oil consumption and relatively stable prices. SSP3 represents the spread of regional conflicts and nationalism, followed by increased oil demand and price. SSP4 shows high inequality within and between countries. Oil prices may fluctuate depending on economic instability. Under SSP5, oil consumption remains high due to fossil fuel development policies, keeping prices high (Behar and Ritz, 2017; Kikstra et al., 2022). However, the IPCC scenarios have limitations. These scenarios do not consider the short-term cycles, shocks, and structural failures that shape oil prices. In this research, according to the changes in oil demand in different climate scenarios, the outlook for oil changes has been evaluated as a system dynamics model (Riahi et al., 2017).

2. Literature review

Oil is one of the most essential commodities in the world, and fluctuations in oil prices have wide-ranging economic, geopolitical, and environmental effects. Therefore, predicting the prospect of accurate changes in oil prices is very important (IEA, 2022). However, due to the high dependence of oil prices on geopolitical events and the behavior of significant market

players, it is tough to accurately predict oil changes in the long term. Of course, this has not caused different mathematical tools not to be used to model the behavior of oil prices. These models can be useful in many cases despite the simplifications considered. The literature review section attempts to provide a comprehensive literature review of modeling approaches to predict oil prices, especially climate policy scenarios.

Various quantitative and qualitative methods have been used to model and predict oil prices. These methods include system dynamics models, econometrics, computational simulation, statistics, machine learning, or multiple techniques. Each approach has relative strengths and weaknesses based on the representation of market structures, predictor variables, and basic assumptions. In the literature review section, the features and applications of these modeling approaches are evaluated with a focus on dynamic systems models.

System dynamics modeling is a method to understand the dynamic behavior of complex systems over time and provides nonlinear feedback relationships between variables in a system in the form of state, flow, and auxiliary variables (Sterman, 2002). System dynamics models are widely used to model the dynamics of the oil market and predict its price by using feedback loops between the key variables of supply, demand, inventory, capacity, and geopolitics to endogenously model the oil price (Mashayekhi, 2001; Rafiq et al., 2016; Samii and Teekasap, 2010). Greenman et al. (1994) integrated physical and economic factors affecting oil markets, such as resources, cost, technology, economic growth, and geopolitical issues. Hosseini et al. (2016) showed structural complexity in oil price dynamics using systemic models in his article. Rafieisakhai et al. (2016) evaluated the impact of different variables on market mechanisms by modeling the oil supply sector, including actors such as OPEC, non-OPEC, and American Shell Oil, and the demand, including sectors such as transportation and industry. Various studies have demonstrated the ability of system dynamics models to reproduce historical price, supply, and demand trends (De la Fe López-Domínguez et al., 2011; Rafieisakhaei et al., 2017). Hosseini et al. (2021) and Samii et al. (2010) argue that the integrated structure of system dynamics models can well represent the complex interactions between economic policies, technological changes, and market geopolitics. However, limitations, such as not considering some aspects of the real world, the need for computational resources in accurate and large models, and real-world simplifications in system dynamics models, make it difficult to accurately predict real oil price changes.

Econometric models estimate economic relationships and predict results using statistical methods. Many econometric techniques have been used to analyze and forecast oil prices, such

as time series models, autoregression, sequential autoregression of random variables, and GARCH[2]. Econometric models use statistical methods of statistical estimation in a large set of data, mostly used for short-term price prediction in financial markets (Bashiri Behmiri and Pires Manso, 2013). However, econometric models are limited in representing structural complexities, feedback effects, and irregular events compared to simulation approaches and are highly dependent on the quality of input data.

Considering the limitations of system dynamics and econometric models, some models have developed hybrid models by combining system dynamics and econometric methods to predict oil prices. The main goal of developing these models is the simultaneous use of feedback loops and statistical estimation of econometric models and data analysis (Rafieisakhaei et al., 2017). These hybrid models increase the accuracy of predictive analysis compared to pure system dynamics or econometric approaches. The basis of system dynamics provides a strong theoretical framework that shows the interdependencies and dynamics inherent in the oil market. Econometric analysis strengthens the validity of the model using statistical methods. However, challenges in effectively integrating different approaches and their potential incompatibility still need to be addressed.

Large-scale computational simulation models have also been widely used by organizations such as the Energy Information Administration, the International Energy Agency, and OPEC to model global energy markets for policy forecasting and analysis. These models simulate the oil market and estimate prices based on accurate physics, technological, economic, and geological data with high computing power (Huntington et al., 2013). As an example, the global energy model of the International Energy Agency shows the economic interactions between demand, supply, prices, and other macro variables under various assumptions and limitations (Lee, 2021). These large computational models incorporate extensive data detail and represent multiple market actors and constraints. Their scale makes it possible to assess the precise effects of events and policies on sectors, regions, and stakeholder groups. However, their complexity can reduce model dynamics, make calibration challenging, and require extensive computational resources.

Beyond the dominant models, some studies have used alternative techniques to analyze and forecast oil prices, such as machine learning, gray, and factor-based models. Machine learning approaches such as artificial neural networks have been applied to detect nonlinear patterns in

[2] The generalized autoregressive conditional heteroskedasticity

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oil price data (Bashiri Behmiri and Pires Manso, 2013; Xiong et al., 2013). While providing good complementary capabilities, these alternative methods have a weaker economic basis than other modeling methods.

In addition to quantitative modeling approaches, qualitative methods and experts' opinions have also been investigated in oil price forecasting processes. These approaches help to account for irregular factors such as geopolitical risks, technological innovations, consumer preferences, and environmental policies that are limited in quantitative modeling despite influencing the oil market (Huntington et al., 2013). However, quantitative models and historical data analysis are the primary inputs to forecasting prices. Qualitative inputs complement scenarios and uncertainties, and their unstructured nature makes integration into formal forecasting processes challenging.

A relatively comprehensive review of various modeling approaches for oil price forecasting and analysis has been presented. Different techniques have relative advantages and limitations, and no single model can fully represent the multifaceted complexities of oil market dynamics in the literature review section (Huntington et al., 2013).

3. Methodology

This study uses the system dynamics approach to determine and analyze the reaction of the global oil price to changes in its demand according to the scenarios of the International Panel on Climate Change, which was introduced in the sixth assessment report under the title of common socio-economic paths (Kikstra et al., 2022), provides a perspective of Brent oil price changes as one of the important indicators of the oil market. System dynamics provide a useful and practical framework for integrating the complex and non-linear relationships between key supply and demand factors and oil prices.

3.1. General model

The oil price outlook model is based on the fundamental analysis model developed in 2015 to check the balance of Brent oil prices as one of the main indicators of the oil market (Li, 2015). This model, developed and implemented in Vansim software, evaluates the equilibrium behavior of oil prices over time based on the balance between the oil supply and demand sectors according to the behavior of the main players in each sector. Figure 1 shows the causal loop diagram of the oil price analytical model.

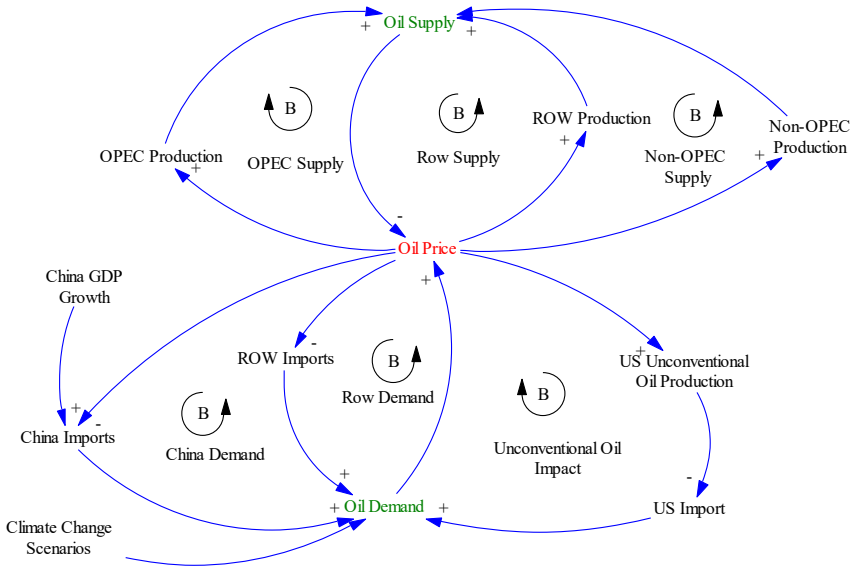

Figure 20. Causal loop diagram of oil price analysis model

As shown in Figure 1, this model models the main dynamics of the oil market in the form of nonlinear relationships by providing the structure of feedback loops, including demand, supply, and price. Key segments in the demand side include demand from China, the United States, and the rest of the world. In the supply sector, the amount of OPEC and non-OPEC oil supply has been introduced as determining variables in oil prices. In this model, the balance of supply and demand determines the price of oil, which affects the supply and demand of the main market players in a feedback loop. After developing the initial model, parameters are adjusted using historical data on oil production, demand, prices, and GDP from 2013 to 2022.

3.2. Demand subsection

The demand part of the model includes the demand of the United States of America and China as the largest oil consumers, and the demand of other countries in the world. The demand for oil in the United States of America is highly dependent on the price of oil due to unconventional oil production technology. Unconventional oil production technology requires higher oil prices so that the production process is economically justified. According to the oil price, the United States determines its demand based on the consumption and production rate of conventional and unconventional oil. The oil demand of China and other countries is increasingly correlated with the growth rate of their GDP. Other factors can also be effective in this model. Considering the demand parameters for the main players that are determined with the help of historical data, the impact of these factors has been simulated in the model. In this article, the oil demand section is determined based on the scenarios of the sixth assessment report of the IPCC, and the effect of the change in oil demand in climate scenarios on the oil price is evaluated.

3.3. Supply subsection

The supply part of the model includes the oil demand of OPEC, non-OPEC, and other world countries. The mutual relationship between the oil supply of each of the main players and the oil price is implemented in the model according to the historical data that determine the relationship between the oil price and the amount of production. In the supply sector, the model models the effect of these factors on the price of oil by considering a parameter that determines the impact of other factors affecting oil supply, which is obtained by calibrating the model with historical data.

3.4. Oil price

Finally, the price of Brent oil is modeled based on excess demand or supply in the entire global oil market. Excess demand puts pressure on prices. Meanwhile, excess supply pushes prices down. OPEC's behavior affects this balance by reducing or increasing production targets. The model uses econometric estimates of the historical relationship between oil inventory levels and prices to capture price dynamics.

3.5. Stock – flow diagram of the model

Figure 2 demonstrates that the oil market model contains several stock and flow diagrams affected by feedback loops of other variables. Oil Supply-Demand Disbalance represents the quantity of oil in surplus or deficit in the market. It is a critical stock in the system, directly affecting the Brent price level. OPEC Production Rate controls the amount of oil entering the system from OPEC countries. The non-OPEC Oil Production Rate represents the oil production from countries not part of OPEC. ROW Production Rate Stands for the Rest of the World and represents the oil production from the remaining global regions. Oil consumption is the outflow of oil consumed, determined by IPCC climate scenarios (Riahi et al., 2017).

Inventory Coverage is an auxiliary variable that affects Brent's price. It could represent how many days of consumption the current inventory levels can cover. Change in Brent Price is a variable influenced by the effect of inventory coverage on the price. It shows the directional change in Brent oil prices based on inventory levels.

A feedback loop connected the Change in Brent Price back to Inventory Coverage. which suggests that changes in the Brent price affect inventory coverage levels, further affecting the Brent price, showing a potential balancing feedback loop where the system tries to stabilize itself. Adjustment time represents the delay in the system before the effects of inventory

coverage are seen on the Brent price. This variable can introduce a time lag in the price response to changes in inventory levels.

Table of Effect of Inventory Coverage on Brent Price as a table function determines how changes in inventory coverage affect Brent's price. It likely contains a set of values that define this relationship, which are used to calculate the effect on the Brent price based on the current level of inventory coverage. In order to create the table functions, the authors relied on data from the 2014 annual report of BP (Li, 2015).

The stock and flow diagram is a simplified representation of the oil market dynamics, focusing on the production side and its immediate effects on price levels. The central stock, Oil Supply-Demand Disbalance, is increased by OPEC, non-OPEC, and ROW production rates. It is decreased by consumption, representing the demand side. The Change in Brent Price is influenced by the Oil Supply-Demand Disbalance, which affects the Brent Price Level through the "Inventory Coverage. According to the model, the Brent price level is significantly determined by inventory coverage, which serves as a proxy for supply robustness. Including Adjustment time shows that the effect of inventory coverage on price does not occur instantaneously but after some time, reflecting real-world delays in market response.

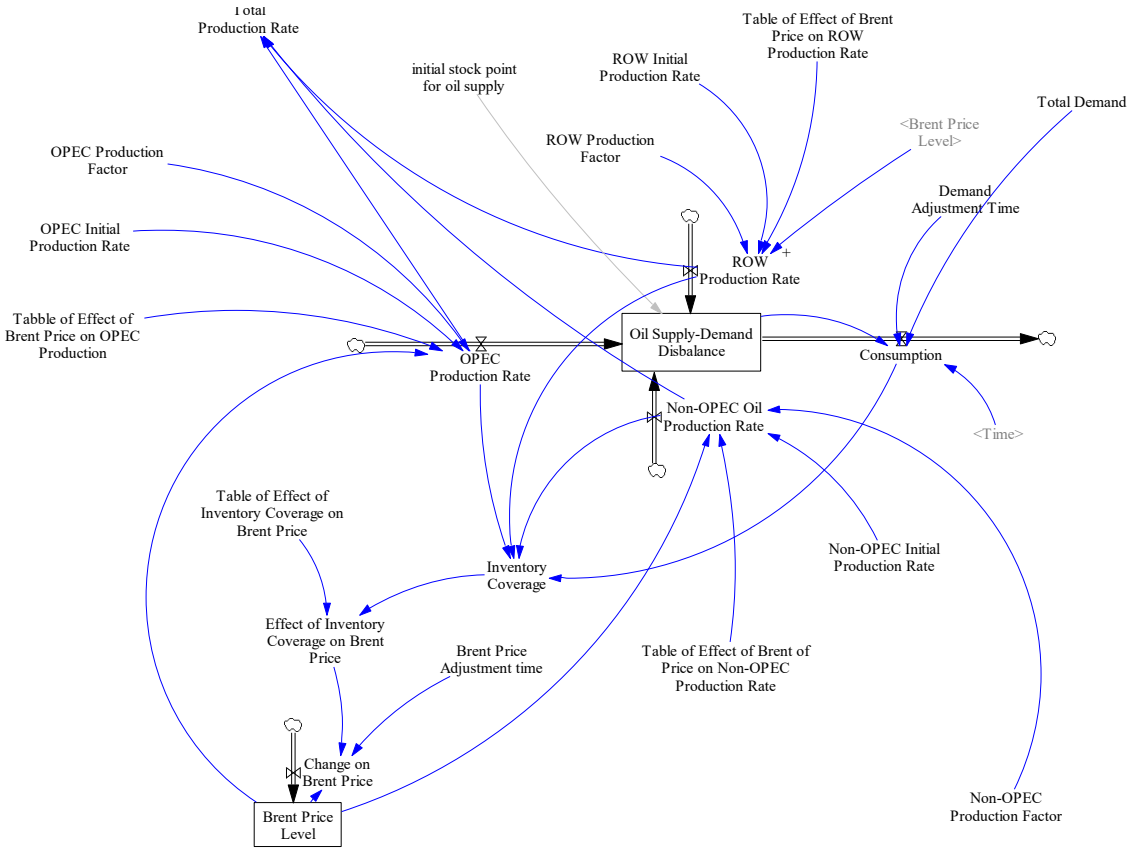

Figure 21. Stock - flow diagram of oil price model

4. Results and discussion

The model results predict a significant difference in the outlook for oil prices in different IPCC socio-economic pathways from 2013 to 2100. Figure 3 shows the assessment results of oil price changes under the SSP1 scenario and in different radiative forcing (RCP) scenarios.

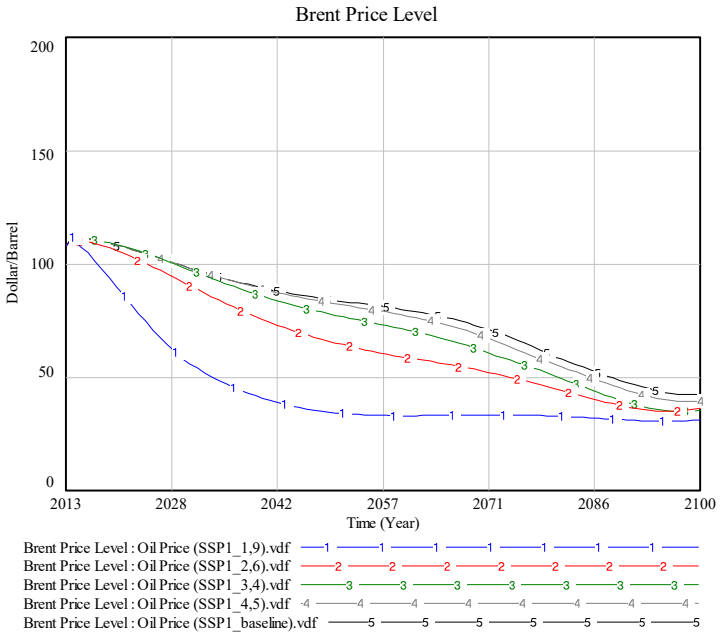

Figure 22. The assessment results of oil price change prospects under the SSP1 scenario and in different radiative force (RCP) scenarios from 2013 to 2100

Figure 3 shows that under the SSP1 sustainability scenario, the average oil price in different forcing scenarios will steadily decline from around $100/bbl in 2020 to around $25-40/bbl by 2100. It indicates a significant decrease in demand for oil. Energy demand is shifting towards alternative fuels, and oil demand is decreasing. Of course, in different RCPs, this price reduction has different intensities. For example, in RCP equal to 1.9 watts per square meter, the intensity of oil price reduction is higher than in other scenarios. Figure 4 shows the results of assessing oil price changes under the SSP2 scenario and in different radiative forcing (RCP) scenarios.

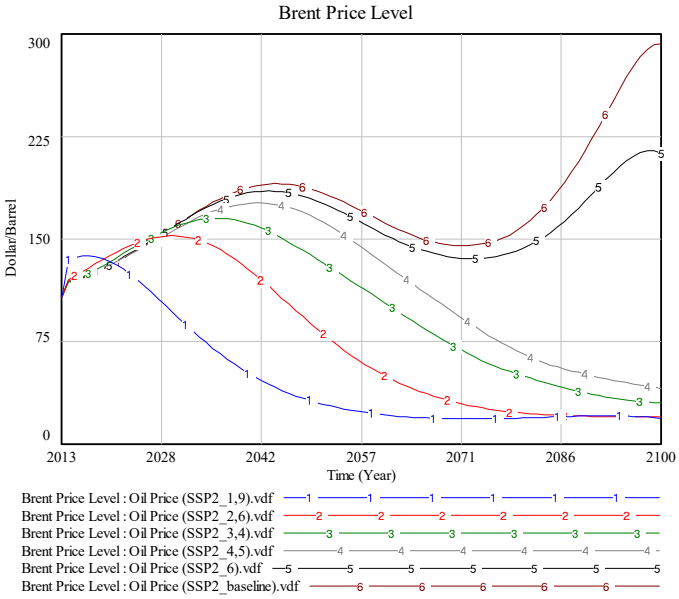

Figure 23. The assessment results of oil price change prospects under the SSP2 scenario and in different radiative force (RCP) scenarios from 2013 to 2100

According to Figure 4, in the SSP2 scenario, which represents the middle path in climate scenarios, the reduction of oil prices depending on different RCPs can be different. In RCPs 1.9, 2.6, 3.4, and 4.5, since there is less strictness than in the SSP1 scenario, the amount of oil demand will peak after several years, and then the price of oil will start a downward trend after an upward period. Of course, the time to reach the peak of oil prices will differ in different RCPs. Figure 4 shows the results of assessing the outlook for oil price changes under the SSP1 scenario and in different radiative force (RCP) scenarios. Figure 5 shows the results of assessing oil price changes under the SSP3 scenario and in different radiative force (RCP) scenarios.

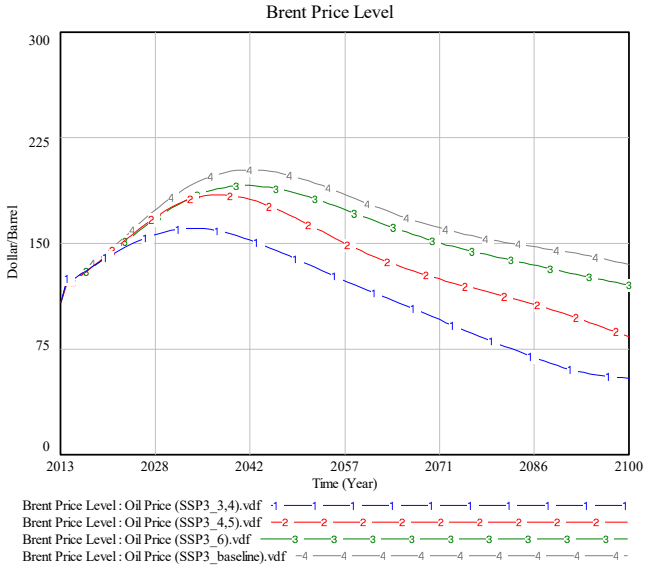

Figure 24. The assessment results of oil price change prospects under the SSP3 scenario and in different radiative force (RCP) scenarios from 2013 to 2100

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As shown in Figure 5, regional competition scenarios of SSP3 lead to sustained high oil demand and prices above $100 per barrel by 2100 in some RCPs. This scenario, defined based on regional competition, has fewer strictures to reduce oil consumption than the SSP2 scenario, which has caused the peak years of oil demand to have higher prices, which can have different rates in different RCPs. Figure 6 shows the assessment results of oil price changes under the SSP4 scenario and in different radiative force (RCP) scenarios.

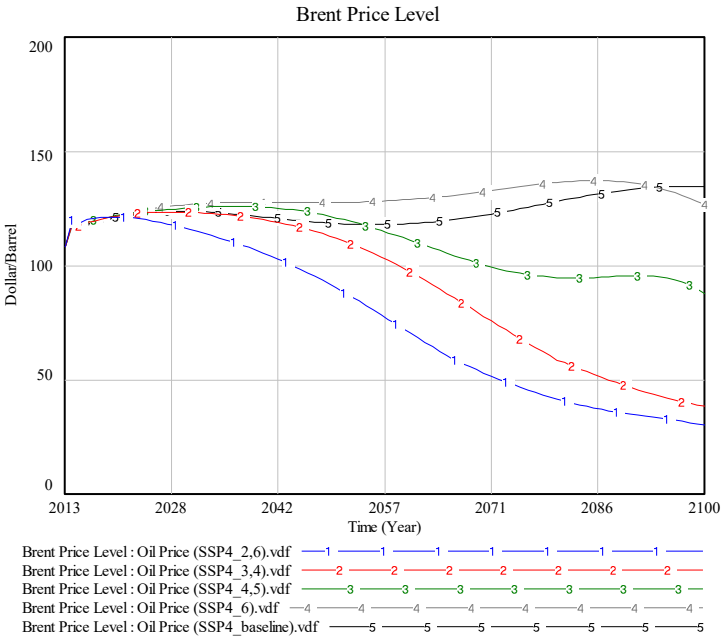

Figure 25. The assessment results of oil price change prospects under the SSP4 scenario and in different radiative force (RCP) scenarios from 2013 to 2100

According to Figure 6, the SSP4 inequality scenario leads to oil price volatility with a generally increasing trend in some RCPs, which reaches about $80 per barrel by 2100. In this scenario, because of the formation of inequality and more intense competition compared to the SSP3 scenario, economic instability causes the progress in climate policies to be pursued in a more limited way. The amount of oil price changes in different RCPs can be decreasing, constant, or even increasing. Finally, Figure 7 shows the results of the assessment of oil price changes under the SSP5 scenario in different radiative forcing (RCP) scenarios.

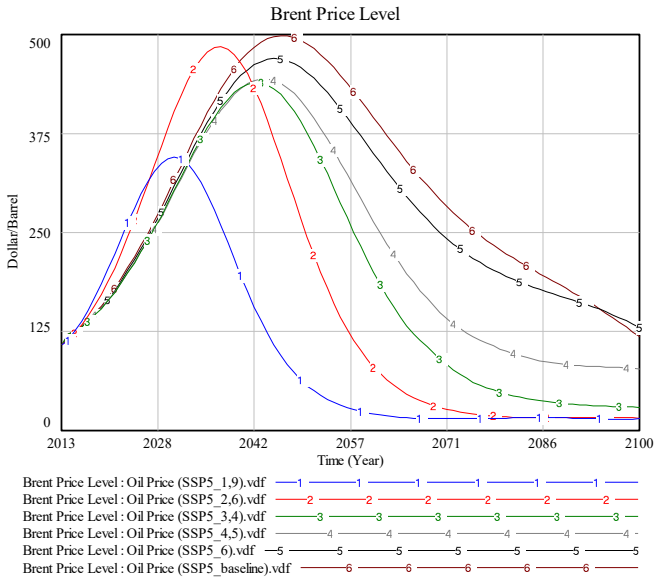

Figure 26. The assessment results of oil price change prospects under the SSP5 scenario and in different radiative force (RCP) scenarios from 2013 to 2100

As shown in Figure 7, the SSP5 scenario, which is based on the growth and socio-economic development based on fossil fuel, predicts the growth of prices in the early years of modeling. Of course, this rate of increase in oil prices, following the reduction of supply compared to demand, after passing its peak, a trend will decrease sharply. This modeling highlights the risk of reducing the ratio of demand to supply in sustainability scenarios, in contrast to reducing supply and increasing prices under regional competition scenarios or scenarios based on economic growth with the priority of fossil fuel consumption. The timing of peak demand for oil varies significantly across scenarios, occurring around 2020 in SSP1 versus after 2100 in SSP3 and SSP5. It has profound consequences on the revenues and budget stability in oil-exporting countries and can directly or indirectly affect the economy of these countries in different sectors.

4.1. Model validation

To validate the model, the authors examine the Brent oil price prediction results in the IPCC climate scenarios with the oil price prediction in the International Energy Agency outlook report. The International Energy Agency has developed forecasts and scenarios to provide better insight into the adoption of policies related to the energy sector, and according to these scenarios, it has provided a forecast of oil price changes in the World Energy Outlook report. A scenario of announced commitments shows that all climate commitments made by governments worldwide will be fully and on time. Under this scenario, global greenhouse gas emissions peaked in the mid-2030s, but there is still a significant gap compared to what is

needed to reach net zero emissions by 2050. The stated policy scenarios consider only the implementation of specific policies supported by law and have a high chance of implementation. Carbon dioxide emissions do not peak in this scenario but are inconsistent with achieving net zero emissions by 2050. The 2050 net-zero emissions scenario provides a tough but achievable path to net-zero emissions by 2050 for the energy sector. It requires the immediate and widespread deployment of all available clean and efficient energy technologies. By 2050, nearly 90 percent of electricity will come from renewables, with wind and solar accounting for roughly 70 percent. This scenario also depends on significant lifestyle changes based on reducing energy demand. Figure 8 compares oil price change prospects in IEA and IPCC climate scenarios until 2050.

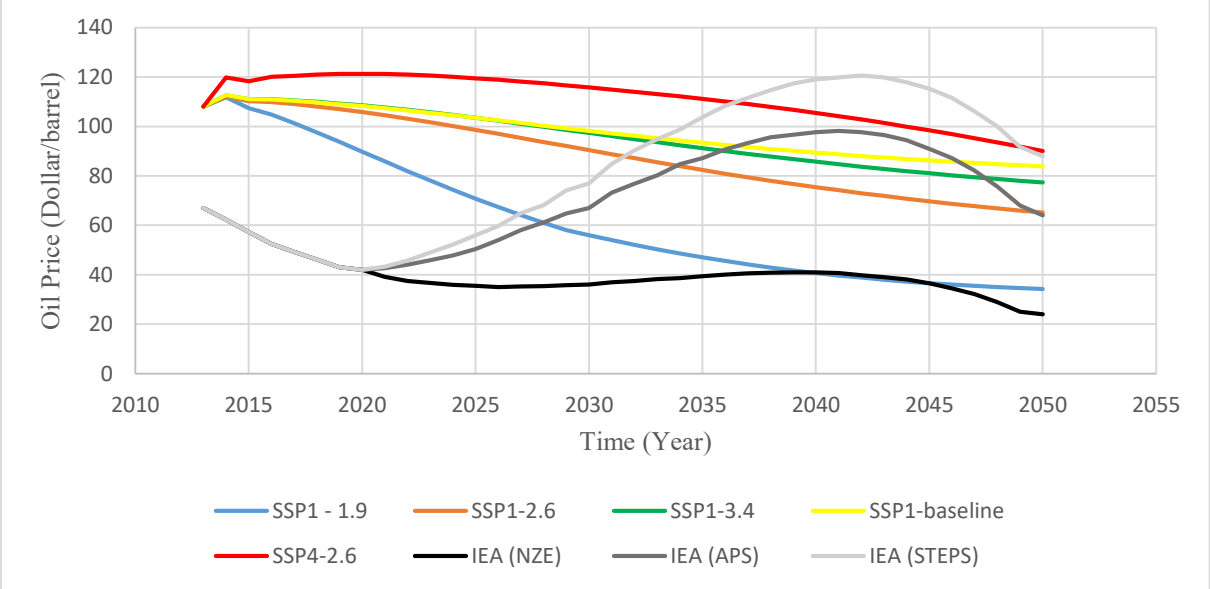

Figure 27. Comparison of prospects for oil price changes in the scenarios of the international energy agency and the climate scenarios of the IPCC

As shown in Figure 8, oil price changes in some IPCC climate scenarios are close to each other in different RCPs and IEA scenarios. Of course, since the International Energy Agency has evaluated the oil price based on the average price of oil importers, and also due to the very different definitions of scenarios, approaches, and the starting year of modeling in the International Energy Agency model, differences between the oil price forecast by the agency and there are research modeling results. However, a similar trend is observed in many scenarios. For example, the net zero emissions scenario follows a trend similar to the SSP1-1.9 scenario, which is a very strict scenario to reduce the consumption of fossil fuels, and the price of oil in 2050 is very close to each other in these two models. Also, the STEPS scenario indicates countries not meeting all their climate commitments and reports prices similar to the SSP4-2.6

scenario in 2050. Of course, as mentioned, due to the different nature of defining these scenarios and modeling methods, the results of price changes also differ.

The oil price model developed in this research reproduces the equilibrium price behavior based on oil supply and demand. The real price of oil can experience various fluctuations due to zeolitic events. In this model, parameters are considered to evaluate and determine the effects of these events. By calibrating the model and adjusting these parameters, the model can produce past behavior. Figure 9 shows the comparison between model results and historical oil price data.

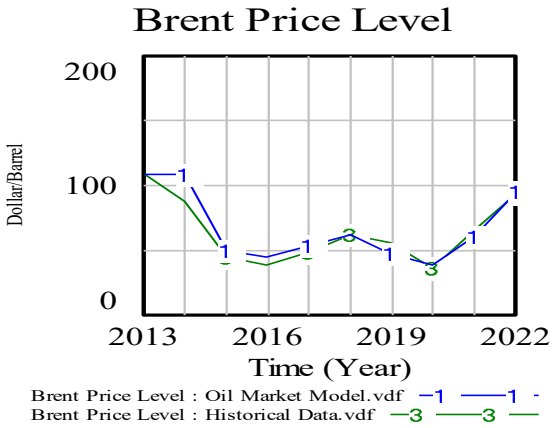

Figure 28. Comparison between model results and historical oil price data

As shown in Figure 9, the model has successfully reproduced the historical behavior of oil prices. The price of oil must change due to various factors. For example, after 2014, due to reasons such as the growth of American shale oil production, OPEC's policy change from price maintenance to market share maintenance, and economic growth slowdown, the price of oil decreased greatly due to excess supply (Prest, 2018). In this research, the main question is to examine oil price changes, focusing on the effects of climate scenarios on it.

5. Conclusions and suggestions

This system dynamics modeling approach integrates the complex interrelationships between drivers of oil supply and demand, geopolitics, climate policies, and economic growth. This model provides a useful framework for drawing oil futures contracts under various assumptions. Simulation analysis can inform industry strategies, investment decisions, and energy policy debates by mapping the outlook for uncertainties surrounding oil price forecasts. Further model development could include alternatives such as natural gas and electric vehicles, regional disaggregation, and game-theoretic aspects of OPEC's behavior.

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The results emphasize the necessity of diversifying the economy and government revenues for oil-dependent countries. Excessive reliance on oil exposes countries to fluctuations in oil revenues. Strategic economic planning should pressure a wide range of oil price futures.

This modeling demonstrates the complex interplay between economic growth, climate policies, energy technologies, and geopolitics in shaping oil market trajectories. Short-term prices provide limited guidance on long-term trends. System dynamics models such as these can help inform robust, risk-informed strategies by public and private oil market players.

Disclosure statement

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

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Attachment

Mathematical equations of the basic model for the evaluation of oil change prospects

Brent Price Adjustment time= 0.5
Units: Year

Brent Price Level= INTEG (Change on Brent Price, 108)
Units: Dollar/Barrel

Change on Brent Price= Brent Price Level*(Effect of Inventory Coverage on Brent Price-1)/Brent Price Adjustment time
Units: Dollar/(Barrel*Year)

China Demand= China Initial Demand*Effect of GDP Growth on China Demand*Effect of Brent Price on China Demand *China Demand Factor
Units: Barrel/Year

China Demand Factor= 1
Units: Dmnl

China GDP Growth= 7.7
Units: Dmnl

China Initial Demand= 3.92594e+09
Units: Barrel/Year

Consumption= "Oil Supply-Demand Disbalance"/Demand Adjustment Time+Total Demand
Units: Barrel/Year

Demand Adjustment Time= 1
Units: Year

Effect of Brent Price on China Demand= Table of Effect of Brent Price on China Demand(Brent Price Level)
Units: Dmnl

Effect of Brent Price on US Conventional Oil Production= IF THEN ELSE(Brent Price Level/US Conventional Oil Breakeven Price<1, 0 , Table of Effect of Brent Price on US Conventional Oil Production(Brent Price Level /US Conventional Oil Breakeven Price))
Units: Dmnl

Effect of Brent Price on US Unconventional Oil Production= IF THEN ELSE(Brent Price Level/US Unconventional Oil Breakeven Price<1, 0 , Table of Effect of Brent Price on US Unconventional Oil Production(Brent Price Level /US Unconventional Oil Breakeven Price))
Units: Dmnl

Effect of GDP Growth on China Demand= Table of Effect of GDP Growth on China Demand(China GDP Growth)
Units: Dmnl

Effect of Inventory Coverage on Brent Price= Table of Effect of Inventory Coverage on Brent Price(Inventory Coverage)
Units: Dmnl

FINAL TIME = 2022
Units: Year
The final time for the simulation.

initial stock point for oil supply=0
Units: Barrel

INITIAL TIME = 2013
Units: Year
The initial time for the simulation.

Initial US Conventional Oil Production Rate= 1.825e+09
Units: Barrel/Year

Initial US Oil Consumption Rate= 6.89375e+09
Units: Barrel/Year

Inventory Coverage= "Oil Supply-Demand Disbalance"/Consumption
Units: Year

"Non-OPEC Oil Production Rate"= "Table of Effect of Brent of Price on Non-OPEC Production Rate"(Brent Price Level)*"Non-OPEC Initial Production Rate"*"Non-OPEC Production Factor"
Units: Barrel/Year

"Oil Supply-Demand Disbalance"= INTEG ("Non-OPEC Oil Production Rate"+OPEC Production Rate+ROW Production Rate-Consumption, initial stock point for oil supply)
Units: Barrel/Year

Effect of Brent Price on ROW Demand= Table of Effect of Brent Price on ROW Demand(Brent Price Level)
Units: Dmnl

Effect of GDP Growth on ROW Demand= Table of Effect of GDP Growth on ROW Demand(ROW GDP Growth)
Units: Dmnl

Initial US Unconventional Oil Production= 1.82609e+09
Units: Barrel/Year

"Non-OPEC Initial Production Rate"= 9.51153e+09
Units: Barrel/Year

"Non-OPEC Production Factor"= 1
Units: Dmnl

OPEC Initial Production Rate=1.34426e+10
Units: Barrel/Year

 DOI: 10.22067/JSTINP.2024.85841.1085

OPEC Production Factor= 1
Units: Dmnl

OPEC Production Rate= Table of Effect of Brent Price on OPEC Production(Brent Price Level)*OPEC Initial Production Rate *OPEC Production Factor
Units: Barrel/Year

ROW Demand= ROW Initial Demand*Effect of Brent Price on ROW Demand*Effect of GDP Growth on ROW Demand*ROW Demand Factor
Units: Barrel/Year

ROW Demand Factor= 1
Units: Dmnl

ROW GDP Growth= 2
Units: Dmnl

ROW Initial Demand= 57111*365*1000
Units: Barrel/Year

ROW Initial Production Rate= 13863*365*1000
Units: Barrel/Year

ROW Production Factor= 1
Units: Dmnl

ROW Production Rate= Table of Effect of Brent Price on ROW Production Rate(Brent Price Level)*ROW Initial Production Rate*ROW Production Factor
Units: Barrel/Year

SAVEPER = TIME STEP
Units: Year [0,?]
The frequency with which output is stored.

Table of Effect of Brent Price on OPEC Production([(10,0)-(250,1.1)], (10,0.1), (20,0.43), (30,0.7), (50,0.85), (60,0.92), (80,0.95),(108,1),(120,1.03),(130,1.05),(150,1.08),(250,1.1))
Units: Dmnl

"Table of Effect of Brent of Price on Non-OPEC Production Rate"([(10,0)-(250,1.01)], (10,0.2), (20,0.6), (30,0.93), (50,0.97), (60,0.98), (80,0.99),(108,1),(120,1.005),(130,1.01),(150,1.01),(250,1.01))
Units: Dmnl

Table of Effect of Brent Price on China Demand([(20,0.49)-(200,3.64)],(20,3.64),(40,2.02), (60,1.48), (80,1.21), (90,1.12),(108,1),(120,0.94),(140,0.82),(160,0.71),(180,0.6),(200,0.49))
Units: Dmnl

Table of Effect of Brent Price on ROW Demand([(20,0.49)-(200,3.64)],(20,3.64),(40,2.02), (60,1.48), (80,1.21), (90,1.12),(108,1),(120,0.94),(140,0.82),(160,0.71),(180,0.6),(200,0.49))
Units: Dmnl

Table of Effect of Brent Price on ROW Production Rate([(10,0.2)-(250,1.05)],(10,0.2),(20,0.5),(30,0.77), (50,0.87), (60,0.93),(80,0.98),(108,1),(120,1.01),(130,1.02),(150,1.03),(250,1.05))
Units: Dmnl

Table of Effect of Brent Price on US Conventional Oil Production([(1,0.5)-(10,4.5)],(1,0.5),(1.1,0.55), (1.2,0.6), (1.3,0.7), (1.5,0.8),(1.9,0.95),(2.16,1),(3,1.3),(5,2),(8,3.5),(10,4.5))
Units: Dmnl

Table of Effect of Brent Price on US Unconventional Oil Production([(1,0)-(10,6)], (1,0.3), (1.1,0.4), (1.2,0.5), (1.3,0.6),(1.5,0.75),(1.9,0.95),(2.16,1),(3,1.3),(5,2.5),(8,4.5),(10,6))

Units: Dmnl

Table of Effect of GDP Growth on China Demand([(0,0)-(20,2.6)],(0,0),(1,0.13),(2,0.26), (3,0.39), (4,0.52), (5,0.65), (6,0.78),(7.7,1),(8,1.04),(10,1.3),(20,2.6))
Units: Dmnl

Table of Effect of GDP Growth on ROW Demand([(0,0)-(10,5)],(0,0),(0.1,0.05),(0.2,0.1), (0.5,0.25), (0.8,0.4), (1,0.5),(1.5,0.78),(2,1),(4,2),(6,3),(10,5))
Units: Dmnl

Table of Effect of Inventory Coverage on Brent Price([(-50,0)-(50,30)], (-50,30), (-35.336,25.8571), (-23.3198,21.1429), (-14.1548,15.1429),(-10.2851,11),(-6.41548,7.71428),(-2.74949,3.71428),(-1,1.8),(0,1), (1,0.2),(5,0.15),(10,0.1),(15,0.05),(20,0.01),(50,0))
Units: Dmnl

TIME STEP = 1
Units: Year [0,?]
The time step for the simulation.

Total Demand= (US Demand+China Demand+ROW Demand)
Units: Barrel/Year

Total Production Rate= "Non-OPEC Oil Production Rate"+OPEC Production Rate+ROW Production Rate
Units: Barrel/Year

US Conventional Oil Breakeven Price= 50
Units: Dollar/Barrel

US Conventional Oil Production Rate= Initial US Conventional Oil Production Rate*Effect of Brent Price on US Conventional Oil Production*US Conventional Production Factor
Units: Barrel/Year

US Conventional Production Factor= 1
Units: Dmnl

US Demand= IF THEN ELSE(US Unconventional Oil Production rate+US Conventional Oil Production Rate - US Oil consumption Rate<0, ABS(US Unconventional Oil Production rate+US Conventional Oil Production Rate -US Oil consumption Rate), 0)
Units: Barrel/Year

US Oil Consumption Factor= 1
Units: Dmnl

US Oil consumption Rate= US Oil Consumption Factor*Initial US Oil Consumption Rate
Units: Barrel/Year

US Oil Inventory= INTEG (US Conventional Oil Production Rate+US Unconventional Oil Production Rate-US Oil consumption Rate,0)
Units: Barrel

US Unconventional Oil Breakeven Price=50
Units: Dollar/Barrel

US Unconventional Oil Production rate= Initial US Unconventional Oil Production*Effect of Brent Price on US Unconventional Oil Production *US Unconventional Production Factor
Units: Barrel/Year

US Unconventional Production Factor=1
Units: Dmnl

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Applying Soft Systems Methodology to Implement Strategy in the Organization: A Case Study of Improving the Motivation System of Statistic Center

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ABSTRACT

The increased complexity of contemporary organizations necessitates adapting analysis and decision-making models as cognitive and analytical tools to cope with this complexity. Systemic thinking and its methodologies offer a way to overcome these complications to a desirable degree. Strategies are enacted in the organization when they are operationalized, as the diverse viewpoints of its stakeholders often hinder the practical attainment of the organization's strategic objectives. Hence, the researcher selected soft systems methodology (SSM) as one of the prevalent systems thinking methodologies to address this challenge and to achieve a relative alignment among the stakeholders' interests. Given that intervention in the organization is the primary prerequisite to resolving organizational problems with this methodology, the Iran Statistics Center (ISC) was chosen as a case study. At the onset of the intervention to enhance the processes of implementing the strategies of ISC with SSM, the main steps of operationalizing the strategies were elicited in the planning department, and then from the steps to devise an operational plan to increase employees molivation the motivation of employeesThe operational plan, developed through stakeholder involvement and consideration of diverse perspectives, facilitated the formulation of task strategies with a focus on executability. This approach aimed to bridge the gap between the strategic and operational layers within ISC. Additionally, the development of evaluation indicators enabled the monitoring of strategy execution within ISC. Besides developing a strategic and operational plan, this research also had other outcomes, such as organizational learning by using SSM. Through the education and facilitation of the researcher and the department staff, they became empowered to develop an operational plan for other strategies.

Keywords

Soft Systems Methodology, Strategy implementation, Iran Statistics center, Strategic operational plan, System methodology.

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1. Introduction

Top managers establish strategic objectives in many organizations, particularly governmental organizations in Iran. Regardless of their validity, middle managers must accomplish them within the predetermined period. Thus, one of the most crucial challenges confronting managers is how to enhance the implementation of objectives and strategies in their organizations. Some researchers contend that the causes of the non-implementation of strategies are largely attributed to the non-implementation of strategies, and there is invariably a deep gap between the strategic and operational layers of the organization. This group employs various methods and models (the number of which is increasing daily) to address the problem and diminish the gap between their organization's strategic and operational layers (David, 2011). It can be asserted that most of those methods are utilized to resolve a portion of strategic problems (Gurl, 2017), and few comprehensively offer management for implementing strategies in the model organization. One of the most extensively used methods in strategy implementation is the BSC, which assesses performance from only four perspectives and more than offers a solution for implementing strategies in an organization (Kaplan and Norton, 2005; 1996). Considering the existing overview of systemic approaches and their success in other fields, this research aims to use the capabilities of this approach's methodologies to implement organizational strategies better and reduce this gap. Among the system methodologies, the soft systems methodology has been selected due to its ability to respond to the how instead of finding the why and its other capabilities in facing complex environments with multiple stakeholders and different worldviews through greater employee participation. Given the necessity of intervening in the organization and implementing its steps, the Iran Statistics Center (ISC) was chosen as the study organization to apply this method. ISC exhibited a preference for employing soft methods to address its organizational challenges. It further explained the intervention steps for developing a strategic, operational plan (a plan that can cover the existing gap). After the researcher's intervention in that center's planning department, how to better implement the strategy in ISC became an important issue. Since the consensus among people to answer this issue was challenging, the SSM methodology was used as the dominant methodology to solve the problem. It was chosen so that with the help of this methodology, operational steps can be developed to access the center's strategies. In this manner, the gap between the strategic and operational layers within the organization was bridged to the desired extent. However, due to research limitations, certain steps were implemented solely for the priority strategy of the center titled "Improving and strengthening the motivational system of employees." It should be noted

that the ISC had previously developed its strategic plan by outsourcing, but this plan could not be fully implemented due to the top-down view. The lack of participation of employees in its development (a problem that most organizations face) and the heavy expenses paid for developing a strategic plan had little help in achieving their goals. In this research, with the help of SSM, in addition to formulating an operational planning step by step, involving people in how to implement strategies in the organization and increasing the commitment and motivation of people, the implementation of organizational strategies was helped to an optimal extent. Delegating the continuation of the work to the planning department reduced the organization's costs.

2. Literature review

A review of the prior research reveals that in the past, the extant methods in the domain of strategic management had a rigid and top-down approach to implementing strategies in the organization (Stead, 2019). However, today, with the complexities of organizations and the proliferation of organizational learning concepts that have a soft and bottom-up view, the impact of systems thinking in management research, including in the domain of strategic management, is conspicuously evident (Prewitt et al., 2012; French, 2009). One of the most significant research conducted in the domain of systemic thinking and strategic management is Stacey's renowned book titled "Strategic Management and Organizational Dynamics" which deals with the ontology of strategic thinking (Stacey, 2007; Stacey and Mowles, 2016). In order to demonstrate the position of systematic approach methodologies in global research in management, Mengers and his colleagues explicate the recent progress of systemic thinking and its expansion in management science in their article. Initially, they reviewed the important system methodologies, including the methodology used in this article. Then, they explained the scope of application of this methodology in various domains such as strategy, organization, production, and quality. They state that the entry of systemic thinking into the strategy domain has a history of 50 years, and they believe that the first strategy planning was done by systemic thinkers (Mingers and White, 2010).

Ackoff was the first person to introduce systemic issues to strategy (Ackoff, 1979). He considers one of the main reasons for his work to be the complexities between interactive relationships and subsequent variables in strategic decision-making. Following him, some researchers used this approach for planning and strategic management (Ma et al., 2011). Haines also used the concepts and tools of systems thinking for strategic planning management

(Haines, 1998). One of the latest related articles in this domain is the work done by a leading Chinese company to develop its performance management system. Initially, this company used the balanced scorecard method for its performance evaluation programs. However, with the emergence of challenges such as rapid change in demand and economic recession in the world, it was not suitable to use this method, so it decided to design a new system for performance evaluation by applying SSM. According to the senior management, the results obtained from its implementation indicate the success of this method compared to other methods (Liu et al., 2012). Also, a management consulting center in Japan uses an innovative combination method called "Project Management Methodology" to simulate strategic communication. This methodology combines BSC, SWOT, and SSM strategic map methods. This methodology is a reinterpretation of the SSM method; with the help of other mentioned methods, it should be noted that this method has also been implemented in a consulting company as a case study (Ishino & Kijima, 2005).

In recent years, researchers have considered the success of using this methodology in some studies as proof of its efficiency and use by other companies in the future (Macías-Barreto & Aguilar-Fernández, 2021), Such as the work of Maarif and his colleagues used SSM to develop strategy and improve quality in the coffee industry (Fadhil and et al., 2018) and Belderrain and her team was applied SSM to structure the planning process at a special educational needs school in Brazil (Françozo et al., 2022), at other article SSM used for cultural changes in a large corporation which was split into several smaller separate corporations, under new vision, mission, and leadership, needs a different culture deal with a fuzzy condition for system online management consultant construction (Anisarida et al., 2020). Also, Ebrahimi used soft systems methodology to analyze the cultural change in the National Petrochemical Company (NPC) (Ebrahimi, 2022). Other articles have also benefited from the achievements of SSM in various domains, especially information systems (Checkland and Holwell, 1993; Sun, 2021). Despite its widespread use of SSM in knowledge management and information systems, it has limited application in strategy (Saad et al., 2005; Delbridge, 2008). It can be said that except for the work in which Azar and his colleagues used SSM for strategic modernization in the insurance industry (Fatemi et al., 2022), in which the problem was addressed from a different perspective, this methodology has not been used in the domain of strategy. Some other articles added to the capability of this method by combining SSM with other methods, especially the System Dynamics methodology (Rodriguez and Paucar-Caceres, 2005; Zlatanovic,2015). Also, in the

other paper, the Viable Systems Model and SSM were chosen to intervene in an artisan enterprise in Mexico (Macías-Barreto & Aguilar-Fernández, 2021).

3. Methodology

Peter Checkland was the founder of Soft Systems Methodology (SSM). He cites three important experiences that led him to shift from system engineering to formulate SSM. The organization encountered severe problems in all three cases, but they could not explicitly state them. The conditions of all three projects were ambiguous and unstructured. By summarizing these three projects, Checkland determined how SSM should distinguish itself from rigid approaches (Checkland, 1981).

The common methodology used to implement SSM is the seven-stage learning cycle system, which he introduced in the book Systems Thinking and System Practice, shown in Figure 1.

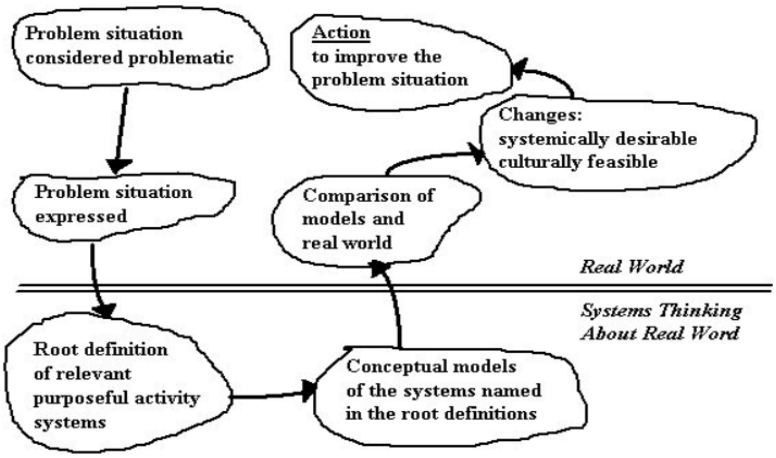

Figure 29. SSM+ implementation steps

3.1. Steps of SSM

Steps 1 and 2: Facing a problematic situation This stage includes entering the problem conditions and identifying the people, culture, standards, and values governing the problem conditions through interviews and discussions, observation, brainstorming, and illustrative images. Illustrative images are cartoon images that depict the actors (in the situation of the problem), consequences, problems, relationships, and conflicts and provide a general idea of the existing situation. Visualizers identify the nature of the situation, determine the related contexts, and ensure the creation of a common understanding and perception according to the different viewpoints.

Step 3: Development of root definitions Providing definitions is one of the requirements of the SSM method. A root definition is a phrase or sentence that describes an ideal system, the objectives of that system, who will be involved in it, who is currently participating in it, and who will be affected by it. It describes what they accept and who influences it. A technique called CATWOE is used to develop root definitions. The word CATWOE is derived from the first letters of several other words and helps the problem owner (employer) formulate the problem using key definitions. The letters that make up this word are:

- The C means customers, that is, those who see profit or loss in this system.
- The A means the actors and people performing the activities in the transformation process.
- The T means the transformation process, which converts input into output in the system.
- The W means the worldview of what gives meaning to the transformation process.
- The O means the owner, who can stop or delete the system.
- The E means the environmental constraints that affect the system but cannot be controlled.

Step 4: Building a conceptual model. A model in SSM is a diagram comprising a series of activities and communication lines between them. These models are directly extracted from the root definitions and express the key activities in the root definitions as expressions. The main goal is to understand more of the activities in the processing process. There are different opinions and beliefs about their activities and communication, and finally, a consensus model is obtained by applying different points of view.

Step 5: Comparing the model with the real world. This stage is designed to structure the negotiations and give them content to improve the existing conditions. At this stage, the models are compared with the real world by using a series of regular questions about each activity and each relationship in the model.

Step 6: Identifying and determining the required changes. This stage includes the systematic determination of desirable, culturally possible changes.

Step 7: The changes determined in the previous step are applied. Finally, it is emphasized that the use of SSM should be collaborative in this step. It is better for as many people as possible to feel that the study process and desired changes belong to them, which is possible with their participation in the methodology. Only in this way will the participants reach a new definition of feasibility by testing and correcting opinions and interpretations. The changes that did not come to mind before the intervention because of the background and culture of the situation can be clarified after it is completed (Hindle, 2023).

4. Conceptual model of strategy implementation

In this section, with the assistance of SSM, a conceptual model was derived for implementing the strategy in the organization, with the involvement of the pertinent employees, to facilitate the implementation of the strategic plan. At the onset of the researcher's intervention in the Planning Department of the ISC, meetings were conducted with the department staff to implement the strategies. During these meetings, which took the shape of brainstorming, the problems and challenges faced by that center in confronting the implementation of strategies were recorded. Moreover, by analyzing and examining the discussions formed in the group with the proposals presented for implementing the strategy by different people (some of which were contradictory), reaching a consensus among the group members became an important challenge. (Mingers and Rosenhead, 2004) Therefore, to address this problem, the researcher suggested using the existing methods in the pluralism approach, which was used due to the familiarity of the group members with the SSM method by the researcher and its extensive use in the literature review. In the following, according to the principles presented (Rosenhead & Mingers, 2001), the following root definition for the strategy implementation system in the organization was explicated.

"A system belonging to the head of the organization, which is used by the planning department and representatives of other departments to extract task strategies (compilation of the operational plan) and communicate it to the employees of the organization to implement the strategy, and this system is limited Financial, time and culture and structure are disproportionately faced." After explicating the root definition, it was time to derive the conceptual model of the activity based on it. At this stage, group discussions were conducted in numerous meetings, and research was conducted in similar organizations, such as John Moore Bryson's strategic planning model in public organizations (Bryson, 1988). This model was derived as shown in Figure 2.

As seen in the conceptual model of strategy implementation, appropriate measures have been defined to measure the model's validity according to the three evaluation criteria of 3E (efficacy, efficiency, and effectiveness) (Checkland and Poulter, 2007). These three criteria are respectively:

A. Efficacy: Does the conversion process work properly?
B. Efficiency: Does the conversion process take place with minimal resources?
C. Effectiveness: Does the conversion process lead us to our original goals?

All three defined criteria were examined during the group meetings. In this way, the efficacy of the model was obtained by attracting the opinion of experts so that each person acknowledged

that the model and the activities defined in it were sufficient for the implementation of the strategy. Further, the model's effectiveness was also determined, considering that the derived activities were based on the purpose of implementing the strategy and were approved by the subject owners. The efficiency criterion was confirmed by comparing it with the previous implementation process in the organization.

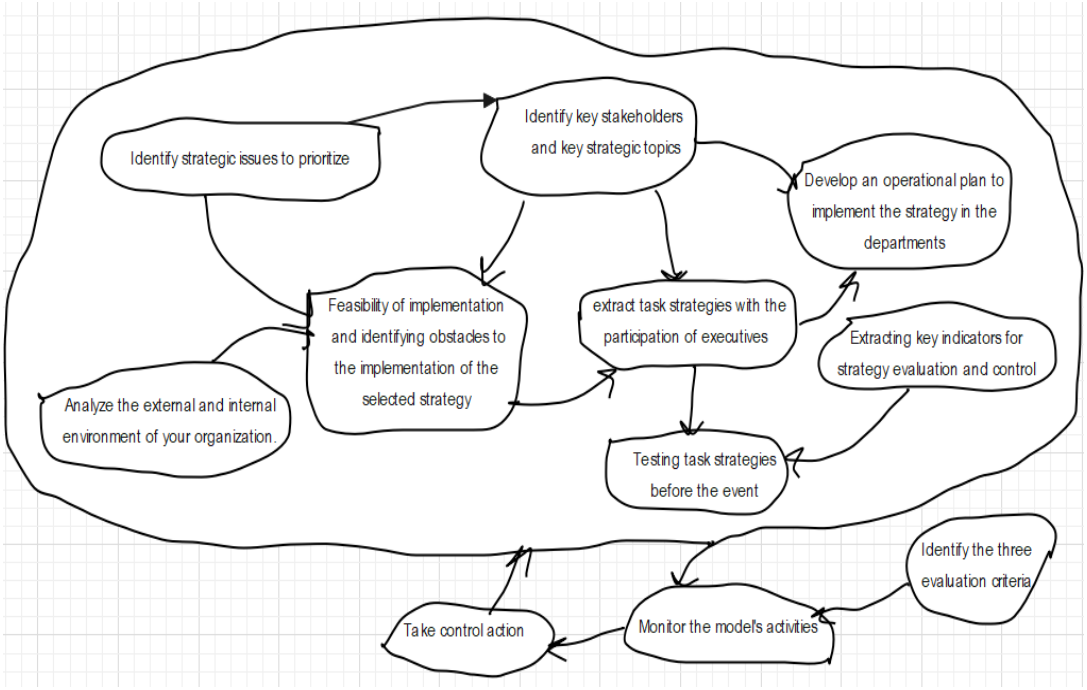

Figure 30. Conceptual model of strategy implementation

The model presented in Figure 2 has the advantage that, compared to other existing models, it reflects the participation of strategy implementers, which helps their implementation in the organization to an optimal extent. Hence, the program derived from this, which has been named the model operational strategic plan. It should be noted that this participation can be achieved through various methods, which was achieved in this research through SSM.

5. Using SSM to implement the strategy of the employee motivation system

The strategy implementation model was the initial theme of the strategy implementation roadmap to initiate intervention in the organization, which was completed during the three years that the researcher was working as a strategic planning consultant of ISC, and finally became a strategy implementation roadmap in the organization (Moghbel Baerz et al., 2021) was presented, which cannot be explicated in this article. Also, some steps derived in the conceptual model of strategy implementation, such as testing strategies in the virtual environment and selecting a priority strategy, have not been explicated, and in the following, other steps for the priority strategy of ISC have been implemented as examples. Considering that at the onset of

the researcher's intervention process, it was necessary to select a group to accompany and participate with him so that the researcher could meet the requirements of the SSM selection method. After consulting with the head of the planning department, seven department employees were selected as the strategic planning team (technical committee) due to their expertise in the domains related to planning. Moreover, due to the low familiarity of the people with the systematic issues and methodology used in the action research process, the researcher provided the necessary education to the selected people for three months. Considering that the issue of strengthening the motivation of employees was one of the challenging issues in ISC and this issue involves stakeholders with different worldviews, according to them, the ways to implement this strategy, which are the same strategies, is a task, it is numerous. Therefore, to derive strategies with an executive guarantee, all of their opinions should be considered. According to the requirements of the SSM method, this work was done by forming different groups of stakeholders to pay attention to their worldviews. In this way, by forming special working groups with each of them, the basic definitions and conceptual models of the strategy system (as a targeted activity system) were derived. In the following, the steps of implementing SSM to derive task strategies related to strengthening the motivational system of employees have been discussed in detail.

5.1. Understanding the problematic situation (employee motivational system)

According to the definition of the strategic problem of strengthening the motivational system of employees above, understanding the problematic situation is recognizing the motivational system of ISC's employees, whose strengthening and improvement has become a discussed issue. In the following, based on triple analysis and rich image, this system's recognition has been discussed to extract targeted activity models for it.

During several meetings with the planning department group, the problem of how to strengthen the motivation of employees in the organization in question was examined from different aspects. From the discussions held in the working groups, the following three tests were analyzed regarding that system.

Analysis 1: This analysis, which was related to the intervention process itself, recognized the stakeholders' worldviews on motivation and identified the following elements.

- The employer in the|ISC was defined as the general manager of the planning office.
- The issue’s owners , the strategic planning group, the vice president of development, and the the department managers were defined, and the executors were also considered the strategic planning group or the technical committee.

Analysis 2: which was called social analysis, led to the identification of the following elements.

- Identifying the expected norms or behaviors related to the roles, some of which in the organization in question include employees' respect for managers, more remuneration for specialized work, and participation in training courses.
- Values were identified from the discussions held in the meetings and observations. For example, the planning department director is an exemplary manager because he values scientific research. Also, roles were identified, both official (for example, so-and-so is a manager) and unofficial (for example, so-and-so is a conservative), and it is not permissible to mention all of them here.

Analysis 3: During a meeting with the technical committee, a political analysis was also carried out on the issue of motivation, and in the end, it was determined that in the organization in question, its president and the board of directors are manifestations of power in the motivation system. Also, in each department, people who secretly have influence and have a high degree of power to influence their managers were identified. According to the information obtained in the meetings and the analysis done, in the next step, it was time to draw a rich picture to show what is happening in the target organization about the motivation system. For this purpose, it was necessary to identify the subsystems related to the motivation system in the organization by the researcher and the technical committee. After several meetings, based on the research conducted and the discussions held in the group, the researcher presented an initial rich picture of the motivation system in ISC. After getting approval, it was drawn in the relevant group.

Based on the initial rich picture, the problem of enhancing the motivation of employees encompasses different dimensions, and therefore, several root definitions based on different worldviews could be derived from it. In the continuation of the steps of using SSM to derive conceptual models based on those definitions, it was necessary to form different groups of stakeholders to scrutinize the problem to have a comprehensive view of the motivation system and validate the obtained results. Therefore, a meeting was conducted with the technical committee to identify different stakeholders in the system and to form special groups to participate in the working groups. During this meeting, according to the limitations in the ISC (one of which is the time limit of the participants), three groups were defined with the titles of planning office, staff, and managers, and the number of participants in each group was respectively 12, 7 and 5 people were considered. In the classification, the group of employees and managers were considered so that employees could easily express their points of view in meetings and working groups. During the selection process, careful consideration was given to factors such as gender, level of education, specialized field, and job position of the individuals.

These selections were made in alignment with their distribution within the ISC, ensuring a diverse representation across various demographics and professional backgrounds.

After the preliminary education of the groups with SSM, in the continuation of the work, the initial rich picture of the motivation system was explicated to them for further discussion and investigation, and from the feedback received from them, this picture became complete and finally, as shown in Figure 3.

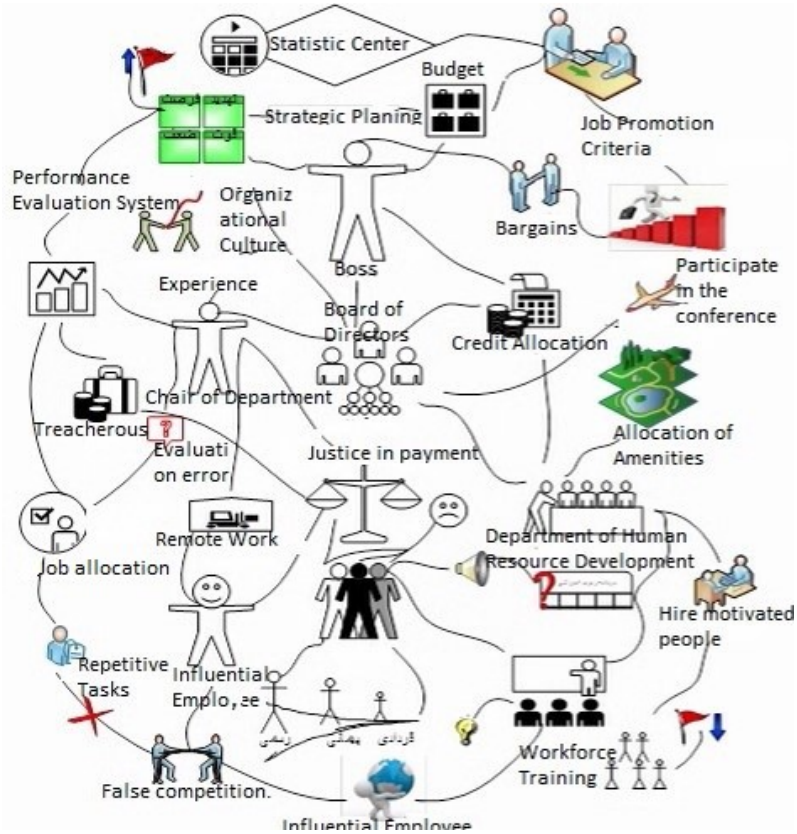

Figure 31. The rich picture of the motivation system

As seen in Figure 3, the important activities related to the motivation system in the ISC are recruitment activities, recruitment and training of employees, empowerment, job promotion, employee evaluation, justice in payments, work allocation, Salaries and benefits and welfare facilities, as well as the key activity of strategic planning, which is the strengthening of the incentive system at the top of all of them, as well as factors such as unfairness in payments, provision of facilities and errors in the evaluation system, and the like. It will cause employees to be demotivated (as obstacles to implementing the strategy), which can be easily seen in the rich picture. All these activities together paint a picture of what is happening in the real world about the motivation system in the ISC.

5.2. Extracting the root definitions and conceptual models of the motivation system

After structuring the problem and forming groups in the previous stages, in the next stage, with the help of the rich picture, a purposeful activities model for the motivation system should be extracted. According to the technical committee's point of view, compared to the activities carried out in the rich picture, which was to increase the motivation of employees, strengthening the motivation system was introduced as the goal of that system. Next, in the specified groups, with the help of CATWOE elements, different root definitions were extracted for that system, and based on them, purposeful activity models or conceptual models were extracted in each group.

5.2.1. The activities of the planning group

The planning group discussed and exchanged opinions, and the group members reached a consensus, defining the elements of CATWOE, as seen in Table 1. By combining these elements according to the principles presented at SSM (Bergvall-Kåreborn et al., 2004), the root definition of "Employee Motivation Enhancement System" was extracted. "A system belonging to the head of the organization, which is created by the head and its managers, the vice president of development and the planning department through activities that motivate employees to reach strategic goals, which this system has legal limitations and lack of credibility is facing."

According to the principles and strategies of using SSM, the activities of the conceptual model should be extracted with the help of the root definition, especially the transformation process and worldview. Therefore, considering the transformation of unmotivated employees into motivated ones was a general transformation process for the motivation enhancement system. In separate meetings, the participants suggested necessary measures based on their worldview. The planning group extracted the list of these activities after standardization, as shown in Table 2.

Table 19. CATWOE elements identified by the planning group

Customers	The head of the organization - the employees of the organization's departments
Actors	The head and managers of the organization - Vice President of Development - Planning Department
Transformation	Turning unmotivated employees into motivated employees
Worldview	Increasing motivation in employees leads to reaching the strategic goals of the organization.
Owner	Head of the organization
Environmental constraints	Lack of credit - legal limitation

Table 20. List of effective measures to increase employee motivation

Description of the activity	Average	Feasibility	Important
Creating justice in payment Training employees according to job needs	86.85	81.2	92.5
Providing facilities to employees (improvement of welfare affairs)	85.6	87.5	83.7
Optimum use of employees' capabilities	84.35	78.7	90
Exact implementation of the law on employee career promotion and meritocracy	84.35	76.2	92.5
Delegation of authority (increasing the authority of employees)	80.6	70.6	90.6
Creating security and a clear career path	78.1	71.2	85
Increasing the salaries and benefits of employees	74.35	68.7	80
Improving the performance of the evaluation system	72.5	50	95
Improving the performance of the evaluation system	67.35	58.7	76

Finally, after accessing the main activities to transform unmotivated people into motivated people, the group established logical connections between the activities, and the conceptual model of the motivation enhancement system of the planning group was extracted.

5.2.2. Activities of the staff group in the staff group

More meetings were needed to understand the issue in order to derive a conceptual model. Finally, according to the discussions and exchange of opinions held in those meetings and the consensus reached between them, the staff defined the elements of CATWOE. By combining those elements (as shown in Table 3), the staff group extracted the following root definition."A system belonging to the head of the organization, which has been created by the managers of the organization and the influential employees, has motivated the employees and created satisfaction in them. This system is facing financial, political, and cultural limitations."

Table 21. CATWOE elements identified by Employees.

Customers	Employees
Actors	Managers of the center - influential people
Transformation	Turning unmotivated or low-motivated employees into motivated people
Worldview	A system that leads to employee satisfaction
Owner	Head of the organization
Environmental constraints	Political, financial, and cultural limitations

In this group, in order to draw a conceptual model similar to the work done in the planning group, necessary measures were taken to select activities that are effective in increasing motivation. Finally, a conceptual model for strengthening employee motivation was extracted after accessing the activities necessary to transform unmotivated people into motivated people and discussions conducted with the employees in their particular meetings. It is worth mentioning that in the list of activities of the staff group, except for the first three items, the rest are different from the activities extracted by the planning group, which indicates the different views of these two groups on a motivational system of employees.

5.2.3. Activities of the group of managers

The group of managers was the last group that participated in the meetings, and the necessary measures to extract their special conceptual model were similar to the two groups of planning and employees, with the difference that reaching a consensus among managers was more difficult than the other two groups. Finally, according to the discussions and exchange of opinions held in their group and the relative consensus that was reached between them, the elements of CATWOE were defined as given in Table 4 by combining these elements of the following root definition by the group of managers was extracted for the motivational system of employees.

"A system belonging to the board of directors, which is created by the president, managers, and employees, as well as the vice president of development through activities that create motivation in employees and managers in order to increase productivity in the organization, which is limited by legal, political and financial is facing."

Table 22. CATWOE elements identified by managers

Customers	Employees (experienced and less experienced)
Actors	managers of the organization The head of the organization-development assistant - managers - employees
Transformation	Improving employee motivation
Worldview	Increasing motivation in employees leads to increasing productivity
Owner	Board of Directors Legal
Environmental constraints	political and financial limitations

Based on this definition and the list of measures extracted by the managers in the relevant meetings, and finally, their conceptual model for strengthening the motivation of employees, the activities extracted by managers are different from other activities extracted from other groups. They have been planning and employees, and in a way, they have shown the main concerns of managers to increase motivation.In general, it can be said that the extraction of conceptual models in this part, accompanied by the participation of different people and their surveys, somehow led to the culture of strategy as a part of the institutionalization of this strategy in the ISC. The more people participate in drawing these models, the better institutionalization will be done. Also, the different conceptual models presented by the groups are a sign of the difference in the participants' views, which were used to extract the general (ideal) conceptual model according to the stated principles.

5.3. The general (ideal) model of the employee motivation system

After drawing the conceptual models by the three groups in this stage according to the SSM stages, these models should be compared with what happens in the real environment (ISC) regarding employee motivation. Finally, through these comparisons, improvement measures, which are the task strategies, should be extracted. Since the comparison of individual models with reality leads to parallel work and takes much time, it was decided that similar to some research done in this regard (Mingers, 2000) to extract a general conceptual model from the employee motivational system. In this way, the common activities of the models extracted by different groups, which are salary increase, justice in facilities and payment, and meritocracy, were listed. The activities related to them were added to the model, which then, From the discussion and investigation of its activities and the group's assurance of their importance and the resurvey conducted regarding the importance of those activities, finally, the ideal (general) model of the system of strengthening the motivation of the ISC employees in a form which you can see in Figure 4, was drawn by the researcher. Each activity in this model has sub-activities. They can be examined as a targeted activity sub-model, and that sub-model's goals are equivalent to strategic goals.

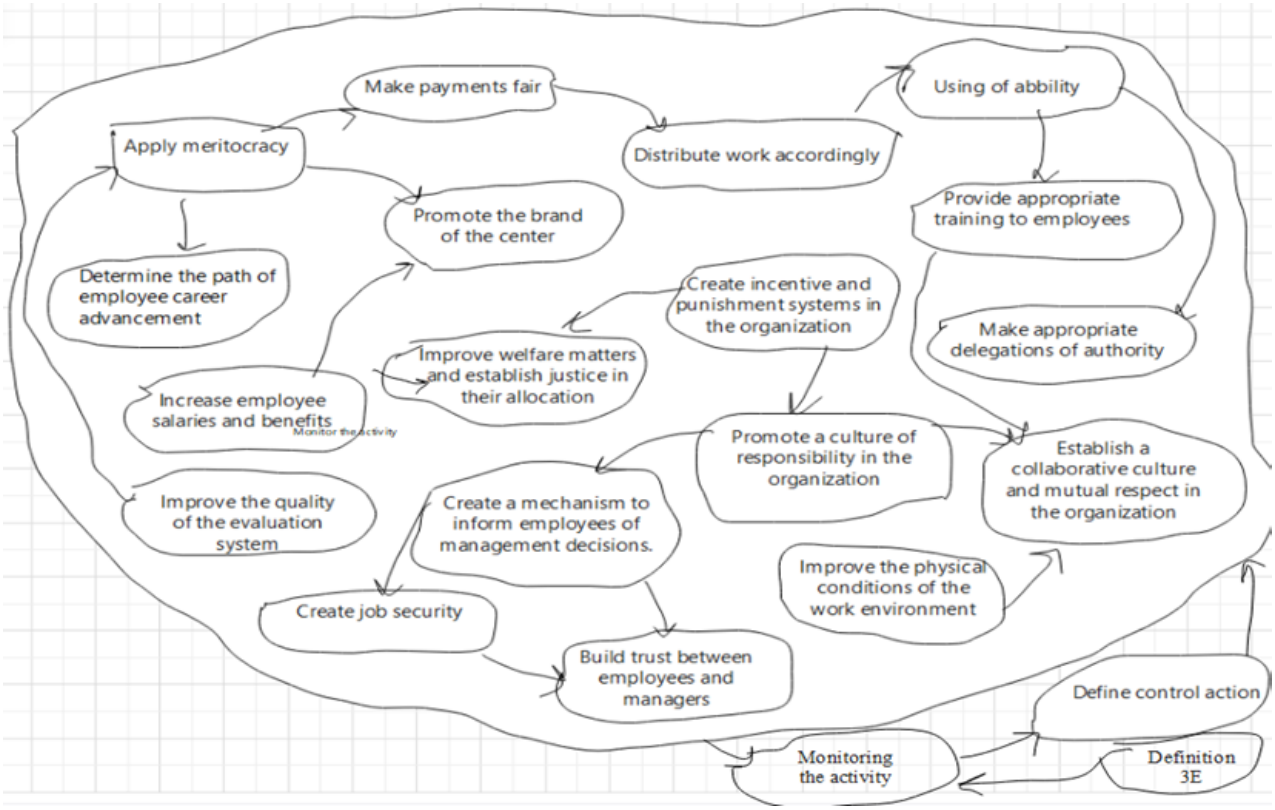

Figure 32. The general model (ideal) of the system of strengthening the motivation of ISC

As seen in Figure 4, this general model does not limit its activities to organizational boundaries and can be divided into different departments. The subject of dispute or the problematic situation in the organization is the formulation of appropriate strategies to increase employee motivation, which can be easily implemented in similar organizations.

5.4. Extracting task strategies to strengthen employee motivation system

In the following, during the meetings with the executives involved in this system, a comparison was made between the activities of the introduced conceptual model and what they do in practice to strengthen the motivation of employees, as can be seen in the picture. Finally, by answering some questions in the comparison, such as (is this activity done? how is this activity done? by whom is it done? What empowerment action is necessary to do it?), they proposed improvement measures to fill the performance gap (between what happens in the purposed world of the system and what happens in the real world) as shown in Table 5 for the tree of the main strategies. These measures are the task strategies that have been extracted with the participation of their executives in ISC.

Table 23. The list of task strategies and relevant executives

Activity (Main strategy)	**Improvement action or the task operational**	**Executives**
Apply meritocracy	Preparing the required indicators for meritocracy according to the ISC	Deputy Development Planning Office
	Preparation of birth certificates of the abilities of qualified employees (Clause A of the Civil Service Law)	Deputy Development Planning Office
	Implementation of the appointment letter of the Transformation Council and its supervision (conducting necessary training courses for manager training)	Vice President of Development
Create justice in payments	Review and reform the payment system of the ISC	Planning Office
	Implementation and implementation (managers' training - informing - reviewing)	Development Office All assistants
	Monitoring the implementation in the form of a payment syntactic performance report to get feedback	Planning Office
Increase the salaries and benefits of the employees	Measures to improve the general performance evaluation indicators of the ISC	Public Relations Base Office Planning and Development Office
	Strengthening the relationship with the management organization	Office of the President

As seen in Table 5, the nature of the improvement proposals presented at this stage has made them easily applicable to the organization's operational plan. Thus, the gap between the strategic layer (measures extracted in the conceptual model of the idea) and the operational layer is covered in ISC. Of course, other measures may be suggested, which are limited to these measures due to the existing limitations in the organization and the requirements of the method.

They are considering that each of the activities in the general model is a sub-system for the more extensive system of strengthening motivation (as its sub-activities were specified in the special models of each of the groups). It has short-term goals compared to the motivation enhancement system's primary goal, equivalent to strategic goals in strategic planning. In this way, strategic goals can be achieved by extracting the goals and activities in the general model. After extracting the strategic goals from the technical committee, suitable indicators for each goal were extracted by finding the 3E indicators for each activity in the conceptual model. Finally, with the goals in hand, task strategies, indicators, and respondents, the operational and strategic plan for the next year was compiled in the ISC regarding improving the employee motivational system.

6. Validation and evaluation

Validation in systematic methodologies is always considered a challenging issue. The nature of validity and the type of tests used to validate these methodologies are very different from other methods, especially in the technical and engineering fields (Checkland and Holwell, 1998). The validity of the models presented with these methods is more in their ability to communicate with the stakeholders and accept the employers, help create new insight and attitude, adapt to the real system, improve understanding, and influence the audience. In general, as this paper move towards soft systematic methodologies, the validity of these models depends more on the opinion of the stakeholders. Checkland believes that in soft methods, the criterion of "Recoverability" is more suitable for complex human situations than the "Repeatability" criterion, which can be obtained mostly in laboratories. Recoverability means that others can understand and retrieve the research and be aware of the work done and how to obtain the results. The criterion of recoverability is not as strong as the criterion of repeatability; instead, in complex human situations, including organizations, it is the criterion of recoverability that distinguishes Well-organized action research from storytelling (which is used in many social science types of research) (Checkland and Poulter, 2007). This article's strategy implementation model was implemented for one of the strategies in ISC, which was approved by all stakeholders. To ensure its recoverability, this article explained these steps precisely and effectively so that similar organizations can benefit from its capabilities and turn them into a native model for every organization. By using it in other fields and obtaining desired results, its recoverability will also be increased.

7. Discussion and conclusion

This paper attempted to apply Soft Systems Methodology (SSM) as one of the widely used methodologies of systems thinking in strategic management to implement strategies in the organization. In this way with applying SSM have been overcome the limitations caused by using existing methods in this domain. With the assistance of SSM and the development of a strategic operational plan for enhancing employee motivation, the gap between the strategic and operational layers in the Iranian Statistic Center (ISC) have been diminished.

As outlined, the application of SSM involved drawing a rich picture of the problem in an unstructured form. This picture was analyzed to identify the defined problematic situation within the political and cultural environment and among stakeholders. Subsequently, root definitions were derived corresponding to the CATWOE elements for each office. Additionally, the purpose of the activities model in each office was defined to align with strategic goals. Due to the clarity of the purpose and to comply with the system principles, it has been used the subject-oriented model in SSM to derive strategies in the following. The ideal model of the strategy have been drown for enhancing the motivation of employees and compared this model with what happens in the real world in the relevant department through questions such as how to carry out activities, their priority and delay, the criteria for measuring the efficiency, the effectiveness, and the efficacy. In the end, appropriate strategies, or improvement measures (such as structural, process, or cultural changes within the organization), were determined by reaching a compromise between stakeholders' opinions for implementation in relevant offices and the operational strategic plan. This plan included strategic objectives, task actions of executives, measurement indicators, and respondents, ultimately satisfying ISC employees. With these insights, the procedure was applied to other strategies within the planning department.

In general, this paper aims to demonstrate the step-by-step application of the SSM methodology within a public organization to enhance strategy implementation. The effort is directed towards advancing the utilization of this methodology in the realm of strategy and solidifying the role of systemic thinking in practical contexts. It is suggested that by doing these steps in the organization, the implementation of strategies in the organization will be helped, and researchers should increase the benefits of this method by combining this method with other methods of strategy implementation.

At the end of this point, it is necessary to mention that there are other outcomes in the domain of practice, among them organizational learning and promotion of organizational culture in the direction of strategic objectives, which cannot be mentioned in the form of a scientific article.

Disclosure statement

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

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The Effect of Social Media Use on Job Performance: Exploring the Role of Technostress, Social Capital, and Job Satisfaction as Mediators

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ABSTRACT

The primary objective of this study is to examine the relationship between social media use and job performance, with a specific focus on exploring the mediating roles of technostress, social capital, and job satisfaction. The study focused on Fars Regional Electric Company employees in Iran. The study relied on a descriptive survey method and collected data through a questionnaire in which the items were measured according to a five-point Likert scale. PLS software has employed structural equation modeling, or SEM, to test the research hypotheses. Results revealed that social media usage led to technostress, although the effects of social media usage on job satisfaction and job performance were not confirmed. However, job satisfaction positively affected the employees' job performance. Furthermore, social media usage increased the employees' level of social capital, while social capital left a positive effect on the employees' job satisfaction and performance. Meanwhile, the effects of technostress on job satisfaction and performance were rejected. Investigating the mediation effects revealed that job satisfaction did not mediate the relationship between social media and job performance and that technostress did not significantly mediate the relationship between social media and job performance. Nevertheless, job satisfaction had a mediation effect on the relationship between social capital and job performance, and social capital had a mediation effect on the relationship between social media usage and job performance. The mediation effect of technostress on the relationship between social media and job performance was rejected.

Keywords

Social media, Technostress, Job satisfaction, Job performance, Social capital.

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1. Introduction

The rapid growth of media technologies in today's world has made it possible for societies and organizations to enjoy multifarious facilities and capacities that were not previously available and enhance their national positive characteristics, such as innovation, which can be related to the development level (Shayan et al., 2015). Implementing innovation and creativity in some of the available facets (e.g. social media) has enhanced many organizational practices, such as firm's overall performance (Vardarlier & Ozsahin, 2021), rapid adaptation, cost reduction, and innovation (Dodokh, Al-Maaitah, 2019) creating new business models and marketing methods, improving demand forecasting, generating new ways of management and training, increasing the rate of novelties and productivity, sharing knowledge, establishing collaborations, and building sustainable relationships (Shayan et al., 2017) . Therefore, one could safely argue that social media has been a factor that has foundationally transformed human methods of communication, collaboration, consumption, and creativity (Ali-Hassan et al., 2015).

The emergence of online social media (e.g., Facebook, Twitter) has enabled people worldwide to communicate with each other through such platforms (Charoensukmongkol, 2015). However, this expansive range of usage has inspired many heated debates and discussions about the impact of such emerging technologies and their possible effects on organizations. Many researchers contend that social media usage has brought about numerous advantages for organizations, underscoring that such online platforms facilitate the process of sharing knowledge and employee learning (Ashraf & Javed, 2015), recruitment and employee branding processes (Vardarlier & Ozsahin, 2021) increase employees' satisfaction (Moqbel et al., 2013), and improve organizational relationships (Kishokumar, 2016).

Despite these functions, growing evidence reveals the negative aspects of such technologies in organizations. At the same time, many studies have observed that social media usage could distract employees from their main tasks (Olalekan, 2017). Such a problem could affect an organization's functioning and achievement of goals. Many researchers believe that the ability to connect to virtual networks from any location via internet-based applications and mobile technology dependence could influence various dimensions of an individual's life (including work and personal relationships) and lead to the experience of technostress (Mak et al., 2018; Jena, 2015). As a modern disorder, technostress can disturb concentration, cause reactivity, and discontinue intentions. The disorder could also lead to disability in using or learning the operations of computer systems and information-based technologies (Mak et al., 2018; Brooks et al., 2017). With the spread of the COVID-19 pandemic and increased technology

dependence, techno-stress studies are trying to develop an understanding of technostress and its consequences in the new environment. The results of this research indicate that the amount of technostress has increased significantly before (Boyer-Davice, 2020; Nimrod, 2020) and negatively affected job performance and satisfaction (Abilleira et al., 2021).

In other words, technostress is primarily experienced with a sense of worry correlated with using communication devices and develops into stress and anxiety caused by a maladaptation of new technologies (Sabaghinezhad et al., 2014). Studies concerned with technostress have emphasized that this disorder is correlated with a negative effect on job performance, job satisfaction, memory problems, and sleep disorders (Al-Ansari & Al-share, 2019; Brooks et al., 2017). It could also have a detrimental effect on job satisfaction (Jena, 2015). Given the importance of job performance and job satisfaction from the perspective of organizations, it would be important for (non-)governmental institutions to consider the effective factors. Among these, given the lack of a comprehensive understanding of the specific mechanisms through which social media, directly and indirectly, affect various aspects of employees' routine and innovative job performance, and considering the limited studies on the mediating effects of some variables that may play an important role in this relationship separately, this study attempts to bridge and cover part of this research gap. Therefore, the present research seeks to answer the following question:

How does the utilization of social media effect job performance, and what are the mediating roles of factors such as technostress, social capital, and job satisfaction in this relationship?

2. Theoretical foundations

2.1. Social media usage

Social media are internet-based applications through which users generate and/or share content (Brooks, 2015). Various modes of such media include weblogs, wikis, podcasts, forums, content communities, and microblogging (Shayan et al., 2017). Among these, social networks are more popular; based on the statistics provided on www.statista.com, the number of current social network users worldwide is 2.62 billion, which will rise to 3.02 billion in 2021. Social media usage has proved to be the most popular online activity, and according to research, people tend to use social media 27% of the time they spend on online activities (Brooks et al., 2017).

Social media as entities enable people to create, share, and exchange ideas and other materials through computerized tools, networks, and virtual communities (Shayan et al., 2017). Meanwhile, as Babiker (2015) observes, social media and virtual networks are usually used

interchangeably. However, they do not refer to the same entities because virtual networks are *one* of the modes of social media. Social media usage does not exclusively include an individual's personal (leisure) time, as social media is now being used in the workplace and has dramatically transformed employees' work-related activities. A study dealing with about 1000 business experts confirmed that they would frequently check their accounts on Facebook, LinkedIn, and Twitter during the day. Another study on human resource managers of 122 firms in Turkey showed they prefer LinkedIn in most human resources management processes, such as recruitment and employee branding (Vardarlier & Ozsahin, 2021).

This routine of checking social media could engender negative effects (Brooks & Califf, 2017). For instance, Brooks's (2015) research found that a higher rate of private social media usage could reduce efficiency at work while increasing technostress and reducing happiness. According to Ali-Hassan et al. (2015), social media usage may appear in three forms: hedonic use, cognitive use, and social use:

Hedonic use of social media: In this mode, social media is used for purposes such as leisure, entertainment, relaxation, and distraction from problems;

Cognitive use of social media: In this mode, users work with social media to generate and share content while having access to the content created by others; otherwise put, in such a case, individuals share their ideas, stories, personal images, and other items;

Social use of social media: In this type of use, social media is used to make contact with current friends and acquaintances, make new social relationships, or find new friends/individuals with interests compatible with those of the user.

2.2. Technostress

Organizational stress typically involves an individual's perception of demands imposed on him/her by intense stimulators called *stressors*; the psychological reaction made to such demands is called *pressure*. Stressors represent accidents, demands, stimulators, or conditions that individuals face in the workplace. Pressures, however, refer to behavioral and psychological consequences seen in individuals (Brooks et al., 2017). Stressors include role conflicts, ambiguities, demanding jobs, and a lack of sufficient skills. In contrast, symptoms of pressure include memory loss, limited concentration, mental/physical fatigue, frustration, and aggression. (Zarei Matin, 2017). Recently, information technology (IT) has adopted a technology-oriented approach to research stress called *technostress* (Brooks et al., 2017).

Craig Brod, who first used the term "technostress", finds this phenomenon to be a modern disorder arising from an individual's ability to adapt healthily to globally used computer technologies (Sabbaghinejad, 2014). As this definition suggests, the first researchers dealing with technostress viewed it as a disorder, although later research considered it a maladaptation to changes introduced by IT (Jena, 2015). Technostress refers to the negative effect technology use will have in/-directly on attitudes, thoughts, behaviors, and even biological systems (Carlotto et al., 2017). The symptoms of technostress are the inability to concentrate, reactivity, and a sense of losing control.

This type of stress prevents individuals from learning or even developing the ability to use computer and IT skills (Brooks et al., 2017). When individuals experience technostress and fail to adapt themselves to rapid changes in information and communications technology (ICT), they tend to process information insufficiently and ineffectively; they can hardly recognize useful information and have little time to explore creative/innovative ways of doing their activities (Carlotto et al., 2017). As a consequence of these experiences, they tend to make frequent mistakes, downgrading their productivity levels and their job satisfaction. Under such circumstances, they are likelier to evaluate their jobs as "negative." Based on the studies conducted, the most important causes of technostress are as follows (Brooks et al., 2017; Carlotto et al., 2017; Ibrahim et al., 2014; Jena, 2015; Sabbaghinejad, 2014; Yasir et al., 2016):

1. Techno-uncertainty: This type of stress is caused by frequent changes and updates in ICT software and hardware; it refers to conditions in which recurrent ICT changes distress users who feel they need to master a new ICT-related change constantly;
2. Techno-insecurity: This mode refers to employees' job security, which depends on the increasing development in ICT. It describes conditions under which users feel they may lose their jobs of competition with individuals who possess more ICT knowledge;
3. Techno-complexity: It explains conditions in which ICT complexities make users' skills insufficient and make them spend more time or effort on learning and perceiving various dimensions of new technologies;
4. Techno-invasion: This item describes the invasive impact of ICT in creating contexts in which users are exposed and reached anywhere and anytime while fleeing the need to be constantly connected; this condition could disturb their work-life balance;
5. Techno-overload: This notion suggests that ICT makes employees work more and faster.

2.3. Job satisfaction

How people view the various aspects of the external world shapes their attitudes; job satisfaction is among the most important attitudes toward one's job (Zarei Matin, 2017). That is to say, a positive attitude toward one's job could bring about job satisfaction. In contrast, a negative or cynical attitude may lead to dissatisfaction (Kumar et al., 2013). Job satisfaction is an employee's emotional response to his/her work, which could be positive or negative (Jena,

2015).

Chung et al. (2017) regard job satisfaction as an emotional reaction that employees make to their jobs, and this factor is determined when their real work outcomes are compared to their expected outcomes. According to research, high job satisfaction leads to better performance, less delay, less turnover, and better psychological, mental, and physical well-being (Zarei Matin, 2017). In other words, job satisfaction could create positive outcomes in duties, roles, and workplace relations (Robertson & Kee, 2017), and it can ultimately guarantee the achievement of organizational goals.

2.4. Performance

Organizational performance has proven to be a significant notion due to its impact on productivity (Bakhshi et al., 2017); given this importance, researchers have tried to find different ways to realize organizational performance (Moqbel, 2012). Performance refers to an employee's level of completing a task, demonstrating how an employee manages to perform the requirements of a task (Shayan et al., 2017). Put otherwise, job performance points to outcomes after completing a task and shows the level decided for every employee regarding job accomplishment, organizational regulations, and expectations/requirements (Bakhshi et al., 2017).

In this study, performance is investigated from two perspectives (Ali-Hassan et al., 2015; Shayan et al., 2017): (a) routine job performance denotes an individual's performance of his/her required job-related tasks and rewards received for conducting them, and (b) innovative job performance involves generating and employing creative and useful ideas in the workplace.

2.5. Social capital

The notion of social capital, which emerged from the beliefs of classical sociologists (Noghani & Asgharpour, 2008), was first introduced by French sociologist Pierre Bourdieu (1930-2002) (Hosseinpour, 2018). Bourdieu views social capital as "the sum of the resources, actual or virtual, that accrue to an individual or a group by possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition" (Gauntlett, 2011). In other words, social capital represents resources or assets rooted in individual or group networks of social relations. As these definitions clarify, the central issue in social capital is the network of relations that produce a valuable source through which associated members can access collective capital (Ali-Hassan et al., 2015).

The social capital theory has been addressed from various perspectives in the literature. It has brought about organization-related insights such as the psychological empowerment of employees (Hassanzadeh Pasikhani & Khodashahri, 2018), knowledge sharing (Mazbohi et al., 2018), and organizational performance (Shayan et al., 2017). A common approach to measuring social capital relies on three dimensions, namely structural, relational, and cognitive (Ali-Hassan et al., 2015; Hassanzadeh Pasikhani & Khodashahri, 2018; Mazbohi et al., 2018; Shayan et al., 2017; Sun & Shang, 2014):

Structural dimension: It represents the general pattern of relationships between users (Sun & Shang, 2014) and involves two networks: the expressive network and the instrumental network. The former makes it possible for the network members to enjoy friendship, emotions, and social support; in the instrumental network, however, ties are weaker and non-mutual and usually occur in a workplace (as in the ties between individuals with very different personalities; see Ali-Hassan et al., 2015). Network hierarchy, composition, and group homogeneity are the main characteristics of this dimension (Shayan et al., 2017);

Elational dimension: This dimension encompasses assets such as trust, norms, obligations, and identity, which are formed through social relations (Sun & Shang, 2014); among these factors, trust seems to be the most important one (Ali-Hassan et al., 2015);

Cognitive dimension: The cognitive aspect of social capital represents a shared ground and mutual understanding that facilitates interactions among parties. This notion emphasizes a common understanding that simplifies the performance among parties (Sun & Shang, 2014).

3. Hypotheses and the research model

3.1. Social media and technostress

Recent research on social media and technostress has found that social media usage in the workplace could be correlated with technostress and the factors contributing to it (Brooks and Califf, 2017). For instance, in the study by Brooks et al. (2017), a positive relationship between distraction caused by social media usage and its contributing factors (Brooks et al., 2017). Another study observed that social media usage could lead to a degree of technostress, stating that the factors affecting technostress were social pressure to use technology, remembering passwords and usernames, the anxiety of losing data, and professional life shaped by technology. It was also found that degrees of technostress differed in gender, profession, and age (Coklar & Sahin, 2011). Moreover, Brooks (2015), creating an artificial workplace in a classroom, demonstrated that social media usage could lead to a higher degree of technostress

and a lower degree of happiness. Given these observations, the first hypothesis of the study is stated as follows:

First hypothesis: Social media usage is positively associated with technostress.

3.2. Social media and job satisfaction

Various studies have explored the positive effect of social media usage on job satisfaction. For instance, Moqbel (2012) found that employees who used their social network in the workplace showed higher of job satisfaction as they received social support from their families and friends. In another research, Gupta (2015) observed that employees' use of Facebook during working hours could inspire a positive sentiment in them toward their jobs (Gupta, 2015) and lead to job satisfaction; of course, this use was limited to their leisure time for entertainment. Robertson and Robertson and Kee (2017) showed that employees' satisfaction improved as they spent more time interacting with others via Facebook, which functioned as a strategic platform for improving employee satisfaction. As these investigations suggest, it could be argued that the three dimensions of social media usage (hedonistic, social, and cognitive) could have an impact on employees' job satisfaction, as stated in the following hypothesis:

Second hypothesis: Social media usage could improve employees' job satisfaction.

3.3. Social media and job performance

Although the term *social media* serves as an umbrella term for a wide spectrum of applied tools and programs, such elements share some features: first, such tools are inherently social and reinforce relations among people; second, as employees start to use them at various levels of the organization, such tools are recognized as "public technology." Finally, most of the tools in social media can be used at home and in the workplace, giving rise to a condition in which the borders between the two contexts become blurred (Ali-Hassan et al., 2015). Given such features, one could question how social media affects employees' performance.

Studies have reported different results regarding the effect of social media on job performance; most researchers have found social media usage an element of distraction that could undermine job performance (Bizzi, 2018). For instance, in Hwang and Jeong's (2017) investigation, it was found that when social media usage was prioritized while the individual performed his/her tasks and was engaged in the media, poor performance could be followed. In a study conducted by Olalekan et al. (2013), it was observed that distraction caused by social

media usage could deteriorate job performance; the solution the authors suggested was restrictions on social media usage in the organization.

On the other hand, most researchers have expressed that social media usage could improve job performance. For instance, Charoensukmongkol (2015) found that excessive social media usage, especially when employees have to deal with highly demanding work, could positively affect their job performance. Therefore, the organization should allow employees to use social media via computer systems instead of cell phones. Another study observed that social media considerably affected employees' performance by affecting their skills, productivity, knowledge, and motivation, although organizations should limit this usage to educational purposes (Ashraf & Javed, 2014).

Kishokumar (2016) traced the positive effect of social media usage on employees' performance and stated that social media had a positive function in distributing shared knowledge and strengthening networked relationships, and consequently increased individuals' adaptability to environmental changes. According to the findings of these studies, social media could distract users from their main duties, although it could increase their learning ability. Given this premise, the three functions of social media usage for hedonistic, cognitive, and social purposes in job performance are investigated through the mediatory role of social capital.

Third hypothesis: Social media usage weakens job performance.

3.4. Job satisfaction and job performance

As Moqbel points out, attitude could affect performance (Moqbel, 2012); Esmaeili and Seyedzadeh (2016), Shayan et al. (2017), and Bin (2015) have provided evidence demonstrating the positive effect of job satisfaction (an attitudinal variable) on employees' job performance (a behavioral variable). However, any possible causal relationship between satisfaction and performance cannot be established with certainty; Berghe and Hyung (2011), for instance, observed a weak or fairly small relationship between job satisfaction and employees' performance, while a causal relationship cannot be taken for granted. Thus, the following hypothesis is proposed in this study:

Fourth hypothesis: Higher rates of job satisfaction could lead to better job performance.

AGiven the second and fourth hypotheses, one could shape an idea about the effect of social media usage on job performance through the mediatory role of employee satisfaction. Therefore, the fifth hypothesis could be stated as follows:

The fifth hypothesis: Job satisfaction mediates the relationship between social media usage and employees' job performance.

3.5. Social media and social capital

Studies in the literature have shown that social media usage can function as a force affecting various dimensions of social capital. For instance, in Kim and Kim's (2017) study, the effect of college students' uses of social media on network heterogeneity (interaction with different people with different backgrounds) was investigated, and the relationship between network heterogeneity and the structural dimension (development of both expressive and compositional relationships) and social capital was explored. They found that social media usage was positively related to network heterogeneity, which was positively associated with social capital.

Chen and Li (2017) conducted another study to probe whether mobile social media impacted social capital and psychological well-being. They observed that mobile social media positively affected the structural dimension of social capital. Sun and Shang (2014) investigated the effect of two dimensions of social media (cognitive and social) on three dimensions of social capital (cognitive, relational, and structural) in China. They showed that social media usage could improve social capital, thus positively affecting individuals' job-related outcomes (Sun & Shang, 2014).

Furthermore, the results of Shane-Simpson et al. (2018) demonstrated that the relationship between privacy settings, self-disclosure, and social capital was different for differences in users' motivation and affordances of specific social media; more specifically, the participants who preferred Twitter were more likely to have a public profile and tended to disclose their information more, showing more social capital. However, participants who preferred Facebook would disclose their information less, although they had more friendly relationships than Instagram users. Another study revealed that Facebook would involve users in political events, increasing their political awareness (Hosseinpour, 2018). As such, the following hypothesis is stated in this study:

The sixth hypothesis: Social media usage could positively affect users' social capital.

3.6. Social capital, job satisfaction, and job performance

Chamanifard et al's (2015) research found that social capital, as mediated by job satisfaction, had an indirect effect on job performance; this indirect effect was even more substantial than its direct effect on job performance. Another study clarified that social capital in the workplace

functioned as a mechanism that increased employees' satisfaction concerning their wages and jobs, ultimately improving organizational commitment (Hauser, 2015). Femina (2016) showed that in advanced countries, social capital in the workplace was positively associated with job satisfaction and physical health in employees, even in the case of financial crises, and could enhance financial performance, too. Of course, these results did not hold in developing countries like Indonesia, where social capital would only increase the levels of job satisfaction and would not affect corporate performance.

Ahmadi and Feyzabadi (2011) revealed that after trust, social capital had a direct association with improved performance, whereas formal networks showed an indirect association with improved performance through trust. Meanwhile, norms of practice had no relationship with improved performance; finally, the results showed a direct relationship between social capital and individuals' improved performance.

Similarly, Jahangiri et al. (2018) state that social capital sets the ground for teachers' development and self-actualization, shaping a condition resulting in improved satisfaction with and attitudes toward their jobs. Therefore, the following hypotheses can be formulated:

Seventh hypothesis: Social capital positively affects performance.

Eighth hypothesis: Social capital positively affects employees' satisfaction.

Given the fourth and eighth hypotheses, the ninth hypothesis could be stated as follows:

The Ninth hypothesis: Job satisfaction mediates the effect of social capital on employees' performance.

Given the sixth and seventh hypotheses, the tenth hypothesis might be stated as follows:

The tenth hypothesis: Social capital mediates the effect of social media usage on employees' job performance.

3.7. Technostress and job performance

Researchers have confirmed the negative effects of technostress on job performance (Tagurum et al., 2017; Tarafdar et al., 2015). In a survey conducted on 144 academic staff, Tagurum et al. (2017) concluded that technostress affected the performance of %39.6 of the respondents. In the study of Odoh et al. (2013), it was observed that technostress did not affect the job performance of bank managers in Nigeria. However, the percentage of individuals who showed poor performance under the influence of technostress was still high. This issue must be considered in organizations. Brooks et al. (2017) investigated the effects of five factors causing technostress in employee job performance, showing that all of the factors led to poor

performance; given these observations, the following hypothesis can be stated:

Eleventh hypothesis: High technostress could negatively affect employees' job performance.

3.8. Technostress caused by social media and job satisfaction

Technostress experienced due to exposure to social media could spread technostress among employees in different ways. In other words, technostress could affect job satisfaction in five ways: techno-uncertainty, techno-insecurity, techno-complexity, techno-invasion, and techno-overload (Qiu, 2013). In Jena's (2015) investigation, the effect of the five dimensions of technostress on teachers' job satisfaction was confirmed in India. In another study, Karimi and Nazari (2018) probed into the relationship between technostress and job satisfaction in public librarians in Ahwaz, Iran; they found a negative relationship between the five dimensions of technostress and job satisfaction in the sample under study, while techno-complexity proved to be the best predictor of job satisfaction.

Kumar et al. (2013) explored the relationship between technostress, job satisfaction, and commitment among IT experts, concluding that technostress was negatively associated with job satisfaction and employee commitment. They also stated that technostress management depended on how the individual would interpret technology changes s/he received and that collaboration in work could minimize the problems. Furthermore, in empirical research, Khan et al. (2013) surveyed the relationship between technostress and job satisfaction in KPK university libraries in Pakistan. Results unveiled a negative relationship between three dimensions of technostress (techno-uncertainty, techno-invasion, and techno-overload) and job satisfaction. However, techno-uncertainty left a stronger effect than the other dimensions. Given these discussions, one could argue that technostress would leave a negative impact on job satisfaction, and on this basis, the following hypothesis could be formulated:

Twelfth hypothesis: The factors causing technostress negatively affect employees' job satisfaction.

As such, the fourth and eleventh hypotheses could help to justify the thirteenth hypothesis:

Thirteenth hypothesis: Job satisfaction mediates the effect of technostress on job performance.

Based on the first and eleventh hypotheses, one could raise the fourth hypothesis:

Fourth hypothesis: Technostress mediates the effect of social media on job performance.

In summary, according to the studies cited, the research model includes five factors: social media usage, technostress, social capital, job satisfaction, and job performance. The premise is that social media usage directly affects employees' technostress, social capital, job satisfaction, and job performance. Additionally, technostress, social capital, and job satisfaction may indirectly mediate the relationship between social media usage and job performance, considering the different dimensions of routine and innovative job performance and potential specific relationships among these variables. Given the discussions and hypotheses proposed in the above sections, the conceptual model in this study is constructed as in Figure 1.

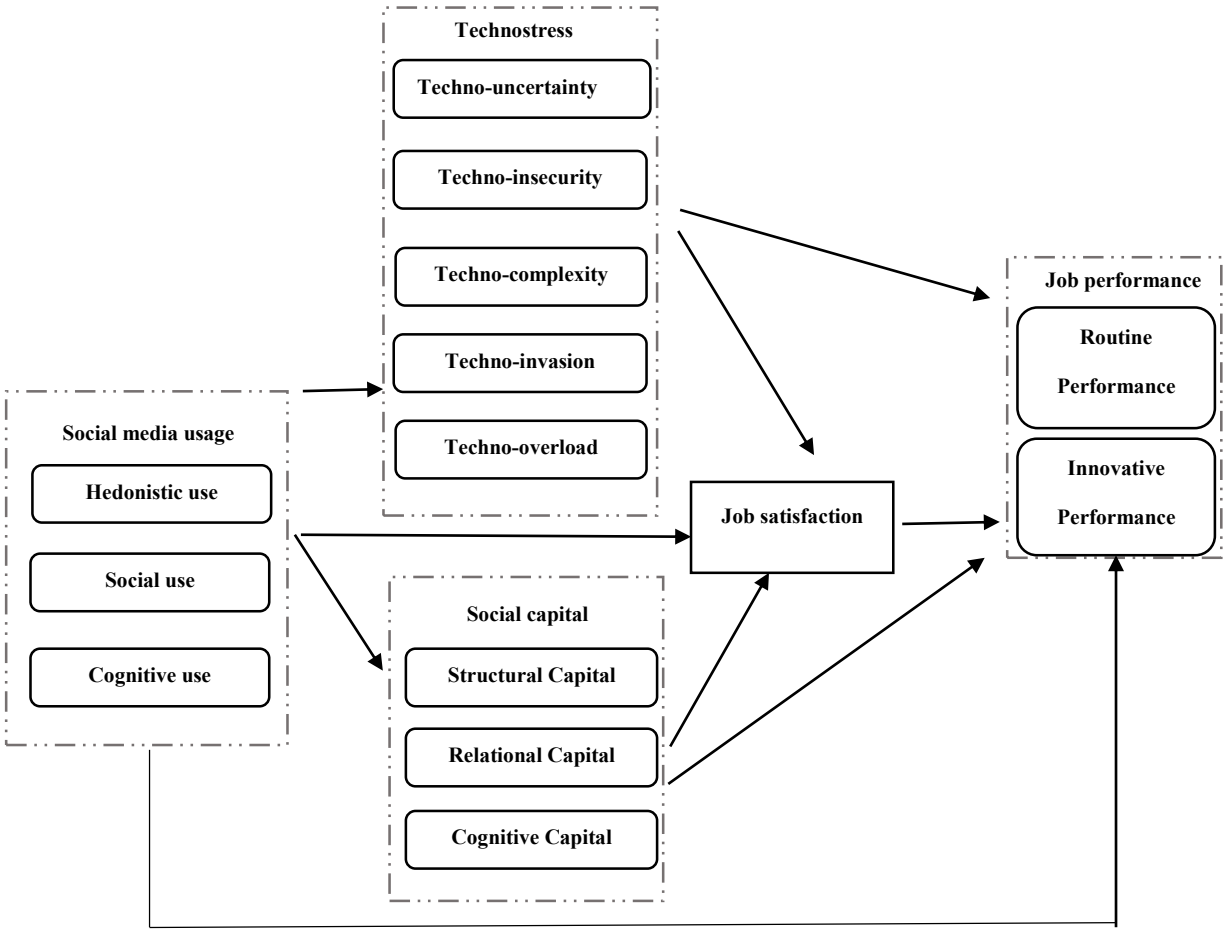

Figure 33. The conceptual model of the study

4. Methodology

This study was a descriptive, cross-sectional survey that followed applied purposes, as it sought to make organizational managers aware of the effects of social media on their employees' satisfaction and performance. The population included 227 employees of the stationary district of Fars Regional Electric Company, Shiraz, Iran. The data were gathered through questionnaires based on the random sampling method; given an estimated population variance, 107 individuals

were selected as the respondents. The scales used to measure the constructs and variables were extracted from the literature. More specifically, in the first section of the questionnaire, researchers used the scale developed by Ali-Hassan et al. (2015) to measure the type of social media usage, as they have been interested in assessing cognitive, hedonic, and social uses, which included 12 items measured according to a five-point Likert scale. In the second part, to measure technostress, the scales constructed by Qiu (2013) and Brooks et al. (2014) were used, which involved 19 items measured according to a five-point Likert scale.

In the third section of the questionnaire, to measure job satisfaction, the scales proposed by Qiu (2013) were utilized in which 4 items were measured through a five-point Likert scale. The items in this scale included questions such as "*How much are you satisfied with YYY?*" This measurement approach was used because it was compatible with the goals of this. In the fourth section, the scales suggested by Ali-Hassan et al. (2015) were used to measure routine and innovative types of job performance; in this case, too, the respondents answered 9 questions based on a 5-point Likert scale (Ali-Hassan et al., 2015). This method was used in the study because, in modern economics, there are few jobs from which data could be collected through objective instruments. However, popular belief suggests that objective instruments are the best tools for measuring personnel performance, although they are tough to conceptualize and operationalize (Pransky et al., 2006).

In the final section of the questionnaire, to measure the three dimensions of social capital, Ali-Hassan et al. (2015) proposed construction was used, which included 15 items measured according to a 5-point Likert scale (ranging from "Totally Disagree" to "Totally Agree"). Confirmatory factor analysis (CFA) was used to assess the questionnaire's validity, and Cronbach's alpha was computed to gauge its reliability (refer to Table 1). Given the values observed for the variables and the dimensions (greater than 0.6), the questionnaire showed a good reliability rate.

Table 24. Cronbach's alpha coefficients of the model variables

Code	Dimension	Mean	Cronbach's alpha	Code	Dimension	Mean	Cronbach's alpha
01	Social use	2.162	0.87	09	Job Satisfaction	3.474	0.88
02	Cognitive use		0.89	10	Routine Job Performance	3.555	0.91
03	Hedonistic use		0.92	11	Innovative Job Performance		0.88
04	Techno-overload	1.986	0.84	12	Structural Social Capital (Expressive Network)	3.150	0.83
05	Techno-invasion		0.82	13	Structural Social Capital (Instrumental Network)		0.87
06	Techno-complexity		0.62	14	Cognitive Capital		0.89
07	Techno-insecurity		0.72	15	Relational Capital		0.84
08	Techno-uncertainty		0.80				

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5. Findings

5.1. Statistical inference of the hypotheses

5.1.1. Model fitting: The measurement model

Before the model's structural equations were constructed, the validity of the measurement tool of the research was confirmed through CFA. Convergent and divergent validity were employed to confirm the validity of the model construct. All question factor load values (except question 23) were greater than 0.5 and significant. Question 23, considering its high AVE index value and the significance of its factor load, stayed in the process, and as such, the convergent validity of the measurement was confirmed, too. Divergent validity was calculated via the correlation matrix, which showed the correlation between the dimensions in the main model. As this matrix revealed, the correlation between all 14 dimensions in the model was less than 0.9, which showed no overlap between the dimensions; as such, divergent validity was confirmed too. Because both convergent and divergent validity were already confirmed, construct validity was also confirmed. Table 2 shows the results of CFA for the items, and Table 3 reports the correlation matrix of the model dimensions.

Table 25. CFA results of the questionnaire items

Measure	Factor loading	t	Result	Measure	Factor loading	t	Result
01	0.810	23.887	confirm	31	0.843	21.849	Confirm
02	0.803	19.235	confirm	32	0.865	24.436	Confirm
03	0.912	64.137	confirm	33	0.920	63.632	Confirm
04	0.870	32.925	confirm	34	0.791	11.125	Confirm
05	0.859	34.763	confirm	35	0.867	31.003	Confirm
06	0.874	35.038	confirm	36	0.897	30.655	Confirm
07	0.918	58.162	confirm	37	0.916	45.001	confirm
08	0.854	27.133	confirm	38	0.906	49.299	confirm
09	0.922	56.281	confirm	39	0.845	25.334	confirm
10	0.843	16.405	confirm	40	0.805	11.599	confirm
11	0.930	63.211	confirm	41	0.824	32.560	confirm
12	0.913	61.026	confirm	42	0.813	15.642	confirm
13	0.859	24.606	confirm	43	0.808	18.848	confirm
14	0.867	27.402	confirm	44	0.851	14.428	confirm
15	0.815	18.364	confirm	45	0.860	34.122	confirm
16	0.765	13.554	confirm	46	0.868	21.621	confirm
17	0.825	19.563	confirm	47	0.858	20.824	confirm
18	0.701	10.900	confirm	48	0.886	41.191	confirm
19	0.810	18.629	confirm	49	0.869	37.378	confirm
20	0.890	34.550	confirm	50	0.855	34.707	confirm
21	0.770	11.370	confirm	51	0.785	14.096	confirm
22	0.782	15.252	confirm	52	0.821	16.855	confirm
23	0.479	3.526	confirm	53	0.902	32.020	confirm
24	0.612	5.278	confirm	54	0.891	21.277	confirm
25	0.523	5.117	confirm	55	0.853	31.688	confirm
26	0.837	26.476	confirm	56	0.825	22.918	confirm
27	0.831	23.229	confirm	57	0.722	8.378	confirm
28	0.758	16.350	confirm	58	0.886	33.767	confirm
29	0.844	23.871	confirm	59	0.847	19.532	confirm
30	0.846	23.11	confirm				

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Table 26. Correlation matrix of the major dimensions in the research model

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
01	1.00														
02	0.81	1.00													
03	0.41	0.44	1.00												
04	0.42	0.42	0.48	1.00											
05	0.29	0.40	0.44	0.58	1.00										
06	0.30	0.38	0.44	0.47	0.70	1.00									
07	0.06	0.10	0.37	0.50	0.57	0.62	1.00								
08	0.04	0.09	0.47	0.28	0.42	0.41	0.58	1.00							
09	0.53	0.47	-0.07	-0.14	-0.00	0.14	0.10	0.21	1.00						
10	0.49	0.56	-0.05	-0.18	0.04	0.05	0.01	0.19	0.59	1.00					
11	0.23	0.13	0.02	-0.13	-0.04	-0.02	0.05	0.23	0.56	0.56	1.00				
12	0.20	0.25	-0.01	-0.00	-0.08	0.08	0.09	0.00	0.03	0.27	0.37	1.00			
13	0.20	0.16	0.05	-0.16	-0.09	0.03	0.06	0.04	0.53	0.49	0.44	0.64	1.00		
14	0.22	0.13	-0.08	0.05	0.02	0.04	0.10	0.09	0.47	0.56	-0.34	0.47	0.54	1.00	
15	0.12	0.12	-0.02	-0.09	-0.01	0.10	0.09	0.11	0.57	0.56	0.53	0.59	0.76	0.61	1.00

5.1.2. Model fitting: The structural model

Figure 2 illustrates the estimated structural model of the study. Based on the coefficient of determination of the fitting model, approximately 50% of the employees' performance was affected by social media usage, technostress, satisfaction, and social capital, and the rest of the effect was left by other factors not incorporated into the model. Furthermore, 34% of the variance in technostress was influenced by social media usage, whereas the remaining 66% was caused by other factors not included in the model. As Figure 2 depicts, 34% of the variance in job satisfaction could be accounted for through technostress, social capital, and social media usage. However, the remaining 66% was influenced by other factors considered in this study. Finally, only 3% of the employees' social capital could be explained by social media usage, and other factors beyond the scope of this investigation caused the rest of the effect.

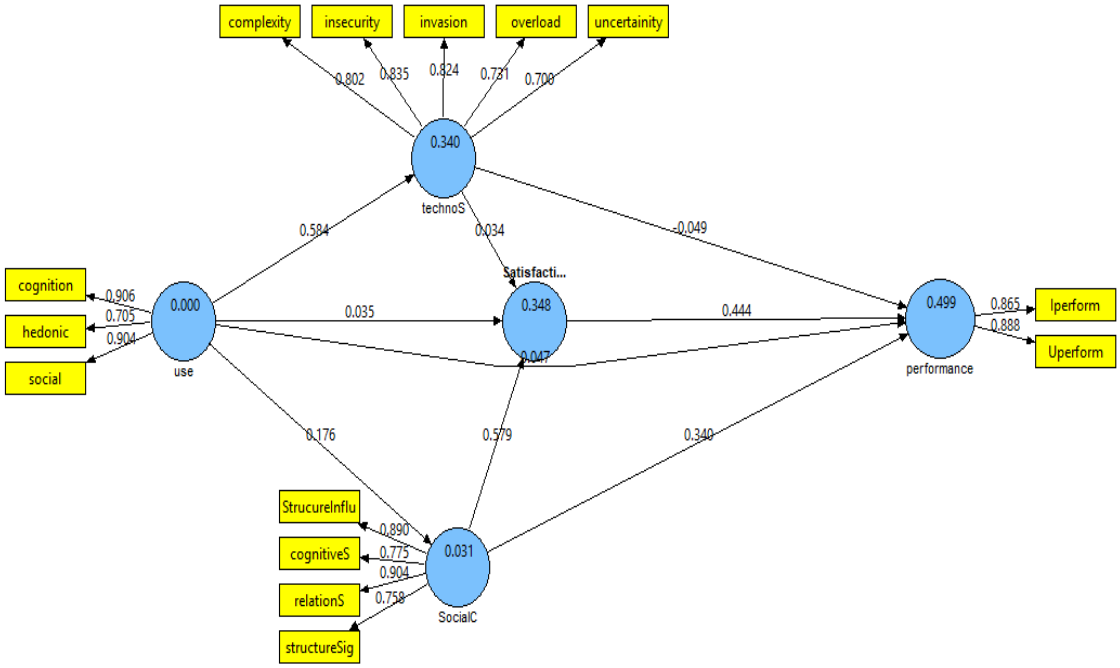

Figure 34. The estimated standard of the research model

5.2. Exploring the hypotheses

The student's t-test distribution was used to confirm or reject the hypotheses; a hypothesis at the 0.05 error level would be confirmed if the t-value were more significant than 1.96. The effect of social media on technostress in the first hypothesis was confirmed because, as Figure 2 and Table 4 show, the t-value in this hypothesis was 7.16, which is more significant than 1.96. It showed that this hypothesis was confirmed at the 95% level of confidence; moreover, given the positive value of the regression coefficient (0.584), it could be concluded that the relationship was positive.

In the second hypothesis, the effect of social media usage on job performance was rejected because, as Table 4 shows, the t-statistic in the hypothesis at the 0.05 significance level was 0.498, which was less than 1.96. This calculation showed that, at the 95% confidence level, social media did not affect performance in the sample under investigation. The third hypothesis addressed the effect of social media on job satisfaction; as Figure 2 and Table 4 show, the regression coefficient was 0.035, and the t-statistic was 0.292, a figure less than 1.96 at the 0.05 level. It suggested that, at the 95% level of confidence, in the sample under investigation, social media usage was effectless on employees' job satisfaction. The fourth hypothesis concerned job satisfaction's impact on employees' performance. As Figure 2 and Table 4 reveal, the path coefficient was 0.444, and the statistic was 4.375, which was significant at the 0.05 level. As a result, it could be stated that job satisfaction positively affected the employees' performance (given the positive value of the regression coefficient).

The fifth hypothesis addressed the mediation effect of job satisfaction on the relationship between social media and job performance; the indirect effect value was 0.0155 (see Figure 2 and Table 4) at the 0.05 significance level, which was an insignificant value. As a result, this hypothesis was rejected at the 95% confidence level. The sixth hypothesis dealt with the effect of social media on social capital; the path coefficient was 0.176, and the t-statistic was 2.545, which was more significant than 1.96 at the 0.05 significance level. Thus, it could be concluded that this path coefficient was significant at the 0.05 error level. Social media then affected the social capital of the employees at the 95% confidence level, and given the regression coefficient, the effect was positive.

Effect of social capital on job performance; as the values in Figure 2 and Table 4 show, the regression coefficient was 0.340, and the t-statistic was 3.625. As such, the t-statistic value was more significant than 1.96 at the 0.05 significance level. The seventh hypothesis was then confirmed at the 95% confidence level. Moreover, considering the positive value of the path coefficient, social capital positively affected performance. The eighth hypothesis explored the effect of social capital on job satisfaction; given the data in Figure 2 and Table 4, the t-statistic value was 8.030, more significant than 1.96 at the 0.05 significance level. It could then be concluded that the path coefficient of this hypothesis was significant at the 0.05 significance level. That is, the effect of social capital on the employees' job satisfaction in the eighth hypothesis was significant at the 95% confidence level, and the relationship was positive given the regression coefficient (0.579). The effect of job satisfaction as the mediator variable in the relationship between social capital and job performance showed an indirect effect value of 0.257.

Considering the significant coefficients of the variables in the direct relationship (at the 0.05 level), one could conclude that the ninth hypothesis could be confirmed due to the mediation of job satisfaction in the relationship between social capital and job performance. The tenth hypothesis addressed the effect of the mediator variable social capital on the relationship between social media and job performance. At the 0.05 level of significance, there was an indirect effect of 0.0598, and considering the significant values of the variables' coefficients in the direct relationship (at the 0.05 level), it could be concluded that the eighth hypothesis was confirmed, too. The eleventh hypothesis was concerned with the effect of technostress on job performance, with a path coefficient of 0.022. This hypothesis was rejected because the coefficient of significance value was less than 1.96 at the 0.05 significance level; therefore, technostress did not affect the employees' job performance at the 95% confidence level.

Effect of technostress on job satisfaction; the path coefficient was 0.034. Table 4 shows that the t-statistic value was 0.048, less than 1.96 at the 0.05 significance level. Thus, this hypothesis was rejected at the 95% confidence level, and that technostress did not affect job satisfaction. In investigating the mediatory effect of job satisfaction on the relationship between technostress and job performance (as reported in Table 4 and Figure 2), the indirect effect was 0.015 at the 0.05 level, and the t-statistic was less than 1.96. As a result, this hypothesis was rejected, meaning that job satisfaction, as a mediator variable, did not affect the relationship between technostress and job performance. Finally, the mediating role of technostress in the relationship between social media and job performance was rejected with an indirect effect of 0.0286 at the 0.05 level. Given Table 4, the t-statistic was less than 1.96. Therefore, the fourteenth hypothesis dealing with the mediator effect of technostress on the relationship between social media and job performance was rejected at the 95% confidence level.

Table 27. Regression coefficients and the significance of the hypotheses tested

Hypothesis	Path	Regression	T	Result
1	Social media →technostress	0.584	7.160	Confirm
2	Social media → job performance	0.047	0.498	Reject
3	Social media → job satisfaction	0.035	0.292	Reject
4	Sob satisfaction → job performance	0.444	4.375	Confirm
5	Social media → job satisfaction→ job performance	0.0155	t>1.96	Reject
6	Social media → social capital	0.176	2.545	Confirm
7	Social capital→ job performance	0.340	3.625	Confirm
8	Social capital→ job satisfaction	0.579	8.030	Confirm
9	Social capital→ job satisfaction→ job performance	0.257	1.96>t	Confirm
10	Social media →social capital→ job performance	0.0598	1.96>t	Confirm
11	Technostress → job performance	-0.049	0.474	Reject
12	Technostress → job satisfaction	0.034	0.250	Reject
13	Technostress → job satisfaction→ job performance	0.015	1.96>t	Reject
14	Social media →technostress → job performance	-0.0286	t>1.96	Reject

6. Conclusion

The development of social media has affected all dimensions of peoples' lives, including their personal lifestyle and work environment. Social media has facilitated knowledge sharing and the functioning of jobs while providing a source of entertainment and developing social relationships for individuals. Given such effects, many researchers believe that social media usage could harm the workplace. Technostress has been recognized as a negative dimension of social media usage. Although many studies have shown its damaging effects on employees' performance and satisfaction, investigations into this phenomenon have remained underdeveloped.

Furthermore, research still needs to consider simultaneously the positive effects of social media usage (e.g., its effects on social capital) and its negative effects (e.g., technostress). This study sought to investigate the effect of social media usage on a sample of employees' technostress, satisfaction, performance, and social capital. The findings showed that social media could lead to technostress (according to the first hypothesis), although the effects of social media on job performance (based on the second hypothesis) and job satisfaction (refer to the third hypothesis) were rejected; such observations, of course, clashed with the findings in the literature (Al-Ansari & Al-share, 2019; Abilleira et al., 2021; Mak et al., 2018). The reason these hypotheses were rejected, as Table 4 shows, might be the low means of social media usage of Fars Regional Electric Company employees. Due to security infrastructure reasons, access to social media is highly restricted within the company, and employees mostly use internal networks. The fourth hypothesis was confirmed, addressing the relationship between job satisfaction and the employees' performance. This finding was compatible with the observations of Moqbel (2012), Esmaeili and Seyedzadeh (2016), Shayan et al. (2017), and Bin (2015).

Furthermore, according to hypothesis no. 6, social media usage increased the employees' level of social capital. This variable left a positive effect on the employees' performance (based on hypothesis no. 7) and satisfaction (according to hypothesis no. 8). These observations, too, confirmed the findings of Hauser (2015), Femina (2015), Ahmadi and Feyzabadi (2011), and Jahangiri et al. (2018). Moreover, the effect of technostress on the employees' performance (based on hypothesis no. 11) and satisfaction (according to hypothesis no. 12) was rejected, which was an observation that clashes with the findings of most researchers, such as Tagurum et al. (2017) and Jena (2015); The reason for this difference might be the mediation level of technostress in the sample under investigation. It means that the company's techno-stress level is not so high as to cause problems for their job performance or employee job satisfaction. Finally, the mediatory effect of job satisfaction on the relationship between social media and job performance (according to hypothesis no. 5) and the mediation effect of technostress on the relationship between social media and job performance (based on hypothesis no. 14) were insignificant. Given the lack of a significant relationship, it is normal statistically.

Meanwhile, the mediation effect of job satisfaction on the relationship between social capital and job performance (refer to hypothesis no. 9) and the mediation effect of social capital on the relationship between social media and job performance (according to hypothesis no. 10) were confirmed. It means that, on the one hand, using social media enhances organizational social

capital. On the other hand, "social capital" increases employee job satisfaction, positively affecting employee job performance.

Based on the findings, recommendations for practitioners may include implementing targeted training and support programs to assist employees in managing technostress associated with social media usage. Managers could provide training and education on the effective use of social media for professional networking and relationship building, thereby enabling employees to utilize social media to enhance their social capital rather than causing stress. Additionally, consideration of job characteristics and their potential effect on employees' experiences with social media usage and its effects is advised. Managers are encouraged to foster a work culture that values face-to-face interactions and relationship-building activities, promoting organizational social through team-building exercises and mentorship programs. Furthermore, it is recommended that resources and support be provided to help employees balance the positive and negative aspects of social media usage in the workplace. It may involve offering mindfulness training, stress management workshops, and access to mental health support services to assist employees in coping with technostress related to social media usage.

This research helps the literature on the effects of social media use and opens up some attractive possibilities for more study. Specifically, this study empirically shows the mediating effects of job satisfaction on social media-induced technostress, social capital, and job performance. Future research should explore more variables, such as job characteristics mediating or moderating social media-induced technostress and social media-induced social capital. Also, multi-job characteristics studies can be done with personnel of different characteristics. Moreover, an overall assumption of this study is that social media usage is sometimes negative and sometimes positive. Future research should explore the positive aspects of social media usage induced by social capital and the negative aspects of social media usage induced by technostress. Finally, the personnel’s social media usage-related technostress level can be investigated with those who do not. This study also has several limitations. One of the primary limitations arises from the sampling strategy. While much care was taken on the survey description, the survey design, and cleaning the data, it is possible that employees were able to respond who did not use social media usage. As of the time of the data collection, researchers needed a way to filter respondents by job characteristics. Targeted sampling can be used in future studies to overcome this problem. Second, this research provides subjective measures of job performance and another critical variable.

Disclosure statement

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

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