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A Novel Approach for Planning Imperfect Preventive Maintenance in Manufacturing Systems by a Simulation-Optimization Approach

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ABSTRACT

This study addresses simulating manufacturing processes and maintenance activities in a multi-product industry to model the complexity of interactions between maintenance strategies and their effects on a manufacturing system. A novel simulation model has been developed using Discrete Event Simulation (DES) to investigate interactions between manufacturing and maintenance systems. A real two-product manufacturing line in an automotive factory was studied to demonstrate the proposed model's efficacy. Two significant challenges were considering Preventative Maintenance (PM) as imperfect PM activities and estimating unknown probability distribution in a real industry. These are new assumptions that generally have not been considered in the prior studies. To overcome these problems, imperfect maintenance activities are defined as different scenarios and unknown probability distributions are estimated based on historical records in the case study. A simulation-based optimization method was developed using OptQuest, and the results of the proposed method were then compared with the current values in the case study. The findings illustrate that the proposed model can reduce the system's manufacturing and maintenance costs by 13%. In addition, the implementation of maintenance planning in this research improved some factors in the manufacturing system efficiently.

Keywords

Preventive maintenance, Simulation-Optimization, Imperfect maintenance, Maintenance cost, OptQuest.

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1. Introduction

Research on maintenance planning was established decades ago, and different approaches are applied to investigate efficient maintenance operations. Some studies are reviewed in the literature in two separate parts, including mathematical and simulation models. The majority of mathematical models have discussed costs and reliability. De Almeida (2012) proposed a multi-criteria decision making (MCDM) approach to select the best preventive maintenance intervals that reduce total cost. Wang and Zhang (2013) surveyed the replacement problem, which consists of two types of failures. The first one is repairable in which maintenance activities are carried out by technicians to repair the system and the second one is unrepairable that the whole system needs replacing at once. The process aims to find the optimal replacement policy, which leads to the minimum average cost rates. Chen et al. (2015) focused on a prognostic model that determines physical deterioration in a stochastic process to minimize the total operational costs, including preventive/corrective, replacement, and downtime costs. Imperfect maintenance is another principal issue related to the optimization of complex maintenance systems. Lim et al. (2016) proposed a repair model, which could find the optimal replacement age in a system with an imperfect repair policy. Aghezzaf et al. (2016) also developed a Mixed Integer Nonlinear Programming (MINP) to represent a manufacturing system where production and maintenance decisions are assumed integrated and preventive maintenance activities occur imperfectly. A heuristic procedure was applied to solve this complex problem. Concerning safety in an industrial environment, Martón et al. (2016) developed Multiple Objective Optimization Problems (MOP) to obtain the optimal maintenance intervals in a maintenance system. The application case that contains multiple items appears that efficient test intervals and maintenance activities had a significant impact on detecting hidden failures. Jun et al. (2017) proposed a mathematical model to estimate the long-run cost Condition-Based Maintenance (CBM) system. To illustrate the maintenance policy, a case study is employed, and the degradation process is described with known and unknown distribution parameters. It is realized that the distribution of the system's lifetime was deeply affected by the degradation rate. Driessen et al. (2017) considered three deterioration states, including normal, defective, and failed states to minimize the average cost over an infinite time horizon by optimizing the maintenance policy. The numerical study demonstrates that the model with constant probabilities costs, on average, 19% higher than non-constant probabilities of inspection errors. Liu et al. (2018) created an integrated decision model that coordinates degradation information of maintenance activities, taking into account the health status and machines' age. A single-

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machine system is used as a case study to demonstrate the value of the proposed method. Nguyen et al. (2019) defined a new objective of grouping individual PM strategies to maximize the planning horizon's profit. On the other hand, some studies do not restrict the maintenance grouping into finite planning and propose a model without specifying the horizon (Wu et al., 2020). Furthermore, some researchers applied predictive group maintenance for multi-system multi-components networks (Liang and Parlikad, 2020) and then, forecast demand distribution for spare parts based on the maintenance plan (Zhu et al., 2020). All these studies entailed mathematical models to optimize maintenance intervals and replacement strategies. It is observed from the literature that most studies considered cost and reliability functions as objectives.

One of the most common approaches in simulating the maintenance system is Monte Carlo simulation. Besnard and Bertling (2010) applied Monte Carlo simulation to compare three maintenance strategies: visual inspection, inspection with a condition-monitoring technique, and online condition monitoring. The results showed that for systems with high rate failure, online condition monitoring is the optimal strategy. Liu et al. (2016) developed a maintenance model that considers long-run cost rates as objective and aims to find the optimal threshold for imperfect PM action. Some previous studies extended the simulation-optimization approach to integrating maintenance and manufacturing systems. Roux et al. (2013) combined several tools to ensure a low frequency of failures and efficient preventative maintenance thresholds. Furthermore, the impact of PM strategy on the production line was studied in this proposed model. Alrabghi and Tiwari (2016) proposed a simulation approach to minimizing the total cost consists of the maintenance cost, spare parts cost, and unavailability cost. To optimize the problem, Simulated Annealing (SA) was used, and the results were compared with other optimization algorithms. Lam and Banjevic (2015) used a proportional hazards model for risk of failure and a Markovian process to model the system covariates. This approach is studied to determine the optimal maintenance inspection in a CBM model. Many studies on maintenance systems used simulation as a vital tool to find the best maintenance decision in complex and multi-component systems (Coit et al., 2015, Sharifi and Taghipour, 2023, Bisht and Singh, 2023). Babishin and Taghipour (2016) studied a multi-component system to obtain the optimal maintenance policy. Their research considers hard and hidden failures for all components and periodic inspection interval is found for the system. Hajipour and Taghipour (2016) developed a simulation model to obtain optimal non-periodic inspection intervals in different multi-component systems. A Genetic Algorithm (GA) was applied to find the minimum total expected cost over the system's lifecycle. Nyemba and Mbohwa (2017) simulated both material flow and maintenance in a multi-product manufacturing system by Arena Simulation Software. Alrabghi et al. (2017) applied a stochastic Discrete Event Simulation (DES) approach to finding the optimal maintenance strategy in two industrial systems. These strategies include Corrective Maintenance (CM), PM, Opportunistic Maintenance (OM), and CBM. The findings suggest a new approach to considering production dynamics in maintenance planning. Regarding spare parts planning, Sharma et al. (2017) proposed a simulation-optimization approach that could forecast future failures while keeping the cost to a minimum. Using GA and simulation, the model aimed to determine the number of spare parts for army equipment with selective maintenance strategies. Wakiru et al. (2019) also defined a simulation approach that study some effective factors such as repair time and availability in a thermal power plant. Finally, different maintenance strategies, the time between overhaul and spare parts have been introduced as the most effective factors for reducing the repair time. Also, the impact of the maintenance policy on the inventory system was investigated in a simulated numerical study (Poppe et al., 2017b). It is understood from the literature that the majority of studies apply a simulation approach to optimize maintenance planning and decrease maintenance costs. Studies that employed simulation in maintenance are highlighted in Table 1. Finally, the new decision variables and approaches in the current research are mentioned and compared with previous studies.

To summarize, maintenance activities typically take the time that could be allocated for manufacturing; however, delaying maintenance may increase the probability of machine failure. Consequently, trade-offs and conflicts between maintenance planning and manufacturing systems should be considered in real industrial environments (Liu et al., 2018). Maintenance in manufacturing systems with an integrated assembly line is particularly crucial because if a workstation or machine fails in this kind of system, the full line may stop working. Thus, maintenance activities are essential to keep the manufacturing system or to restore it to an acceptable productivity level (Aghezzaf et al., 2016).

This paper aims to develop a model to generate optimal imperfect PM periods by considering the relevant manufacturing data in a real industrial case. Based on previous maintenance research, simulation models, which are typically appropriate models to consider both manufacturing and maintenance systems in detail, is used in this paper. The key questions are "How to illustrate a methodology to model the maintenance system in this two-product manufacturing line" and "What is the effect of considering imperfect PM activities in a real industrial environment. To overcome these challenges, this paper proposes a new approach to model maintenance activities in the factory. Imperfect PM maintenance activities are defined as three scenarios in which total costs are evaluated. Then the best scenario is selected to fulfill in the case study. Another new assumption is that some data such as repair time and Mean Time Between Failures (MFTB) were unknown in the case study, so they needed to be estimated based on recorded data. Overall, this model enables the decision-makers to decide about PM intervals while the manufacturing system is operating and costs are evaluated in the whole system. Simulation-based optimization is applied to obtain the optimal decision variables. The proposed model could successfully decrease the costs and improve some factors in the manufacturing system.

The remainder of the paper is organized as follows. Section 2 discusses the methodology and explains the assumptions in the model. Section 3 introduces the proposed simulation model in detail. Section 4 indicates the case study and the results. Section 5 discusses the results, and finally, Section 6 summarizes the conclusions.

Table 1. Summary of simulation-based approaches for maintenance strategies

Research	Objective function	Decision variables	Solution Method	Case study
Liu et al., 2018)(	Production cost and tardiness cost	Job sequence PM intervals	GA	A research laboratory facility
Besnard and Bertling, 2010)(	Costs of maintenance strategy	Maintenance inspection time	Monte Carlo simulation	Wind turbine
Liu et al., 2016)(	Long-run cost rate	The threshold for imperfect PM action	Monte Carlo simulation	-
Roux et al., (2013)	Unavailability of the system	PM inspection interval	Nelder–Mead (Simplex) method	-
Alrabghi and Tiwari (2016)	Total cost (maintenance cost, spare parts cost, and unavailability cost)	Preventive maintenance frequency, and the type of maintenance strategy	Simulated Annealing (SA)	-
Lam and Banjevic (2015)	Costs of maintenance policy per unit time	Next PM inspection time	Simulate possible scenarios by Markovian process	-
Babishin and Taghipour (2016)	The total cost of maintenance and repair policy	Periodic inspection interval	Simulation Of each maintenance policy	-
Hajipour and Taghipour (2016)	The total expected cost of the system over the lifecycle	non-periodic inspection scheme	Simulation and GA	-
Nyemba and Mbohwa (2017)	Production costs	Production and maintenance intervals	Simulation via software	Furniture assembling plant
Alrabghi et al., (2017)	Maintenance cost and the production throughput	Maintenance strategy	Non-dominated Sorting Genetic Algorithms (NSGA II)	A tyre re-treading factory and a petrochemical plant
Sharma et al., (2017)	Maintenance cost	Maintenance replacements	GA	Army equipment

Research	Objective function	Decision variables	Solution Method	Case study
Wakiru et al., (2019)	Total repair time	The time between overhaul, Fill rate that deals with the inventory policy, Maintenance strategy reliance factors	Design of Experiment (DOE)	Thermal power plant
Poppe et al., (2017a)	Inventory costs of maintenance policy, Maintenance intervention costs of maintenance policy	Reorder point, Order quantity, Maintenance interval in running hours under a PM policy, Intervention threshold	Simulation via software	Equipment manufacturing in the compressed air industry
Madu (2000)	Availability and total maintenance cost	The time between failure, The time between failure of components	DES algorithm	Mining industry
Present study	Total costs (maintenance and production)	PM intervals, Imperfect PM intervals, the number of technicians in maintenance, and buffer size	OptQuest	Automotive industry

2. Methodology

The combination of simulation and optimization is a new and powerful approach to maintenance planning problems. This approach can be applied in different ways; it depends on the simulation pattern that is selected in maintenance problems. Some simulation ways such as the Markovian process (Lam and Banjevic, 2015), DES (Roux et al., 2013, Alrabghi and Tiwari, 2016), and Monte Carlo method (Liu et al., 2016, Besnard and Bertling, 2010) can be found in maintenance problems. In this study, due to the interactions between machines and the effect of maintenance on production, discrete-event simulation (DES) is applied and implemented by the Arena simulation software package. DES is a technique representing changes and real-world behavior in industrial systems (Roux et al., 2013, Alrabghi and Tiwari, 2016).The simulation-based optimization method also allows the decision-makers to observe both the maintenance and manufacturing processes at the same time and then find the optimal decision variables. In this section, the assumptions and mathematical model in this research are defined.

2.1. Assumptions

The main model assumptions are as follows:

- The case study is a multi-product manufacturing system with different workstations and non-identical machines
- Mean Time Between Failures (MTBF) is unknown. Historical data captured over three months in the factory were used to estimate MTBF for each machine.
- PM and CM activities are scheduled in the model. Likewise, in the proposed model, PM activities will carry out imperfectly.
- To carry out maintenance activities, the production line should be stopped.
- Total costs formulated in the objective function include both production cost and maintenance cost.
- Repair time and MTBF distributions are unknown, and a tool in Arena software is used to estimate them.

2.2. Modelling manufacturing system and preventive maintenance

The optimization model, which defines the decision variables in the maintenance and manufacturing system, is mentioned in this subsection. There is a notation of variables and information used in the model.

2.2.1. Notations

Sets:

J: Set of machines in the manufacturing system- indexed by j

2.2.2. Parameters:

B_{lj}: Lower bound for buffer capacity in machine j $\in J$
B_{uj}: Upper bound for buffer capacity in machine j $\in J$
PMI_{lj}: Lower bound for PM activity interval in machine j $\in J$
PMI_{uj}: Upper bound for PM activity interval in machine j $\in J$
PMI_{j}: PM intervals for machine j$\in J$
HR_{l}: Minimum number of available technicians in the maintenance system
HR_{u}: Maximum number of available technicians in the maintenance system

2.2.3. Decision variables

Buf_{j}: Buffer capacity in machine j $\in J$

$HR\ Maintenance$: Number of available technicians in the maintenance system

2.2.4. Objective function

Z: Total cost

To optimize the maintenance and manufacturing system, the objective function should include both maintenance and manufacturing costs. As a result, the total cost formulated as follows:

$$\text{Minimize total cost} = \text{Maintenance cost} + \text{Manufacturing cost}$$

$$\text{Maintenance cost} = \text{PM cost} + \text{CM cost} + \text{labor cost}$$

$$\text{Manufacturing cost} = \text{Variable cost of manufacturing} + \text{Fixed cost of manufacturing} + \text{Holding cost at buffer}$$

PM and CM costs are evaluated per each maintenance task. Labor costs in this maintenance system concentrate on technicians' wages and are calculated per hour. In the manufacturing system, fixed costs refer to costs that do not change when output changes. However, variable cost is dependent on the number of products produced. Holding cost at buffer also refers to how much holding a unit of product costs per day. All of the manufacturing and maintenance systems' expenses were collected from prior recorded data in the factory. To define new decision variables in the problem and determine bounds for them, some discussions were conducted with experts in the manufacturing and maintenance team, respectively. In the following model, equation (1) demonstrates the objective function.

$$\text{Minimize } Z = \text{Total cost} \quad (1)$$

Subject to:

$$B_{lj} \leq Buf_j \leq B_{uj} \quad (2)$$

$$PMI_{lj} \leq PMI_j \leq PMI_{uj} \quad (3)$$

$$HR_l \leq HR\ Maintenance \leq HR_u \quad (4)$$

Constraint (2) shows the minimum and maximum of products that can be stored in the buffer and mentions buffer capacity ranges between B_{lj} and B_{uj}. Constraint (3) mentions that PM intervals range between PMI_{lj} and PMI_{uj} for machine j. In addition, constraint (4) shows available technicians in the maintenance system range between HR_l and HR_u. The optimal value for the buffer size, PM intervals, and technicians system will be determined in the simulation-optimization model.

2.3. A novel approach to model maintenance systems

Notation

T: Simulation run length

Type 1 PM: The PM activities that only control and inspect different parts of machines

Type 2 PM: In addition to inspection of the system, theses PM activities repair the broken-down parts

3. Simulation model

To simplify the industrial environment, we developed a generic simulation model in Figure 1, which involves manufacturing systems and maintenance strategies. The simulation model begins with the manufacturing system, some information such as manufacturing sequence for each product, machines' cycle time, buffers, and product's transfer time were collected and considered in the model.

3.1. Maintenance model

Required maintenance data such as maintenance cost, repair time, MTBF, and the number of technicians engaged in the maintenance system are identified in the model. Then, we considered that when the simulation runs, the simulation clock moves forward to the next event. A novel approach for maintenance modelling is presented in Figure 1. At first, it is checked if failures occur in the system, a CM activity must be carried out to repair the system. Thus, production processes are stopped, and the machine's state is changed to the inactive state. Having done CM action, the manufacturing system can start operation again.

Additionally, if any failures do not happen in the system, CM activity will be suspended until the simulation clock exceeds the MTBF. To carry out PM activities, at first, it is monitored that CM and PM do not happen simultaneously. Then, to begin a PM activity machine's state is changed to an inactive state. The type 2 PM takes more time and needs more technicians because more actions should be carried out to repair the parts. Then, having done these steps, the cost will be updated, and human resources will be released. The simulation model inputs are PM and CM cost, variable and fixed cost at manufacturing, and holding cost at buffer. The simulation model output is the total cost. Until the simulation clock reaches simulation run length, the same steps as described above are followed.

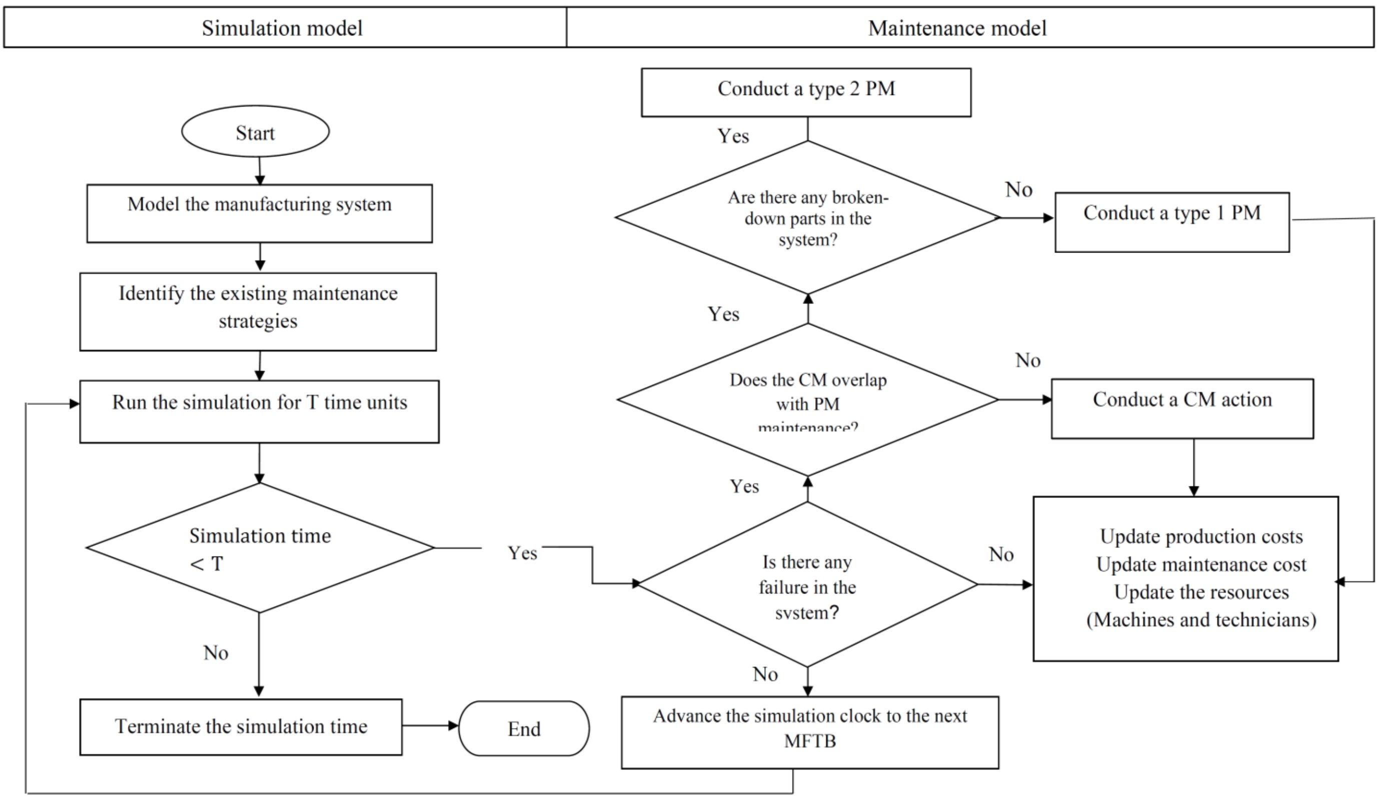

Figure 1. A generic approach to model maintenance systems

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3.2. Simulation-based optimization approach

A simulation-based optimization approach has been a common method in maintenance problems. OptQuest is a tool that can consider a series of simulations to uncover optimal or near-optimal solution scenarios. OptQuest is a generic optimizer that runs the simulation model and the optimization method separately. There are interactions between simulation and optimization procedures, enabling decision-makers to apply optimization methods in their simulation models (Nakagawa and Zhao, 2015). OptQuest uses a group of meta-heuristics, including Neural Networks, Scatter Search, Tabu search, and then combines them into a single search heuristic (Golbasi and Turan, 2020). Metaheuristics are methods, which guide other procedures (heuristic or truncated exact methods) to enable them to overcome the trap of local optimality for complex optimization problems (Glover et al., 1999). If a candidate solution does not fit the constraints, that solution is eliminated, and OptQuest explores candidates that are more likely to be better. Thanks to OptQuest, it allows users to define integer and linear constraints on the deterministic simulation inputs. It also enables users to control the search by defining different criteria. In addition, It allows different precision criteria for objective and the constrained simulation outputs. For instance, the user can specify a fixed or the number of replicates between lower and upper bounds, stopping the replication if any inferior solution is found. OptQuest also allows various stopping criteria; for example, the search can be stopped after a specific time duration or after specific non-improving solutions. We can obtain the optimal PM intervals, buffer size, and the number of technicians, using only available algorithms via OptQuest. For this problem, to create a relationship between the optimization process and simulation model, the number of replications is investigated in more detail in the optimization results section.

4. Case study and computation results

To illustrate the value of the model, an industrial case was used in the research. To find an empirical case, initial discussions were conducted to choose the most critical manufacturing line in the factory. Finally, a production line where automotive weather-stripping was produced, with high-tech machines, was selected. A case study will be explained in detail in the following sections, and the results will be argued.

4.1. Manufacturing system

The manufacturing line is a multi-product system that consists of five non-identical machines. Two types of weather-stripping are produced for a car in this production line, which we called them product A and product B. Product A is the outer weather-stripping, and product B is the inner weather-stripping that their manufacturing process is slightly different. Figure 2 shows the manufacturing process and its equipment in this factory. Both products enter the manufacturing system simultaneously, whereas product B needs an additional stage, processed by machine 5 (M5). There is a buffer after machine 4 (M4), where products are prepared for the next stage; we define its size as a decision variable. Each machine needs an operator in order to run the machine and transfer products to subsequent steps.

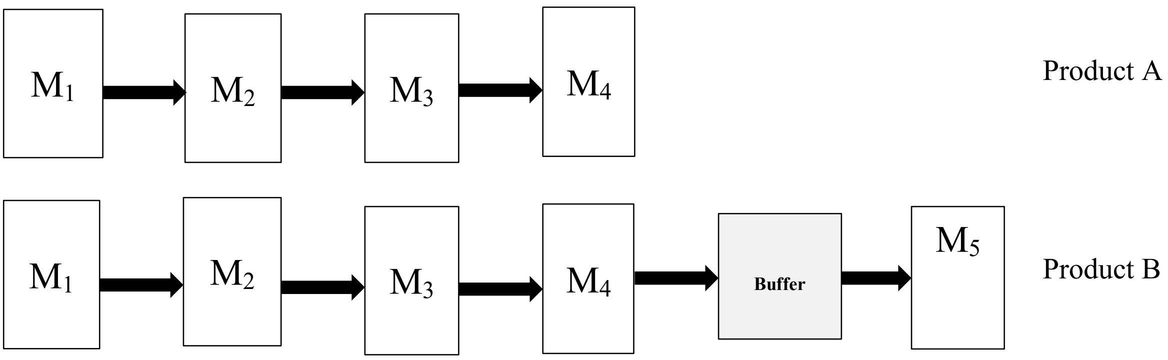

Figure 2. Production processes in the manufacturing system

The production line involves five processes as follows:

1. Injection: preformed rubber material and other chemicals are mixed in machine 1 (M1).
2. Extrusion: rubber seals are measured and cut (M2).
3. Moulding: rubber strips are moulded into particular shapes (M3).
4. Velvet insertion: rubber strips are covered with a velvet layer in machine 4 (M4). After that, rubber strips are gathered in the buffer to cool down.
5. Metal insertion: rubber strips are covered with a metal layer (M5). This process is only done for product B.

Cycle times related to each machine are given in Table 2. All machines need labor to operate.

Table 2. Cycle times for the machines in the manufacturing system

Machine	Process	Cycle time	
		Product A (minute)	Product B (minute)
1	Injection	1	1
2	Extrusion	6	11
3	Moulding	4	4
4	Velvet insertion	3	3
5	Metal insertion	-	7

Index j that represents the machines in the manufacturing system range between 1 and 5. The manufacturing costs during the simulation are as follows:

Variable cost of manufacturing = 150000/ unit
Fixed cost of manufacturing = 200000/ set up
Holding cost at buffer = 12000/unit/hour

In the manufacturing system, the buffer capacity ranges between 600 and 880.

$$600 \leq \text{BUF} \leq 880 \tag{5}$$

4.2. Maintenance system

In the maintenance system, two maintenance strategies are carried out; PM activities considered as decision variables and CM activities. To study the maintenance system, historical data were used to fit all probability distributions. MTBF, which shows when a CM action is carried out, follows BETA. Repair times for CM and PM activities follow Triangle distribution and vary between machines. All distributions for the maintenance system are shown in Table 3. P-value is more than 0.15, which indicates the similarity between data and estimated distributions is acceptable.

Table 3. MTBF and repair time distributions in the maintenance system

Machines	MTBF (Mean Time Between Failure)*	CM repair time	PM repair time in type 1 PM	PM repair time in type 2 PM	Corresponding p-value K-S test[1]
1	25 + 48 BETA (0.0156, 0.0159)	TRIA[2](6.5, 7, 8.5)	TRIA(4.5, 5, 6.5)	TRIA(5.5, 6, 7.5)	> 0.15
2	248 + 188 BETA (0.246, 0.173)	TRIA(4.5, 5, 6.5)	TRIA(4.5, 5, 6.5)	TRIA(5.5, 6, 7.5)	> 0.15
3	258 + GAMMA (289, 0.335)	TRIA(2.5, 3, 4.5)	TRIA(4, 4.5, 6)	TRIA(4, 4.5, 6)	> 0.15
4	148 + 188 BETA (0.246, 0.173)	TRIA(8,8.5, 10)	TRIA(4.5, 5, 6.5)	TRIA(5, 5.5, 7)	> 0.22
5	87 + 102 BETA (0.192, 0.147)	TRIA(3.5, 4, 5.5)	TRIA(4.5, 5, 6.5)	TRIA(5.5, 6, 7.5)	> 0.15

*MTBF is assumed as the CM threshold in this study. In other words, after machines failed, the CM action is performed.

PM intervals (PMI) and the available number of technicians (HR maintenance) in the maintenance system are as follows:

1 Kolmogorov–Smirnov test

2 Triangular

$$10 \le PMI \le 16 \tag{6}$$

$$12 \le HR\ Maintenance \le 16 \tag{7}$$

4.3. Imperfect PM maintenance scenarios

In this research, a new approach is proposed to consider PM strategies imperfectly. The concept of imperfect maintenance refers to a maintenance operation, which leads to a system that brings to an operating state between the two extreme operating states called the 'as bad as old' and the 'as good as new' states. Consequently, to add imperfect PM strategies to the model, three scenarios are defined in Table 4. Each scenario presents the quality and accuracy of PM strategies. A weak strategy is the cheapest one, but it cannot influence failures' distribution. Weak strategy means a PM takes place with low-quality spare parts or unskilled technicians and only increases Mean Time Between Failures (MTBF) by 20 percent. However, the most expensive PM strategy, which is called high, uses the best spare parts and skilled technicians and can increase MTBF significantly.

Moreover, the average strategy is cheaper than high strategy, which provides technicians and spare parts with the quality level between weak and the high strategy. It is also assumed that imperfect maintenance has an impact on the mean time between failures. As a result, the mean time between failures is expected to increase specific amounts. We simply define α (α ≥1) coefficient that increases MTBFs; after each imperfect maintenance, the MTBF of the machines is modified to become α×MTBF. For instance, the time interval between the two failures increased by 20 percent in the weak strategy. The last PM strategy explains the current PM activities that are carried out in the industrial case study. The scenarios illustrated in Table 4, and all required data are captured from the maintenance team and management.

Table 4. Imperfect PM Scenarios based on expert's knowledge

PM scenarios	PM cost	Increase in MTBF	α	New MFTB
Weak	210000/task	20 percent	1.2	α × MTBF
Average	238000/task	50 percent	1.5	
High	300000/task	90 percent	1.9	
Factory	230000/task	-	1	

4.4. Comparison of scenarios for imperfect preventive maintenance

We employed the Process Analyzer tool in Arena software to decide about three scenarios and the factory's current maintenance strategy. Table 5 illustrates controls and responses for imperfect PM maintenance scenarios in Process Analyzer. Figure 3, a result of Arena software, compares the objective function (total cost) of scenarios and shows that the Average scenario is the best PM strategy with the minimum total cost. Consequently, in the rest of the study, the Average scenario is called the proposed scenario. The following data will be optimized in OptQuest, and the findings will be compared with the current case.

Table 5. Comparison of imperfect preventive scenarios

Scenarios properties		Controls								Response
Name	Replications	PMI[M1]*[3] (Days)	PMI[M2]	PMI[M3]	PMI[M4]	PMI[M5]	α	HR Maintenance	PM cost	Total cost
Weak	20	10	10	10	10	10	1.2	13000	2100000	270501400
Average	20	12	12	12	12	12	1.5	15000	2380000	255155750
High	20	16	16	16	16	16	1.9	17000	300000	289822400
Factory	20	14	14	14	14	14	1	15000	230000	279091845

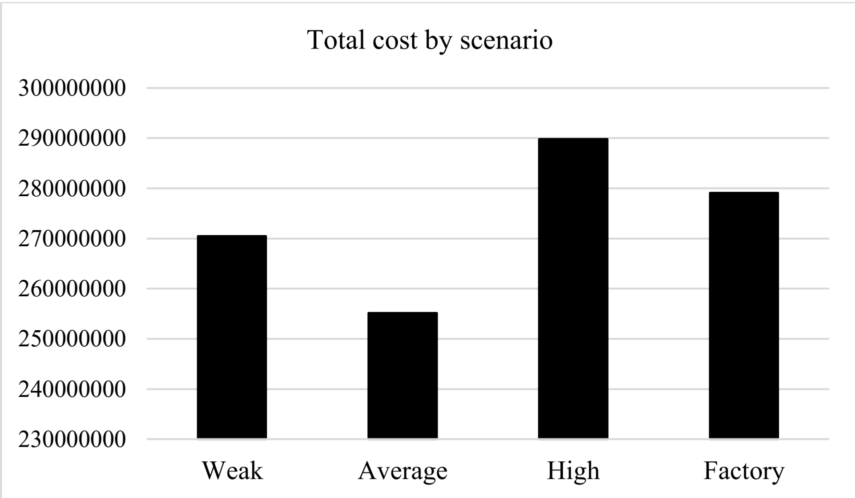

Figure 3. Comparison between scenarios and current maintenance strategy

4.5. Optimization results

The OptQuest tool in Arena simulation software package (V.14) allows the user to select special parameters and then begins to find the optimal values while simultaneously changing these parameters (Kelton et al., 2009).This tool is used to optimize the simulation model in this paper, and Table 7 show the optimal buffer size, the optimal number of technicians in the maintenance system, and the optimal PM intervals for the current model in the factory and the proposed scenario respectively.

3 PMI [M1]: PM inspection for machine 1

Table 6. The optimal solution for the current model in the factory

Decision variables	Current values in factory	Optimal values
Buffer size	652	758
HR Maintenance	15	12
PMI[M1]	14	10
PMI[M2]	14	11
PMI[M3]	14	11
PMI[M4]	14	10
PMI[M5]	14	10
Optimal total cost: 261099800		

Surprisingly, if PM activities take place imperfectly, as mentioned in Table 7, this study's proposed maintenance scenario causes a significant decrease in total cost. To be precise, imperfect PM activities cause a 13.03 percent fall in the total cost function. To determine the sufficient number of replications, a 95% confidence interval of 'Total cost' is considered, then around 30 replications, the half-width achieves less than 5 million units. Hence, the number of replications is set to 30 to ensure we obtain a better estimate of 'Total cost'. The objective, the total cost is also calculated for 50 simulation runs with 30 replications. Figure 4 shows the optimization graph for the total cost associated with the case study's current model. According to the graph, the best total cost is attained at the 27th simulation, and no further change is seen.

Table 7. The optimal solution for the proposed scenario

Decision variables	Default values in the scenario	Optimal values
Buffer size	652	773
HR Maintenance	12	12
PMI[M1]	12	16
PMI[M2]	12	16
PMI[M3]	12	16
PMI[M4]	12	13
PMI[M5]	12	15
Optimal total cost: 227053900		

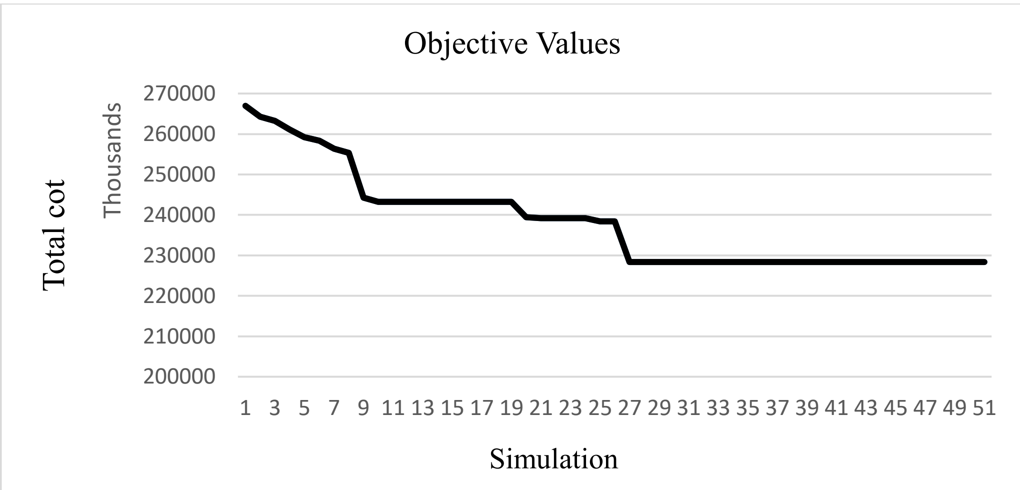

Figure 4. Optimization graph for the total cost of the current model in the factory

Furthermore, other factors, which are effective in deciding on the maintenance and manufacturing system, have been studied in the models. As seen in Table 8, wait time, WIP , and the number of waiting in the queue are extracted from the Arena software reports. To evaluate whether the differences between the current model and optimal design were statistically meaningful, 95% confidence intervals for these four factors are obtained after 30 simulations in Table 8.

Table 8. Comparative results of the simulation-based optimization method

Factors		Current design	Optimal design (proposed model)	Improvement		
				mean	Confidence interval (95%)	Significance
Wait time	Product A	295.42	294.69	0.24 %	(0.217,0.473)	Yes
	Product B	389.27	384.09	1.33 %	(0.791,1.057)	Yes
Work In Process	Product A	795.62	778.97	2.92 %	(0.294,0.451)	Yes
	Product B	5955.53	5943.14	0.208 %	(-0.215,0.107)	No
Number of waiting	Machine 1	62.1439	389.829	37.26 %	(-5.31,2.08)	No
	Machine 2	118.57	107.11	9.66 %	(0.65,0.84)	Yes
	Machine 3	38.98	28.37	27.2 %	(0.126,0.39)	Yes
	Machine 4	23.87	12.96	45.7 %	(0.146,0.935)	Yes
	Machine 5	19.36	13.02	32 %	(0.369,0.564)	Yes
Total cost		146289690	138278177	5.47 %	(0.449,2.69)	Yes

The confidence intervals confirm that the mean is statistically significant at the significance level of 0.05. As Table 8 indicates, all values are significant with the exception of WIP for product B and the number waiting for machine 1.

5. Results and discussion

Concerning the optimization results in Section 4.5, it is evident that the proposed maintenance strategy leads to a lower cost and could improve some important factors. Wait time, which shows that each product is waiting in the system, decreases by 0.24 and 1.33 percent for products A and B, respectively. After optimizing the problem, there is a decrease in the number of waiting products for product A, falling from 795.62 to 778.97; however, a decrease in WIP for product B is not statistically significant. While the number of waiting products improves in all machines, a decrease in this criterion for machine 1 is not statistically appropriate; this indicates that the number of waiting factor does not depend on the simulation-based optimization method. The total cost improvement is considerable, decreasing by 5.47%, falling from 146289690 in current design to 138278177 in optimal design. Therefore, it is shown that the proposed model and optimization approach was employed in this research can boost several factors in the maintenance and manufacturing system. Moreover, as Table 6 and Table 7 show, we find the optimal decision variables for PM intervals, the number of technicians, and buffer size by the proposed model causing a 13.03% decrease in the total cost. This paper's current approach can be used for planning maintenance activities in industrial environments with integrated production lines that a failure in a workstation may cause a full stop in the assembly line. However, based on confidence intervals, some factors did not change logically. The number waiting for machine 1, for instance, does not change after optimization, which may depend on other factors such as the machine's age since machine 1 was the oldest in our case study.

In prior studies, very little was found on discussing the scope of optimization, finding a new approach for maintenance action in a real case industry; however, this research aimed to create a simulation model and proper optimization process to address the gaps. While the majority of prior studies concentrated on mathematical models to consider imperfect maintenance activities, this paper tried to model maintenance activities by a simulation model. Although many studies in maintenance research used numerical examples to verify their model, current research developed an attempt to find an appropriate industrial case as a result; a factory that produced plastic automotive parts was selected as a case study.

6. Conclusion

This paper develops a new model to plan maintenance activities by considering the manufacturing data in industrial environments. Consequently, in addition to PM intervals and the number of technicians, buffer size was assumed to be the model's decision variables. We propose a novel approach for CM and PM activities to plan and model these activities in maintenance systems. A new assumption is carrying out PM activities imperfectly. Three scenarios were defined based on the expert's knowledge to add imperfect maintenance assumptions, and then the best scenario was selected to carry out imperfect maintenance activities in the model. The results have shown that the model can lead to a noticeable decrease in the total cost, and it offers different impacts on other factors in a manufacturing system. In addition to maintenance, data wait time, work in process, and the number of waiting were studied in the manufacturing system. Finally, after the optimization of an automotive factory, the findings support the hypothesis that maintenance improvement plays a role in boosting other manufacturing systems. There was a limitation to find a case study because only factories with high-tech machines could provide accurate information for this model; therefore, we investigated a particular factory, however; only one production line in the factory provides data for the model.

Future research can be undertaken to implement the proposed approach to other case studies with more details. For example, the spare parts management or inventory costs can be considered in future studies. Also, the equipment's age can be studied in a manufacturing system with different MTBF distribution. It is possible to formulate other functions such as reliability in the objective function and change the model to a multi-objective problem. It is also suggested that the currently proposed model can be used with other maintenance policies such as OM and CBM.

Disclosure statement

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

References

Aghezzaf, E.-H., Khatab, A. and Le Tam, P. 2016. Optimizing production and imperfect preventive maintenance planning′ s integration in failure-prone manufacturing systems. *Reliability Engineering & System Safety, 145*, pp.190-198. https://doi.org/10.1016/j.ress.2015.09.017.

Alrabghi, A. and Tiwari, A. 2016. A novel approach for modelling complex maintenance systems using discrete event simulation. *Reliability Engineering & System Safety, 154*, pp.160-170. https://doi.org/10.1016/j.ress.2016.06.003.

Alrabghi, A., Tiwari, A. and Savill, M. 2017. Simulation-based optimisation of maintenance systems: Industrial case studies. *Journal of Manufacturing Systems, 44*, pp. 191-206. https://doi.org/10.1016/j.jmsy.2017.05.008.

Babishin, V. and Taghipour, S. 2016. Optimal maintenance policy for multicomponent systems with periodic and opportunistic inspections and preventive replacements. *Applied Mathematical Modelling, 40*, pp.10480-10505. https://doi.org/10.1016/j.apm.2016.07.019.

Besnard, F. and Bertling, L. 2010. An approach for condition-based maintenance optimization applied to wind turbine blades. *IEEE Transactions on Sustainable Energy, 1*, pp.77-83. https://doi.org/10.1109/TSTE.2010.2049452.

Bisht, V. and Singh, S. B. 2023. Lz-transform approach to evaluate reliability indices of multi-state repairable weighted K-out-of-n systems. *Quality and Reliability Engineering International, 39*, 1043-1057. https://doi.org/10.1002/qre.3279.

Chen, N., YE, Z.-S., Xiang, Y. and Zhang, L. 2015. Condition-based maintenance using the inverse Gaussian degradation model. *European Journal of Operational Research, 243*, pp.190-199. https://doi.org/10.1016/j.ejor.2014.11.029.

Coit, D. W., Chatwattanasiri, N., Wattanapongsakorn, N. and Konak, A. 2015. Dynamic k-out-of-n system reliability with component partnership. *Reliability Engineering & System Safety, 138*, pp.82-92. https://doi.org/10.1016/j.ress.2015.01.004.

De Almeida, A. T. 2012. Multicriteria model for selection of preventive maintenance intervals. *Quality and Reliability Engineering International, 28*, pp.585-593. https://doi.org/10.1002/qre.1415.

Driessen, J., Peng, H. and Van Houtum, G. 2017. Maintenance optimization under non-constant probabilities of imperfect inspections. *Reliability Engineering & System Safety, 165*, pp.115-123. https://doi.org/10.1016/j.ress.2017.03.020.

Glover, F., Kelly, J. P. and Laguna, M. 1999. New advances for wedding optimization and simulation. Proceedings of the 31st conference on Winter simulation: Simulation---a bridge to the future, *1*, pp.255-260.

Golbasi, O. and Turan, M. O. 2020. A discrete-event simulation algorithm for the optimization of multi-scenario maintenance policies. *Computers & Industrial Engineering, 145*, p.106514. https://doi.org/10.1016/j.cie.2020.106514.

Hajipour, Y. and Taghipour, S. 2016. Non-periodic inspection optimization of multi-component and k-out-of-m systems. *Reliability Engineering & System Safety, 156*, pp.228-243. https://doi.org/10.1016/j.ress.2016.08.008.

Jun, Z., Wei-Liang, J. and Jiang-Hong, M. 2017. Experimental study on steel bars' fatigue damage based on piezomagnetism. *Journal of ZheJiang University (Engineering Science), 51*, pp.1681-1687. https://doi.org/10.3785/j.issn.1008-973X.2017.02.001.

Kelton, W., Sadowski, R. and SWETS, N. 2009. *Simulation with Arena*, McGraw-Hill Science/Engineering/Math.

Lam, J. Y. J. and Banjevic, D. 2015. A myopic policy for optimal inspection scheduling for condition based maintenance. *Reliability Engineering & System Safety, 144*, pp.1-11. https://doi.org/10.1016/j.ress.2015.06.009.

Liang, Z. and Parlikad, A. K. 2020. Predictive group maintenance for multi-system multi-component networks. *Reliability Engineering & System Safety,* and, p.106704. https://doi.org/10.1016/j.ress.2019.106704.

Lim, J., QU, J. and Zuo, M. J. 2016. Age replacement policy based on imperfect repair with random probability. *Reliability Engineering & System Safety, 149*, pp.24-33. https://doi.org/10.1016/j.ress.2015.10.020.

Liu, B., Xie, M., Xu, Z. and Kuo, W. 2016. An imperfect maintenance policy for mission-oriented systems subject to degradation and external shocks. *Computers & Industrial Engineering, 102*, pp.21-32. https://doi.org/10.1016/j.cie.2016.10.008.

Liu, Q., Dong, M. and Chen, F. 2018. Single-machine-based joint optimization of predictive maintenance planning and production scheduling. *Robotics and Computer-Integrated Manufacturing, 51*, pp.238-247. https://doi.org/10.1016/j.rcim.2018.01.002.

Madu, C. N. 2000. Competing through maintenance strategies. *International Journal of Quality & Reliability Management, 17*, pp.937-949. https://doi.org/10.1108/02656710010378752.

Martón, I., Martorell, P., Mullor, R., SÁNCHEZ, A. I. and Martorell, S. 2016. Optimization of test and maintenance of ageing components consisting of multiple items and addressing effectiveness. *Reliability Engineering & System Safety, 153*, pp.151-158. https://doi.org/10.1016/j.ress.2016.04.015.

Nakagawa, T. and Zhao, X. 2015. *Maintenance overtime policies in reliability theory: models with random working cycles*, Springer.

Nguyen, H. S. H., Do, P., Vu, H.-C. and Iung, B. 2019. Dynamic maintenance grouping and routing for geographically dispersed production systems. *Reliability Engineering & System Safety, 185*, pp.392-404. https://doi.org/10.1016/j.ress.2018.12.031.

Nyemba, W. R. and Mbohwa, C. 2017. Modelling, simulation and optimization of the materials flow of a multi-product assembling plant. *Procedia Manufacturing, 8*, pp.59-66. https://doi.org/10.1016/j.promfg.2017.02.007.

Poppe, J., Basten, R. J., Boute, R. N. and Lambrecht, M. R. 2017a. Numerical study of inventory management under various maintenance policies. *Reliability Engineering & System Safety, 168*, pp.262-273. https://doi.org/10.1016/j.ress.2017.06.012.

Poppe, J., Basten, R. J. I., Boute, R. N. and Lambrecht, M. R. 2017b. Numerical study of inventory management under various maintenance policies. *Reliability Engineering & System Safety, 168*, pp.262-273. https://doi.org/10.1016/j.ress.2017.06.012.

Roux, O., Duvivier, D., Quesnel, G. and Ramat, E. 2013. Optimization of preventive maintenance through a combined maintenance-production simulation model. *International journal of production economics, 143*, pp.3-12. https://doi.org/10.1016/j.ijpe.2010.11.004.

Sharifi, M. and Taghipour, S. 2023. Inspection Interval Optimization of a Weighted-K-out-of-N System with Identical Multi-State Load-Sharing Components. *Reliability Engineering & System Safety*, p.109412. https://doi.org/10.1016/j.ress.2023.109412.

Sharma, P., Kulkarni, M. S. and Yadav, V. 2017. A simulation based optimization approach for spare parts forecasting and selective maintenance. *Reliability Engineering & System Safety, 16*8, pp.274-289. https://doi.org/10.1016/j.ress.2017.05.013.

Wakiru, J. M., Pintelon, L., Muchiri, P. N. and Chemweno, P. K. 2019. A simulation-based optimization approach evaluating maintenance and spare parts demand interaction effects. *International journal of production economics, 208*, pp.329-342. https://doi.org/10.1016/j.ijpe.2018.12.014.

Wang, G. J. and Zhang, Y. L. 2013. Optimal repair–replacement policies for a system with two types of failures. *European Journal of Operational Research, 226*, pp.500-506. https://doi.org/10.1016/j.ejor.2012.11.053.

Wu, T., Yang, L., MA, X., ZHANG, Z. and ZHAO, Y. 2020. Dynamic maintenance strategy with iteratively updated group information. *Reliability Engineering & System Safety, 197*, p.106820. https://doi.org/10.1016/j.ress.2020.106820.

Zhu, S., Van Jaarsveld, W. and Dekker, R. 2020. Spare parts inventory control based on maintenance planning. *Reliability Engineering & System Safety, 193*, p.106600. https://doi.org/10.1016/j.ress.2019.106600.

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Analysis of Urban Waste Management Using System Dynamics Approach

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ABSTRACT

Nowadays, the increase in waste generated by citizens and its consequences, including environmental pollution, human and animal health endangerment, and depletion of natural resources, have become fundamental issues and challenges in Isfahan. The research proposes a comprehensive and systemic model to offer effective solutions for reducing waste volume by applying a system dynamics approach within Isfahan. In order to achieve this objective, the study first identified and localized the influencing factors on waste generation within the city by reviewing pertinent literature and research background, as well as consulting experts and officials from Isfahan. Subsequently, the relationships between these factors were delineated using insights from 32 experts and officials from Isfahan, who were selected through a snowball sampling. A causal loop diagram was constructed based on the identified relationships among factors affecting waste generation. Moreover, a stock-and-flow diagram was developed based on information extracted from municipal records of the identified variables' quantities and values. The results of this study demonstrate the significance of investing in waste collection equipment and advertising to raise citizens' awareness and reduce waste production in Isfahan. These efforts play a crucial role in decreasing the overall volume of urban waste. Moreover, they contribute to the saving and sustainability of resources while enhancing the city's beauty, ultimately attracting more tourists.

Keywords

Urban waste management, System dynamics, Urban waste, Isfahan municipality.

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1. Introduction

The focus on environmental protection and the conservation of natural resources has become a societal responsibility across all communities (Beyene et al., 2018; Zhang et al., 2023). In addition to the depletion of existing natural resources, the excessive utilization of these resources has not only disrupted biological and natural cycles (Smol et al., 2020) but has also had an impact on human life by causing various forms of pollution (Hosseinalizadeh et al., 2021). Over the past two decades, global consumption of products and natural resources has been rapidly increasing (Crutchik et al., 2023), leading to a significant rise in waste generation by humans and raising significant concerns about environmental degradation and human health (Sarigiannis et al., 2021).

In the past decade, urban waste management has emerged as a focal point that has garnered the attention of numerous researchers (Arifin et al., 2021; Qu et al., 2022). Urban waste management encompasses crucial aspects such as production, collection, transportation, recycling, and disposal of waste generated in urban areas (Das et al., 2019). Urban waste refers to the refuse and discarded materials individuals produce daily (Nanda and Berruti, 2020). In other words, urban waste encompasses waste originating from domestic, commercial, and construction activities conducted by humans (Xiao et al., 2020), collected by municipal authorities, and potentially recycled or reused (Karak et al., 2012). Currently, cities are grappling with the increasing volume of waste and urban waste, which puts significant pressure on waste disposal capacities and the environment (Jaligot and Chenal, 2018; Magazzino et al., 2020). Urban waste has become a critical concern in developing nations (Yao et al., 2019). Population growth is one of the factors driving the rise in urban waste production (Triassi et al., 2023). The urban population in developing countries is rapidly expanding, making urban waste one of the foremost challenges (Sharma and Jain, 2020). Among other factors contributing to increased waste production in urban areas, we can mention the need for more awareness among citizens about the importance of proper waste management, neglecting recycling materials, and disposing of them in nature (Zhang et al., 2010).

Neglecting the factors influencing waste collection and urban waste management can result in hazardous substances permeating communities, triggering explosions, and endangering human health and the environment (Ali et al., 2014). Moreover, disregarding waste and urban waste management can lead to resource depletion (Liu et al., 2015), hinder sustainable urban growth (Golroudbary and Zahraee, 2015), diminish the city's appeal to tourists (Pinha & Sagawa, 2020), and more.

Nowadays, waste and urban waste management are significant challenges in the country's major cities, such as Isfahan. Over recent years, waste generation has surged due to the population increase in Isfahan, negatively impacting the city's appearance and cleanliness. The growing waste production has also contributed to environmental pollution, leading to dissatisfaction among Isfahan's residents. Furthermore, the surge in waste production has resulted in the loss of valuable natural resources that could be conserved through recycling, ensuring their availability for future generations.

Due to the significance of urban waste and its impact on societal health, citizen satisfaction, the aesthetics of the city, and more, numerous studies have been undertaken in this field by researchers in recent years. These studies encompass a range of topics in urban waste management, including waste generation (Zanjani et al., 2012), identification and categorization of urban waste, waste segregation (Wang and Yu, 2021), methods and processes related to disposal and incineration (Magnanelli et al., 2020) and the role of urban waste management in preserving and sustaining resources and energy (Zhang et al., 2023). Additionally, attention has been given to the role of advanced technologies in waste volume reduction and proper management, among other areas. While most of these studies have focused on waste classification, recycling, and effective urban waste management outcomes, more have yet to concentrate on proposing viable solutions for reducing waste production and its associated consequences. Recognizing the existing research gap and the growing issue of increasing waste volumes in Isfahan, this research aims to present a systematic and comprehensive approach. It employs a system dynamics model to predict urban waste quantities and devise suitable waste volume reduction solutions, promoting and enhancing sustainable urban development and resource conservation.

2. Literature review

Urban waste inevitably impacts societies and nations, particularly in achieving environmentally sustainable lifestyles (Przydatek, 2020). Introducing effective waste management methods encompassing collection, recycling, and proper disposal is not only necessary but also vital (Tsoulfas and Pappis, 2006). Urban solid waste poses a significant environmental challenge within urban regions (Batool and Ch, 2009). Improper waste management releases greenhouse gases into the atmosphere (Rai et al., 2019) and impedes maintaining clean and aesthetically pleasing cities (Ferronato and Torretta, 2019). Mismanagement of waste and urban refuse contaminates soil, water, and air (Koda et al., 2016), potentially adversely impacting public health (Seo et al., 2004).

Moreover, activities related to waste and urban refuse management, such as incineration (Boldrin et al., 2009) and landfilling (Figueroa et al., 2009), release greenhouse gases, including methane, nitrogen oxide, and carbon dioxide into the atmosphere (Mohareb et al., 2008). Additionally, uncontrolled waste accumulation can obstruct drainage systems (Rowe et al., 2000), contributing to flooding and waste entry into urban water bodies (Pervin et al., 2020). Municipal waste management poses a significant challenge for local authorities (Yukalang et al., 2018) owing to the exponential growth in waste volume alongside urban population expansion (Jha et al., 2013).

Triassi et al. (2023) conducted a study to assess residual solid waste composition in rural and urban areas to optimize the waste management system. The study revealed that the highest proportion of organic waste was found in rural areas, accounting for 11.9%. Additionally, the study results indicated that plastic and paper collectively constitute approximately 50% of urban waste in Italy. The study conducted by Moreno Solaz et al. (2023) focuses on prioritizing action plans to achieve better resource savings and improved performance of key indicators in urban solid waste management. The research aims to identify and evaluate effective measures for properly managing urban waste, particularly to optimize financial resources. In a study, Mariyam et al. (2022) conducted a systematic review to enhance the waste management system in Qatar. The research findings revealed that food, plastic, and electronic waste constitute the primary types of waste generated in the country.

Furthermore, the study demonstrated that the attention and support of managers, as well as the awareness of employees regarding waste management processes and methods, significantly contribute to the reduction of waste production. In a study, Ferronato et al. (2021) evaluated urban solid waste collection in Bolivia to prevent unregulated disposal and enhance recycling efforts. The model outcomes could reduce household waste collection costs and capitalize on the economic and environmental advantages of recycling. Afshar et al. (2021) analyzed factors influencing social engagement in urban waste management. The findings highlighted the paramount importance of social, economic, educational, and cultural aspects and legal frameworks. Among social factors, lifestyle, and dietary patterns were of great significance. Valizadeh (2020) presented a mathematical model for waste collection and energy generation in Kermanshah. The proposed model minimizes costs and optimizes revenue through recycled materials and energy production. Bányai et al. (2019) explored urban waste routing optimization and the influence of Industry 4.0 technologies on environmental awareness and sustainability. This research aimed to allocate waste resources optimally to waste trucks, minimizing operational costs and enhancing reliability. Ogundele et al. (2018) investigated the effects of urban waste disposal methods on community health, revealing that improper management leads to health issues such as skin infections, sore throats, abdominal pain, and typhoid. Nnaji (2015) assessed municipal solid waste production and disposal in Nigeria, showing that food waste constitutes around 50% of municipal waste. This study highlighted the rising trend in plastic, waterproof materials, and diaper waste. Due to inefficient waste management authorities, many cities grapple with open waste dumping, with over 50% of people in parts of Nigeria resorting to free waste disposal. This indiscriminate disposal has resulted in the prevalence of toxic heavy metals in agricultural soils, leading to bioaccumulation in plants and groundwater pollution.

3. Research method

This study adopts a descriptive-causal approach for its applied purpose and employs a survey method for data collection. The study's statistical population consists of experts and administrators of Isfahan Municipality, selected through the snowball sampling method, totalling 32 individuals. Information and documents available within Isfahan Municipality related to various investigated variables have been utilized to gather the necessary data.

In tackling issues concerning urban waste volume, this study employs the system dynamics approach. System dynamics was introduced by J. Wright Forrester in 1960 to address industrial challenges (Forrester, 1961). It is valuable in addressing linear and nonlinear interactions within large-scale, intricate, and dynamic systems (Kollikkathara et al., 2010). The system dynamics model comprehensively analyzes the structure, interactions, and behavior of complex systems, evaluating and forecasting their effects in an integrated manner (Jung, 2017). System dynamics aims to identify system variables and their temporal interplay (Wolstenholme, 1990). This approach adeptly handles the configuration assumptions and dynamic structures of systems, enabling the management of changes within subsystems and interrelationships across the complete system (Sukholthaman and Sharp, 2016).

System dynamics is a technique for analyzing intricate systems over time, facilitated by computer simulation software (Richardson and Otto, 2008a). Variables are perceived as system components interconnected through mathematical mappings established by differential equations, which are numerically solved via simulation (Kunc, 2017). The process of this research is outlined in Figure 1.

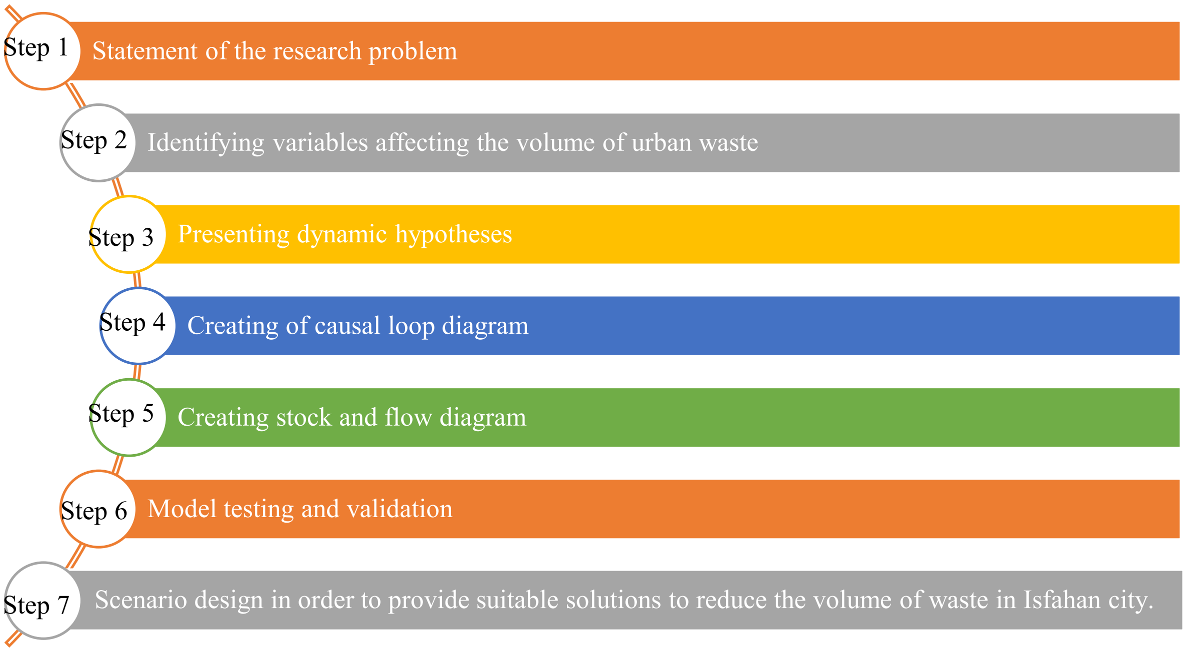

Figure 1. Research implementation steps

As shown in Figure 1, the research began by identifying the variables influencing the quantity of waste and urban refuse. These variables were identified based on existing studies in the field. Next, dynamic hypotheses were formulated grounded in the relationships established within the research context. Dynamic hypotheses represent robust theories that explain the causes and mechanisms underlying observed behaviors. After defining the dynamic hypotheses, the model's boundary diagram is designed. A model boundary diagram delineates the model's scope by listing the indigenous and exogenous variables and variables that are not included in the model. Next, a causal loop diagram was constructed, encompassing the identified variables. This diagram serves as a fundamental tool for illustrating the feedback structure of the system. It aids in formulating both system dynamic models and the mental models of developers (Sterman, 2000). Each causal link within the diagram is attributed to either a positive or negative sign. A positive sign signifies that the variables' changes align in the same direction, while a negative sign indicates opposing changes (Yao et al., 2018). After constructing the causal loop diagram, the stock and flow diagram is utilized to formulate relationships between the variables under study. It enables the examination of the system's behavior over time. Ultimately, the constructed stock and flow diagram has been evaluated through various tests, and different scenarios have been explored to investigate ways of reducing waste in the city of Isfahan.

4. The proposed model

Combining insights from research literature and input from experts and managers in Isfahan Municipality, the interrelationships among the identified variables were explored, constructing a cause-and-effect diagram.

4.1. Dynamic hypothesis

The dynamic hypothesis is a conceptual model proposed by the researcher based on the key variables of the problem. It involves drawing basic reinforcing and balancing loops using the main variables, facilitating reasoning and knowledge extraction from the expanded model. The dynamic hypothesis serves as a crucial starting point for model conceptualization. One of the main advantages of the dynamic hypothesis is that it enhances readers' understanding of the model's complexity. The verbal description of the dynamic hypothesis for this problem, using signals H1 through H5, is as follows:

H1: Investment in waste collection has a positive impact on waste collection performance.
H2: Waste collection performance has an impact on the volume of waste.
H3: Volume of waste has an impact on saving resources.
H4: Save resources have an impact on sustainable urban growth.
H5: Sustainable urban growth has an impact on the beauty of the city.
The dynamic hypothesis of the problem under study is depicted in Figure 2 below.

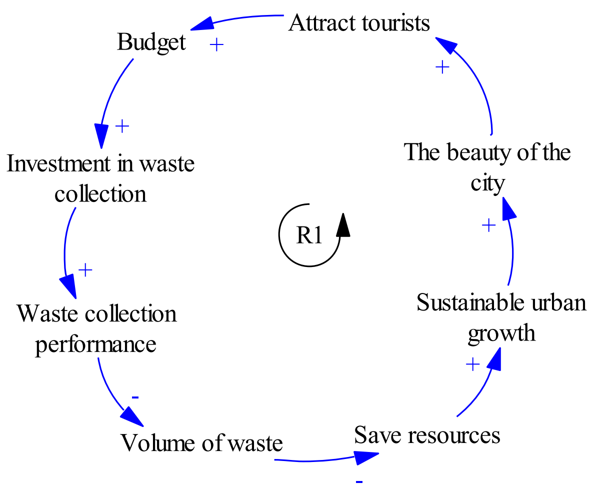

Figure 2. The feedback loop

As depicted in Figure 2, a positive feedback loop has been established. The efficiency of waste collection is enhanced through the allocation of funds for investments in waste collection, including procuring equipment, transportation means, hiring personnel, and covering salaries. The heightened performance in waste collection leads to a reduction in the volume of waste within Isfahan. Consequently, the conservation of resources and their efficient utilization is promoted. As resources are preserved and managed efficiently, the prospects of sustainable growth and resource availability for future generations are amplified. Furthermore, preserving the city's aesthetic appeal is upheld due to reduced pollution safeguarding recreational and historical sites from damage. The improved attractiveness and beauty of Isfahan foster increased tourist engagement, ultimately contributing to an augmented budget for Isfahan.

4.2. System's boundary diagram

After analyzing the dynamic hypotheses, these have proceeded to create the boundary diagram of the model and identify the indigenous and exogenous variables. The findings of this examination are summarized in Table 1.

Table 1. Classification of factors into indigenous and exogenous factors

NO	Factors		References
1	Indigenous factors	Volume of waste	(Fadda et al., 2018; Kumar et al., 2017)
2		Waste production	(Leal Filhoet al., 2016; Sufian and Bala, 2007)
3		Waste collection equipment	(Mbina and Edem, 2015)
4		Environmental pollution	(Chen et al., 2010; Mian et al., 2017; Tirkolaee et al., 2020)
5		Population	(Kumar and Agrawal, 2020)
6		Quality of Life	(Zorpas, 2020)
7		Investment in waste collection	(Jouhara et al., 2017; Vassanadumrongdee and Kittipongvises, 2018)
8		Advertising	(Romano et al., 2022; Xiao et al., 2017)
9		People's awareness	(Almulhim, 2022)
10		Budget	(Anuardo et al., 2022)
11		Attract tourists	(Anuardo et al., 2022; Ridho et al., 2023)
12		The beauty of the city	(Fidowaty et al., 2022)
13		Sustainable urban growth	(Abubakar et al., 2022; Chen et al., 2022)
14		General health	(Adeniran and Shakantu, 2022)
15		Citizen satisfaction	(Corrente et al., 2023)
16		Save resources	(Nelles et al., 2016; Tutunchian and Altınbaş, 2023)
17	Exogenous factors	Citizen cooperation	(Rodić and Wilson, 2017)
18		Citizen culture	(Almasi et al., 2019; Rodić and Wilson, 2017)

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4.3. Causal loop diagram

According to the determination of dynamic hypotheses and the identification of indigenous and exogenous variables of the model, the causal loop diagram is shown in Figure 3.

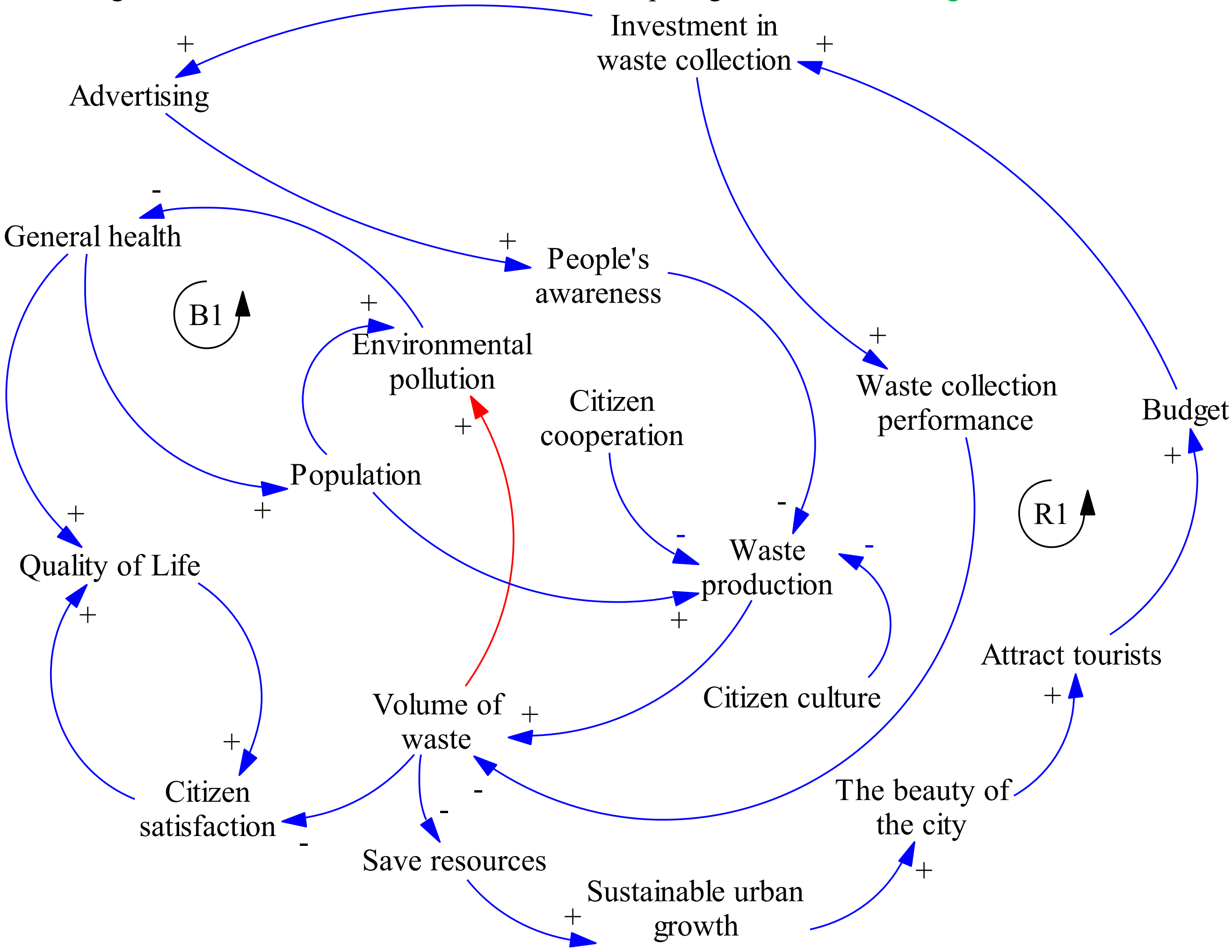

Figure 3. Causal loop diagram

4.4. Stock and flow diagram

After creating the causal loop diagram, the stock and flow diagram has developed by establishing relationships and mathematical equations among the variables under investigation. In the appendix, we outline several key relationships among variables in the current research. In Figure 4, the stock and flow diagram are drawn.

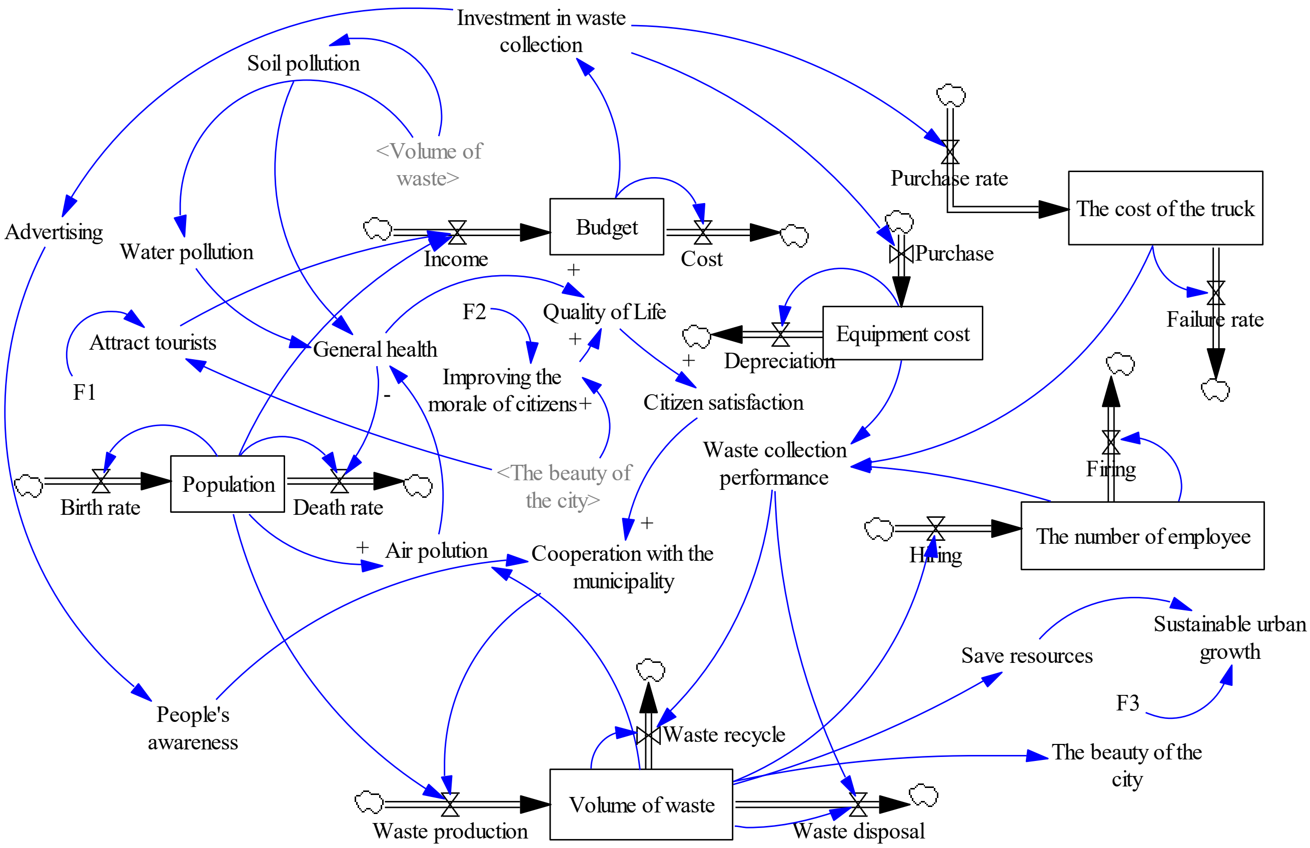

Figure 4. Stock and flow diagram

The presented diagram illustrates the interactions of Volume of waste and forms the foundation for constructing a quantitative model. The development of the stock and flow diagram involved utilizing quantitative and qualitative relationships and numerical functions. The stock and flow diagram, as demonstrated in Figure 4, encompasses a total of 35 variables, out of which six are stock variables. A 10-year timeframe was chosen, evaluated, and analyzed at 12-month intervals to imitate the study.

5. Model validation

The model's validation process is conducted in three phases, as outlined below.

5.1. Model structure evaluation test

This evaluation aims to align the model's structure with the existing knowledge within the system. In this research, urban waste management was initially identified based on the research context and subsequently refined through insights from experts and administrators in Isfahan. Ultimately, the structure of the designed model was validated by incorporating the feedback and opinions of Isfahan's experts and administrators.

5.2. Parameter evaluation test

The parameter evaluation test ensures the congruence between parameter values and their counterparts. Since the variables in this study were derived from the research context, related literature, Isfahan Municipality's documents, and expert opinions, the values align with those presented in pertinent documents and research.

5.3. The limit condition test

The assessment was conducted to evaluate the logical behavior of model variables under extreme scenariosIn this test, the value of a specific model variable gradually decreases toward zero while observing the resulting behavior of other variables that are influenced by the changed variable. For this research, the income variable has been selected to be reduced to zero, and the subsequent behavior of certain impactful variables from the budget is illustrated in Figure 5.

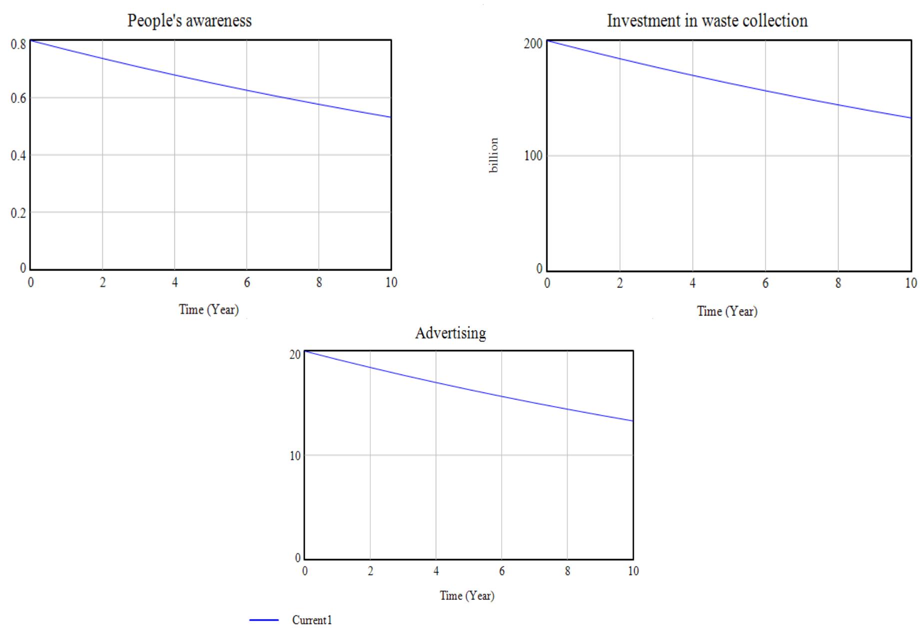

Figure 5. Model testing and validation

As shown in Figure 5, if the income amount approaches zero, the waste collection, advertising, and public awareness investment will gradually diminish over time. It demonstrates how changes in income can directly impact the allocation of resources towards waste management activities and initiatives.

5.4. Behavior reproduction test

In order to verify the correctness of the model's behavior, this test will compare the simulation results with actual data. The figures' findings demonstrate how well the researched variable may be replicated. The results are shown in Figure 6.

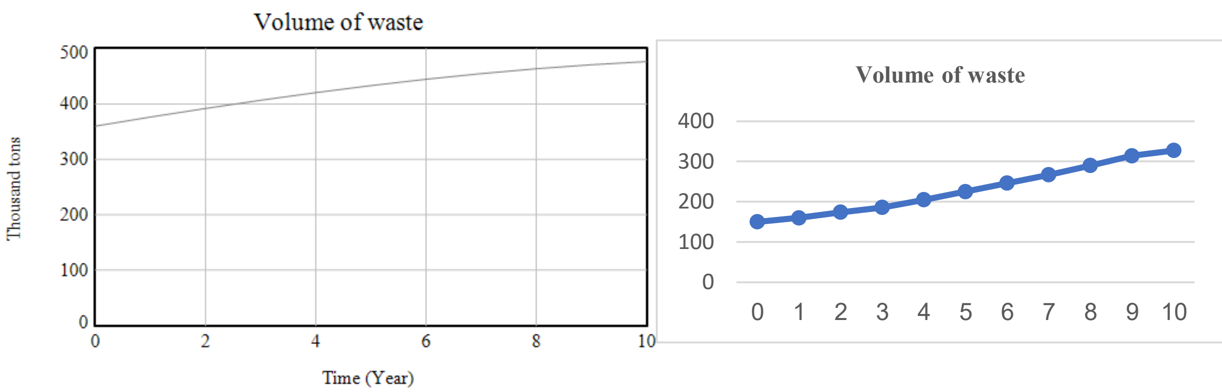

Figure 6. Comparison test with reference behaviour

6. Simulation results

The model has produced the following results as a consequence of the behavior of the key factors and key indicators in the volume of waste by the relationships between the model's variables that were indicated.

6.1. Implementation and evaluation of policies

This section presents the simulation results and analysis of three carefully designed scenarios. It is worth noting that in this research, three specific scenarios are developed: one that increases investment allocation in the equipment sector, another that enhances investment in advertising to boost people's awareness of waste management and urban waste, and a third scenario that simultaneously increases investments in both advertising and equipment.

6.1.1. The policy of increases investment allocation in the equipment sector

Figure 7 illustrates the behaviors of variables associated with waste volume when there is an increase in investment in the equipment sector for waste collection.

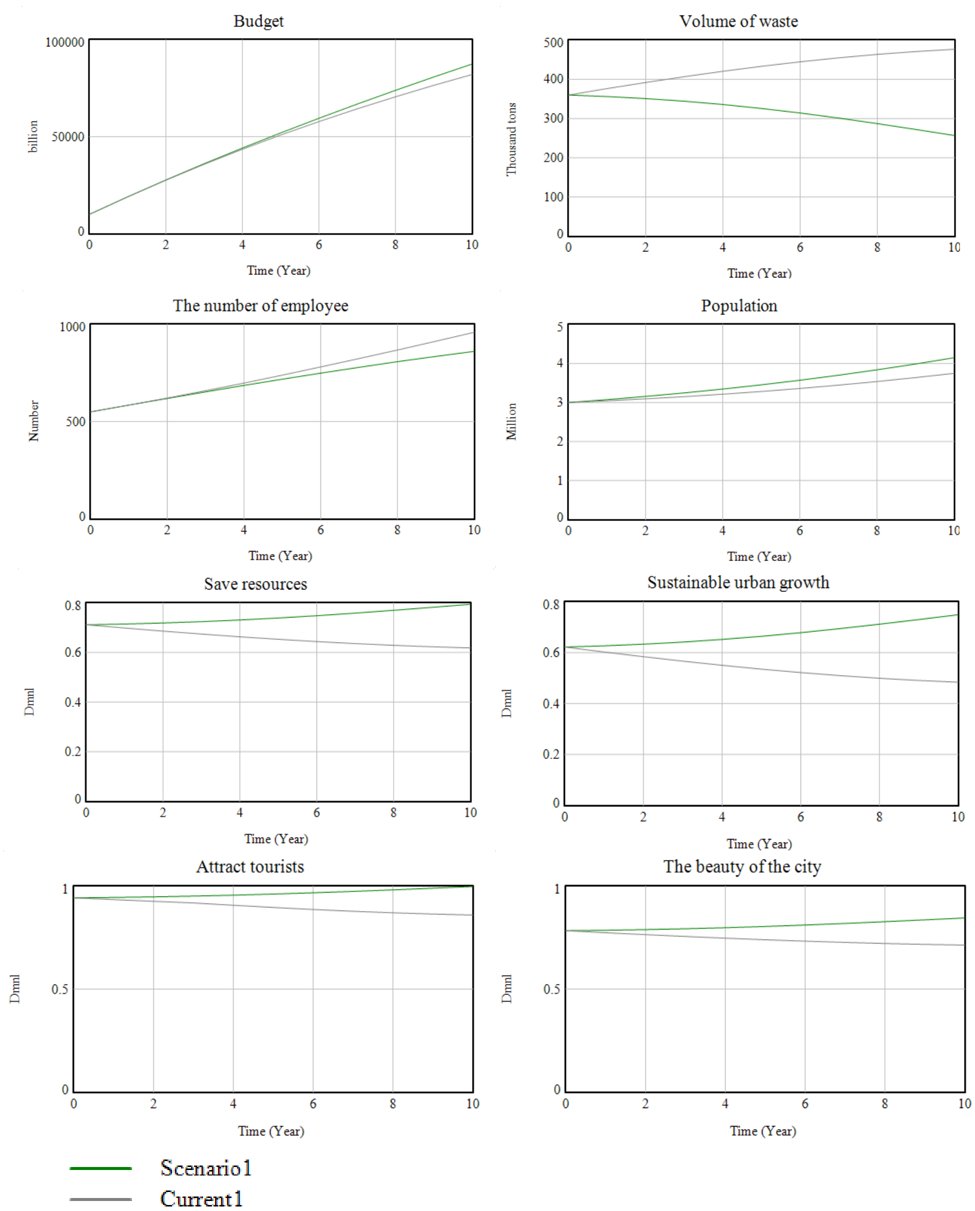

Figure 7. Result of policy of increases investment allocation in the equipment sector

Figure 7 shows that the amount of urban waste in Isfahan will gradually decrease as investment in the sector of waste collection equipment rises. Consequently, the demand for employees in waste collection will decrease gradually, leading to increased budget allocation due to reduced investment needs in the waste collection sector. Moreover, the increased investment in the equipment sector for waste collection and pollution reduction is a foundation for enhancing public health. As a result, the mortality rate due to environmental pollution will decrease over time, fostering population growth. Furthermore, the outcomes of increased investment in waste collection equipment indicate that other aspects will also witness improvement. These include the storage and sustainability of resources, the aesthetics of the city, and the attraction of tourists.

6.1.2. The policy of increases investment allocation in advertising

Figure 8 illustrates the behaviors of variables associated with waste volume when there is an increase in investment in advertising.

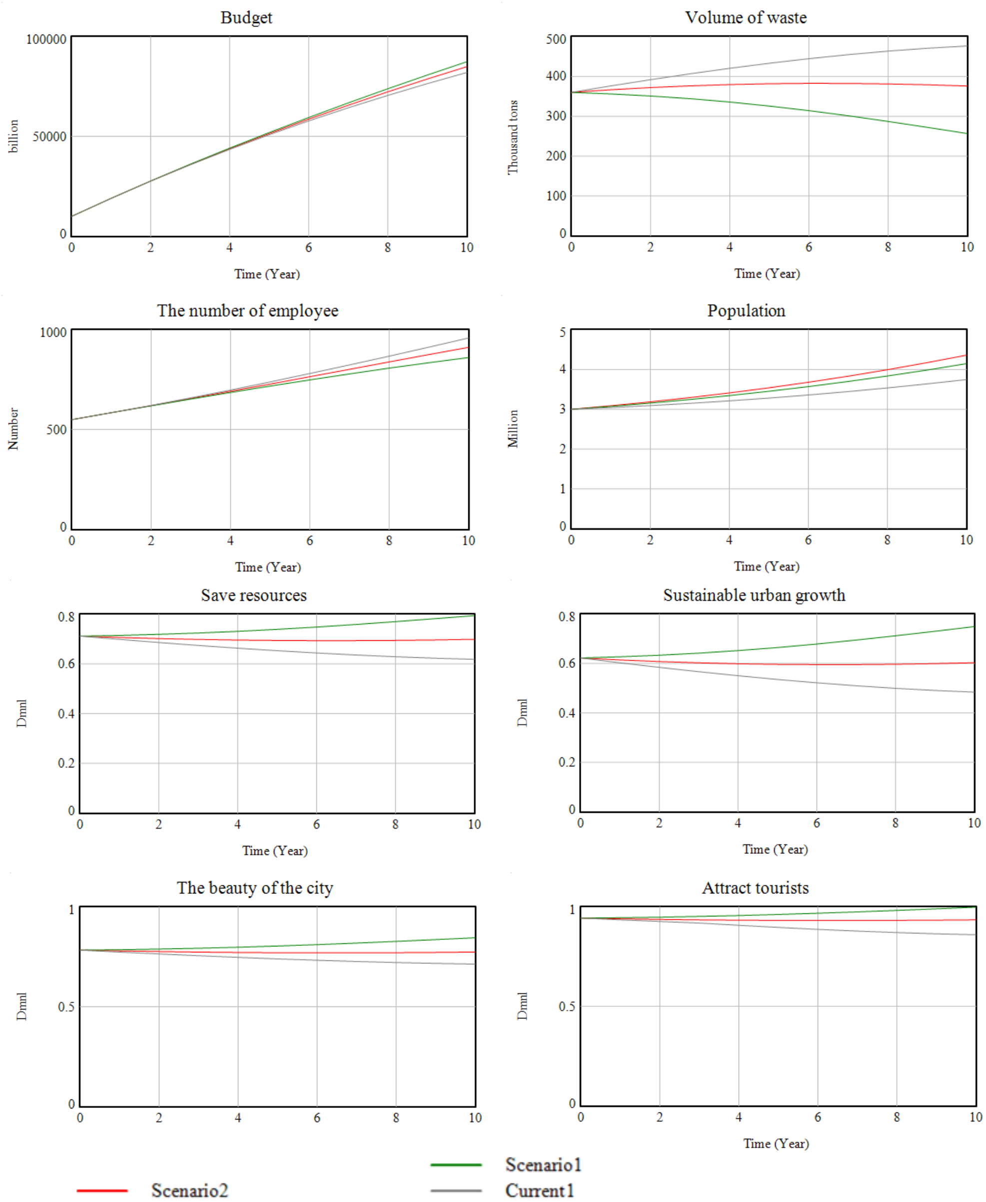

Figure 8. Result of policy of increases investment in advertising

According to Figure 8, increased advertising investment reduces waste volume and requires employees. Additionally, increased investment in advertising and citizens' awareness of the waste disposal process results in an increased budget allocation for waste collection. It is due to citizens' compliance and improved waste production practices. Moreover, reducing waste production and pollution will contribute to population growth. Furthermore, increasing the investment in advertising improves resources and sustainability, enhances the city's beauty, and attracts more tourists.

6.1.3. The policy of increases investment allocation in the equipment sector and advertising simultaneously

Figure 9 illustrates the behaviors of variables associated with waste volume when there is a simultaneous increase in investment in the equipment sector for waste collection and advertising.

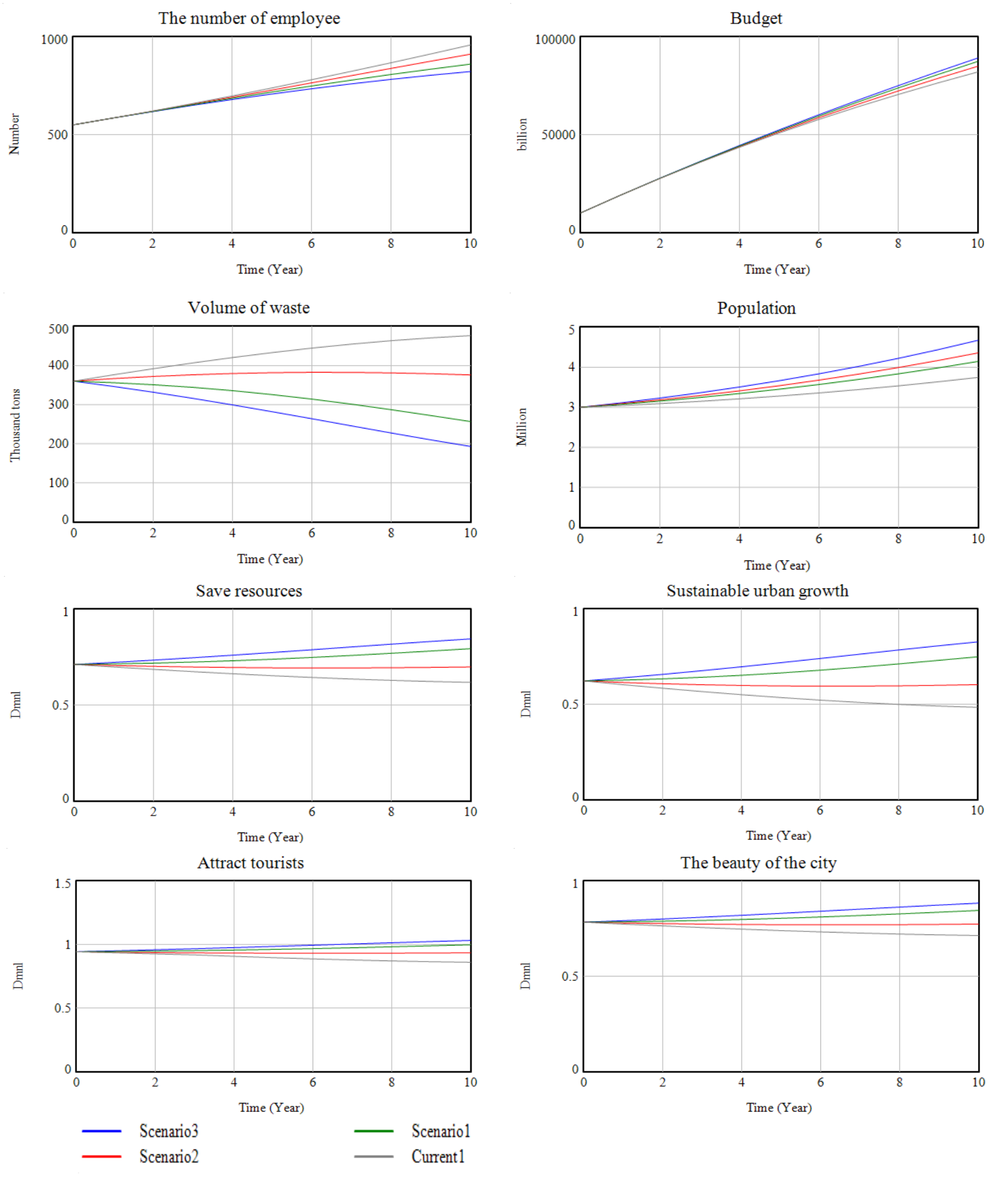

Figure 9. Result of policy of increases investment allocation in the equipment sector and advertising simultaneously

As shown in Figure 9, the simulation results indicate that increasing the investment allocation for waste collection equipment and advertising initiatives in Isfahan decreases the urban waste volume and the required employees while bolstering the budget. Furthermore, the behavior of city beauty, population, saving resources, urban sustainable growth, and tourist attraction variables is investigated. Furthermore, the simultaneous increase in investment in equipment and advertising will result in significant growth and improvement in various aspects. It includes the population, the beauty of the city, the saving and sustainability of resources, and the attraction of tourists.

7. Discussion

In today's world, effective urban waste management holds significant importance for various societies. Neglecting waste management and urban conditions can have numerous consequences, including escalated environmental pollution and compromised citizen health. Additionally, it can diminish the beauty of the city and attractiveness, resulting in citizen dissatisfaction, resource depletion, and a decline in tourist attraction, among other issues.

This research aims to develop a simulation model that predicts the volume of urban waste in Isfahan over the next ten years and assesses its consequences. In order to achieve this goal, the research literature was analyzed to identify the factors influencing the volume of urban waste. Subsequently, the identified factors were adapted to the local context of Isfahan through the valuable insights of experts and administrators. The research investigated the dynamics and behavior of each identified factor in urban waste management through the system dynamics approach.

The outcomes of the system dynamics simulation revealed that the growth of Isfahan's population in the upcoming years will increase both the quantity and volume of waste generated within the city. This rise in urban waste volume poses a threat, leading to the wastage of valuable and reusable materials such as metals, glass, plastic, and others, which could otherwise be recycled, thus conserving resources. In essence, the surge in urban waste will diminish the resource-saving rate and ultimately impact the sustainability of resources for future generations. This research finding aligns with the conclusions drawn from Lehmann's (2011) and Frata et al.'s (2019) studies. On the other hand, the rise in urban waste volume impacts the population growth rate. In other words, as the volume of waste increases, population growth is expected to occur at a lower rate in the coming years due to the amplified pollution and the resulting increase in deaths caused by the waste produced.

Additionally, the rise in urban waste volume impacts the population growth rate. In other words, as the volume of waste increases, population growth is projected to occur slower in the forthcoming years. It is attributed to the elevated pollution levels and associated health issues resulting from the increased waste production, which can lead to increased mortality rates.

Furthermore, the escalating urban waste levels in Isfahan have negatively impacted the city's attractiveness and aesthetics. It triggers dissatisfaction among citizens regarding the municipality's performance and diminishes the city's appeal as a tourist destination. Consequently, it can lead to a decline in the number of tourists visiting the city.

In this research, three scenarios have been proposed to offer viable solutions for reducing waste in Isfahan. The findings of the first scenario indicate that allocating the budget towards waste collection equipment, such as containers and automated separation devices, as well as safety and health equipment, like gloves, masks, and disinfectants, along with implementing management software, will result in an improvement in waste collection performance. The urban waste could be reduced through effective recycling and proper disposal methods. This finding aligns with Santos et al.'s (2022) research. Moreover, increasing investments in equipment will contribute to the city's aesthetics, resource conservation, urban sustainability, tourist attraction, budget enhancement, and population growth by reducing environmental pollution and mortality rates.

The findings of the second scenario in this research reveal that allocating a higher budget for advertising efforts aimed at raising citizens' awareness about waste and urban waste management can effectively reduce both individual waste generation and the overall waste volume in Isfahan. Several positive outcomes can be achieved by increasing citizens' understanding of waste management. These include enhancing the city's beauty, reducing the need for additional employees, improving resources by avoiding the disposal of recyclable and reusable containers, ensuring resource sustainability, and ultimately attracting more tourists. Moreover, this scenario highlights other notable results, such as an increased municipal budget due to reduced waste collection costs and enhanced tourist attraction. These findings are consistent with the findings of (Magazzino et al., 2020).

Comparatively, the first scenario's investment in waste collection equipment holds a more pronounced effect on reducing urban waste volume. It underscores the pivotal role of equipping the city with ample containers, employing waste management software, and automating waste separation processes. However, it is imperative to acknowledge that citizen awareness still significantly influences waste volume, as demonstrated by the second scenario. The analysis demonstrates that investing in waste collection equipment tends to have a more substantial impact than advertising initiatives for enhancing citizen awareness.

The third scenario encapsulates the most comprehensive approach. Simultaneously directing resources towards advertising and equipment, Isfahan municipality can substantially reduce urban waste volume. This integrated approach enhances awareness and triggers notable improvements in variables such as city aesthetics, resource conservation, urban sustainability, tourist attraction, and budget allocation compared to the first two scenarios. The steeper slope over ten years illustrates the potential for more significant improvements in this holistic approach.

This research underscores the contemporary significance of effective urban waste management. It illuminates the potential consequences of neglecting waste management and offers actionable scenarios to mitigate waste volume. By emphasizing investment in equipment and raising citizen awareness, Isfahan can better manage its waste and engender positive transformations across various urban facets.

8. Conclusion

This research employed the system dynamics approach to develop an effective model for optimizing waste and urban waste management in Isfahan. The study commenced by identifying the variables influencing waste volume through an extensive review of the literature and research background. These factors were refined and localized by integrating insights from experts and city administrators in Isfahan. Subsequently, dynamic hypotheses and causal loop diagrams were constructed based on the amalgamation of literature findings and expert opinions.

The study developed a stock and flow diagram by designing the causal loop diagram, delving into the quantitative relationships among the identified variables. The research established a comprehensive framework to curtail waste volume in Isfahan by formulating various scenarios. The research outcomes indicated that waste production and volume could be effectively controlled within the city while enhancing resource conservation and sustainability growth.

It is recommended that future research extend the scope beyond the factors examined in this study. It could encompass investigating additional aspects, such as the impact of immigration on waste production, considering waste generated by newcomers, and analyzing the potential role of government assistance in aiding the municipality's waste control efforts. By expanding the research focus, a more holistic understanding of waste management dynamics can be attained, enabling the development of even more comprehensive strategies.

Disclosure statement

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

References

Abubakar, I.R., Maniruzzaman, K.M., Dano, U.L., AlShihri, F.S., AlShammari, M.S., Ahmed, S.M.S., Al-Gehlani, W.A.G. and Alrawaf, T.I., 2022. Environmental sustainability impacts of solid waste management practices in the global South. *International Journal of Environmental Research and Public Health*, *19*(19), p.12717. https://doi.org/10.3390/ijerph191912717.

Adeniran, A.A. and Shakantu, W., 2022. The health and environmental impact of plastic waste disposal in South African Townships: A review. *International Journal of Environmental Research and Public Health*, *19*(2), p.779. https://doi.org/10.3390/ijerph19020779.

Afshar, F., Abbaspour, M., Lahijanian, A.A.M. and Azizinezhad, R., 2021. Analysis of Factors Affecting Social Participation in Municipal Waste Management. *Environmental Energy and Economic Research*, *5*(1), pp.1-19. https://doi.org/10.22097/eeer.2020.245299.1168.

Ali, S.M., Pervaiz, A., Afzal, B., Hamid, N. and Yasmin, A., 2014. Open dumping of municipal solid waste and its hazardous impacts on soil and vegetation diversity at waste dumping sites of Islamabad city. *Journal of King Saud University-Science*, *26*(1), pp.59-65. https://doi.org/10.1016/j.jksus.2013.08.003.

Almasi, A., Mohammadi, M., Azizi, A., Berizi, Z., Shamsi, K., Shahbazi, A. and Mosavi, S.A., 2019. Assessing the knowledge, attitude and practice of the kermanshahi women towards reducing, recycling and reusing of municipal solid waste. *Resources, Conservation and Recycling*, *141*, pp.329-338. https://doi.org/10.1016/j.resconrec.2018.10.017.

Almulhim, A.I., 2022. Household's awareness and participation in sustainable electronic waste management practices in Saudi Arabia. *Ain Shams Engineering Journal*, *13*(4), p.101729. https://doi.org/10.1016/j.asej.2022.101729.

Arifin, M.H., Kayode, J.S., Ismail, M.K.I., Abdullah, A.M., Embrandiri, A., Nazer, N.S.M. and Azmi, A., 2021. A novel method for the quantification of industrial and municipal waste materials for environmental hazard assessment. *MethodsX*, *8*, p.101182. https://doi.org/10.1016/j.mex.2020.101182.

Anuardo, R.G., Espuny, M., Costa, A.C.F. and Oliveira, O.J., 2022. Toward a cleaner and more sustainable world: A framework to develop and improve waste management through organizations, governments and academia. *Heliyon*, *8*(4). https://doi.org/10.1016/j.heliyon.2022.e09225.

Bányai, T., Tamás, P., Illés, B., Stankevičiūtė, Ž. and Bányai, Á., 2019. Optimization of municipal waste collection routing: Impact of industry 4.0 technologies on environmental awareness and sustainability. *International journal of environmental research and public health*, *16*(4), p.634. https://doi.org/10.3390/ijerph16040634.

Batool, S.A. and Ch, M.N., 2009. Municipal solid waste management in Lahore city district, Pakistan. *Waste management*, *29*(6), pp.1971-1981. https://doi.org/10.1016/j.wasman.2008.12.016.

Beyene, H.D., Werkneh, A.A. and Ambaye, T.G., 2018. Current updates on waste to energy (WtE) technologies: a review. *Renewable Energy Focus*, *24*, pp.1-11. https://doi.org/10.1016/j.ref.2017.11.001.

Boldrin, A., Andersen, J.K., Møller, J., Christensen, T.H. and Favoino, E., 2009. Composting and compost utilization: accounting of greenhouse gases and global warming contributions. *Waste Management & Research*, *27*(8), pp.800-812. https://doi/abs/10.1177/0734242x09345275.

Chen, W., Wang, Y., Ren, Y., Yan, H. and Shen, C., 2022. A novel methodology (WM-TCM) for urban health examination: A case study of Wuhan in China. *Ecological Indicators*, *136*, p.108602. https://doi.org/10.1016/j.ecolind.2022.108602.

Chen, X., Geng, Y. and Fujita, T., 2010. An overview of municipal solid waste management in China. *Waste management*, *30*(4), pp.716-724. https://doi.org/10.1016/j.wasman.2009.10.011.

Corrente, S., Ingrao, C., Punzo, A. and Matarazzo, A., 2023. Evaluating citizens' satisfaction on the urban environmental management through a multi-criteria approach: An application experience in Sicily. *Environmental Impact Assessment Review*, *99*, p.107029. https://doi.org/10.1016/j.eiar.2022.107029.

Crutchik, D., Barboza, J., Vázquez-Padín, J.R., Pedrouso, A., Del Río, Á.V., Mosquera-Corral, A. and Campos, J.L., 2023. Integrating food waste management into urban wastewater treatment: Economic and environmental impacts. *Journal of environmental management*, *345*, p.118517. https://doi.org/10.1016/j.jenvman.2023.118517.

Das, S., Lee, S.H., Kumar, P., Kim, K.H., Lee, S.S. and Bhattacharya, S.S., 2019. Solid waste management: Scope and the challenge of sustainability. *Journal of cleaner production*, *228*, pp.658-678. https://doi.org/10.1016/j.jclepro.2019.04.323.

Fadda, E., Gobbato, L., Perboli, G., Rosano, M. and Tadei, R., 2018. Waste collection in urban areas: A case study. *Interfaces*, *48*(4), pp.307-322. https://doi.org/10.1287/inte.2018.0943.

Ferronato, N., Alarcón, G.P.P., Lizarazu, E.G.G. and Torretta, V., 2021. Assessment of municipal solid waste collection in Bolivia: Perspectives for avoiding uncontrolled disposal and boosting waste recycling options. *Resources, Conservation and Recycling*, *167*, p.105234. https://doi.org/10.1016/j.resconrec.2020.105234.

Fidowaty, T., Wulantika, L. and Mulyana, A., 2022. Waste Management Based on Smart City Management by Using Internet of Things (IoT) and Artificial Intelligence (AI) Technology. *ABDIMAS: Jurnal Pengabdian Masyarakat*, *5*(1), pp.1756-1762. https://doi.org/10.35568/abdimas.v5i1.1763 .

Figueroa, V.K., Mackie, K.R., Guarriello, N. and Cooper, C.D., 2009. A robust method for estimating landfill methane emissions. *Journal of the Air & Waste Management Association*, *59*(8), pp.925-935. https://doi.org/10.3155/1047-3289.59.8.925.

Forrester, J.W. and Brink, H.M., 1961. *Industrial Dynamics*, MITPress. Cambridge, MA.

Fratta, K.D.D.S.A., Toneli, J.T.D.C.L. and Antonio, G.C., 2019. Diagnosis of the management of solid urban waste of the municipalities of ABC Paulista of Brasil through the application of sustainability indicators. *Waste Management*, *85*, pp.11-17. https://doi.org/10.1016/j.wasman.2018.12.001.

Golroudbary, S.R. and Zahraee, S.M., 2015. System dynamics model for optimizing the recycling and collection of waste material in a closed-loop supply chain. *Simulation modelling practice and theory*, *53*, pp.88-102. https://doi.org/10.1016/j.simpat.2015.02.001.

Hosseinalizadeh, R., Izadbakhsh, H. and Shakouri, H., 2021. A planning model for using municipal solid waste management technologies-considering Energy, Economic, and Environmental Impacts in Tehran-Iran. *Sustainable Cities and Society*, *65*, p.102566. https://doi.org/10.1016/j.scs.2020.102566.

Jaligot, R. and Chenal, J., 2018. Decoupling municipal solid waste generation and economic growth in the canton of Vaud, Switzerland. *Resources, Conservation and Recycling*, *130*, pp.260-266. https://doi.org/10.1016/j.resconrec.2017.12.014

Jha, A.K., Sharma, C., Singh, N., Ramesh, R., Purvaja, R. and Gupta, P.K., 2008. Greenhouse gas emissions from municipal solid waste management in Indian mega-cities: A case study of Chennai landfill sites. *Chemosphere*, *71*(4), pp.750-758. https://doi.org/10.1016/j.chemosphere.2007.10.024.

Jouhara, H., Czajczyńska, D., Ghazal, H., Krzyżyńska, R., Anguilano, L., Reynolds, A.J. and Spencer, N., 2017. Municipal waste management systems for domestic use. *Energy*, *139*, pp.485-506. https://doi.org/10.1016/j.energy.2017.07.162.

Jung, J.U., 2017. Reducing Subjectivity in the System Dynamics Modeling Process: An Interdisciplinary Approach. In *Intelligent Data Engineering and Automated Learning–IDEAL 2017: 18th International Conference, Guilin, China, October 30–November 1, 2017, Proceedings 18*,pp. 365-375.Springer, Cham. https://doi.org/10.1007/978-3-319-68935-7_40.

Karak, T., Bhagat, R.M. and Bhattacharyya, P., 2012. Municipal solid waste generation, composition, and management: the world scenario. *Critical Reviews in Environmental Science and Technology*, *42*(15), pp.1509-1630. https://doi.org/10.1080/10643389.2011.569871.

Koda, E., Sieczka, A. and Osinski, P., 2016. Ammonium concentration and migration in groundwater in the vicinity of waste management site located in the neighborhood of protected areas of Warsaw, Poland. *Sustainability*, *8*(12), p.1253. https://doi.org/10.3390/su8121253.

Kollikkathara, N., Feng, H. and Yu, D., 2010. A system dynamic modeling approach for evaluating municipal solid waste generation, landfill capacity and related cost management issues. *Waste management*, *30*(11), pp.2194-2203. https://doi.org/10.1016/j.wasman.2010.05.012.

Kumar, A. and Agrawal, A., 2020. Recent trends in solid waste management status, challenges, and potential for the future Indian cities–A review. *Current Research in Environmental Sustainability*, *2*, p.100011. https://doi.org/10.1016/j.crsust.2020.100011.

Kumar, S., Smith, S.R., Fowler, G., Velis, C., Kumar, S.J., Arya, S., Rena, Kumar, R. and Cheeseman, C., 2017. Challenges and opportunities associated with waste management in India. *Royal Society open science*, *4*(3), p.160764. https://doi.org/10.1098/rsos.160764.

Kunc, M., 2017, December. System dynamics: A soft and hard approach to modelling. In *2017 Winter Simulation Conference (WSC)* (pp. 597-606). IEEE. https://doi.org/10.1109/WSC.2017.8247818,

Leal Filho, W., Brandli, L., Moora, H., Kruopienė, J. and Stenmarck, Å., 2016. Benchmarking approaches and methods in the field of urban waste management. *Journal of Cleaner Production*, *112*, pp.4377-4386. https://doi.org/10.1016/j.jclepro.2015.09.065.

Lehmann, S., 2011. Optimizing urban material flows and waste streams in urban development through principles of zero waste and sustainable consumption. *Sustainability*, *3*(1), pp.155-183. https://doi.org/10.3390/su3010155.

Liu, A., Ren, F., Lin, W.Y. and Wang, J.Y., 2015. A review of municipal solid waste environmental standards with a focus on incinerator residues. *International Journal of Sustainable Built Environment*, *4*(2), pp.165-188. https://doi.org/10.1016/j.ijsbe.2015.11.002.

Magazzino, C., Mele, M. and Schneider, N., 2020. The relationship between municipal solid waste and greenhouse gas emissions: Evidence from Switzerland. *Waste Management*, *113*, pp.508-520. https://doi.org/10.1016/j.wasman.2020.05.033.

Magnanelli, E., Tranås, O.L., Carlsson, P., Mosby, J. and Becidan, M., 2020. Dynamic modeling of municipal solid waste incineration. *Energy*, *209*, p.118426. https://doi.org/10.1016/j.energy.2020.118426.

Mariyam, S., Cochrane, L., Zuhara, S. and McKay, G., 2022. Waste management in Qatar: A systematic literature review and recommendations for system strengthening. *Sustainability*, *14*(15), p.8991. https://doi.org/10.3390/su14158991.

Mbina, A.A. and Edem, E.E., 2015. Challenges of urban waste management in Uyo Metropolis, Nigeria. *waste management*, *7*(2).

Mian, M.M., Zeng, X., Nasry, A.A.N.B. and Al-Hamadani, S.M., 2017. Municipal solid waste management in China: a comparative analysis. *Journal of material cycles and waste management*, *19*, pp.1127-1135. https://doi.org/10.1007/s10163-016-0509-9.

Mohareb, A.K., Warith, M.A. and Diaz, R., 2008. Modelling greenhouse gas emissions for municipal solid waste management strategies in Ottawa, Ontario, Canada. *Resources, Conservation and Recycling*, *52*(11), pp.1241-1251. https://doi.org/10.1016/j.resconrec.2008.06.006.

Moreno Solaz, H., Artacho-Ramírez, M.Á., Cloquell-Ballester, V.A. and Badenes Catalán, C., 2023. Prioritizing action plans to save resources and better achieve municipal solid waste management KPIs: An urban case study. *Journal of the Air & Waste Management Association*, (just-accepted). https://doi.org/10.1080/10962247.2023.2244461.

Nanda, S. and Berruti, F., 2021. A technical review of bioenergy and resource recovery from municipal solid waste. *Journal of hazardous materials*, *403*, p.123970. https://doi.org/10.1016/j.jhazmat.2020.123970.

Nelles, M., Gruenes, J. and Morscheck, G., 2016. Waste management in Germany–development to a sustainable circular economy?. *Procedia Environmental Sciences*, *35*, pp.6-14. https://doi.org/10.1016/j.proenv.2016.07.001.

Nnaji, C.C., 2015. Status of municipal solid waste generation and disposal in Nigeria. *Management of Environmental Quality: An International Journal*, *26*(1), pp.53-71. https://doi.org/10.1108/MEQ-08-2013-0092.

Ogundele, O.M., Rapheal, O.M. and Abiodun, A.M., 2018. Effects of municipal waste disposal methods on community health in Ibadan-Nigeria. *Polytechnica*, *1*(1-2), pp.61-72. https://doi.org/10.1007/s41050-018-0008-y.

Pervin, I.A., Rahman, S.M.M., Nepal, M., Haque, A.K.E., Karim, H. and Dhakal, G., 2020. Adapting to urban flooding: a case of two cities in South Asia. *Water Policy*, *22*(S1), pp.162-188. https://doi.org/10.2166/wp.2019.174 .

Pinha, A.C.H. and Sagawa, J.K., 2020. A system dynamics modelling approach for municipal solid waste management and financial analysis. *Journal of Cleaner Production*, *269*, p.122350. https://doi.org/10.1016/j.jclepro.2020.122350.

Przydatek, G., 2020. Assessment of changes in the municipal waste accumulation in Poland. *Environmental Science and Pollution Research*, *27*(20), pp.25766-25773. https://doi.org/10.1007/s11356-020-08943-6.

Qu, J., Dai, X., Hu, H.Y., Huang, X., Chen, Z., Li, T., Cao, Y. and Daigger, G.T., 2022. Emerging trends and prospects for municipal wastewater management in China. *ACS ES&T Engineering*, *2*(3), pp.323-336. https://doi.org/10.1021/acsestengg.1c00345.

Rai, R.K., Nepal, M., Khadayat, M.S. and Bhardwaj, B., 2019. Improving municipal solid waste collection services in developing countries: A case of Bharatpur Metropolitan City, Nepal. *Sustainability*, *11*(11), p.3010. https://doi.org/10.3390/su11113010.

Richardson, G.P. and Otto, P., 2008a. Applications of system dynamics in marketing. *Journal of Business Research*, *61*(11), pp.1099-1101.

Richardson, G.P. and Otto, P., 2008b. Applications of system dynamics in marketing. *Journal of Business Research*, *61*(11), pp.1099-1101. https://doi.org/10.1016/j.jbusres.2007.11.003.

Ridho, H., Thamrin, M.H., Nasution, F.A. and Indainanto, Y.I., 2023. Disposition of waste management policy implementers through the regional cooperation scheme. https://dupakdosen.usu.ac.id/handle/123456789/7236

Rodić, L. and Wilson, D.C., 2017. Resolving governance issues to achieve priority sustainable development goals related to solid waste management in developing countries. *Sustainability*, *9*(3), p.404. https://doi.org/10.3390/su9030404.

Romano, G., Lombardi, G.V., Rapposelli, A. and Gastaldi, M., 2022. The factors affecting Italian provinces' separate waste-collection rates: An empirical investigation. *Waste Management*, *139*, pp.217-226. https://doi.org/10.1016/j.wasman.2021.12.037.

Rowe, R.K., Armstrong, M.D. and Cullimore, D.R., 2000. Mass loading and the rate of clogging due to municipal solid waste leachate. *Canadian Geotechnical Journal*, *37*(2), pp.355-370. https://doi.org/10.1139/t99-107.

Santos, A.A., da Silva, A.F., Gouveia, A., Felgueiras, C. and Caetano, N., 2022. Reducing Volume to Increase Capacity—Measures to Reduce Transport Energy for Recyclable Waste Collection. *Energies*, *15*(19), p.7351. https://doi.org/10.3390/en15197351.

Sarigiannis, D.A., Handakas, E.J., Karakitsios, S.P. and Gotti, A., 2021. Life cycle assessment of municipal waste management options. *Environmental Research*, *193*, p.110307. https://doi.org/10.1016/j.envres.2020.110307.

Seo, S., Aramaki, T., Hwang, Y. and Hanaki, K., 2004. Environmental impact of solid waste treatment methods in Korea. *Journal of environmental engineering*, *130*(1), pp.81-89. https://doi.org/10.1061/(ASCE)0733-9372(2004)130:1(81).

Sharma, K.D. and Jain, S., 2020. Municipal solid waste generation, composition, and management: the global scenario. *Social Responsibility Journal*, *16*(6), pp.917-948. https://doi.org/10.1108/SRJ-06-2019-0210.

Smol, M., Duda, J., Czaplicka-Kotas, A. and Szołdrowska, D., 2020. Transformation towards circular economy (CE) in municipal waste management system: Model solutions for Poland. *Sustainability*, *12*(11), p.4561. https://doi.org/10.3390/su12114561.

Sterman, J., 2000. *Instructor's manual to accompany business dyanmics: systems thinking and modeling for a complex world*. McGraw-Hill.

Sufian, M.A. and Bala, B.K., 2007. Modeling of urban solid waste management system: The case of Dhaka city. *Waste management*, *27*(7), pp.858-868. https://doi.org/10.1016/j.wasman.2006.04.011.

Sukholthaman, P. and Sharp, A., 2016. A system dynamics model to evaluate effects of source separation of municipal solid waste management: A case of Bangkok, Thailand. *Waste management*, *52*, pp.50-61. https://doi.org/10.1016/j.wasman.2016.03.026.

Triassi, M., De Simone, B., Montuori, P., Russo, I., De Rosa, E., Di Duca, F., Crivaro, C., Cerullo, V., Pontillo, P. and Díez, S., 2023. Determination of Residual Municipal Solid Waste Composition from Rural and Urban Areas: A Step toward the Optimization of a Waste Management System for Efficient Material Recovery. *Sustainability*, *15*(18), p.13378. https://doi.org/10.3390/su151813378.

Tirkolaee, E.B., Mahdavi, I., Esfahani, M.M.S. and Weber, G.W., 2020. A robust green location-allocation-inventory problem to design an urban waste management system under uncertainty. *Waste Management*, *102*, pp.340-350. https://doi.org/10.1016/j.wasman.2019.10.038.

Tutunchian, S. and Altınbaş, M., 2023. Assessment of an appropriate integrated waste management plan targeting the Circular Economy based on the LCA method. *Journal of Material Cycles and Waste Management*, *25*(1), pp.456-478. https://doi.org/10.1007/s10163-022-01552-0.

Tsoulfas, G.T. and Pappis, C.P., 2006. Environmental principles applicable to supply chains design and operation. *Journal of Cleaner production*, *14*(18), pp.1593-1602. https://doi.org/10.1016/j.jclepro.2005.05.021.

Valizadeh, J., 2020. A novel mathematical model for municipal waste collection and energy generation: case study of Kermanshah city. *Management of Environmental Quality: An International Journal*, *31*(5), pp.1437-1453. https://doi.org/10.1108/MEQ-02-2020-0027.

Vassanadumrongdee, S. and Kittipongvises, S., 2018. Factors influencing source separation intention and willingness to pay for improving waste management in Bangkok, Thailand. *Sustainable Environment Research*, *28*(2), pp.90-99. https://doi.org/10.1016/j.serj.2017.11.003.

Wang, W.J. and You, X.Y., 2021. Benefits analysis of classification of municipal solid waste based on system dynamics. *Journal of Cleaner Production*, *279*, p.123686. https://doi.org/10.1016/j.jclepro.2020.123686.

Wolstenholme, E.F., 1990. *System enquiry: a system dynamics approach*. John Wiley & Sons, Inc.

Xiao, S., Dong, H., Geng, Y., Tian, X., Liu, C. and Li, H., 2020. Policy impacts on Municipal Solid Waste management in Shanghai: A system dynamics model analysis. *Journal of Cleaner Production*, *262*, p.121366. https://doi.org/10.1016/j.jclepro.2020.121366.

Xiao, L., Zhang, G., Zhu, Y. and Lin, T., 2017. Promoting public participation in household waste management: A survey based method and case study in Xiamen city, China. *Journal of cleaner production*, *144*, pp.313-322. https://doi.org/10.1016/j.jclepro.2017.01.022.

Yao, L., Liu, T., Chen, X., Mahdi, M. and Ni, J., 2018. An integrated method of life-cycle assessment and system dynamics for waste mobile phone management and recycling in China. *Journal of cleaner production*, *187*, pp.852-862. https://doi.org/10.1016/j.jclepro.2018.03.195.

Yao, X., Guo, Z., Liu, Y., Li, J., Feng, W., Lei, H. and Gao, Y., 2019. Reduction potential of GHG emissions from municipal solid waste incineration for power generation in Beijing. *Journal of Cleaner Production*, *241*, p.118283. https://doi.org/10.1016/j.jclepro.2019.118283.

Yukalang, N., Clarke, B. and Ross, K., 2018. Solid waste management solutions for a rapidly urbanizing area in Thailand: Recommendations based on stakeholder input. *International journal of environmental research and public health*, *15*(7), p.1302. https://doi.org/10.3390/ijerph15071302.

Zanjani, A.J., Saeedi, M. and Vosoogh, A., 2012. The effect of the waste separation policy in municipal solid waste management using the system dynamic approach. *International Journal of Environmental Health Engineering*, *1*(1), p.5.

Zhang, S., Omar, A.H., Hashim, A.S., Alam, T., Khalifa, H.A.E.W. and Elkotb, M.A., 2023. Enhancing waste management and prediction of water quality in the sustainable urban environment using optimized algorithm of least square support vector machine and deep learning techniques. *Urban Climate*, *49*, p.101487. https://doi.org/10.1016/j.uclim.2023.101487.

Zhang, D.Q., Tan, S.K. and Gersberg, R.M., 2010. Municipal solid waste management in China: status, problems and challenges. *Journal of environmental management*, *91*(8), pp.1623-1633. https://doi.org/10.1016/j.jenvman.2010.03.012.

Zorpas, A.A., 2020. Strategy development in the framework of waste management. *Science of the total environment*, *716*, p.137088. https://doi.org/10.1016/j.scitotenv.2020.137088.

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A Fuzzy Expert System for Selecting Green Information Technology Strategy

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ABSTRACT

The pressure on Chief Information Officers (CIOs) to focus on Green Information Technology (GIT) has recently increased. However, many organizations still need to manage their environmental efforts due to a lack of strategic planning. This study aims to design a fuzzy expert system to suggest a proper GIT strategy for organizations, considering qualitative, obscure, and fuzzy factors. The study employs questionnaires distributed to experts to evaluate the factors that impact the level of GIT maturity using fuzzy logic. Based on the results obtained, a fuzzy expert system is designed to suggest a proper GIT strategy. The proposed expert system has been used at Alzahra University as a case study for selecting GIT strategies and activities. The findings suggest that Alzahra University should adopt a primary-level GIT strategy involving a three-year process of implementation, which includes actions such as removing old monitors, developing a green supply chain, reengineering organizational processes, disposing of useless ICT equipment in a green manner, and adopting green marketing practices. The fuzzy expert system designed in this study can help organizations adopt appropriate GIT strategies.

Keywords

Green information technology, Green information technology maturity, Green information technology strategy, Fuzzy expert system.

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1. Introduction

Air pollution and climate change are the most significant global environmental challenges. The increase in global temperatures, primarily caused by human-driven emissions of greenhouse gases into the atmosphere, can lead to severe environmental, societal, and economic consequences worldwide if temperature trends continue to rise (Santos et al., 2022). Parallelly, The growing world population and increasing use of renewable and non-renewable energy sources have led to a rise in greenhouse gases, pollution, and global warming. The demand for energy at various organizational levels has also increased, often accompanied by a need for IT systems. Unfortunately, over half of the energy produced is lost due to poorly designed systems and inefficient performance, resulting in hefty costs (Nishant et al., 2013). In today's fast-paced business world, organizations must adapt quickly to keep up. Information technology (IT) is critical in achieving efficiency and effectiveness in business models, governance, and waste management. Organizations are turning to Green IT as an alternative strategy to combat the negative environmental impact of technology. Green IT encompasses various topics such as green computing, e-waste, and organizational governance, aiming to reduce environmental impact, increase cost efficiency, and improve energy effectiveness (Nabila‘Aini and Subriadi, 2022).

One of the organizations' significant sources of greenhouse gas emissions is their information sources. However, these sources can also provide a key solution to reducing carbon emissions through green management. Information technology offers organizations excellent opportunities to improve their green performance, reduce costs, and increase revenue (Akman and Mishra, 2015). Green IT has become an active research field in information technology, and recent studies reveal that it has become a popular topic for researchers. Figure 1 shows the results of an analysis using VOSviewer software, a network visualization and analysis tool, on green IT studies found in Scopus. Figure 2 demonstrates that green IT has become a popular research topic in recent years in the Scopus database. (McAllister et al., 2022). Although GIT practices may not constitute a firm's core activities, such as manufacturing, supply chain, logistics, or service delivery, they reflect conscious and autonomous efforts to preserve environmental sustainability in IT practices. By adopting green IT practices, firms can use technology to meet the present generation's needs without compromising the ability to satisfy future generations' demands (Hu et al., 2022).

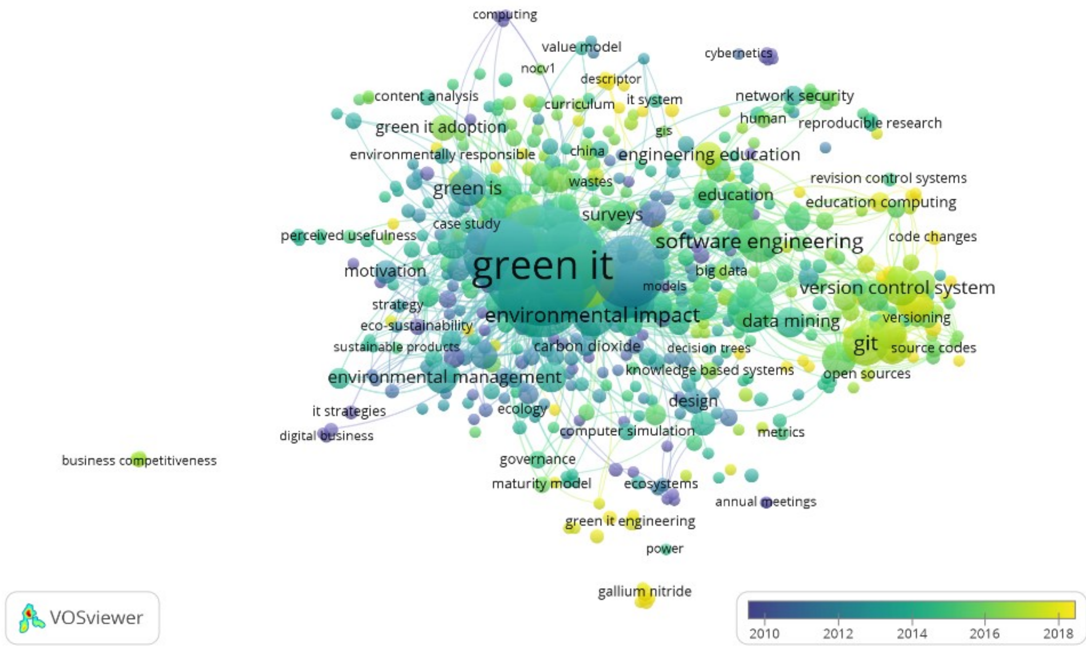

Figure 1. The keyword co-occurrence of GIT in scopus studies

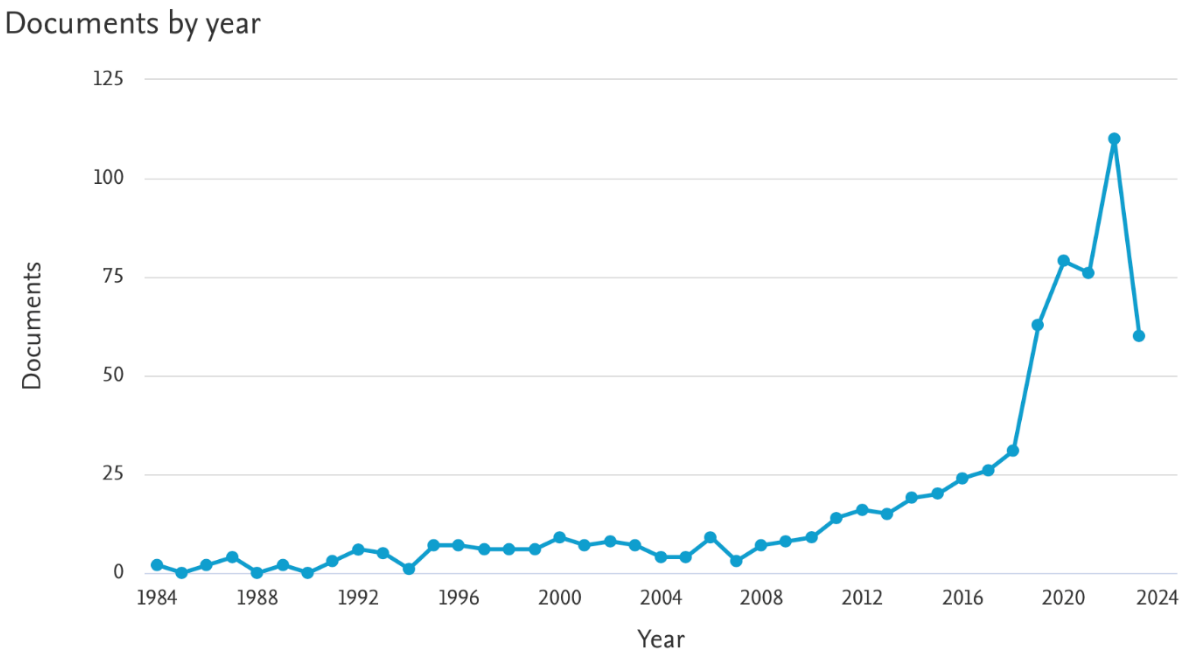

Figure 2. Research trend on GIT in scopus studies

Green IT strategies encourage organizations to take environmental responsibility by adopting long-term and consistent strategies (Asadi et al., 2015). Moreover, the rapid advancement of information technology (IT) has facilitated the wider adoption of environmentally friendly practices, supporting various technology-driven green initiatives. The swift growth of digital technology has been a key driver in bringing about significant changes in advancing the cause of the sustainable development field (Qu and Liu, 2022). As organizations increasingly rely on IT, and IT itself relies on energy sources, it is crucial to use Green IT. Therefore, it is vital to identify and implement strategies that utilize green energies and improve environmental conditions. Different organizational factors affect GIT strategies. These factors can include both internal and external organizational factors. One of the most significant internal factors is the organization's maturity level in implementing green information technology. Previous studies have sporadically referred to factors that can influence the selection of green information technology strategies, but no model has been proposed for decision-making. Since most of these factors are qualitative and vague, and their impact on strategy is also vague and qualitative, this study proposes a fuzzy inference system for modeling this decision. In this study, the influential factors and their impact were extracted using the results of a questionnaire completed by experts in the field of green information technology, and based on these results, a fuzzy inference system was developed. The system's functioning entails organizations providing input regarding their internal and environmental attributes. Additionally, the system identifies the level of maturity of green information technology within the organization and proposes suitable strategies and corresponding actions.

2. Literature review

2.1. Green information technology (GIT)

Green IT (GIT) refers to the efficient and effective use of information and communication technologies (ICTs) in organizations to promote sustainable business practices (Deng et al., 2009). While there are multiple perspectives and definitions of Green IT, they all revolve around energy consumption and waste generation in the computer hardware and software domains (Zaman and Sedera, 2016). The core objective of GIT is to systematically apply environmental sustainability and clean technologies (Molla and Abareshi, 2011). It aims to reduce the environmental impact of IT operations by designing data centers and IT infrastructure that optimizes energy consumption and minimizes costs (Hernandez, 2020). It involves implementing energy-efficient hardware and software solutions, employing power management techniques, and utilizing virtualization and cloud computing technologies to consolidate servers and reduce energy usage.

Additionally, GIT addresses the issue of electronic waste (e-waste) generated by outdated or discarded IT equipment. It promotes responsible disposal, recycling, and refurbishment practices to minimize the environmental impact of e-waste. Organizations develop and adopt specific policies and strategies to achieve sustainable IT practices. These include sustainable procurement practices that consider IT products' energy efficiency and environmental attributes. Organizations also focus on optimizing data centers with energy-efficient cooling and power distribution systems, employing renewable energy sources, and implementing green software development practices.

Overall, GIT enables organizations to use resources sustainably in environmental and business contexts, aligning IT operations with sustainability goals and objectives (Loeser et al., 2017). By embracing Green IT, organizations can reduce their environmental footprint and improve operational efficiency and cost-effectiveness.

Table1. Factors affecting GIT strategy

Main factors	Sub-categories	Description	Reference
	Greenwashing aims	Greenwashing occurs when an organization conveys a false impression about its products, services, or brand	Taghva et al., (2017)
	Economic goals and saving financial resources	Economic goals aim to improve financial well-being. Saving financial resources is a way to achieve these goals and achieve financial security.	Taghva et al., (2017), Molla et al., (2009), Kazovsky et al., (2017), Unhelkar (2016) Atkinson et al., (2014)
	LESS consumption or production from environmental and not financial or operational perspective	Less consumption or production from an environmental perspective" refers to reducing the use of resources or minimizing waste and pollution to protect the environment, regardless of financial or operational considerations.	Molla et al., (2009), Hankel et al., (2014), Philipson (2010), Donnellan et al., (2011),
	EFFICIENCY	Improve work performance or better ways of doing work	Murugesan (2008), Molla et al., (2009), Forrest et al., (2008)
	OFFSET	Increase awareness and offset anything which may harm the environment	Taghva et al., (2017), Unhelkar and Tiwary(2011)
Green management policies of organization	Policies for changing and affecting staff attitudes (Awareness and positive attitude)	Awareness and positive attitudes of consumers and staff of an organization about carbon emission can significantly change how it works. This awareness should be institutionalized in the culture of the organization.	Taghva et al., (2017), Unhelkar (2016), Su and Al-Hakim (2010), Jenkin et al., (2011)
	Policies on proper disposal of the waste, equipment sans toxic materials	Policies on proper disposal of waste and equipment without toxic materials refer to established guidelines for safely and environmentally friendly discarding of waste and devices that do not contain harmful substances.	Atkinson et al., (2014) Su and Al-Hakim (2010), Britt et al., (2019) AlHarbi and Pattinson (2016)
	Policies for purchasing green equipment and the related services	Policies for acquiring environmentally friendly equipment and associated services" refer to established guidelines for procuring equipment and services that prioritize environmental sustainability and reduce ecological impact.	(Halchin et al., 2010) (Dedrick, 2010)
	Policies for accepting and implementing recyclable equipment	A policy of accepting and implementing the recycling of equipment recycles the materials that can be reused; it delays the replacement of active equipment and increases awareness about how to reuse the equipment.	Unhelkar (2016), Su and Al-Hakim (2010), Murugesan (2008)
	Policies for optimizing energy consumption in organizational procedures	Policies for efficient energy use in organizational processes" refer to those established to minimize energy consumption and improve efficiency within an organization's operations.	Nanath and Pillai (2017) (Atkinson et al., 2014)

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Main factors	Sub-categories	Description	Reference
	Policies for using renewable energies (solar, nuclear energy)	Policies for utilizing renewable energies refer to established guidelines for adopting and responsible use of sustainable energy sources like solar power and nuclear energy within an organization's operations.	Melville (2010), Faucheux and Nicolaï, (2011), Du et al., (2023)
	Compensatory measures	Make up the negative environmental impacts by taking compensatory measures to improve bad environmental conditions.	Taghva et al., (2017), Unhelkar and Tiwary(2011)
Individuals	Leader	A leader guides, directs, and inspires others towards a common goal or vision.	Dao et al., (2011), Unhelkar (2016), Atkinson et al., (2014)
	Employees	Employees are individuals hired by an organization to perform specific tasks or duties in exchange for compensation.	Unhelkar (2016), Murugesan (2008), Atkinson et al., (2014),
	Beneficiaries	Beneficiaries and shareholders support new IT plans, ideas, and opinions to make improvements.	Dao et al., (2011), Tokkozhina et al., (2023), Corbett (2010), Molla et al., (2009)
Structural elements	Capacities	Capacities refer to an individual, organization, or system's abilities, skills, resources, and potential to achieve a particular goal or objective.	Corbett (2010), Unhelkar (2016), Melville (2010), Taghva et al., (2017)
	Structure	Structure refers to the organization, arrangement, and framework of a system, organization, or entity.	Melville (2010)
	Organizational processes	Organizational processes refer to the series of steps or activities an organization takes to achieve its objectives.	Dao et al., (2011),)Unhelkar (2016), Donnellan et al., (2011), Murugesan (2008)
	Economic factors and budgeting	Economic factors impact the production, distribution, and consumption of goods and services, while budgeting involves planning and allocating financial resources to achieve specific goals.	Faucheux and Nicolaï (2011), (Dedrick, 2010), Molla et al., (2009), Tokkozhina et al., (2023), Corbett (2010), Zheng, (2013), Nanath and Pillai (2017)
Social, cultural environmental factors	Environmental values Beliefs and trends Social responsibility External, natural and artificial resources of organization Demolition and productivity rate of resources	Environmental values refer to the beliefs, attitudes, and principles that individuals and society hold regarding protecting and preserving the natural environment. Beliefs are ideas or convictions about reality shaped by cultural, social, or personal factors. Trends are the direction or pattern of change in a particular area over time. Social responsibility is the ethical obligation of individuals, organizations, and businesses to benefit society and the environment through practices. External resources come from outside sources like suppliers, customers, or partners. Natural resources are materials or substances that occur naturally and are used by organizations. Artificial resources are tools, machinery, or technology organizations use to facilitate operations and achieve goals. Demolition is the act of destroying a building or structure. The productivity rate of resources is the efficiency with which an organization or individual uses their resources.	Taghva et al., (2017),) Unhelkar (2016), Su and Al-Hakim (2010), Jenkin et al., (2011), Jailani et al., (2016), Molla et al., (2009), Forrest et al., (2008), Dalvi-Esfahani et al., (2020)
Marke	Special standards	These factors reflect the impact of current standards, obligatory rules and regulations, and various	Murugesan (2008), Nanath and Pillai (2017),

Main factors	Sub-categories	Description	Reference
		pressures from the market and environmental pressures on organizations, people, and corporate measures.	Atkinson et al., (2014) Donnellan et al., (2011), Halchin et al., (2010)
	Rules and regulations	Rules and regulations refer to established guidelines or directives that govern behavior, actions, or procedures within a specific context, such as an industry, organization, or society.	Faucheux and Nicolaï (2011), Taghva et al., (2017), Su and Al-Hakim (2010), Jenkin et al., (2011), Unhelkar (2016), Donnellan et al., (2011)
	Market pressure	Market pressure refers to the forces or factors that influence the behavior and decisions of buyers, sellers, and other participants in a market.	Unhelkar (2016), Su and Al-Hakim (2010), Jenkin et al., (2011)
Technological factors	Technological infrastructure and available technologies	Technological infrastructure refers to the underlying hardware, software, and networks that support the use of technology in an organization or society.	Unhelkar (2016), Taghva et al., (2017), Su and Al-Hakim (2010), Jenkin et al., (2011)
	Hardware (network, data center, and monitors)	Hardware refers to the physical components of a computer or electronic device, such as the central processing unit (CPU), memory, hard drive, keyboard, and monitor.	
	Environmental intelligence	Environmental intelligence is the capacity of people and organizations to comprehend and tackle environmental problems.	
Maturity level of an organizatio	Data center	The data center is responsible for assessing the physical equipment, server property, and infrastructure support to evaluate capital management procurement, capital expenditure, and operating expenditure.	

2.2. Green IT maturity model

Organizations often rely on maturity models to enhance business processes and effectively manage sustainability initiatives. However, it is crucial to complement these models with sustainability performance assessment tools to gain deeper insights into sustainability concerns and develop effective improvement plans. These tools enable organizations to evaluate their sustainability practices against industry benchmarks and best practices, facilitating the identification of areas for improvement and creating a roadmap to achieve sustainability goals. By leveraging assessment tools, organizations can bridge gaps and enhance their sustainability practices to meet the growing demand for sustainable business operations (Sohns et al., 2023). One widely used assessment tool in creating Green IT is the maturity model. This model encompasses various techniques and processes to guide organizations in developing mature green information technology practices. It evaluates different aspects of an organization's operations, behaviors, and accomplishments. To provide a comprehensive report, the model conducts a detailed analysis of each department separately, closely examining the organization's internal functions (Desai, 2014). Green IT models function as assessment and measurement tools, providing organizations with a clear roadmap to follow (Foogooa et al., 2015).

The Green IT maturity model allows organizations to assess their current level of sustainability practices, identify strengths and weaknesses, and prioritize areas for improvement. It covers energy efficiency, waste management, sustainable procurement, data center optimization, and green software development. This model allows organizations to evaluate performance, set targets, implement strategies, and monitor progress toward sustainable IT practices within a structured framework. Furthermore, the Green IT maturity model enables organizations to benchmark themselves against industry peers and best practices. This benchmarking process allows organizations to set realistic goals and track their sustainability performance over time. The model guides organizations through different stages of maturity, from initial implementation to advanced and innovative practices, providing a systematic approach to enhancing sustainability practices.

In conclusion, the Green IT maturity model and sustainability performance assessment tools empower organizations to evaluate, improve, and monitor their sustainability practices effectively. By leveraging these tools, organizations can align their IT operations with sustainability goals, reduce environmental impact, and contribute to their business's overall sustainability and success.

3. Methodology

The purpose of this study is applied-developmental, as it aims to evaluate the factors that influence the level of green IT maturity. In order to accomplish this objective, questionnaires were disseminated to collect pertinent data and evaluate professionals' perspectives. A fuzzy expert system was designed to suggest an appropriate green IT strategy based on the results obtained. The system was tested and implemented at Alzahra University for selecting the appropriate GIT strategy. The tool used for data collection is a questionnaire. The study framework comprises several steps, which are illustrated in Figure 3. Overall, this research is a practical guide for organizations looking to improve their green IT maturity level and implement effective sustainability strategies.

Step 1: The problem addressed in this study is selecting an appropriate green IT strategy for an organization. Decision-makers should consider various internal and external factors, such as the capacity and readiness of people, organizational structure, green IT maturity level, and technological factors. These factors were identified and examined through a literature review, and the findings are presented in Table 1.

Step 2: After identifying the problem and relevant factors, rules were established to make inferences based on the findings. In order to ascertain the authenticity of the regulations, questionnaires were devised and disseminated to professionals in the field of information technology to solicit their viewpoints. Based on the results obtained from the experts' responses, the rules were edited, and a fuzzy expert system was designed.

The results obtained from the expert questionnaire are presented in Table 2. This table‘s sub-criteria correspond to the identical subcategories delineated in Table 1. Within this context, we have furnished the mean evaluations derived from expert assessments for each subcategory and the notation employed for these evaluations within the MATLAB environment.

Step 3: In this step, the designed fuzzy expert system was used to select a green IT strategy for Alzahra University. This step is a practical demonstration of how the fuzzy expert system can be used to select an appropriate green IT strategy for an organization.

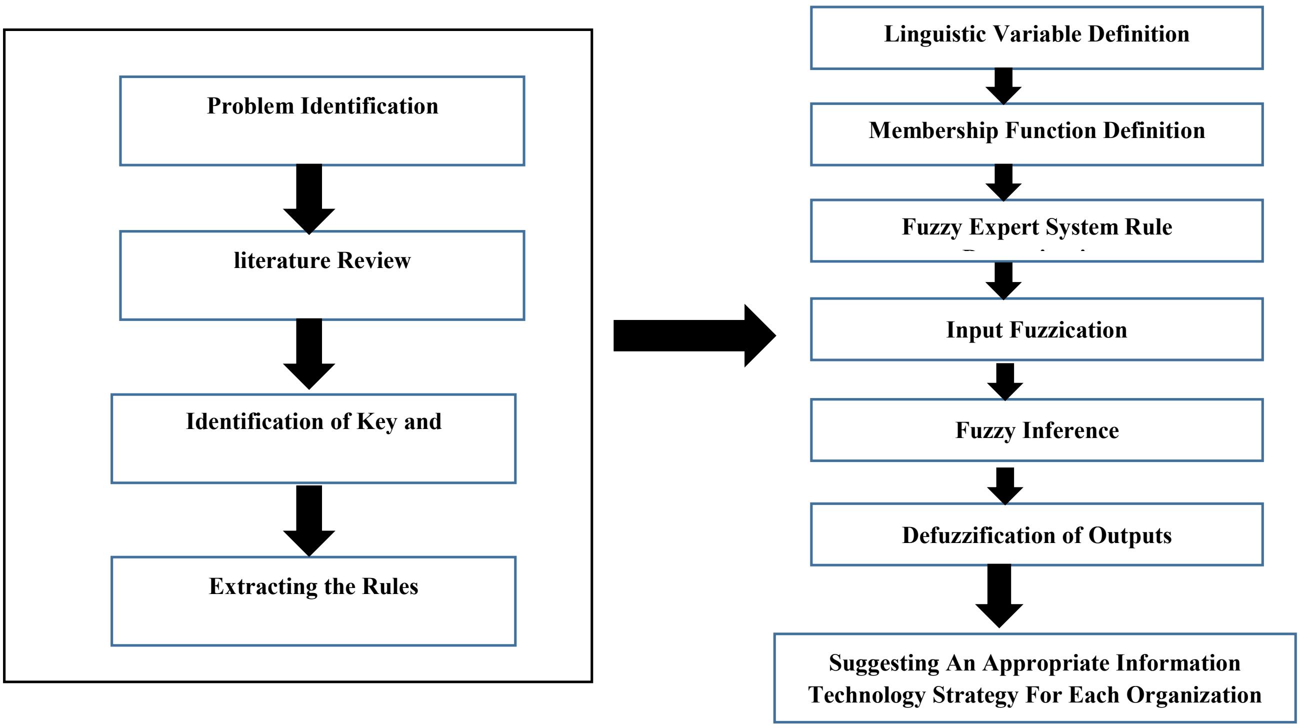

Figure 3. The research framework

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Table 2. Average experts' responsiveness regarding key system criteria

Sub-criteria (Notation in MATLAB)	The average responses of experts	Sub-criteria (Notation in MATLAB)	The average responses of experts
Reducing the amount of energy consumed by the organization **(V1)**	0.75	Reducing the operational cost of the organization **(V2)**	0.68
Social acceptability **(V3)**	0.9	Implementation of rules and regulations **(V4)**	0.83
Income and profitability **(V5)**	0.5	Reducing carbon footprint **(V6)**	0.89
Sustainability of resources **(V7)**	0.79	Organizational sustainability **(V8)**	0.61
Environmental survival **(V9)**	0.67		
Average level of green information technology strategy based on objectives Green organization (OO)			0.5
Proper disposal of waste equipment and toxic materials **(V1)**	0.58	Impact on employees' views **(V2)**	0.86
Optimizing energy consumption in organizational processes **(V3)**	0.79	Implementation of recyclable equipment **(V4)**	0.52
Green equipment and related services **(V5)**	0.57	Renewable energies **(V6)**	0.12
compensatory measures **(V7)**	0.23		
Average level of green information technology strategy based on organizational policies (OE1)			0.5
The amount of participation and influence leadership **(V1)**	0.75	The amount of participation and influence Employees **(V2)**	0.5
The amount of participation and influence Beneficiaries **(V3)**	0.5	priorities for people's involvement in green information technology projects **(V4)**	0.67
The average level of green information technology strategy based on the level of participation and influence of people (VP)			0.58
knowledge and awareness **(V1)**	0.6	ability **(V2)**	0.6
Support and support **(V3)**	0.86	Desire and interest **(V4)**	0.83
risk taking **(V5)**	0.19		
Average level of green information technology strategy based on participation and leadership influence (P1)			0.75
Positive outlook and approach **(V1)**	0.83	Related education **(V2)**	0.22
ability **(V3)**	0.21	Teachability and learning **(V4)**	0.6
Average level of green information technology strategy based on employee participation and influence (O1)			0.5
knowledge and awareness **(V1)**	0.41	Interest and desire **(V2)**	0.65
Support and support **(V3)**	0.53	ability **(V4)**	0.45
risk taking **(V5)**	0.6		
The average level of green information technology strategy based on the level of participation influence of stakeholders (P2)			0.5
The level of the organization's capabilities **(V1)**	0.5	Internal structure level **(V2)**	0.25
The level of organizational processes **(V3)**	0.5	Level of financial resources and budget **(V4)**	0.65
The average level of green information technology strategy according to organizational structure factors (CC1)			0.5
The degree of flexibility and change in the organization **(V1)**	0.4	The extent of process redesign **(V2)**	0.83
Changing the culture in the organization **(V3)**	0.39	The power of promotion in front of the shareholders **(V4)**	0.81
Bargaining power against suppliers **(V5)**	0.83	Comprehensive map planning **(V6)**	0.34
Average level of green information technology strategy based on capabilities (P3)			0.5
Dominant and strong support group **(V1)**	0.38	Dedicated resources for project implementation **(V2)**	0.41

Sub-criteria (Notation in MATLAB)	The average responses of experts	Sub-criteria (Notation in MATLAB)	The average responses of experts
Appropriate educational structure **(V3)**	0.22	Independent consultation **(V4)**	0.43
Evaluation and audit system **(V5)**	0.15		
Average level of green information technology strategy based on internal structure (P4)			0.25
Coordination between the processes of the organization **(V1)**	0.34	The possibility of implementing green process management **(V2)**	0.5
Business process modeling **(V3)**	0.76	process optimization **(V4)**	0.18
Process Performance Reporting **(V5)**	0.42		
Average level of green information technology strategy according to organizational processes (CC2)			0.5
Allocated budget level **(V1)**	0.65	Expected rate of return on investment **(V2)**	0.4
Investment time frame **(V3)**	0.5		
Average level of green information technology strategy based on financial and economic issues (CC3)			0.65
Environmental values **(V1)**	0.41	Adherence to the beliefs and trends of green information technology **(V2)**	0.52
The organization's commitment to social responsibility **(V3)**	0.93	External, natural and artificial resources available to the organization **(V4)**	0.67
The rate of resource destruction **(V5)**	0.6		
Average level of green information technology strategy by issues Environmental social and cultural (CC4)			0.735
Organizational specific standards in line with green information technology **(V1)**	0.4	Government rules and regulations in line with green information technology **(V2)**	0.2
Market pressure in the direction of moving towards green information technology **(V3)**	0.19		
Average level of green information technology strategy based on regulatory market factors (CC5)			0.238
Information technology infrastructure and available technologies **(V1)**	0.54	Hardware provided **(V2)**	0.5
Environmental intelligence **(V3)**	0.4	Green IT specialists **(V4)**	0.8
Integration of information systems **(V5)**	0.4		
Average level of green information technology strategy based on technological factors (CC6)			0.5
Basic application of server virtualization solutions **(V1)**	0.42	Using orchestration tools **(V2)**	0.2
Optimal use of server instances **(V3)**	0.2	Server performance **(V4)**	0.44
Electrical efficiency **(V5)**	0.32	Storage integration **(V6)**	0.42
Management of storage equipment using indicators **(V7)**	0.20	Network convergence **(V8)**	0.42
Intelligent power allocation management **(V9)**	0.4	Separate platform integration support **(V10)**	0.33
Timely monitoring of electricity consumption **(V11)**	0.8	Efficient design **(V12)**	0.37
DC efficient in energy consumption **(V13)**	0.41	Automation of temperature and humidity control **(V14)**	0.2
Center Green IT Maturity Score (DC)			0.25
Disable the screen saver **(V1)**	0.15	Power control using the power management system of IT tools **(V2)**	0.41
Replacing desktops with laptop computers **(V3)**	0.2	Using thin client solutions **(V4)**	0.4
Cut off power for tools that are not in use **(V5)**	0.76	Use of multifunction printing tools **(V6)**	0.88
Using virtual fax services **(V7)**	0.67	Use toner saving solutions **(V8)**	0.62
Automating power cuts at night and on holidays **(V9)**	0.4	Integration of print management services **(V10)**	0.56

Sub-criteria (Notation in MATLAB)	The average responses of experts	Sub-criteria (Notation in MATLAB)	The average responses of experts
Wireless network instead of fixed line network **(V11)**	0.42	Intelligent lighting systems **(V12)**	0.4
Energy efficient lighting systems **(V13)**	0.36	Automation of temperature control **(V14)**	0.8
Power cuts at night and on holidays **(V15)**	0.8		
Office Environment Green IT Maturity Score (OE2)			0.5
Work processes that are done electronically **(V1)**	0.78	Electronic verification system **(V2)**	0.78
Online real-time transactions in providing services to customers **(V3)**	0.4	Implementation of the Internet organization system **(V4)**	0.79
Issuing invoices (or payment receipts) for customers using an electronic system **(V5)**	0.41	Programs that conform to rational principles (a specific program to reduce the size of your application portfolio and achieve a unified standard architecture) **(V6)**	0.4
Durability and improvement of processes **(V7)**	0.2	Using integrated communication tools **(V8)**	0.46
Use of video conferencing systems (V9)	0.37	Support and encourage remote communication **(V10)**	0.21
Ability to support in the form of remote services **(V11)**	0.4	Training green technology to employees (V12)	0.4
Environmental impact analysis **(V13)**	0.4	Costing systems for IT services **(V14)**	0.33
The costing mechanism of carbon costs released for units or projects **(V15)**	0.4	enterprise resource planning system (ERP) **(V16)**	0.37
Business Activity Green IT **Maturity Score (WP)**			0.5
IT assets **(V1)**	0.18	Database configuration management (CMDB) **(V2)**	0.21
Linking the database configuration management)CMDB (with the relevant catalog service **(V3)**	0.14	Using information technology tools and equipment that are efficient in terms of energy consumption **(V4)**	0.41
Consider carbon emissions when purchasing new assets **(V5)**	0.48	The existence of policy and rules required to use products in accordance with environmental laws and regulations **(V6)**	0.23
Use of intelligent logistics systems **(V7)**	0.10	Minimize the use of consumables **(V8)**	0.34
Use of environmentally friendly office products **(V9)**	0.42		
Maturity of green IT **based on logistics (P5)**			0.25
Management of toxic and hazardous materials on materials that are sold or discarded **(V1)**	0.43	Incentives and rewards offered to employees to reduce waste **(V2)**	0.23
Efforts to reduce environmental impact **(V3)**	0.41	Reusing waste water and thermal waste from offices and IT resources **(V4)**	0.12
Existence of an incentive program for the participation of employees in environmental movements **(V5)**	0.28	Use of intelligent redundancy **(V6)**	0.36
Electronic distribution of customer / vendor brochures **(V7)**	0.81	Rules required for reuse of assets **(V8)**	0.14
Reuse of consumables **(V9)**	0.21		
Corporate Citizenship Green IT **Maturity Score (CC7)**			0.5
Maturity level of green information technology			0.5
Appropriate level of hybrid system green information technology strategy			0.5

3.1. Conceptual model

When designing the conceptual model for a hybrid expert system, it is essential to consider the significant research criteria, including their sub-criteria. The inputs for the fuzzy expert system comprise various factors, such as green objectives, the collaborative capacity of people, green management policies, and technological, environmental, socio-cultural, structural, market regulatory, and corporate maturity levels. The system represents these factors as linguistic variables, such as very poor, poor, average, good, and excellent. The system output is the most appropriate green IT strategy for the organization.

Then, the system rules were designed and placed in the inference engine to build the system's knowledge base. A field-type fuzzy inference was used for the system production. The conceptual model of the research has been presented in Figure 4 hierarchy levels.

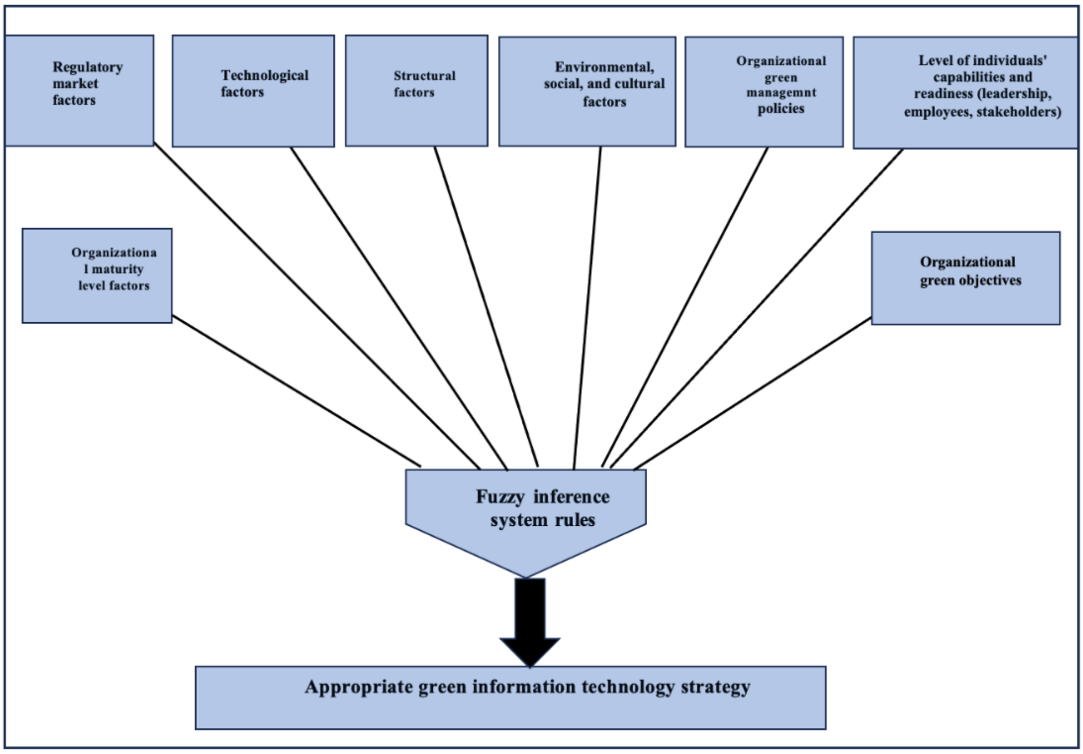

Figure 4. A conceptual research model for selecting green information technology strategies

3.2. System architecture

This study involved designing an expert system for each significant criterion identified, which was then integrated to form a single hybrid expert system. The output of each subsystem served as the input for the hybrid system, and the output of the hybrid system was the appropriate green IT strategy for the organization.

The hybrid expert system was designed to address organizational challenges in precisely calculating sub-criteria. It is often easier for organizations to calculate the weights of primary criteria, which are generally more applicable in organizations that use information technology. Therefore, a hybrid system that can calculate the output separately by averaging the input scores is more efficient and applicable than a single-payer system.

4. Result

The system was designed using the Fuzzy Logic Toolbox in MATLAB. The system's fuzzy membership functions, intervals, and rule base were designed using MATLAB. The input criteria are listed in Table, and the output is the Green IT strategy level. The Mamdani fuzzy inference system was used to design the system, with triangular and Gaussian functions used as membership functions and the Centroid method used for defuzzification. The proposed system has a two-tier architecture, with 120 inputs introduced to 8 independent fuzzy systems.

4.1. System 1: Corporate green objectives system (factors related to the organization's green objectives).

System input: Reduced operational costs of the organization, fake labels and false claims, false suggestions in catalogs and websites, increased or maintained sales by using green labels, reduced energy consumption in the organization, improved reputation and popularity of the organization (social acceptance), observation of government rules and regulations, increased revenue and profitability of green IT plans, the reduced carbon footprint of the organization and its negative effects on the environment, resource sustainability objectives and improved environmental conditions, environmental survival for future generations and related considerations, green social responsibility, compensatory measures to reduce negative effects on the environment, and carbon credit purchase.

System output: The corporate level of green objectives (concerning factors influencing the Green IT strategy level) depends on applying Green IT. Figure 5 shows the corporate objectives system.

Figure 5. Corporate objectives system

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4.2. System 2: Green management policy system (factors related to green management policies of the organization).

System input: Proper disposal of waste, equipment, and toxic materials, reception and implementation of recyclable equipment, delay in replacement of active equipment, increased awareness about reusing equipment, optimized energy consumption in organizational processes, the influence of employee attitudes, green equipment, and relevant services, enforcement of EPAT and Energy Star standards at federal, state, and local levels, use of renewable energies (solar, nuclear), and taking compensatory actions to improve bad environmental conditions.

System output: The alignment of organizational green management policies and Green IT (from a set of factors influencing the Green IT strategy level) depends on applying Green IT.

4.3. System 3: System of capacity and the extent of people's participation in the organization (factors related to capacity and people's participation).

System input: Inputs of this system include leaders, employees, and beneficiaries, and the organization prioritizes people's broad participation.

System output: The effectiveness level is people's capacity and participation to implement Green IT strategies in the organization.

4.3.1. Sub-system: Leader capacity and participation sub-system.

System input: Leader's support for new IT plans as well as new opinions and ideas to make improvements, enabling the leader to create a dynamic environment to accept and implement Green IT plans, the leader's knowledge of new science, promotion of knowledge and updating of IT knowledge consistently, the leader's knowledge of ongoing affairs in line with new science and technology and IT, the leader's interest and tendency to search for new technologies and apply them in major and vital activities of the organization, the leader's risk-taking to implement IT and new technologies for the first time as a pioneer, and beneficiaries and shareholders' cooperation with the Green IT executive team.

System output: The effectiveness level is considered the leader's capacity and participation in implementing Green IT strategies.

4.3.2. Sub-system: Employees' capacity and participation sub-system.

System input: Employees' capacity to implement new IT plans, employees' education, ability to pick up training and learn Green IT plans, and employees' environmental orientation. *System output*: The employees' capacity and participation level align with the organization's Green IT strategy implementation.

4.3.3. Sub-system: Beneficiaries' capacity and participation sub-system.

System input: Beneficiaries' and shareholders' support for new IT plans, ideas, and opinions to make improvements; beneficiaries' and shareholders' ability to provide a dynamic environment to accept and implement Green IT plans; beneficiaries' and shareholders' knowledge of new science, enhancement of knowledge and updating of IT knowledge consistently; beneficiaries' and shareholders' knowledge of ongoing affairs in line with new science and technology and IT, beneficiaries' and shareholders' interest and tendency to search for new technologies and apply them in significant and vital activities of the organization, and beneficiaries' and shareholders' risk-taking to implement IT and new technologies for the first time as a pioneer.

System output: The beneficiaries' capacity and participation level align with the organization's Green IT strategy implementation.

4.4. System 4: Organizational structure system (factors related to organizational structure).

System input: This system consists of four sub-systems as input, which include capacities, internal structure, processes, economic factors, and budgeting.

System output: The level of the organizational structure's alignment with the Green IT strategy (from a set of factors that influence the Green IT strategy level) depends on applying Green IT.

4.4.1. Sub-system: Capacities sub-system

System input: Capacities such as knowledge and understanding of Green IT, staff size and capability, and the number of qualified personnel in Green IT.

System output: The organization's capacity level in Green IT implementation.

4.4.2. Sub-system: Internal structure sub-system

System input: Internal structure factors such as the level of communication between different departments and levels of the organization, the level of flexibility in the organization's structure, the level of decentralization, and the level of autonomy in decision-making. *System output*: The level of the organization's internal structure alignment with the Green IT strategy.

4.4.3. Sub-system: Processes sub-system

System input: Process factors such as the level of coordination between different processes, the level of automation in processes, and the level of documentation and record-keeping in processes.

System output: The synchronization of organizational processes with the Green IT strategy.

4.4.4. Sub-system: Economic factors and budgeting sub-system

System input: Economic and budgetary factors encompass the allocation of funds towards Green IT, the level of financial support for Green IT initiatives, and the return on investment in Green IT.

System output: The level of alignment of economic factors and budgeting with the Green IT strategy.

4.5. System 5: Economic, social environmental factors (cultural, social environmental factors.

System input: Green IT practices such as the level of energy-efficient equipment use, virtualization, electronic document management, telecommuting and videoconferencing, server consolidation, data center consolidation, and level of cloud computing use.

System output: The alignment of Green IT practices with the Green IT strategy.

4.6. System 6: Market regulatory factors system (factors related to market regulation).

System input: Market pressures, government legislation, and organizational norms that support green IT.

System output: Influential market regulatory factors in line with green IT strategies.

4.7. System 7: Technological factors system (organizational technology-related factors).

System input: The extent of the organization's environmental consciousness, the level of hardware accessibility, the information technology infrastructure, and the level of integrated information systems.

System output: Capacity of technological factors in line with green IT strategies.

4.8. System 8: Green IT maturity system (green it maturity-related factors)

System input: This includes five subsystems of data center, administrative environment, organizational citizenship, and procurement.

System output: Assess the organization's final score of green IT.

4.8.1. Subsystem: Data center system

System input: Application of server virtualization solutions, the initial application of server virtualization solutions, using orchestration tools, optimal use of server samples, server function, electrical efficiency, storage integration, storage devices management using indicators, network convergence, smart power allocation management, integration of separate platform to support, on-time electricity consumption monitoring, designing an energy-efficient data center, automate the temperature and humidity control, planning according to logical data center principles.

System output: Green IT maturity level concerning the data center.

4.8.2. Subsystem: Administrative environment system

System input: Disable screen saver, power control using the system of power management of IT devices, replace desktop PCs with laptops, use a client IT solution, cut the power to unused devices, use multifunction print devices, use virtual fax services, use toner-saving solutions, automate power cut at night and holidays, integrate printing management services, use a wireless network instead of a landline network, smart lighting systems, energy-efficient lighting systems, automated temperature control, a power outage at night and holidays.

System output: Level of green IT maturity concerning the administrative environment.

4.8.3. Subsystem: Work activities system

System input: Electronic work processes, electronic confirmation systems, online real-time transactions to provide service for customers, issue invoices (or receipts) to customers through an electronic system, rational programs (specific plans to reduce application portfolio size to achieve an integrated standard architecture), process durability improvement, use integrated communication tools, use video conferencing tools, support and encourage remote communication, ability to support through providing remote services, teach green technology to employees, environmental impact analysis, costing systems for IT services, costing mechanism to find carbon emission cost for units or projects, the system of planning organizational resources.

System output: Green IT maturity level concerning work activities.

4.8.4. Subsystem: Procurement system

System input: Efficient IT asset replacement cycle, data center configuration management, linking of data center configuration management to the relevant catalog service, use of energy-efficient IT devices and equipment, considering carbon emission when purchasing new assets, set policies and rules to use products according to environmental rules and regulations, use logistic intelligent systems, minimize the use of consumables, use environmentally-friendly office products.

System output: Green IT maturity level concerning procurement.

4.8.5. Subsystem: Organizational citizenship system

System input: Management of hazardous and toxic materials that are sold or disposed of, employee rewards and incentives to reduce waste, efforts to reduce environmental impacts, reuse wastewater and thermal waste of IT resources and offices, incentive programs to involve employees in environmental movements, deploy smart redundancy, electronic distribution of customer/seller brochures, rules required for asset reuse, reuse consumables.

System output: Green IT maturity level concerning organizational citizenship.

4.9. Final synthetic system: Green IT strategy system

System input: Outputs of the former 8 systems are defined as inputs for this system. System output: Green IT strategy level.

Overall, these individual systems are integrated to generate a comprehensive Green IT strategy level. The output of each system is used as an input to the next system. The overall output of the system is the Green IT strategy level, which measures the organization's level of alignment with Green IT strategies and practices. The proposed system can help organizations assess their current level of alignment with Green IT and identify areas for improvement to implement Green IT strategies effectively.

5. Fuzzy system membership functions

A fuzzy set is defined by its membership function, where each element of X is mapped to a value between 0 and 1, and each member has a degree of membership. The membership

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function of a fuzzy set X is a function of X between 0 and 1. The membership function of X represents the fuzzy subset of X. The membership function of a fuzzy set A is usually represented as μA. For each element of X, the degree of μA(x) is called the membership degree of X in the fuzzy set A (Zheng, 2013).

Functions of trapezoidal fuzzy numbers can be calculated in MATLAB according to the following equation:

$$f(x;a,b,c,d)=\begin{cases}0, & x\le a\\ \frac{x-a}{b-a} & a\le x\le b\\ 1, & b\le x\le c\\ \frac{d-x}{d-c}, & c\le x\le d\\ 0, & d\le x\end{cases} \quad (1)$$

$$\mathrm{f(x;a,b,c,d)=max(min\left(\frac{x-a}{b-a},1,\frac{d-x}{d-c}\right),0)} \quad (2)$$

Table 1 provides fuzzy numbers for the fuzzy IT strategy system and the related sub-systems.

Table 1. Fuzzy numbers of systems

Fuzzy membership function values	Variable intervals	Type of membership function
Very poor (-0.225, -0.025, 0.025, 0.225)	(0, 1)	Trapmf
Poor (0.025, 0.225, 0.275,0.475)		
Average (0.275, 0.475, 0.525, 0.725)		
Good (0.525, 0.725, 0.775, 0.975)		
Excellent (0.775, 0.975, 1.025, 1.225)		

6. Hybrid fuzzy expert system

In this study, considering the important effects of the criteria, some rules were omitted, and 12 rules were set for each sub-system. As the number of rules is multiplied by each other in the synthetic system, it resulted in more than 100 rules, which is an appropriate number for designing an expert system. The results of testing the system would confirm this. The input to the system is the final synthetic fuzzy system, and the output is the proposed green IT strategy level. The fuzzy inference system applied in this study is Mamdani. The center of gravity was used for defuzzification, and the Max function was used for the union of fuzzy sets. Figure 6 shows some fuzzy inference system rules.

Figure 6. The final synthetic fuzzy inference system

6.1. Examining the system function using sensitivity analysis of variables

In order to test the model, the output behavior analysis method was used, which involves fixing the values of all input variables except one and then increasing or decreasing the value of this variable. For each increase or decrease in inputs, the value of each output was calculated by the expert system, and the resulting behavior was analyzed. If the output-input behaviors are consistent with expert opinions and literature review, the credibility of the expert system is confirmed. Otherwise, the system must be improved. The relevant literature confirmed the expert system output in this research. Each output was measured using MATLAB.

6.2. Testing the system's performance at Alzahra University

Alzahra University was selected as the case study to evaluate the system's performance. Five experts in green information technology were asked to complete questionnaires based on the criteria of the fuzzy expert system, and the average response rate was measured for each criterion. These values were then entered into the system to propose an appropriate green IT strategy for the university. After computing the organization's green IT level, the appropriate strategy level was determined, and suggestions were made to improve the GIT level. The findings suggest that Alzahra University should adopt a primary-level GIT strategy involving a three-year process of implementation, which includes actions such as removing old monitors, developing a green supply chain, reengineering organizational processes, disposing of useless ICT equipment in a green manner, and adopting green marketing practices.

7. Discussion and conclusion

This study aimed to identify and classify the factors that are effective in selecting a green IT strategy. Based on the identified factors and knowledge obtained from experts, an expert system was designed to propose a green IT strategy. The system was evaluated using a sensitivity analysis of variables and a case study at Alzahra University. The results obtained from implementing the system at Alzahra University indicate that the proposed strategy for the university is at the middle level (primary strategic strategy). This organization thoroughly considers the factors that significantly influence the formulation of the ultimate strategy. Nevertheless, should a non-systematic approach be employed, the practicality of comprehensively considering all these factors concurrently could be severely limited. Conversely, over various time intervals, the organization can refine its strategy using the devised system, and in contrast to alternative methods, this capability might be unattainable.

The study findings suggest that Alzahra University should engage in a three-year implementation process to advance its green IT objectives. During this period, organizational processes should be reengineered, old monitors should be removed, a green supply chain should be developed, unusable Information and Communication Technology (ICT) devices should be disposed of and buried, and green marketing should be established as the core organizational process.

The expert system designed in this study can be used by all industries producing green products and information technology. It can provide tools to evaluate organizations' current condition and readiness for green IT. It allows them to identify their green IT level, make strategic decisions regarding changing their organizational level, and determine how much to invest in green IT. The utilization of a fuzzy approach in this article for modeling rules provided us with the capability to account for the influence of qualitative and ambiguous variables in the final decision-making process, representing one of the innovations of this paper.

It is suggested that the indicators used in Iran and other countries be reconsidered and that the system rules be modified, as these indicators may vary based on geographical conditions, government rules, frameworks, and requirements necessary to implement information technology in different countries. It may improve the efficiency of the fuzzy expert system.

This study has some limitations that should be taken into consideration. For example, the way the research was evaluated and the criteria used to assess its novelty may not have been comprehensive enough, which could impact the results' accuracy. Additionally, there is no established maturity model in Iran to compare with, and there is not much literature on selecting green IT strategies. The researcher had limited access to resources, meaning they had to rely on online sources to gather information. Lastly, there are few studies available in this field, which could make it difficult to compare the results of this research with previous studies.

For future research, it is recommended that the design of the fuzzy expert system for evaluating and proposing green IT strategies be done using artificial neural networks, which have more advantages than fuzzy expert systems. The study's indices should also be reviewed for reconsideration in Iran or other countries, as laws, regulations, frameworks, and requirements for implementing information technology may differ by country. Designing online questionnaires to make it easier for people to participate in the study is also recommended.

Regarding practical suggestions, the system designed in this study can be used in all industries involved in green products and information technology. The system can also be used in various organizations and industries, and the results can be analyzed to determine the system's strengths and weaknesses and which industry it can perform more successfully in. The system can also evaluate organizations' current conditions and readiness for green IT and make strategic decisions accordingly.

Disclosure statement

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

References

Akman, I. and Mishra, A., 2015. Sector diversity in green information technology practices: technology acceptance model perspective. *Computers in human behavior*, *49*, pp.477-486. https://doi.org/10.1016/j.chb.2015.03.009.

AlHarbi, L.M. and Pattinson, C., 2016, August. Effective green it strategy in a uk higher education institute. In *2016 IEEE 14th Intl Conf on Dependable, Autonomic and Secure Computing, 14th Intl Conf on Pervasive Intelligence and Computing, 2nd Intl Conf on Big Data Intelligence and Computing and Cyber Science and Technology Congress (DASC/PiCom/DataCom/CyberSciTech)* (pp. 251-256). IEEE.

Asadi, S., Hussin, A.R.C., Dahlan, H.M. and Yadegaridehkordi, E., 2015. Theoretical model for green information technology adoption. *ARPN Journal of Engineering and Applied Sciences*, *10*(23), pp.17720-17729.

Atkinson, C., Schulze, T. and Klingert, S., 2014. Facilitating greener it through green specifications. *IEEE software*, *31*(3), pp.56-63. https://doi.org/10.1109/MS.2014.19.

Britt, P.F., Coates, G.W., Winey, K.I., Byers, J., Chen, E., Coughlin, B., Ellison, C., Garcia, J., Goldman, A., Guzman, J. and Hartwig, J., 2019. *Report of the Basic Energy Sciences Roundtable on Chemical Upcycling of Polymers*. USDOE Office of Science (SC)(United States). https://doi.org/10.2172/1616517.

Corbett, J., 2010. Unearthing the value of green IT.

Dalvi-Esfahani, M., Alaedini, Z., Nilashi, M., Samad, S., Asadi, S. and Mohammadi, M., 2020. Students' green information technology behavior: Beliefs and personality traits. *Journal of cleaner production*, *257*, p.120406. https://doi.org/10.1016/j.jclepro.2020.120406.

Dao, V., Langella, I. and Carbo, J., 2011. From green to sustainability: Information Technology and an integrated sustainability framework. *The Journal of Strategic Information Systems*, *20*(1), pp.63-79. https://doi.org/10.1016/j.jsis.2011.01.002.

Dedrick, J., 2010. Green IS: Concepts and issues for information systems research. *Communications of the Association for Information Systems*, *27*(1), p.11. https://doi.org/10.17705/1CAIS.02711.

Deng, H., Molla, A. and Corbitt, B., 2009, November. A fuzzy logic based green information technology readiness model. In *2009 International Conference on Artificial Intelligence and Computational Intelligence*, *1*, pp. 465-470. IEEE. https://doi.org/10.1109/AICI.2009.247.

Desai, H.P., 2014. Business models for inclusiveness. *Procedia-Social and Behavioral Sciences*, *157*, pp.353-362. https://doi.org/10.1016/j.sbspro.2014.11.039.

Donnellan, B., Sheridan, C. and Curry, E., 2011. A capability maturity framework for sustainable information and communication technology. *IT professional*, *13*(1), pp.33-40. https://doi.org/10.1109/MITP.2011.2.

Du, L., Wei, M. and Wu, K., 2023. Information technology and firm's green innovation: evidence from China. *Environmental Science and Pollution Research*, pp.1-15. https://doi.org/10.1007/s11356-023-29320-z.

Faucheux, S. and Nicolaï, I., 2011. IT for green and green IT: A proposed typology of eco-innovation. *Ecological economics*, *70*(11), pp.2020-2027. https://doi.org/10.1016/j.ecolecon.2011.05.019.

Foogooa, R., Bokhoree, C. and Dookhitram, K., 2015, December. Green ICT maturity models Towards a general approach. In *2015 International Conference on Computing, Communication and Security (ICCCS)*, pp. 1-6. IEEE. https://doi.org/10.1109/CCCS.2015.7374163.

Forrest, W., Kalpan, J.M. and Kindler, N., 2008. Data centers: How to cut carbon emissions and costs. McKinsey Quarterly.

Halchin, L.E., Manuel, K.M., Reese, S. and Schwartz, M., 2010. Inherently governmental functions and other work reserved for performance by federal government employees: The Obama Administration's proposed policy letter. https://hdl.handle.net/1813/79390.

Hankel, A., Oud, L., Saan, M. and Lago, P., 2014, September. A Maturity Model for Green ICT: The Case of the SURF Green ICT Maturity Model. *International Conference on Informatics for Environmental Protection*, pp. 33-40. http://oops.uni-oldenburg.de/1919/.

Hernandez, A.A., 2020. Exploring the factors to green IT adoption of SMEs in the Philippines. In *Start-Ups and SMEs: Concepts, Methodologies, Tools, and Applications*. IGI Global, pp. 907-926. https://doi.org/10.4018/978-1-7998-1760-4.ch047.

Hu, H.F., Hu, P.J.H., Yen, H.R. and Yen, B.P.C., 2022. Examining the Mediating Roles of Green Image and Readiness in Firms' Green Information Technology Practices: An Organizational Legitimation Perspective. *Journal of Organizational Computing and Electronic Commerce*, *32*(2), pp.130-152. https://doi.org/10.1080/10919392.2022.2069455.

Jailani, S.F.A.K., Abdullah, L.M., Kartiwi, M. and Hussin, H., 2016, November. A Conceptual Model of Green It Practices on Organisational Sustainability. In *2016 6th International Conference on Information and Communication Technology for The Muslim World (ICT4M),* IEEE, pp. 254-259. https://doi.org/10.1109/ICT4M.2016.059.

Jenkin, T.A., Webster, J. and McShane, L., 2011. An agenda for 'Green'information technology and systems research. *Information and organization*, *21*(1), pp.17-40. https://doi.org/10.1016/j.infoandorg.2010.09.003.

Kazovsky, L., Gowda, A.S. and Prat, J., 2017, July. Small networks, large energy: New frontiers in green IT. In *2017 19th International Conference on Transparent Optical Networks (ICTON)* ,IEEE, pp. 1-6. https://doi.org/10.1109/ICTON.2017.8024729.

Loeser, F., Recker, J., Brocke, J.V., Molla, A. and Zarnekow, R., 2017. How IT executives create organizational benefits by translating environmental strategies into Green IS initiatives. *Information Systems Journal*, *27*(4), pp.503-553. https://doi.org/10.1111/isj.12136.

McAllister, J.T., Lennertz, L. and Atencio Mojica, Z., 2022. Mapping a discipline: a guide to using VOSviewer for bibliometric and visual analysis. *Science & Technology Libraries*, *41*(3), pp.319-348. https://doi.org/10.1080/0194262X.2021.1991547.

Melville, N.P., 2010. Information systems innovation for environmental sustainability. *MIS quarterly*, pp.1-21. https://doi.org/10.2307/20721412.

Molla, A. and Abareshi, A., 2011. Green IT adoption: A motivational perspective.

Molla, A., Pittayachawan, S., Corbitt, B. and Deng, H., 2009. An international comparison of Green IT diffusion. *International Journal of e-Business Management*, *3*(2), pp.3-23. https://doi/abs/10.3316/informit.160324752509708.

Murugesan, S., 2008. Harnessing green IT: Principles and practices. *IT professional*, *10*(1), pp.24-33. https://doi.org/10.1109/MITP.2008.10.

Nabila'Aini, N. and Subriadi, A.P., 2022. Governance and practice approach of green information technology. *Procedia Computer Science*, *197*, pp.650-659. https://doi.org/10.1016/j.procs.2021.12.186.

Nanath, K. and Pillai, R.R., 2017. The influence of green is practices on competitive advantage: Mediation role of green innovation performance. *Information Systems Management*, *34*(1), pp.3-19. https://doi.org/10.1080/10580530.2017.1254436.

Nishant, R., Teo, T.S. and Goh, M., 2013. Understanding the environmental impact of sustainable IT: An empirical examination. https://aisel.aisnet.org/pacis2013/94/.

Philipson, G., 2010. A Green ICT Framework: Understanding and Measuring Green ICT. Connection Research. *New South Wales*.

Qu, K. and Liu, Z., 2022. Green innovations, supply chain integration and green information system: A model of moderation. *Journal of Cleaner Production*, *339*, p.130557. https://doi.org/10.1016/j.jclepro.2022.130557.

Santos, J., Torres-Machi, C., Morillas, S. and Cerezo, V., 2022. A fuzzy logic expert system for selecting optimal and sustainable life cycle maintenance and rehabilitation strategies for road pavements. *International journal of pavement engineering*, *23*(2), pp.425-437. https://doi.org/10.1080/10298436.2020.1751161.

Sohns, T.M., Aysolmaz, B., Figge, L. and Joshi, A., 2023. Green business process management for business sustainability: A case study of manufacturing small and medium-sized enterprises (SMEs) from Germany. *Journal of Cleaner Production*, *401*, p.136667. https://doi.org/10.1016/j.jclepro.2023.136667.

Su, Y. and Al-Hakim, L., 2010, March. System dynamics modeling for green IT strategies: SAP sustainability development case. In *2010 international conference on challenges in environmental science and computer engineering*, *2*, pp. 504-507. https://doi.org/10.1109/CESCE.2010.244.

Tokkozhina, U., Lucia Martins, A. and Ferreira, J.C., 2023. Uncovering dimensions of the impact of blockchain technology in supply chain management. *Operations Management Research*, *16*(1), pp.99-125. https://doi.org/10.1007/s12063-022-00273-9.

Taghva, M; Zohrabi, M; Dehdashti, Z. 2017. *'The effect of Green Information Technology on the corporate sustainable economics: (Review of Iranian Small and Medium-Sized Enterprises (SMEs))', Iranian Journal of Information Management*, 3(1), pp. 143-161. [in Persian]

Unhelkar, B., 2016. *Green IT strategies and applications: using environmental intelligence*. CRC Press.

Unhelkar, B. and Tiwary, A., 2011. Extending and applying business intelligence and customer strategies for green ICT. In *Green Technologies: Concepts, Methodologies, Tools and Applications*, IGI Global. pp. 1198-1212. https://doi.org/10.4018/978-1-60960-472-1.ch505.

Zaman, B. and Sedera, D., 2016. Green information technology as administrative innovation-Organizational factors for successful implementation: Literature review. *arXiv preprint arXiv:1606.03503*. https://doi.org/10.48550/arXiv.1606.03503.

Zheng, D.Q., 2013. The Discussion on Mechanism and Research Framework of Green Information Technology and Information Systems Adoption. *Advanced Materials Research*, *694*, pp.2286-2290. https://doi.org/10.4028/www.scientific.net/AMR.694-697.2286.

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Selecting an Appropriate Scenario for Implementing RCM and RCA to Reduce System Average Interruption Duration Index with Systems Dynamics Approach in Power Distribution Companies

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ABSTRACT

The mission of power companies is to provide standard and reliable electricity to their customers, and one of the threats of not fulfilling this mission is breakdowns and accidents in the electricity network equipment. The System Average Interruption Duration Index (SAIDI) is a critical indicator in the power distribution industry to determine network reliability; Reliability Centered Maintenance (RCM) and root cause analysis (RCA) of failures and applying the results of these two in two dimensions of network maintenance and design, are two effective measures in reducing SAIDI. This paper presents a model for the system and structure that creates SAIDI behavior, which can be simulated to achieve appropriate policies to determine the level of use of RCM and RCA and, thus, the optimal value to reduce the index value. The System simulation method has been used to simulate system behavior. After designing and simulating the cyclic causal model, various scenarios for determining RCM and RCA policies are proposed and reviewed, and the results are presented. The criterion for selecting the appropriate scenario in this article is to reduce the SAIDI index's value further. Based on the research findings, the policies selected have a suitable reducing effect on SAIDI. The model's validity was evaluated through behavior replication testing, extreme condition assessment, and sensitivity analysis. Since the organization's vision in 2026 is to reduce SAIDI to 14 minutes per year, the impact of RCM and RCA policies in different scenarios on the model variables was evaluated. The results showed that if the existing policies are not changed, the process of SAIDI changes will increase. Changing the system approach from non-implementation to implementing RCM and RCA under optimal conditions will decrease SAIDI from 26.73 minutes at the beginning of 2020 to 41.34 minutes by the end of 2026.

Keywords

System dynamics, System average interruption Duration index, Reliability centered maintenance, Root cause analysis, Power distribution companies.

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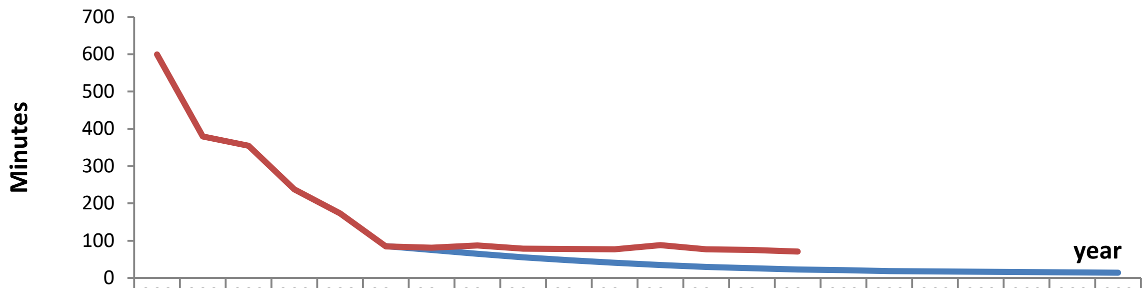
1. Introduction

One of the problems in planning in the management of macro organizations is the failure to achieve the vision and goals of the organization following what has been planned. This issue can be due to the system's resistance to change and the feedback and nonlinear relationships of factors affecting the achievement of goals. Considering the mission of power distribution companies to provide electricity to their subscribers in a stable, reliable, and standard way, the strategic importance of the index "Average shutdown time per subscriber per year"(System Average Interruption Duration Index (SAIDI)) (IEEE, 2012, Jasim Mohammad Al Shaheen, 2017, Tavanir, 2018) From the perspective of these companies and the electricity industry in general, and recognizing the factors affecting the changes in this index has a special place for the development of effective reform programs; Obviously, this indicator indicates the reliability of the power supply network, which also affects another strategic indicator called "Energy Not Supplied"(ENS). Given this mission, the importance of the SAIDI index is evident, and indeed, this philosophy of existence applies to all power distribution companies. Therefore, this index can be considered a "universal" issue for the electricity industry. In this research, Mashhad Electric Energy Distribution Co. (MEEDC), which provides services in Iran, was selected as a case study. This company has reduced SAIDI to 14 minutes in 2026 AD (1405 Hijri-Shamsi). Therefore, it is necessary to study the factors affecting achieving the desired goal and monitor each policy's effectiveness. These factors can be divided into two subsets: "technical" and "non-technical" factors (Anbiaei, 2004). Technical factors and non-technical factors are two categories of factors that affect the behavior of the power grid. Technical factors are related to the physical structure of the power grid and can influence the shutdown rate. Non-technical factors, on the other hand, are not directly related to the physical structure and topology of the network.

According to the company's strategic plan, a trend in 2011-2026 AD to reduce the SAIDI index from 86 to 14 minutes per year was set, and this decreasing trend was estimated annually. In this regard, the company set up operational plans and controlled them through "historical trend control" tables to implement and monitor these plans properly. However, despite all the seriousness and efforts made, this index did not go according to the initial regulatory plan for nine years until 2020, and according to the plan, it should be reduced from 86 to nearly 20 minutes per year. This amount has reached 72 minutes per year (Figure). In this study, SAIDI is the critical variable that needs to be analyzed. However, to understand the behavior of this variable, other concepts should also be considered. These concepts include planned and unplanned blackout rates and delivered energy to subscribers yearly. The reference behavior of the key SAIDI variable from 2005 to 2019 shows a downward and Goal Seeking trend. This trend has had asymmetric fluctuations from 2010 to 2019 (Figure).



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Forecast						86	75	65	56	48	41	35	30	26	23	21	19	18	17	16	15	14
Performance	600	380	355	238	173	85	81	87	79	78	77	88	77	75	71							

Figure 7. Comparison of SAIDI forecasting trend and its realized value (reference behavior)

Figure 1 is prepared based on the forecasted trend in the strategic plan and historical trend data that are available in the MEEDC Dispatching Department. This behavior shows that the purpose of the system is not in line with the purpose of policymakers for the system. The policies set cannot overcome the system's resistance, and there is a need to review existing policies and design new policies. Therefore, this study presents the effect of these policies on the behavior of SAIDI by modeling, simulating, and systematically analyzing the impact of RCM and RCA implementation policies in network design on SAIDI with a systems dynamics approach.

According to the above, the primary purpose of this study is to identify the factors affecting system dynamics affecting the amount of SAIDI in MEEDC as an example to study and model the interaction of these factors with each other and also on the results of the studied system and check the future results of the system, based on applying the selected policies in simulating the model and finally selecting the optimal conditions for implementing the selected policy to change the behavior of the SAIDI index in the desired direction, to achieve the company's goal in 2026. There is little research explicitly examining Energy Not Supplied in systems dynamics. Thurlby (2013) presents an article entitled "Managing the asset time bomb: A system dynamics approach" that examines an asset time bomb through the role of system dynamics in creating modeling capabilities.

By providing a SAIDI chart for 20 years, the researcher shows that if the current asset management policy does not change, there will be a real threat of an asset time bomb, and its impact is imminent. On the other hand, the policy change can eliminate the threat and, in addition, reduce the number of interruptions. Quentara and Suryani (2017) separate the integrated electrical operating system into five subsystems in the system dynamics development model for the operation strategy in the power generation system through the integrated transmission and distribution system. The researchers' main goal is to plan the appropriate operation strategy for the power generation system required on the Indonesian island of Madura so that they can consider the decision to invest in this sector. In their paper, Ghasemianfard and Moosavirad (2017), using the theory of system dynamics, have identified and prioritized the factors affecting the reduction of blackouts and show that implementing improvement policies reduces ENS. Among the policies that these researchers have studied are the practical training of staff and justification of instructions, power outages during off-peak hours and seasons and in the shortest range, standardization of the network, and non-frequent outages in a particular area.

2. Literature review and innovation

With a more general look at the history of studies, these studies have addressed various aspects in recognizing the factors affecting changes in the SAIDI index. However, these efforts are more with a specialized approach and without systemic thinking to examine the effects of a particular factor, and different factors and their effect on each other and SAIDI have yet to be studied simultaneously. Examples of these specialized studies are listed in Table . Of course, the research that Ghasemianfard and Moosavirad (2017) have done concerning the analysis of factors affecting ENS from the system dynamics perspective can be mentioned as an example of research. Nevertheless, Meadows et al. (1982) say that A central principle of system dynamics is to examine issues from multiple perspectives, to expand the boundaries of our mental models to consider the long-term consequences and “side effects” of our actions, including their environmental, cultural, and moral implications (Sterman, 2000); This critique can be attributed to the mentioned study which has paid attention only to the technical aspects of the subject of ENS and has neglected the non-technical aspect; That is, they have studied the effect of technical and non-technical factors without distinguishing between them, in a model that models the system only from a technical point of view. Now, according to the above, in this study, an attempt has been made to pay attention to the dynamics of factors affecting power outages in technical and non-technical dimensions to separate and model these factors in two separate subsystems and create a holistic and systematic view on this issue, to be able, to simulate the actual effect of technical factors on system behavior. In their research, Ghasemianfard and Moosavirad (2017) investigated the analysis of ENS system dynamics in the North Kerman Electricity Distribution Company. In that study, the separation of the effects of non-technical and technical factors was neglected, and technical factors were studied only from the dimension of incidents in the electricity distribution network. Therefore, in this article, with the system thinking approach and using the "systems dynamics" technique, by separating the "technical and non-technical" factors from each other; an attempt has been made to determine their effects on interaction with each other simultaneously in the SAIDI index behavior; and By modeling the existing structure and simulating its behavior, different policies be tested in simulating system behavior; In other words, based on the past behavior of the system, by modeling the system, its behavior in relation to the future effects of selected policies is simulated and then by changing the controllable factors of these selected policies, different scenarios are designed; and these new policies-scenarios, with the same system model that has been discovered, are in the simulation process and the results of future simulation of the selected policies-scenarios are compared, and finally, among these policies-scenarios, the best one is the one whose effects In the future, it shows better results in achieving the goals of the organization, has been selected and introduced as a desirable policy.

Table 2. Examples of research background

Researcher (s)	Model type	Method / approach	Research goal	Type of factors examined
Mohammadi and Rajabi Mashhadi (2019)	Analytical	Game theory/ modeling	a game theoretic approach is designed to model possible strategic behavior of customers in distribution system reliability provision	technical & non-technical
Nourizadeh and Niasati (2020)	Analytical	Optimization	Locating distribution substations to reduce losses and ENS	technical & non-technical
Alimohammadi and Behnamian (2021)	Analytical	Optimization	Preventive maintenance planning of the electricity distribution network to reduce ENS	technical
Gord et al., (2020)	Analytical	transient analysis	Provide fault locating method for distributed networks with distributed generation to reduce the amount of ENS	technical
Tatiétsé et al., (2002)	Analytical	statistical techniques density estimation	proposes an approach to network reliability through modelling the interruptions on medium voltage lines.	technical
Mercado and Sanchez (2021)	Analytical	Mixed Integer Nonlinear Programming (MINLP)/ Optimization	presents a methodology for optimization of reclosers placement in distribution networks	technical

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3. Research methodology

The approach in this study is naturalistic, and qualitative and quantitative methods are the basis of this research. The purpose of this research is applied, which has been in line with the development of knowledge of systems dynamics in electrical energy distribution. It is a descriptive study, and a case study is systemic dynamics affecting the rate of SAIDI in MEEDC.

Due to the limited number of qualified experts in the entire field of operation and issues related to subscriber shutdown in MEEDC, the sample is selected from the community of experts in the field of network operation and maintenance, which, in selecting selected policies for modeling, among the current policies of the organization that affects SAIDI, as well as to discover the factors affecting SAIDI changes and its relationships, this Agents cooperated by participating in expert meetings. The TOPSIS method was used to select the selected policies for modeling, by which, among the policies the organization implements or intends to implement shortly, select two policies or implement the results of RCM and RCA. Then, considering that the RCA committee was held in MEEDC to identify the primary factors effective in reducing SAIDI, the documents of this committee were studied, and based on the results, the relationships between these factors were discovered. In order to formulate the Stocks and Flows Diagram, interview sessions were organized with relevant experts; finally, the Vensim DSS 6.4E software Optimize tool was used to identify and select the optimal policy. Stocks and Flows Diagram parameters such as zero moment values, relationship coefficients between variables, exogenous and other required values, from records of accident registration databases and Geographic Information System (GIS), available in the Deputy of Operation and Maintenance, and interviews with relevant experts, have been collected. The time horizon of the simulation is 21 years, from the beginning of 2005 to the end of 2026, and the simulation period is one year. The available data collected, which can be used to estimate other values, are from 2015 to 2019.

4. Modeling system dynamics

The method used in this research to model the problem is the Sterman (2000) modeling process.

4.1. Problem articulation and boundary selection

The steps of this stage are explained in four sections: Theme selection, introducing critical variables, determination of time horizon, and dynamic problem definition (reference modes). Based on this model, the organization's issues and challenges, which are the system-goal-seeking behavior and resistance to SAIDI reduction, have been explained. Also, according to Figure , the reference behavior of this key variable in the time horizon of 2005 to 2026 was shown from two dimensions: behavior (performance) and desirable behavior (forecast). At this stage, to obtain information about the boundary, the level of integration, and the main endogenous and exogenous variables of the system (Sterman, 2000), a subsystem diagram is designed (Figure 8). This diagram shows how the SAIDI subsystem is affected by other subsystems within the model. This diagram shows that the SAIDI subsystem is affected by three variables: ENS, SAIDI Vision, and DE.

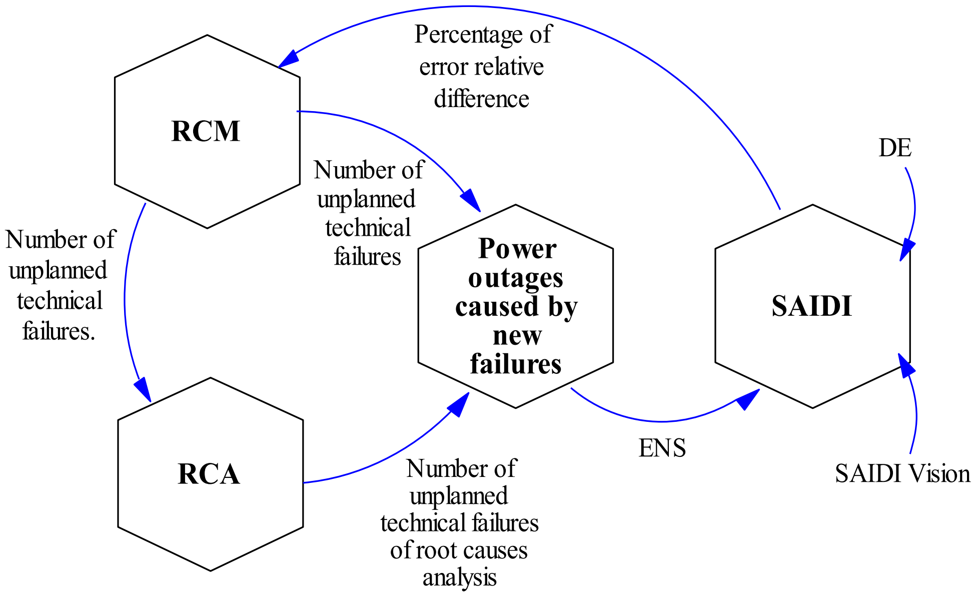

Figure 8. Diagram of SAIDI creator subsystem

4.2. Causal loop diagrams and dynamic hypothesis

Due to raising the issue and demonstrating the system's dynamics, CLDs of the initial dynamics hypothesis were presented to a committee of experts, and the proposed hypothesis and model were reviewed using the SODA II (Azar et al., 2013) method. The steps of this method were carried out so that an initial group mental map was prepared by holding a brainstorming session and presenting the experts' opinions. After that, in the second session, this mental map was exposed to the group of experts, new relationships and concepts were discussed, and amendments were included in the final map (which is the CLD of Figure 3); finally, Figure 3 as the model of The CLDs of the dynamic hypothesis have been determined.

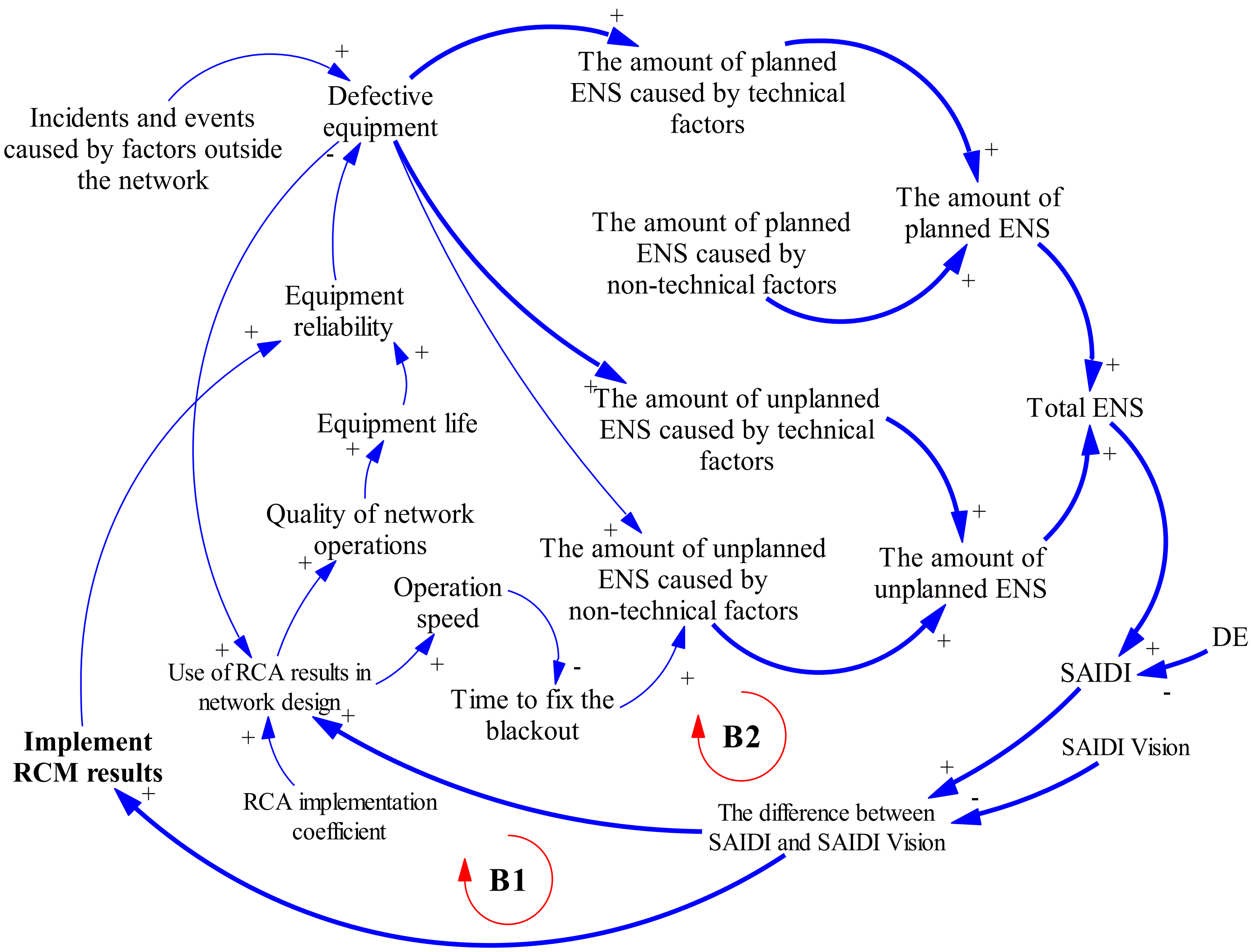

Figure 9. CLDs of dynamic hypothesis

Loop B1 with a negative impact on SAIDI in Figure 9 shows how increasing/decreasing the implementation of RCM results in decreasing/increasing the SAIDI behavioral process. Loop B2, with its negative impact on SAIDI, shows how implementing RCA results in network operation.

Increase/decrease incidents caused by factors outside the network will increase/decrease defective equipment. On the other hand, increasing/decreasing equipment reliability will decrease/increase the variable of faulty equipment. When a piece of equipment becomes defective, it needs to be repaired. The increase/decrease of these repairs, depending on the type and severity of the incidents, causes an increase/decrease in the amount of ENS in two categories: planned and unplanned. On the other hand, some ENSs in these two categories are caused by technical factors, and non-technical factors cause others. DE also influences SAIDI as an exogenous variable; their relationship ratio is increase/decrease to decrease/increase.

Finally, SAIDI and SAIDI Vision are compared, and their difference determines the values needed to change in performing RCM and RCA. RCM and RCA will change the reliability of the equipment, and as these two increase/decrease, the value of the reliability of the equipment will increase/decrease. In Figure 3, an attempt has been made to show the effects of RCM and RCA on SAIDI behavior in two loops, B1 and B2.

4.3. Formulation of simulation model

According to the CLD of the dynamic hypothesis (Figure 9) and the governing relationships between the model variables (Appendix-Table 1), the Stocks and Flows corresponding Diagram was created (Figure 10). In this modeling, by dividing the model into four subsystems and establishing a relationship between these subsystems, the behavior of the whole system was simulated based on Vensim DSS 6.4E software.

4.3.1. Subsystem that detects the difference between actual behavior and perspective

The first key loop in this model (Figure 11) is the negative feedback loop, which produces the primary goal-seeking behavior at a decreasing rate for SAIDI. As shown in the CLD in Figure 11, if the ENS variable increases/decreases, the SAIDI variable will increase/decrease more than it would otherwise. Then, by comparing the value of SAIDI with the value of perspective and discovering the difference between these two variables, the system determines the number of corrective actions needed to direct the system behavior toward the system goal. This set of corrective actions, ultimately with a negative effect on the ENS variable, causes a guiding effect on the SAIDI variable and directs its behavior towards the system's goal, the vision. The DE variable is considered an exogenous variable because it changes annually based on the consumption needs of subscribers and is not under the system's control.

Electricity distribution companies calculate SAIDI according to Equation 1:

$$SAIDI_{(minute/year)} = (ENS_{(MWH)}/DE_{(MWH)}) * 1440 * 365 \quad (1)$$

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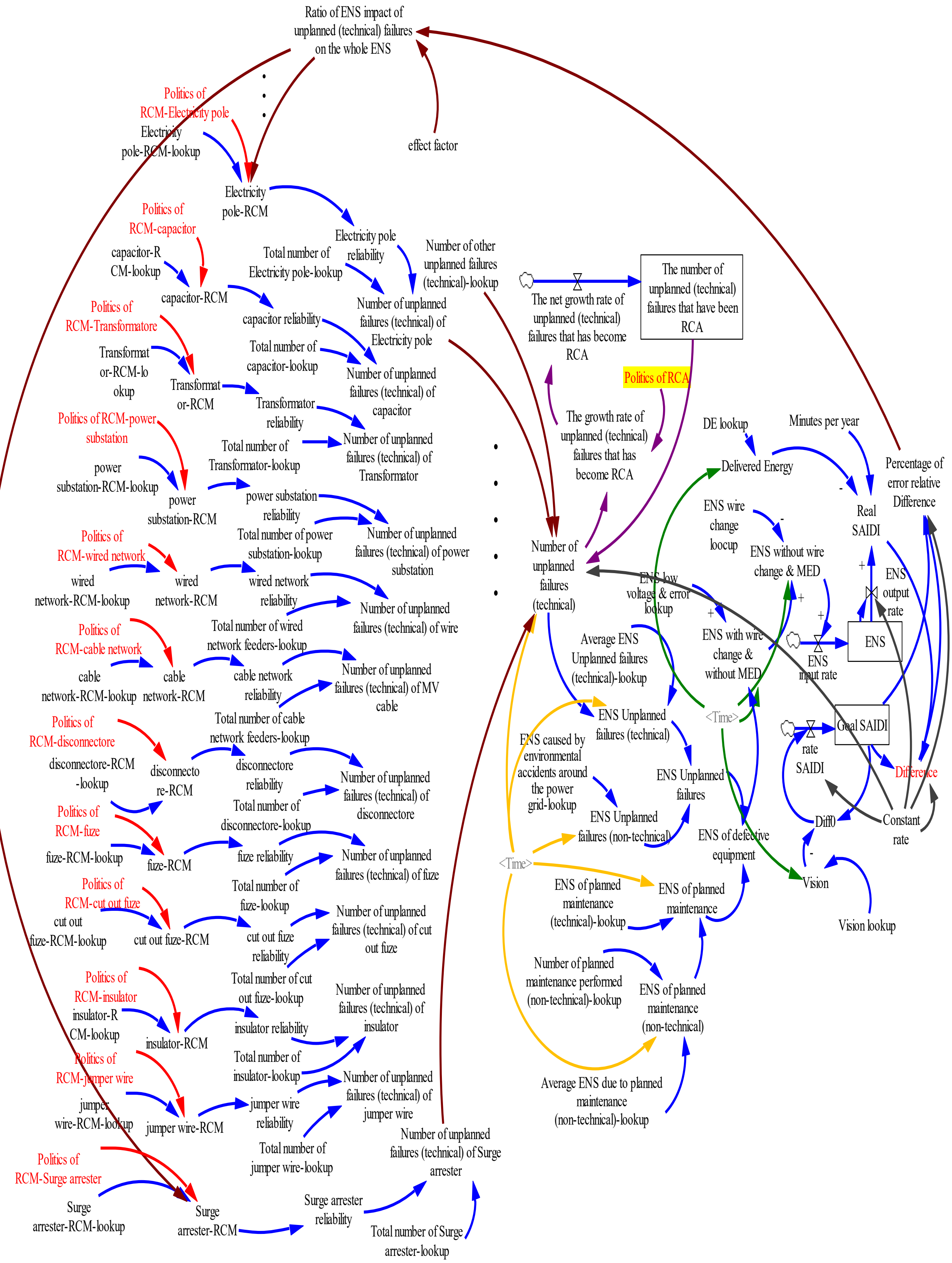

Figure 10. Stocks and flows diagram of the system

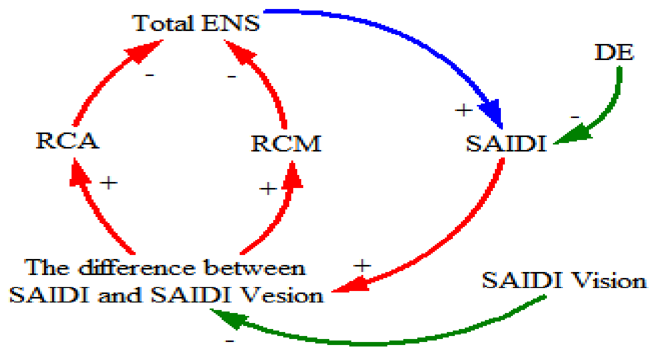

Figure 11. Negative feedback loop that produces SAIDI core behavior

By considering Figure 11 as the basis, the stock and flow model shown in Figure 12 was created. In this model (Figure 12), short-term annual goals have been designed to realize the 14-minute vision for SAIDI for each subscriber per year, and the company's correction plans in previous years have been adjusted accordingly. Therefore, the Vision variable is defined to show the desired target value each year to move toward the organization's vision. The role of loop B0 in the following model is to create the desired behavior for SAIDI, shown in the Goal SAIDI stock variable. Now, the desired behavior is compared with the actual and probable behavior of the system, which is generated in the Real SAIDI variable, and the detected difference is displayed in the Difference variable (Equation 2). The system's goal is to minimize this discrepancy during the realization of the vision.

$$Difference = Real\ SAIDI - Goal\ SAIDI \qquad (2)$$

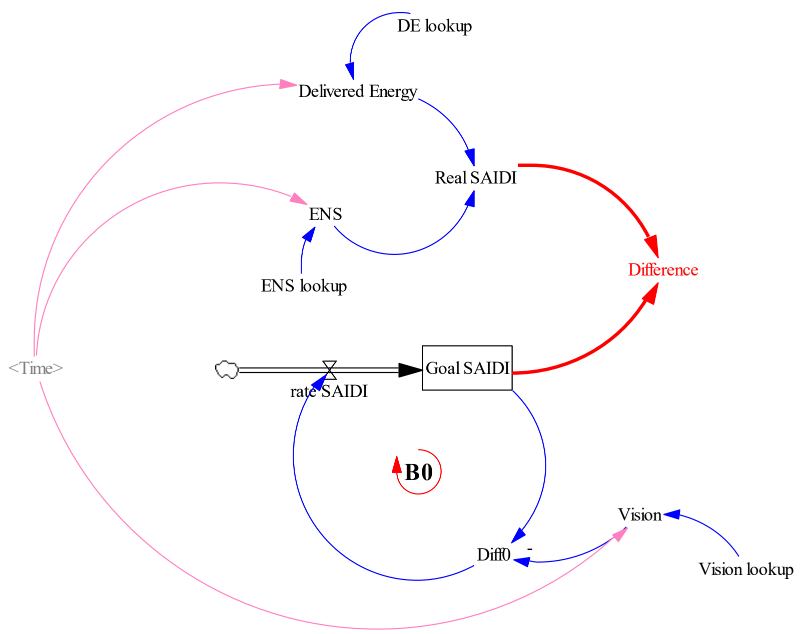

Figure 12. A model that shows the difference between the desired situation and the current and probable situation

As shown in Figure 12, Real SAIDI is calculated with two variables, DE and ENS, the same as Equation 1. DE is an exogenous and out-of-control variable of the system, the values of which, at times, did not exist due to data shortages or data defects, are calculated approximately based on available data and linear regression estimates. The other variable is the "Percentage of error relative Difference", which represents the percentage of relative error (Equation 3) that Real SAIDI has with the Goal SAIDI (Figure 13).

$$Percentage\ of\ error\ relative\ difference\ = (Diffrence/Goal\ SAIDI) \times 100 \quad (3)$$

4.3.2. SAIDI subsystem

ENS has a combination of two components, which should be excluded from the calculations according to the SAIDI calculation guidelines related to the MEEDC perspective. "ENS wire change" and "ENS MED" are two components. After subtracting these two components, "ENS without wire change & MED" is considered input to the SAIDI calculation formula (Figure 13). In this project, to minimize and simplify the model, "ENS low voltage & error"(ENS of low voltage network and computational discrepancies in summarizing the data of the emergency database), which has a more negligible effect on SAIDI, was used as an exogenous variable; based on the model's records, the modeling of this section was refused. The variable "ENS of defective equipment" represents the total ENS in the medium pressure network, converted to the variable "ENS without wire change & MED", respectively.

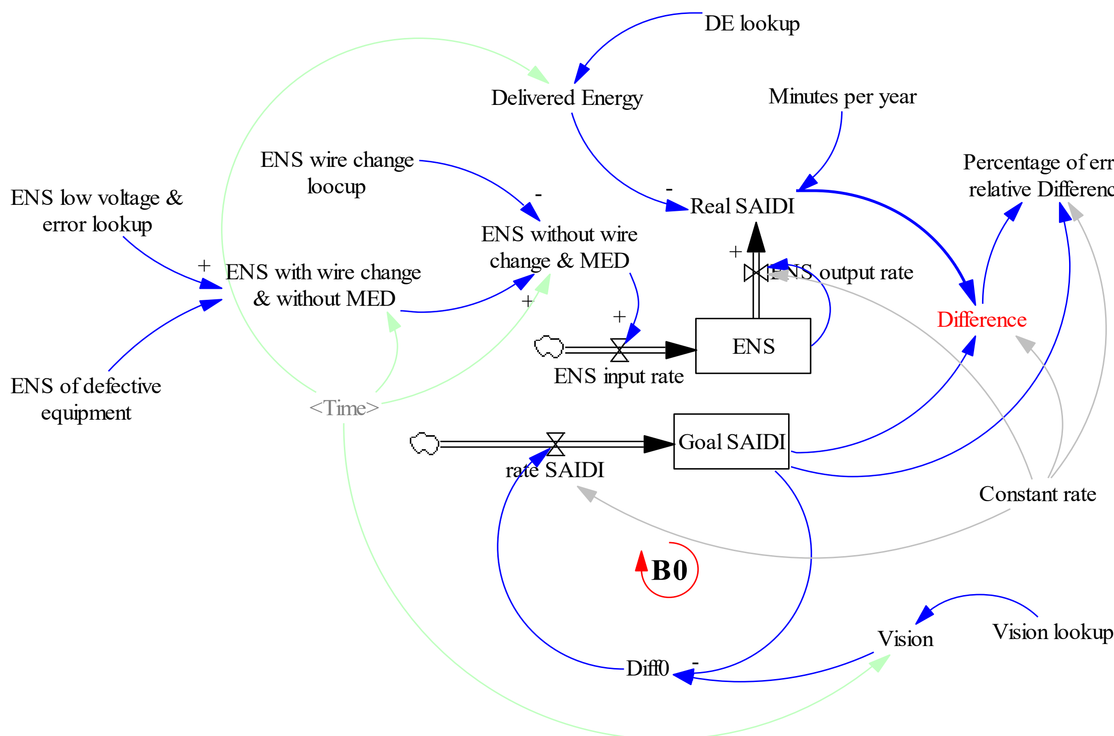

Figure 13. Separation of SAIDI calculation components

4.3.3. *Subsystem of power outages caused by new failures*

In the next step, the "ENS of defective equipment", made of ENS in the medium voltage network, is divided into constituent components based on the initial research approach. Figure 14 shows that "ENS of defective equipment" is divided into two main components, "ENS Unplanned failures" and "ENS of planned maintenance," In the continuation of these components, each with two components from a technical point of view and non-technical can be modeled. It was now necessary to determine which sub-component of the power outage each of the policies considered in the study would affect.

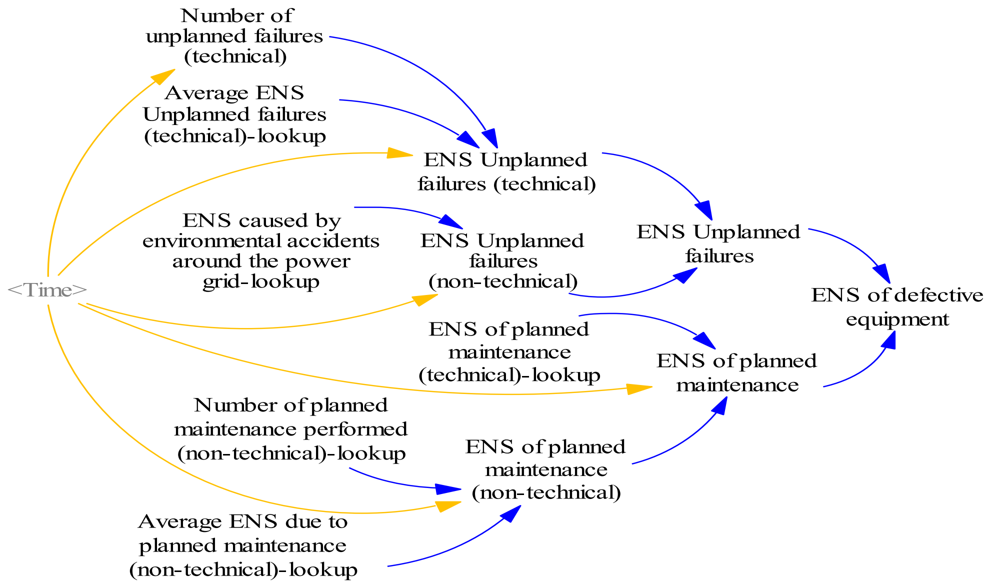

Figure 14. Components of "ENS of defective equipment"

4.3.4. *RCM subsystem*

Referring to Figure 9, it is clear that in the identified cyclical causal relationships, the variable "Implement RCM results" has a positive effect on "Equipment reliability," and "Equipment reliability" subsequently has a negative effect on "Defective equipment", and "Defective equipment" also has a positive effect on "the number of unplanned ENS caused by technical factors" on "the amount of unplanned ENS"; which is one of It is a sub-component of "Total ENS", which has a positive effect on the calculation of SAIDI. After calculating SAIDI, the difference with SAIDI Vision is calculated. The value obtained is used to modify the value of the "Implement RCM results" variable, which is the policy in this area, and this feedback loop is closed at this point. Therefore, it can be concluded that the "Implement RCM results" policy, by affecting the "Number of unplanned failures (technical)", can affect "the amount of unplanned ENS".

According to Figure 10, the "effect factor", the average ratio of "the number of unplanned ENS caused by technical factors" to "ENS of defective equipment", is introduced each year. The coefficient of this parameter with the variable "Percentage of error relative Difference" shows what percentage of the difference in Goal SAIDI and Real SAIDI is due to "the amount of unplanned ENS caused by technical factors"; This ratio is defined by the variable "Ratio of ENS impact of unplanned (technical) failures on the whole ENS".

4.3.5. RCA subsystem

The most significant effect of the policy of implementing RCA results is on the component "the number of unplanned ENS caused by technical factors". The more network equipment failures are analyzed and rooted out. The more RCA results are used in equipment design, redesign, and maintenance to prevent a recurrence, the lower the power outage (Figure 10). In order to make changes in RCA policy and to explain this policy to the model, the variable Politics of RCA, which is a number in the range [0,1], has been used. This variable indicates the percentage of policy implementation during simulation in the model.

4.4. Testing

In this research, validation has been performed to investigate the dimensional compatibility of the equations, test the limit conditions of the model, and create trust in the model, and the sensitivity of the system model has been analyzed. Testing and validation are the two essential notions of building confidence in system dynamics models. Testing means comparing a model to empirical reality for accepting or rejecting the model, and validation means establishing confidence in the soundness and usefulness of the model (Bala et al., 2017).

4.4.1. Behavior reproduction test

This test examines whether or not the model simulation, given the appropriate values, can simulate the past behavior of important variables with reasonable accuracy. The proper use of the behavior reproduction test is to uncover flaws in the structure or parameters of the model and assess whether they matter relative to the purpose (Sterman, 2000). Figure 15 shows the simulation results performed in two different modes simultaneously. This diagram shows that the model can display the actual reference behavior with the "Reference Mode Real SAIDI" curve and the simulated reference behavior with the "Current" curve. This diagram simulates the reference behavior of Figure . Of course, it calculates and plots the values of the "Current" curve before the 10th period due to insufficient information in MEEDC to simulate through the

Vensim software extrapolation system. As shown in the diagram, the two curves are almost identical from the fifth period onwards.

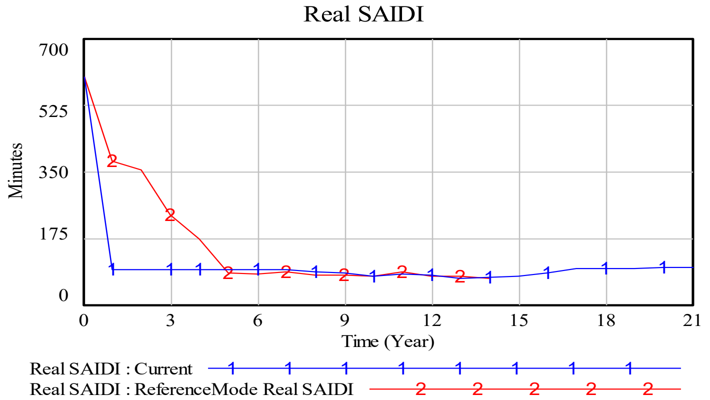

Figure 15. SAIDI behavior in reality and simulation

Table 2 shows the simulated values (Figure 9, curve 1) and the actual SAIDI (Figure 9, curve 2) from 10 to 14, which have complete and correct data in the databases. As it is apparent in the table, for the values before the 10th interval, Vensim software has extrapolated the values in the simulation without having complete input information, which is only the values up to the fifth time interval that are close to the real values. In this table, the average value of the absolute value of the error in the period from 10 to 14 for real and simulated values is calculated and placed. The MAE value equals 3.0388 minutes per year, which is a good value.

Table 3. SAIDI values in reality and simulation

Time (Year)	Real SAIDI	Reference mode real SAIDI
0	601.48	600
1	92.716	380
2	92.716	355
3	92.716	238
4	92.716	173
5	92.716	85
6	92.716	81
7	92.716	87
8	89.035	79
9	85.091	78
10	76.433	77
11	82.949	88
12	79.962	77
13	70.645	75
14	73.259	71
15	76.487	--
16	83.899	--
17	96.294	--
18	96.182	--
19	96.079	--
20	98.767	--
21	98.767	--
In the period from 10 to 14	(MAE) Mean Absolute Error	3.0388

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4.4.2. *Extreme condition test*

This test evaluates and validates the model under extreme conditions. Extreme conditions are related to the time when, if the value of the model indices reaches its maximum or minimum limit, the model equilibrium is not disturbed, and the model variables do not exhibit misbehavior (Sterman, 2000). The model's main exogenous variables are the variables that apply the value of RCM and RCA policies to the equipment. These variables have a value of zero in the simulation default because these two policies have not been implemented in the organization yet, so they do not have past results to apply to the past results of the organization's behavior. Therefore, in the zero extreme conditions for these indices, the simulation result is the same as in Figure 15. Now, for example, by changing the index of RCM and RCA policies (Politics of RCA and Politics ... RCM variables) to the maximum value of 1, which is a sign of 100% application of these policies on equipment. the behavior of the system changes to the "Limit condition test" curve in Figure 16. As shown in the behavior of this curve, the equilibrium of the model is established, and the behavior of the behavioral model is correct and decreasing.

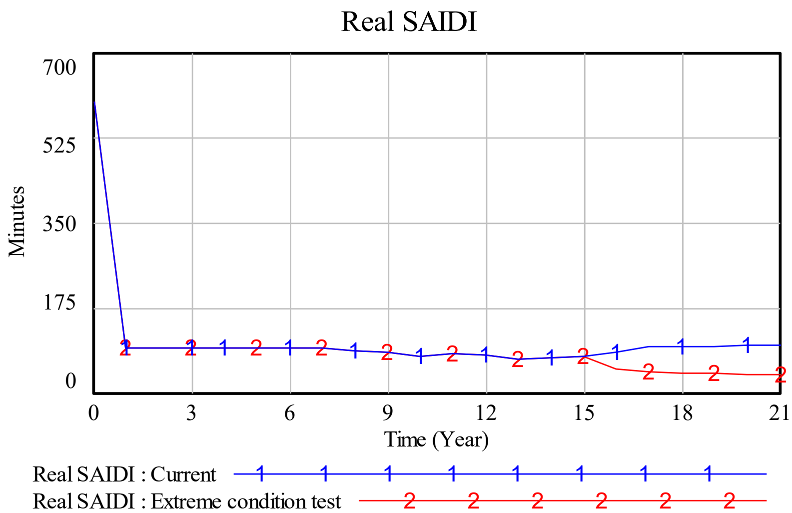

Figure 16. Extreme condition test

4.4.3. *Sensitivity analysis*

Since all models are wrong, it must test the robustness of the conclusions to uncertainty in the assumptions. Sensitivity analysis asks whether its conclusions change in ways necessary to purpose when assumptions vary over the plausible uncertainty range (Sterman, 2000). The sensitivity test indicates the model's sensitivity in simulating small changes in input indicators. With these small changes, the balance of the model should not be disturbed, and the behavior of variables should not change much. For example, suppose the RCM and RCA policy input

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indicators change to 0.01 each. In this case, the changes are shown in Figure 17, with the "Sensitivity test" curve indicating the model equilibrium and small and correct changes in the SIADI behavior curve.

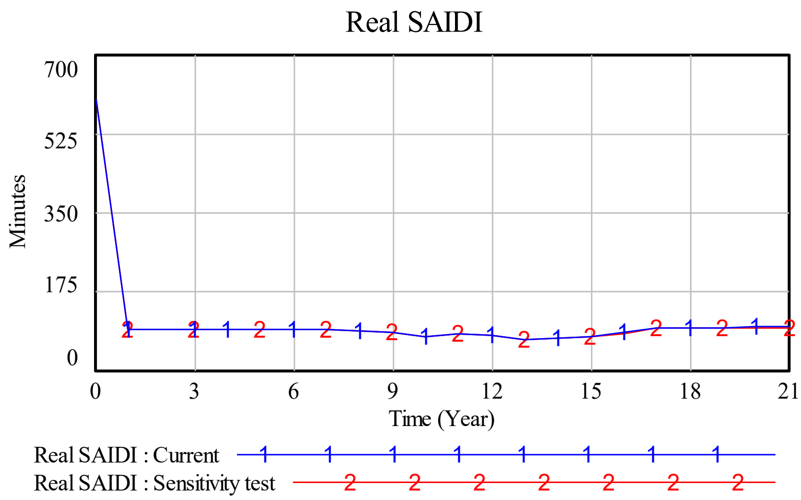

Figure 17. Sensitivity analysis

4.5. Policy design and evaluation

Policies' robustness and sensitivity to uncertainties in model parameters and structure must be assessed, including their performance under various alternative scenarios (Sterman, 2000). As can be seen from SAIDI's behavior in Figure 18 and its simulation results in Table 4, if the organization changes its policies to reduce ENS, only in the part of policies implementing RCM and RCA results on network equipment; and, in other cases, maintain existing policies; The amount of SAIDI will be affected, and will follow a decreasing trend; These policies, however, only affect the amount of "ENS Unplanned failures (technical)" (Figure 19), and the SAIDI value will eventually come close to the sum of the values of the other ENS components; In this simulation, the lowest value of SAIDI is obtained in "Scenario Optimize", with a value of 41.34 minutes per year (Table 4). It means that the SAIDI vision of 14 minutes per year cannot be achieved by the RCM and RCA implementation policy alone, and other policies that have a mitigating effect on other components of the ENS need to be explored, designed, and implemented.

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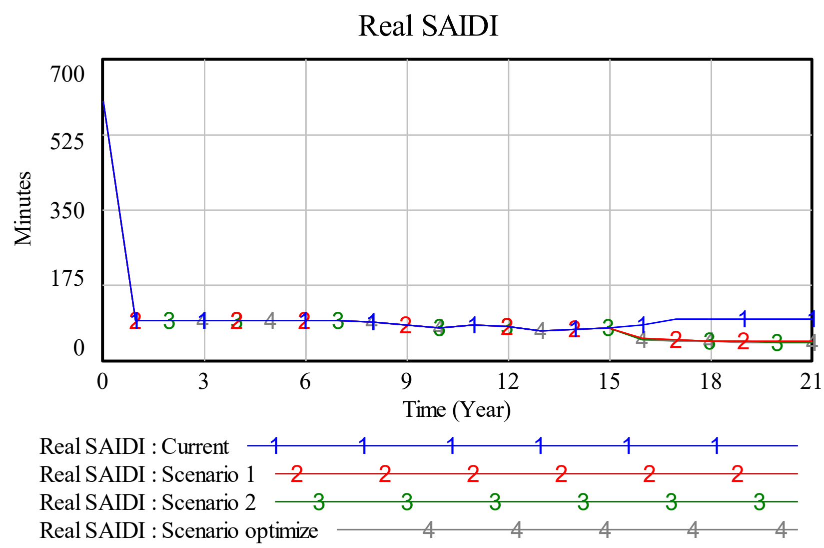

Figure 18. Results of RCM and RCA policies on SAIDI behavior

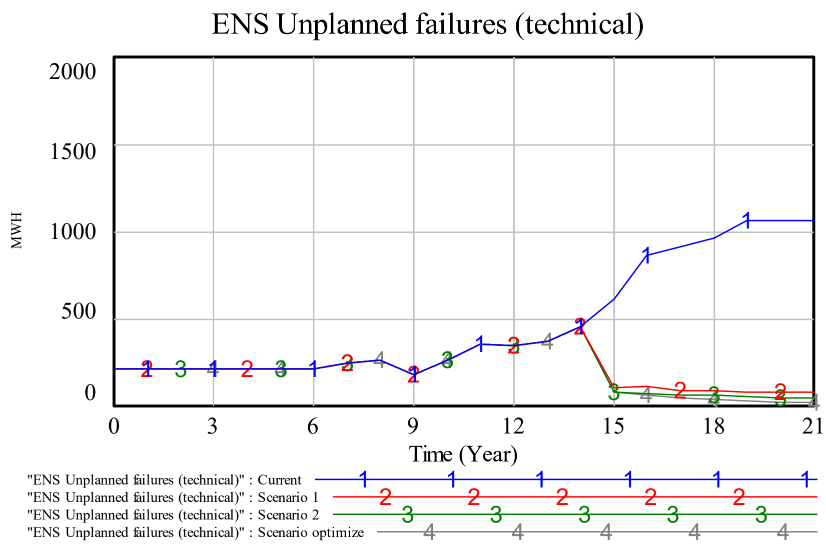

Figure 19. Results of RCM and RCA policies on "ENS Unplanned failures (technical)"

Table 4. Results of RCM and RCA policies on SAIDI at the end of 2026

Politics	**Current**		**Scenario 1**		**Scenario 2**		**Scenario Optimize**	
	The amount applied	Real SAIDI 2026	The amount applied	Real SAIDI 2026	The amount applied	Real SAIDI 2026	The amount applied	Real SAIDI 2026
RCA	0		0.05		0.1		0.2	
Electricity pole	0		0.5		0.9		0.9049	
Capacitor	0		0.5		0.9		0.1105	
Transformatore	0		0.5		0.9		1	
Power substation	0		0.5		0.9		0.4227	
Wired network	0		0.5		0.9		0.0911	
Cable network	0	98.77	0.5	44.45	0.9	42.66	0.8819	41.34
Disconnector	0		0.5		0.9		0.6171	
Fuze	0		0.5		0.9		1	
Cut out fuze	0		0.5		0.9		1	
Insulator	0		0.5		0.9		0.7774	
Jumper wire	0		0.5		0.9		0.9549	
Surge arrester	0		0.5		0.9		1	

Table 5 presents the results of simulating different scenarios in the defined values of different policies applied in Table 4 over 21 years. As shown in the "Current" scenario results column, SAIDI behavior will be bullish from the 14th period onwards if the status quo is maintained and there are no policy changes.

Table 5. Results of SAIDI in simulating different scenarios, under different policy conditions, over a period of 21 years

Year	Time (Year)	Real SAIDI			
		Current	Scenario 1	Scenario 2	Scenario Optimize
2005	0	601.48	601.48	601.48	601.48
2006	1	92.72	92.72	92.72	92.72
2007	2	92.72	92.72	92.72	92.72
2008	3	92.72	92.72	92.72	92.72
2009	4	92.72	92.72	92.72	92.72
2010	5	92.72	92.72	92.72	92.72
2011	6	92.72	92.72	92.72	92.72
2012	7	92.72	92.72	92.72	92.72
2013	8	89.04	89.04	89.04	89.04
2014	9	85.09	85.09	85.09	85.09
2015	10	76.43	76.43	76.43	76.43
2016	11	82.95	82.95	82.95	82.95
2017	12	79.96	79.96	79.96	79.96
2018	13	70.65	70.65	70.65	70.65
2019	14	73.26	73.26	73.26	73.26
2020	15	76.49	76.49	76.49	76.49
2021	16	83.90	52.11	50.55	50.22
2022	17	96.29	50.64	48.32	47.63
2023	18	96.18	47.67	46.43	45.39
2024	19	96.08	46.00	44.62	43.42
2025	20	98.77	44.55	42.96	41.68
2026	21	98.77	44.45	42.66	41.34

5. Discussion and conclusion

Given the importance of electricity supply continuously, from the perspective of the power distribution company and its customers, this study investigates the structure of SAIDI and the effects of implementation policies of RCM and RCA results on the behavior of this structure in the power distribution company, as a system in which policy-making affects many variables, as well as much feedback, Systems are affected, the dynamics method of systems is used.

Thurlby (2013), in the article "Managing the asset time bomb: a system dynamics approach," deals with the case study of a German power distributor who models using system dynamics tools and methods to understand and solve the problem of their asset time bomb, Developed. At its simplest, the asset time bomb is a threat that, when a critical set of assets reaches middle age, their performance declines rapidly, causing them to fail to achieve their desired performance goals. The organization in this study is one of the four most significant water and electricity companies in Germany, which manages urban and rural electricity distribution networks in the western part of the country. These networks were built in the late 1950s and early 1960s, and in the first decade of the 21st century, they were nearing the end of their life expectancy. Although the network's performance, whose key indicators were System Average Interruption Frequency Index (SAIFI) and SAIDI, is slightly better than the average of the German electricity industry, there was growing concern among the organization's network planners that existing asset management strategies would not maintain current performance levels with age. In essence, was the organization facing a potential asset time bomb? However, if existing strategies were to be changed, it would be necessary first to prove that the performance concerns were real by a forensic model and, second, to know the strategy changes that would solve them. In order to examine the first concern, which is related to the performance of the power grid, the researcher has modeled the two indicators, SAIDI and SAIFI, which were driven by the asset condition chains and, in turn, influenced the revenue stock and the rate at which assets deteriorated. This segment provided the other main feedback mechanisms in the model. The researcher also presents a 20-year SAIDI chart showing that if asset management policy does not change, there will be a real threat such as an hourly asset bomb, and its impact is imminent.

On the other hand, policy change can eliminate the threat and reduce the number of interruptions. Because of the above, in this study, the issue of the impact of changing Physical Asset Management policy on the SAIDI process has been modeled with a general and introspective view of equipment failure and the effects of Physical Asset Management subsystems and ENS on technical and non-technical dimensions, with planned and unplanned characteristics, and the relationships of these subsystems with each other and their interactions, As well as the effects of external destructive factors that occur as off-net events. They happen, it has not been noticed, so the research can be considered as having more abstract thinking than it can be considered as research with objective thinking.

By examining the research background, we can mention the study of Ghasemianfard and Moosavirad (2017) as a similar example of this research. Of course, this critique has entered the study, which has paid attention only to technical factors and accidents and has not paid attention to the effects of other factors.

According to these issues, in the present study, an attempt has been made to address the dynamics of the factors affecting SAIDI in the technical (planned and unplanned) and non-technical (planned and unplanned) dimensions and to create a holistic and systematic view of this issue; Therefore, it can be concluded that this research can be considered more extensive. The model presented in this study has considered unplanned ENS sub-components in both technical and non-technical dimensions and planned ENS in both technical and non-technical dimensions as factors affecting the ENS of medium-pressure networks. The models and previous research are complete. After creating a CLD with the opinion of experts and turning it into a Stocks and Flows Diagram, the effect of various factors in this system was determined. The model's validity was evaluated using three test methods: Behavior reproduction, Extreme condition, and Sensitivity analysis; the results of all tests indicate the model's accuracy in simulating the behavior of the primary variable. Since MEEDC's vision is to reduce SAIDI to 14 minutes per year, the effect of RCM and RCA policies in different scenarios on model variables was evaluated. The results showed that if the existing policies are not changed, the trend of SAIDI changes will increase. In case of a change of system approach, from non-implementation to implementation of RCM and RCA results (with optimized conditions), SAIDI will decrease from 73/26 at the beginning of 2020 to 41.34 minutes at the end of 2026. It is found that this time is the end of the deadline for the realization of the vision; therefore, it can be concluded that these policies have a mitigating effect on SAIDI, but they are not enough to realize the vision alone, and other policies need to be used.

In this study, to avoid the over-complexity of the model, only two policies, RCM and RCA, were selected, modeled, simulated, and analyzed from all MEEDC policies by the TOPSIS method with expert supervision. Therefore, adding other policies can improve the model presented in this research. Some areas that can complement the model presented in this research are modeling the role of network maneuvering systems, network equipment automation, workforce training, and hot-line operations. Also, since physical asset management tools are not limited to RCM and RCA of failures, By defining new variables and relationships in the model of this research, other tools (such as RCD (Reliability Centered Design) can be modeled as selected policies in other subsystems, and the model can be evaluated with these subsystems added. Other variables that affect SAIDI could also be included in this modeling; however, due to the over-complexity of the model, the lack of accurate information about them, and the lack of connection between some of them and the selected policies, they were omitted in this modeling. Among these influential factors can be mentioned the following: maneuvering in low voltage networks, the effect of logistics factors of incident groups and operation groups in faster elimination of blackouts, the use of distributed generation resources, and the use of mobile diesel generators, and the use of the skilled workforce, and supply resources financial. In addition to the above, examining the selected policies from other perspectives, such as reducing costs, energy losses, and equipment failure, is essential. Given the need to invest in the implementation of selected policies; Examining the effects of these policies in preventing energy waste and reducing ENS is essential in terms of economic productivity, and it should be borne in mind that the current model in the electricity industry confirms the positive effects of these policies, That is, there is a view that the implementation of these selected policies will reduce the ENS, and increase revenues from the sale of energy, for the power distribution company and the electricity industry. Also, due to the dependence on the production of goods, services, and all aspects of the life of people in society, electricity, reducing ENS, improves the quality of life in society and further prosperity of economic activities.

Disclosure statement

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

References

Azar, A., Khosravani, F. & Jalali, R. 2013. Research in software operations: structuring approaches to problems, Tehran, Industrial Management Organization. 978-600-275-047-1/ISSN [In Persian].

Alimohammadi, M. and Behnamian, J., 2021. Preventive maintenance scheduling of electricity distribution network feeders to reduce undistributed energy: A case study in Iran. *Electric Power Systems Research*, *201*, p.107509. https://doi.org/10.1016/j.epsr.2021.107509.

Anbiaei, M. S. 2004. Important factors increase the power outage time. *9th Conference on Electrical Power Distribution Networks.* Iranian Association of Electrical &Electronics Engineers.

Bala, B.K., Arshad, F.M. and Noh, K.M., 2017. System dynamics. *Modelling and Simulation*, *274*. Singapore, Springer. https://doi.org/10.1007/978-981-10-2045-2.

Ghasemianfard, E. and Moosavirad, S.H., 2017. Undelivered Electricity in North-Kerman Electricity Distribution Company: System Dynamics Analysis. *Journal of Energy Planning And Policy Research*, *3*(3), pp.119-145. [In Persian]. Available at: http://epprjournal.ir/article-1-278-en.html.

Gord, E., Dashti, R., Najafi, M., Santos, A.Q. and Shaker, H.R., 2020. Determining an accurate fault location in electrical energy distribution networks in the presence of DGs using transient analysis. *Measurement*, *151*, p.107270. https://doi.org/10.1016/j.measurement.2019.107270.

IEEE 2012. IEEE Guide for Electric Power Distribution Reliability Indices. *IEEE Std 1366-2012 (Revision of IEEE Std 1366-2003).* IEEE.null. http://dx.doi.org/10.1109/IEEESTD.2012.6209381.

Jasim Mohammad AL Shaheen, M. 2017. *Improvement of reliability by reducing power outages in the 11kV power distrbution network of Fuhood city - Thi-qar province / Iraq.* Master of Science in Electrical Engineering Thesis, Ferdowsi University of Mashhad-Department of Electrical Engineering. [In Persian].

Meadows, D., Richardson, J. and Bruckmann, G., 1982. *Groping in the dark: the first decade of global modelling*. John Wiley & Sons.

Mercado, G.A.G. and Sanchez, J.W.G., 2021. Optimization of reclosers placement in distribution networks to improve service quality indices. *IEEE Latin America Transactions*, *20*(2), pp.241-249. https://doi.org/10.1109/TLA.2022.9661463.

Mohammadi, R. and Rajabi Mashhadi, H.R., 2019. A Game Theory Approach to Distribution System Reliability Improvement Based on Customer Requests. *Iranian Journal of Electrical & Electronic Engineering*, *15*(1). http://dx.doi.org/10.22068/IJEEE.15.1.1.

Nourizadeh, H. and Niasati, M., 2020. Optimal Placement of Distribution substations with The Purpose of Reducing Losses and Energy Not Supplied by A Multi-Objective Function and Artificial Bee Colony (ABC) Optimization Algorithm. *Computational Intelligence in Electrical Engineering*, *11*(4), pp.65-80. http://dx.doi.org/10.22108/isee.2020.121806.1339.

Quentara, L.T. and Suryani, E., 2017. System Dynamics Development Model for Operations Strategy in Power Generation System through Integrated Transmission and Distribution System. *IPTEK Journal of Science*, *2*(1), pp.5-10. http://dx.doi.org/10.12962/j23378530.v2i1.a2253.

Sterman, J., 2000. *Instructor's manual to accompany business dyanmics: systems thinking and modeling for a complex world*. McGraw-Hill.

Tatietse, T.T., Villeneuve, P., Ndong, E.P.N. and Kenfack, F., 2002. Interruption modelling in medium voltage electrical networks. *International journal of electrical power & energy systems*, *24*(10), pp.859-865. https://doi.org/10.1016/S0142-0615(02)00010-8.

Tavanir 2018. Instructions for calculating the reliability indicators of power distribution networks with limited information. Tehran: Tavanir Company, Distribution Coordination Deputy, Distribution Supervision Office.3136/274. [In Persian].

Thurlby, R., 2013. Managing the asset time bomb: a system dynamics approach. *Proceedings of the Institution of Civil Engineers-Forensic Engineering*, *166*(3), pp.134-142. https://doi.org/10.1680/feng.12.00026.

Appendix

Appendix-Table 1. Variable types and related subsystem domains

Subsystem	Stock	Flow	Auxiliary
SAIDI	ENS; Goal SAIDI	ENS input rate; ENS output rate; rate SAIDI	Diff0; Difference; ENS with wire change & without MED; ENS without wire change & MED; Percentage error relative Difference; Real SAIDI; DE lookup; Delivered Energy; ENS low voltage & error lookup; ENS low voltage & error lookup; ENS wire change lookup; Vision; Vision lookup
power outages caused by new failures			Number of unplanned failures (technical)؛ Number of unplanned failures (technical) of MV cable؛ Number of unplanned failures (technical) of fuze ؛ Number of unplanned failures (technical) of Surge arrester ؛ Number of unplanned failures (technical) of Transformator ؛ Number of unplanned failures (technical) of jumper wire ؛ Number of unplanned failures (technical) of capacitor ؛ Number of unplanned failures (technical) of wire؛ Number of unplanned failures (technical) of disconnectore ؛ Number of unplanned failures (technical) of insulator ؛ Number of unplanned failures (technical) of Electricity pole ؛ Number of unplanned failures (technical) of Number of unplanned failures (technical) of power substation ؛ Number of unplanned failures (technical) of cut out fuze ؛ENS of defective equipment ؛ ENS Unplanned failures ؛ ENS Unplanned failures (technical) ؛ ENS of planned maintenance ؛ ENS of planned maintenance (non-technical); Number of planned maintenance performed (non-technical)-lookup; Number of other unplanned failures (technical)-lookup; ENS Unplanned failures (non-technical); ENS caused by environmental accidents around the power grid-lookup; ENS of planned maintenance (technical)-lookup; Average ENS Unplanned failures (technical)-lookup; Average ENS due to planned maintenance (non-technical)-lookup;
RCA	The number of unplanned (technical) failures that have been RCA	The net growth rate of unplanned (technical) failures that has become RCA	The growth rate of unplanned (technical) failures that has become RCA؛ Politics of RCA
RCM			Surge arrester-RCM ؛ Transformator-RCM؛ jumper wire-RCM ؛ capacitor-RCM ؛ cable network-RCM ؛ wired network-RCM ؛ fuze-RCM ؛ disconnectore-RCM ؛ insulator-RCM ؛ Electricity pole-RCM ؛ power substation-RCM ؛ cut out fuze-RCM ؛ jumper wire reliability ؛Surge arrester reliability ؛ Transformator reliability ؛ capacitor reliability ؛ cable network reliability ؛ wired network reliability ؛ fuze reliability ؛ disconnectore reliability ؛ insulator reliability ؛ Electricity pole reliability ؛ power substation reliability ؛ cut out fuze reliability ؛ Ratio of ENS impact of unplanned (technical) failures on the whole ENS effect factor; Politics of RCM-Surge arrester; Politics of RCM-Transformatore; Politics of RCM-jumper wire; Politics of RCM-capacitor; Politics of RCM-cable network; Politics of RCM-wired network; Politics of RCM-fuze; Politics of RCM-disconnectore; Politics of RCM-insulator; Politics of RCM-Electricity pole;

	Politics of RCM-power substation; Politics of RCM-cut out fuze; Surge arrester-RCM-lookup; Transformator-RCM-lookup; jumper wire-RCM-lookup; capacitor-RCM-lookup; cable network-RCM-lookup; wired network-RCM-lookup; fuze-RCM-lookup; disconnectore-RCM-lookup; insulator-RCM-lookup; Electricity pole-RCM-lookup; power substation-RCM-lookup; cut out fuze-RCM-lookup; Total number of cable network feeders-lookup; Total number of capacitor-lookup; Total number of cut out fuze-lookup; Total number of disconnectore-lookup; Total number of Electricity pole-lookup; Total number of fuze-lookup; Total number of insulator-lookup; Total number of jumper wire-lookup; Total number of power substation-lookup; Total number of Surge arrester-lookup; Total number of Transformator-lookup; Total number of wired network feeders-lookup

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Identify and Prioritize Marketing Methods by IPA-G-FGAHP Technique

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ABSTRACT

This study aims to identify and prioritize the influential variables in the marketing tactics used by Bank Melli Iran. Key elements impacting Bank Melli Iran's marketing strategies have been employed to identify the system's various components and sub-components. Then, in order to adapt these factors to the situation of the studied bank, the opinions and collective agreement of the experts of the studied bank, in the form of a 15-member decision team, were taken on the influential factors in the studied bank. In the next step, the weight of each component and subcomponent was determined using the group-fuzzy hierarchical analysis process and experts' participation. Following this step, the decision team of the National Bank of the Khorasan Razavi Province filled out the present situation appraisal questionnaire. This research analyzed a comprehensive set of 5 components and 22 subcomponents. By assessing the weight of these aspects and quantifying their deviation from the planned condition, the balanced gap was calculated to establish the priority for improvement. Based on the results, the subcomponents of sales meetings, television marketing, and the press and media were identified as the top three factors. Therefore, it shows that the bank has a good capability in these sub-components, and suitable infrastructures are also available. Also, fourteen sub-components of awareness in the stadium, catalogs, films and tapes, written and verbal advertisements, placing advertisements on buses, specialized magazines and brochures and booklets, doing charity work, presenting services in person, selling with catalogs, contests and entertainment, low-interest credits, prizes and gifts, business negotiations, raffles, and annual reports are of low importance or at a favorable level of the status quo.

Keywords

Marketing methods, Fuzzy Analytical hierarchy process, Improvement priority.

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1. Introduction

The contemporary global landscape is now seeing many transformations due to heightened rivalry across several sectors, with markets being particularly prominent. Change is a well-recognized concept that may lead to positive outcomes, such as growth and development, and negative consequences, such as worry and tiredness. These effects are seen when change is encountered in different societal and professional contexts, where it interacts with possibilities and dangers. According to Weinreich (2010), nations and enterprises that aspire for dynamism see construction and development in the act of change. Conversely, a faction satisfied with the existing state of affairs exhibits apprehension towards any alteration in the status quo. It will exhibit substantial opposition until compelled to acknowledge and embrace it. Marketing is essential for both nations and enterprises in the forthcoming marketplace and the era of unrestricted competition. Individuals, institutions, and diverse communities all need the practice of marketology, market formation, and market management to ensure their survival (Kotler & Keller, 2016). The importance of marketing in the contemporary market cannot be overstated, particularly for any purposeful and unbiased initiative. The progressive manifestation of commercial globalization is a noteworthy phenomenon.

The phrase "think global, act local" encapsulates the contemporary marketing motto for entrepreneurs, managers, and professional marketers (Weinreich 2010). Marketing encompasses a range of strategic efforts firms undertake to provide potential buyers with informative content about a product's perceived worth and attractiveness, ultimately influencing their purchasing decisions in favor of the promoted product within a certain industry (Wymer and Samu, 2009). Marketing has a crucial role in business, particularly inIslamic banking. The marketing idea of Islamic banks is mainly similar to the prevailing marketing notions, as stated by Aravik et al. (2022). According to Kotler and Keller (2016), marketing may be defined as a social and managerial process that involves individuals and groups fulfilling their wants and aspirations by creating, offering, and exchanging valued and beneficial items with others. Moreover, according to Kotler and Keller (2016), it has been said that the marketing department is responsible for making the most arduous business choices. The marketing movement's core philosophy is to avoid squandering resources and facilities and determine the most appropriate market positions for products or companies.

Banks, as one of the country's economic pillars, seek to improve the effectiveness of their marketing activities in recent years due to the competitive banking services in the market, the emergence of private banks one after the other, the presence of foreign banks soon, and the need to survive in that time. A bank's success may be greatly influenced by the implementation of effective marketing operations (Pirayesh and Alipour, 2012). In the contemporary banking sector, achieving success by commercial banks necessitates a growing dependence on marketing strategies, plans, and programs (Sarmad and Jamshidian, 2012). In the current competitive landscape, banks must establish a solid rapport with their clients to distinguish themselves and sustain a consistent presence. Establishing and sustaining a long-term connection necessitates deliberate effort and suitable marketing methods (Evans and Laskin, 1994). The effectiveness of marketing activities is considered crucial to a bank's success. Therefore, it is necessary to identify the key elements that influence the effectiveness of marketing strategies (Nazaritehrani and Mashali, 2020).

The banking sector is a significant and intricate industry that has immense importance on a global scale. Economic operations in the twenty-first century have been organized to render their sustainability attainable with the indispensable support of financial institutions, namely banks. Hence, the banking sector is widely recognized as a fundamental pillar of national economies. The dynamism, efficacy, and competence of banking systems have significant implications for the corporate environment and the broader external environment, including macroeconomic and commercial factors (Egbunike and Okerekeoti, 2018). The banking sector in Iran plays a crucial role in facilitating economic operations, making it one of the nation's most influential pillars. The growth and development of the country's economy will heavily rely on the efficiency and efficacy of operations within this sector (Tarkhani et al., 2020). Like other commercial enterprises, banks aim to profit from their activities and establish a competitive advantage. According to Nazaritehrani and Mashali (2020), the contemporary consensus among experts in the banking business is that the attainment of success for banks is contingent upon the implementation of a marketing plan that is both successful and efficient.

Historically, the banking business in Iran needed more integration of marketing science and technology due to factors such as monopolistic practices and inadequate privacy measures. However, a significant transformation has occurred, leading to the emergence of a competitive environment in recent years. Islamic banks often provide a diverse range of goods tailored to meet the community's specific requirements. The provision of their respective goods engenders rivalry between Islamic and conventional banks, necessitating the formulation of marketing strategies for each of these banking institutions (Rahma and Nasution, 2022). Despite being cognizant of the competitive landscape and fundamental changes within the banking industry, financial institutions persist using non-specialized viewpoints when addressing marketing obstacles, employing outdated methodologies, and exhibiting unprofessional dispositions. The primary aim and function of a marketing strategy is to provide clarity on the future trajectory of the business landscape, thus entailing the ability to forecast future outcomes. Therefore, it is essential that marketing serves as the fundamental principle directing all phases, operations, and activities within the banking industry. Due to elucidate, within banking organizations, various activities are commonly undertaken in specific domains, including but not limited to planning, allocating, and distributing budgets, designing services, identifying the market or target markets, providing consultation on optimal communication and advertising channels, establishing and inaugurating branches, and recruiting human resources. Marketing has a significant role in establishing a company's rules and procedures. In addition to executive actions, it is responsible for promoting uniformity throughout different divisions of the firm (Hund et al., 2021).

The absence of competitiveness in the banks' working environment allows for the operation of supply and demand dynamics and financial intermediation within the banking sector. Nevertheless, a complication develops when the competitive dynamics among depositors, facility seekers, and banks inside the triangle result in the elimination of a monopolistic market position. In this particular scenario, as each bank endeavors to attract consumers via two distinct approaches, namely capital absorption and distinctive provision of facilities, comprehending and prioritizing the factors that influence both approaches may greatly enhance the performance of banks. This study will focus on examining the marketing strategies that are most suitable for Melli Bank. Additionally, given the bank's limited resources, how these marketing tactics are prioritized inside Melli Bank has been studied.

2. Literature review

2.1. Marketing mix

The first investigation of the marketing mix was conducted at Harvard College in 1929. These investigations aimed to establish the connections between marketing activities and duties inside a food industry enterprise. Subsequently, research was undertaken by James Collinton to investigate this matter, resulting in diverse outcomes and finally identifying marketing managers as the key decision-makers, artists, and ingredient mixers. The concept of "marketing mix" was invented by Harvard professor Neil Borden, who drew inspiration from Collinton's perspective (Dominici, 2009). The marketing mix management paradigm has been the prevailing approach since 1990, with McCarthy introducing the concept in 1999 and subsequently refining it into the concepts currently recognized as the 4P framework (Dominici, 2009). The marketing mix is a strategic framework firms use to achieve their marketing goals within specific target markets effectively. The concept consists of four essential components: product, price, marketing, and location. The use of the phrase "marketing mix" was based on the premise that the selection of each ingredient should be in harmony with the other three (Constantinides, 2006). The formulation of marketing mix choices should be aligned with the distribution networks and end consumers. Several elements of the marketing mix have the potential to be adjusted within a relatively short timeframe. For instance, a company can modify its pricing strategy, sales personnel, and advertising scope in the immediate future. However, in the long term, the organization may also develop novel goods and implement alterations to its distribution systems.

2.2. Different types of marketing mix models

2.2.1. Social marketing mix

Social marketing is a collaborative endeavor characterized by enduring partnerships that mutually benefit the participants and the larger society. This approach serves to establish connections between the company and non-monetary goals. The abovementioned advertising has shown efficacy and has garnered significant popularity in contemporary times. The emergence of social marketing may be traced back to the 1970s. Marketers engage in extensive research to effectively promote their goods, using certain ideas and tactics to get desired outcomes. According to Kotler and Keller (2016), in order to influence the connections of others, individuals should adhere to principles and guidelines and do thorough research to promote their perspectives and convictions in the marketplace effectively. The definition of social marketing, as articulated by Cutler and Anderson, is as follows: Social marketing encompasses more than the mere attainment of the marketer's or organization's objectives; it also entails the manipulation of social behavior to provide advantages for both the marketer and the broader target market. Weinreich (2010) asserts that social marketing, similar to commercial marketing, primarily centers on clients, aiming to fulfill their demands and requirements rather than just promoting produced goods.

According to empirical research, social marketing strategies have been found to improve the customer's level of brand awareness, cultivate a positive brand perception, and positively influence the customer's overall attitude toward the company. Social marketing may be considered a mutually beneficial technique as it leverages the customer's social interests to foster loyalty towards the firm. The community emerges as the beneficiary of enhanced financial contributions, while the corporation attains success using customer relationship management strategies. McCarthy's original framework of the 4Ps, which encompasses product, price, place, and promotion, has been expanded in social marketing. This revised social marketing mix incorporates new ideas and introduces a few extra Ps. The following section describes each P under this framework.

Public groups: To achieve effectiveness, social marketers must tailor their campaigns to suit diverse audiences. In the words of Weinrich, public groups may be classified into two categories: external and internal. External groups include several stakeholders, such as target and secondary audiences and politicians, among others. Conversely, internal groups include people who use social marketing initiatives differently. Consequently, due to the inherent focus on individuals and collectives within social marketing endeavors, public groups have been included as a constituent element of this amalgamation (Baptista et al., 2021).

Partnership: Katsioloudes et al. (2007) view health and community issues as complex problems that a single entity cannot solve. According to them, organizations must collaborate with other businesses to be more efficient and seek out organizations with similar goals and collaborate with them. Social marketing (Baptista et al., 2021) identifies collaboration with other organizations as crucial.

Policy: Weinrich (2010) describes social marketing programs as an incentive for altering individual behavior and argues that these programs can only be implemented in an environment that facilitates these alterations. For this reason, he believes that political change is required to achieve this objective, as attracting the attention of legislators and stakeholders to the implementation of social programs is of great assistance and requires the use of political strategies (Baptista et al., 2021).

Pure strings: The majority of organizations aim to develop a social marketing campaign and acquire government grants and donations. Katsioloudes states that the first step in implementing social marketing is determining how to support the campaign (Baptista et al., 2021).

4C marketing mix: It is worth noting that the 4P tool represents the sellers' perspective on impressing buyers; however, from the buyer's perspective, every marketing tool is intended to provide advantages to the customer (Kotler and Keller, 2016). The 4P concept is a marketing approach focused on the product, not the customer. Latin Borna claimed that each element should be examined from the customer's viewpoint (Baptista et al., 2021).

2.2.2. *5V marketing mix*

Bennett (1997) defined a concept comparable to supplier marketing. This concept identifies the purchase process, which is essentially the actions performed by the customer to locate the appropriate resources to cover their needs. A distinguishing element of this perspective is that the client is more concerned with the supplier's services than the product itself. Five criteria define the buying process, collectively called the 5V marketing mix, and represent the buyer's perception of a product or service. The following is a brief overview of each component.

Value: Apart from the prominent features such as quality, appropriateness for the purpose, and reliability, the buyer also considers the supplier's pricing, performance, and reputation (Wu, 2017). When discussing value, Bennett (1997) considers more than just money and other important factors to buyers. He also thinks the physical effort, persistence, and time it takes to find a good source of product supply, as well as problems like multiple product intermediaries and the monopoly of the source of the supply, help customers think the product is worth more.

Efficiency: Bennett (1997) considers characteristics such as brand strength and reputation, repeatability, purchase outcomes, and shelf shape as helpful for efficiency. According to him, efficiency happens when the customer has general access to the provider following his expectations.

Volume: Bennett (1997) defines volume as the sum of quantity, number, divisibility, stability, spare parts, and package size. He introduced one of the issues with the targeting approach: the restricted availability of some products (goods and services) for delivery to the consumer. For instance, a mechanic needing a part must purchase the entire set. It is an example of economies of scale in stores and does not appear to attract customers. Indeed, economies of scale are costly to the consumer, and the manufacturer must devise strategies to offset these losses.

Variety: Customers require freedom of choice. The ability to choose is frequently "ignored" by manufacturers, service providers, and marketers. Selecting is the customer's inalienable right and critical for good marketing (Bennett,1997).

2.2.3. *Comprehensive marketing communications*

As a guiding concept, comprehensive marketing communications enable organizations to pursue their relationship with their target market. Comprehensive marketing communications aims to coordinate and regulate the diverse components of the promotion mix - advertising, personal selling, public relations, and reputation management, direct marketing, sales promotion - to provide a customer-focused message and to generate and accomplish a variety of organizational objectives (Mangold and Fold, 2009).

2.2.4. Elements of the marketing communication mix

Advertisements: A separate section will discuss advertising in full detail.

Sales promotion: Sales promotion is the spread of information to persuade potential buyers (Kim and Hyun, 2010). Sales promotion uses tools and events to encourage people to stimulate and purchase more for a limited period (Guizani et al. 2011).

Public relations: Professor Lawrence W. Lang and Professor Vincent Hazleton provided the most remarkable definition of modern public relations. They describe public relations as "a management communication task by which a company adopts, modifies, or preserves its identity with the surrounding environment to accomplish its objectives (Baptista et al., 2021).

Face-to-face sales: Face-to-face sales are those made through interpersonal communication. The emphasis on face-to-face sales varies for each company, depending on the nature of the product or service being promoted, the size of the organization, and the industry. Face-to-face sales are often playing a significant role in industrial organizations. In contrast, they play a lesser role in other companies, such as those that create less durable items cheaply. In most industries, these roles are changing toward a more balanced approach, emphasizing other promotion program aspects. In an integrated marketing communication program, face-to-face sales complement other promotional mix elements and are not used as an alternative (Belch and Belch, 2003).

Direct marketing: Direct marketing uses direct communication channels with customers to locate customers and provide products and services without marketing intermediaries. Direct marketing helps a marketer to acquire more direct reactions from clients, better aim at the target market, and sell a product without going through the long and expensive process of traditional channels (Keller, 2001).

Packaging/point of sale: Refers to preparing and designing attractive shop signs, showcases (stands), and shelves to introduce a product. Because of the formed connection with the buyer by its color, size, and dimensions, the packaging is one of the marketing communication mix elements (Biranvand, 2013).

2.2.5. Banking marketing

The level of development of its activities determines the significance of marketing within the bank's organizational structure. As competition intensifies, systematic efforts are required to assess profitability or provide additional services, and the bank recognizes that traditional marketing divisions cannot meet these demands. In this situation, the concept of incorporating a marketing department into middle management is being considered, and activities such as marketing research, advertising, crediting, and establishing relationships with service providers are crucial. In this situation, the marketing department has strategic responsibilities, such as identifying the bank's long-term objectives regarding activity type, target market specifications, and actual and potential clients. In addition, it must develop and implement strategies to achieve these objectives (Shamloo, 2015).

2.3. Identify factors based on theoretical and experimental background

In order to enhance their performance within the contemporary complex, dynamic, and volatile landscape, banks must devise and execute strategies aimed at improvement. In a highly competitive market, the survival of banks is contingent upon their ability to stay competitive and adapt to evolving and dynamic competitive circumstances. Bank executives will assess the consequences of their strategic choices by examining performance measures. Examining and comparing observed performance in relation to historical patterns, rivals, and industry benchmarks provide useful insights for informing future decision-making processes. Consequently, enhancing marketing methods has emerged as a critical objective for banks, aiming to make ongoing improvements over time (Table 1).

Table 1. Factors affecting marketing in the bank

Row	Groups	Row	Indicator definition	Extracted indicator	Source
1	Advertisement	1	Using banner advertisements and marketers to interact with potential clients face to face	Written and oral advertisements	Davari et al. (2015)
		2	Using catalogs, promotional CDs and audiotapes to introduce banking services and their benefits	Catalogs, films and tapes	Biranvand (2013)
		3	Production and distribution of specialist magazines and booklets among customers to make them aware of the benefits of Bank Melli Iran services	Specialized magazines, brochures and booklets	Tabibi et al. (2011)
		4	Introducing Bank Melli Iran's services and benefits in intercity buses	Installing Ads on buses	Davari et al. (2015)
		5	Using ads at stadiums	Advertisement at the stadium	Dominici (2009)
2	Sales promotion	1	Conducting competitions and entertainments in which those with knowledge of bank services can participate and win	Competition and entertainment	Sarmad Saeedi and Abdollahi (2015)
		3	Consideration of prizes and gifts for customers who accumulate a certain number of points through the use of Bank Melli Iran services	Gifts and prizes	Egbunike and Okerekeoti (2018)
		4	Providing customers who use Bank Melli Iran's banking services and meet certain criteria with a low-interest loan	Low-interest loans	Asghari zade and Amin (2017)
		5	Using entertainment programs to increase bank customers loyalty	Entertaining programs	Sarmad Saeedi and Abdollahi (2015)

Row	Groups	Row	Indicator definition	Extracted indicator	Source
		2	Using newspapers and magazines to promote banking services	Press and media	Rafiei et al. (2011)
		3	Providing the public with access to the bank's financial statements, profits and losses	Annual reports	Experts
		4	Organizing charitable events to attract public donations and advertising Bank Melli Iran services through these events	Charitable and social affairs	Gao et al. (2021)
4	Face-to-face sales	1	Recruiting marketers in the bank branches to introduce services and attract potential customers	Face-to-face representation of services	Van Esch et al. (2021)
		2	Holding face-to-face meetings with the bank's important customers and introducing the bank's services to them	Sales meetings	Rafiei et al. (2011)
		4	Using television and audio-visual media to introduce and encourage customers to use the bank's services	TV marketing	Sanayei et al. (2016)
5	Direct marketing	1	Using professional marketers to meet with consumers outside of the bank to advertise services	Sales through catalogs	Sarmad Saeedi and Abdollahi (2015)

3. Methodology

The current research employs a combined qualitative-quantitative methodology, characterized by a purposeful approach and a descriptive-exploratory implementation and nature. The components and sub-components that define the marketing tactics of Bank Melli Iran have been identified by considering the key elements that influence them. The viewpoints and consensus of a group of fifteen bank specialists, who were participants in the Delphi panel, were then solicited to assess the elements influencing the bank and tailor these aspects to the specific circumstances of the bank being examined. All elements received from sources and references were verified, and no supplementary factors were included. Therefore, the components listed in Table 1 were used as the basis for further research. The weight of each component and subcomponent was determined via a systematic procedure, including the collaboration of experts and the group-fuzzy hierarchical analysis method. The total inconsistency rate for each table and the inconsistency rate for all tables completed by experts were found to be below 0.1. Following completing the current state assessment questionnaire, a decision panel consisting of fifteen senior, middle, operational, and expert members from the Melli Bank of Khorasan Razavi Province participated in this step. The content and face validity of the questionnaire were established by using the field of literature and the situation of the bank under study. The data analysis methodology used in this research is known as IPA-G-FGAHP (Figure 1).

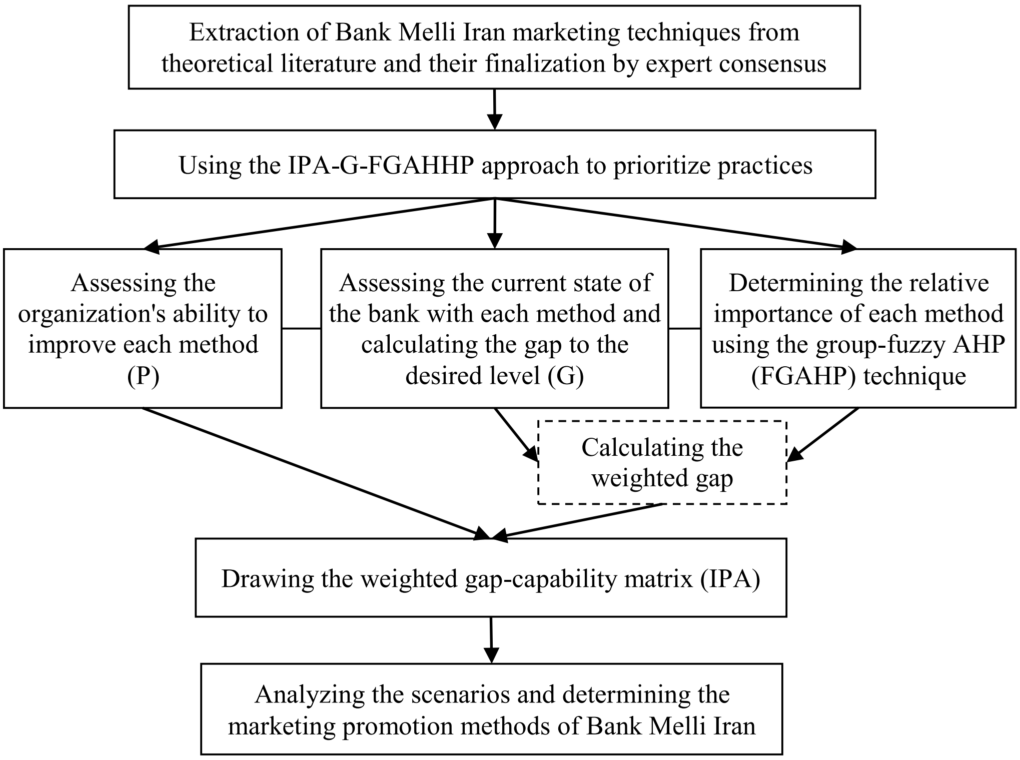

Figure 1. Research model

As mentioned above, the approach may be succinctly outlined in four sequential stages (Figure 1) . In the first phase, the process entails using a group-fuzzy Analytic Hierarchy Process (AHP) to compare issues pairwise. Experts are responsible for assessing and assigning weights to each problem during this stage. The last phase involves evaluating the company's present condition in each domain, a process undertaken by experts on a Likert scale from 1 to 7. In the third step, a weighted gap is derived by integrating the outcomes from the first and second phases. In other words, this particular stage's result yields the same data used in the International Phonetic Alphabet (IPA) matrix. The fourth stage assesses the organization's capacity to improve its current situation on each issue using a 1 to 7 Likert scale.

4. Findings

4.1. Descriptive information of the decision team

The organizational structure of the decision team consists of eleven specialists, three operational managers, one middle manager, and three middle managers. Three individuals are older than 45, while the other twelve are aged 35 and 45. There are three bachelor's degree holders and twelve master's degree holders in the group. In addition, each of them has more than 15 years of working experience (Table 2).

Table 2. Demographic characteristics

Organizational position of decision team members	Senior manager	0	**Age of decision team members**	Less than 25	0
	Middle manager	1		Between 25 and 35	0
	Operational manager	3		Between 35 and 45	12
	Expert	11		More than 45	3
	Total	15		Total	15
Education of decision team members	Associate degree	0	**Work history of decision team members**	Less than 3	0
	Bachelor's degree	3		Between 3 and 9	0
	Master's degree	12		Between 9 and 15	0
	Doctorate	0		More than 15	15
	Total	15		Total	15

4.2. Final weights of components

Comments from industry professionals were solicited to assist in the organization of Bank Melli Iran's marketing strategies. The professionals agree that marketing techniques should be categorized according to the components and sub-components indicated in the relevant body of literature. Some experts suggested some items as recommended parameters; however, all of these suggestions were already included in the indicators in this table; thus, no new indicators were added to the suggested items. Table 3 shows the final data after the software performed the calculations.

Table 3. Weight, status quo, and improvement capability for each marketing approach

Components	**Components' weight**	**Code**	**Indicators**	**Indicators' weight**	**Normal weight**	**Current state**	**The gap to the desired level**	**Weighted gap**	**Capability**
	A			B	C=A×B	D	E=7-D	Y= C×E	X
Advertisements	0.26	C1I1	Written and oral advertisements	0.23	0.06003	3.07	3.93	0.236	5.73
		C1I2	Catalogs, films and tapes	0.22	0.05742	3	4	0.229	6.2
		C1I3	Specialized magazines, brochures and booklets	0.21	0.05481	3.07	3.93	0.215	6.06
		C1I4	Installing ads on buses	0.15	0.03915	1.2	5.8	0.227	5.73
		C1I5	Ads at stadiums	0.19	0.04959	2.07	4.93	0.244	6
Sales promotion	0.20	C2I1	Competition and entertainment	0.19	0.03819	2.2	4.8	0.183	5.93
		C2I2	lottery	0.24	0.04824	4.33	2.67	0.128	6.13
		C2I3	Gifts and prizes	0.23	0.04623	4.07	2.93	0.135	5.86
		C2I4	Low-interest loans	0.19	0.03819	2.4	4.6	0.175	5.8
		C2I5	Entertaining programs	0.15	0.03015	1.53	5.47	0.164	5.13
Social relations	0.173	C3I1	Ceremony	0.33	0.05676	2.4	4.6	0.26	5.66
		C3I2	Press and media	0.31	0.05332	2.13	4.87	0.259	6
		C3I3	Annual report	0.05	0.0086	1.8	5.2	0.044	5.73
		C3I4	Charitable and social affaris	0.31	0.05332	3.13	3.87	0.206	6.06
Face-to-face sales	0.257	C4I1	Face-to-face services presentation	0.157	0.04034 9	2.4	4.6	0.185	6.06
		C4I2	Sales meetings	0.447	0.11487	2.8	4.2	0.478	6.33
		C4I3	Trading meetings	0.111	0.02853	2.47	4.53	0.129	6
		C4I4	TV marketing	0.29	0.07453	3.27	3.73	0.278	6.2
Direct marketing	0.11	C5I1	Sales through catalogs	0.38	0.0418	2.53	4.47	0.186	5.8
		C5I2	Sales through postal mail	0.17	0.0187	2.8	4.2	0.078	4.2
		C5I3	Sales through fax	0.19	0.0209	1.33	5.67	0.118	4.06
		C5I4	Sales through email	0.26	0.0286	1.53	5.47	0.156	4.66

The weight of the components is indicated in column A, followed by several indicators. The numbers in this column are derived from group-fuzzy AHP calculations. The weight of the indicators is calculated using group-fuzzy AHP calculations in column B. Column C is the result of multiplying column A by column B, and it represents the normal weight of all factors in comparison to one another. The higher a factor's normal weight, the more important that indicator is. In column D, the results of the current status questionnaire are expressed using a 7-point Likert scale. The higher the current status number, the better the current status of that factor and the smaller the gap to the desired level (column D). Column Y is the product of multiplying normal weight (column C) by the gap to the intended level (column E); the number resulting from this multiplication is known as the weighted gap and is located on the vertical axis of the IPA matrix. The number for column X is also obtained from the improvement ability questionnaire for each factor; the higher the number of capabilities for a factor, the higher the organization's potential and capability to improve that factor. The number for this column is also located on the X-axis of the IPA chart. The study of the scenarios presented in the weighted gap-capability matrix (Figure 2) in four areas is as follows:

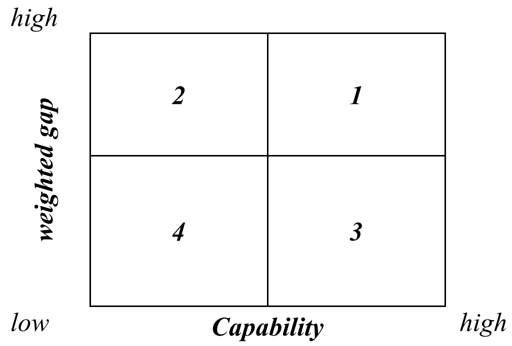

Figure 2. Weighted gap – capability matrix and its four areas

Area 1: First, the elements in this area are essential; second, the gap between them and the desired level is considerable. Third, the company can enhance it since the essential infrastructure is available. As a result, these components are a priority for improvement.

Area 2: The weighted gap is vast, and the organization's capacity to handle these issues and provide the required infrastructure must be strengthened. As a result, this area is the second priority.

Area 3: Although the organization can improve the elements of this area, it does not require as much attention and improvement as areas 1 and 2. It is because it has a smaller weighted gap; that is, the issue is minor, the existing condition is favorable, or even both.

Area 4: If there is a problem in this area, it indicates that it was unnecessary to enhance it or insufficient infrastructure and capability to do so.

The weighted gap-capability diagram for the research factors is displayed in Figure 3 using the data from the preceding table and data obtained from the horizontal (X) and vertical (Y) axes.

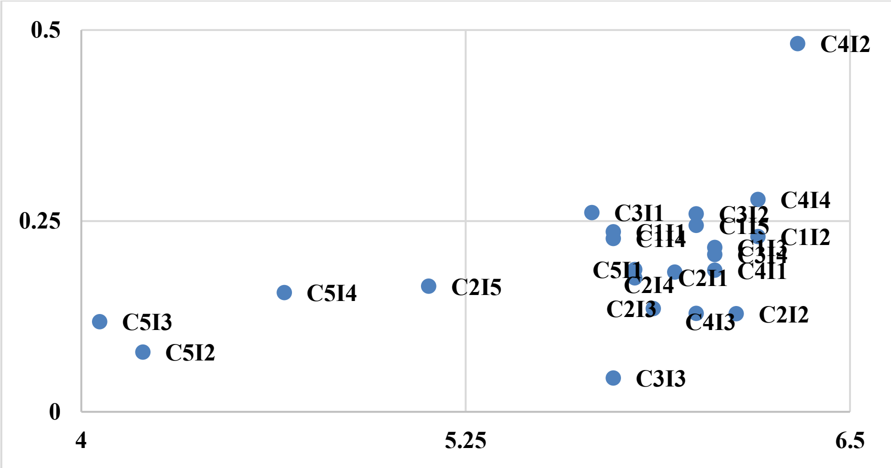

Figure 3. The weighted gap - capability diagram

While the categorization offered for the four sections of this diagram is an approximation (Figure 3), it was also said that the order of priority for the elements in areas 2 and 3 depends on the decision team's preference and the organization's requirements. The outputs of the weighted gap-capability matrix are presented in Table 4.

Table 4. The results of weighted gap-capability prioritization chart

Area	Desired behavior	Codes	Indicators
first	It is the first priority and needs the company to focus on enhancing it.	C4I2	Sales meeting
		C4I4	TV ads
		C3I2	Press and media
		C3I1	Ceremony
third	While the organization has the capability to enhance them, they do not require the same level of attention and improvement as Area 1.	C1I5	Ads at stadiums
		C1I2	Catalogs, movies, and tapes
		C1I1	Written and oral ads
		C1I4	Installing ads on buses
		C1I3	Specialized magazines, brochures, and booklets
		C3I4	Charitable and social affairs
		C4I1	Face-to-face presentation of services
		C4I1	Sales through catalogs
		C2I1	Competition and entertainment
		C2I4	Low-interest loans
		C2I3	Gifts and prizes
		C4I3	Trading meetings
		C2I2	Lottery
		C3I3	Annual reports
fourth	It does not require improvement and lacks the infrastructure and capacity to do so.	C2I5	Entertaining programs
		C4I4	Sales through email
		C4I3	Sales through fax
		C4I2	Sales through postal mail

The elements in the four categories were identified using Figure 3 and Table 4. None of the cases in this research appeared in area 2.

5. Conclusion and recommendations

In the current research, the third category includes fourteen sub-components. These sub-components include advertisements in stadiums, catalogs, films and tapes, written and oral advertisements, installation of advertisements on buses, specialized magazines, brochures and booklets, charity, presentation of face-to-face services, selling with catalogs, competitions and entertainment, low-interest loans, prizes and gifts, trading meetings, lotteries, and annual reports. As a result, while the organization can enhance the components described in this area, the elements do not need as much concentration and development as the first and second areas do since the weighted gaps in these areas are very modest. Consequently, it suggests that the sub-components mentioned above are either unimportant or are performing at the expected level given the circumstances now at play.

Based on the study results, placing a sub-component in the fourth region suggests that its enhancement was deemed superfluous. Secondly, there is a deficiency in infrastructure and capacity to enhance this sub-component. The existence of the subcomponents in the third and fourth zones does not suggest their lack of importance. However, considering the actions taken inside the organization, there is a minimal disparity between the current and planned states for these subcomponents (Okhravi, 2014).

The fourth domain included four subordinate elements about disseminating entertainment programs and sales via electronic mail, facsimile transmission, and conventional postal services. Consequently, the positioning of these sub-components inside this region suggests that their enhancement is not deemed imperative, indicating a deficiency in the organization's infrastructure and capability to address such improvements. Considering the actions used by the organization, there is now a slight disparity between their present state and their intended outcome.

The following recommendations are based on the questionnaire results and interviews with bank experts.

The findings from the data analysis indicate that sales meetings play a crucial role due to the presence of essential infrastructure, and a substantial disparity exists between the present and intended levels. This objective may be achieved by extending invitations to key clientele of banking services and organizing regular gatherings to encourage their use of those services.

Furthermore, the bank has the potential to enhance its sales meets by enlisting external marketers who are not affiliated with the bank and compensating them via commissions for successfully promoting the bank's services to consumers.

Moreover, concerning the allocation of television marketing in region one, it is recommended that bank managers enhance their television advertising expenditures. Market segmentation is often advised as a strategy to minimize the inefficient allocation of resources. Therefore, the first step in advertising is to identify the target market based on the specific service being promoted, followed by strategically disseminating a relevant message at an appropriate time. For example, if the service's target audience comprises corporate executives, who typically have limited leisure time for television or other media consumption and often rely on radio for information during their morning commutes, it would be most effective to advertise during early morning hours through radio channels. If the target demographic comprises individuals who begin their workday in the early morning, it is advisable to refrain from advertising during the late nocturnal hours. These results are consistent with the findings obtained from the research of Wong et al. (2022). The increase in the level of knowledge and awareness of the audience due to the broadcasting of suitable commercial messages can influence the attitude, and the person's attitude can lead to a behavior aligned with the goals of the sender of the message.

The study results show that the use of newspapers and other media forms is a significant component of Bank Melli Iran's marketing tactics. When making decisions regarding press advertisements, bank managers should consider several factors. These include the range of available publications, their circulation figures, the target audience of each publication, the associated costs of advertising, the dimensions of the advertisement, the specific section within the publication where the advertisement will be placed, the potential use of colors and the specified color range, the frequency of advertisement printing, and the time intervals between each publication. This result is consistent with Nilson's (2013) and Petur Samundsson's (2012) research results. From the American consumers, word of mouth (recommendations from familiar people) took the first place with 84% of the votes, followed by the websites of famous brands and traditional mass media such as television, newspapers, and magazines with a difference of 15% less. Are. However, the European audience chose print as the most reliable advertising medium.

In order to provide novel services, managers may choose to organize social gatherings, extend invitations to key clientele, and proffer their services for their consideration. Significantly, the rewards and presents are situated inside the third category, showcasing the bank's competence in this domain and its comparatively lesser importance. The bank can reduce a fraction of the gifts and prizes it distributes to customers annually through the lottery. The third domain encompasses the constituent elements of advertising inside stadiums and on buses. Due to the coordination of these elements' effects with television advertising, it is proposed that the bank lower its advertising budget at stadiums and buses and increase its budget for television advertising.

The use of catalogs, videos, cassettes, specialist periodicals, brochures, and booklets is situated within the third domain. Moreover, it should be noted that the expenses associated with replicating and publishing these components are substantial across all sectors. Hence, it is advisable to minimize the use of such technologies inside banking institutions and allocate resources towards hiring personnel for each branch to address inquiries and facilitate the introduction of bank services via face-to-face sales interactions.

The most important limitation of the research is its scope. Considering that this research was carried out in the National Bank of Khorasan province, it may be necessary to generalize its results to other branches in other regions due to the different types of attitudes and some norms. Also, considering that the obtained results are related to the situation of the National Bank, the results of this research cannot be generalized to other banks. Another limitation of this research is the decision team's busy schedule and delay in answering questions.

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References

Aravik, H., Amri, H., & Febrianti, R. (2022). The Marketing Ethics of Islamic Banks: A Theoretical Study. *Islamic Banking : Jurnal Pemikiran Dan Pengembangan Perbankan Syariah, 7*(2), 263-282. https://doi.org/10.36908/isbank.v7i2.344

Asghari Zadeh, E., & Amin, F. (2006) Improving the Productivity of Banking Services Regarding Ranking Customers Using Quantitative Methods. *QJERP. 13*(36) :5-32

Baptista, N., Alves, H., & Pinho, J. (2021). The case for social support in social marketing. *RAUSP Management Journal, 56* (3), 295–313. https://doi.org/10.1108/RAUSP-08-2020-0193

Belch, G. E., & Belch, M. A. (2003). *Advertising and Promotion: An Integrated Marketing Communications Perspective* (6th). McGraw-Hill.

Bennett, N. L. (1997). *The voices of evaluation. Journal of Continuing Education in the Health Professions, 17*(4), 198–206. https://doi.org/10.1002/chp.4750170402

Biranvand, H. (2013). *Marketing advertising management (methods and strategies) based on the perspective of integrated marketing communications*. Industrial Management Organization.

Constantinides, E. (2006). The Marketing Mix Revisited: Towards the 21st Century Marketing. *Journal of Marketing Management, 22*(3-4), 407–438. https://doi.org/10.1362/026725706776861190

Davari, A., Mohammadi Almani, A., Pournaserani, A. (2016). The Effect of Word of Mouth on Intention to Use Insurance Services among Customers of Insurance Companies in Rasht. *Jounal of Marketing Management, 10*(26), 115-137.

Dominici, G. (2009). From Marketing Mix to e-Marketing Mix: ALiterature Overview and Classification. *International Journal of Business and Management, 4*(9). 17–24. https://doi.org/10.5539/ijbm.v4n9p17

Egbunike, C. F. & Okerekeoti, C. U. (2018). Macroeconomic Factors, Firm Characteristics and Financial Performance: A Study of Selected Quoted Manufacturing Firms in Nigeria. *Asian Journal of Accounting Research*, 3 (2), 142–168. https://doi.org/10.1108/AJAR-09-2018-0029.

Evans, J. R., & Laskin, R. L. (1994). The relationship marketing process: A conceptualization and application. *Industrial Marketing Management, 23*(5), 439–452. https://doi.org/10.1016/0019-8501(94)90007.

Gao, J., Ren, X., & Li, Q. (2022). *Modes of Charitable Fundraising and Innovation.* In: Gao, J. (eds) Mechanisms of Charitable Donations in China. Research Series on the Chinese Dream and China's Development Path. Springer, https://doi.org/10.1007/978-981-16-6194-5_5.

Guizani, H , Valette-Florence, P., & Merunka, D. (2011). The impact of brand personality and sales promotions on brand equity. Journal of Business Research, 64(1), 24-28.

Hund, A., Wagner, H., Beimborn, D., & Weitzel, T. (2021). Digital Innovation: Review and Novel Perspective. *The Journal of Strategic Information Systems, 30*(4), 1–39. *https://doi.org/10.1016/j.jsis.2021.101695*.

Katsioloudes, M., Grant, J., & McKechnie, D. S. (2007). Social Marketing: Strengthening Company-Customer Bonds. *Journal of Business Strategy, 28*(3), 56–64. https://10.1108/02756660710746283.

Keller, K. L. (2001). Mastering the Marketing Communications Mix: Micro and Macro Perspectives on Integrated Marketing Communication Programs. *Journal of Marketing Management, 17*(7-8), 819-847. https://doi.org/ 10.1362/026725701323366836.

Kim, J. H., & Hyun, Y. J. (2010). A model to investigate the influence of marketing-mix efforts and corporate image on brand equity in the IT software sector. *Industrial marketing management, 40*(3), 424-438.

Kotler, P., & Keller, K. (2016). *Marketing management 15th ed.* (15th). Harlow.

Mangold, W. G., & Faulds, D. J. (2009). Social Media: The New Hybrid Element of The Promotion Mix. *Business Horizons, 52*(4), 357–365. https://doi.org/10.1016/j.bushor.2009.03.002.

Nazaritehrani, A., & Mashali, B. (2020). Development of E-banking Channels and Market Share in Developing Countries. *Financial Innovation, 6* (12), 1–19. https://doi.org/10.1186/s40854-020-0171-z.

Nilson. (2013). *Which Forms of Advertising Do Consumers Trust – and Act On–the Most?* Marketing Charts staff. http://www. marketingcharts.com/television/which-forms-of-advertising-doconsumers rust-and-act-on-the-most-36767.

Okhravi, A. (2014). Realistic Solution for Prioritizing Different Problems: A Synthesis of IPA-G-FGAHP and Grace-Capabilities Matrix. Journal of Operational Research and Its Applications. (4), 85-96.

Petur Samundsson, K. (2012). "Consumer trust in advertising in different media". a dissertation submitted to the graduate division of the university of Iceland in partial fulfillment of the requirement for BSc in Psychology in business and marketing.

Pirayesh, R. Alipour, V. (2012). Examining The Relationship Between CompetitiveIntelligence and Effectiveness of Marketing Strategies Among Public and Private Banks of Zanjan, *Journal of Business Management 6*(3), 455–474. https://doi.org/10.22059/jibm.2014.50742.

Rafiei, S., haghighi nasab, M., Yazdani, H. (2013). The effect of marketing-mix efforts and corporate image on brand equity in the IT software sector. *New Marketing Research Journal, 2*(4), 182-195.

Rahma, A., & Nasution , M. L. I. (2022). Marketing Strategy for Financing Products of PT. Bank of North Sumatra KCP Syari'ah Simpang Kayu Besar. *Jurnal Ekonomi, Manajemen, Akuntansi Dan Keuangan, 3*(3), 951–. https://doi.org/10.53697/emak.v3i3.636.

Sanayei, A., Mohammad Shafiee, M., Amini Velashani, M. (2016). Analyzing and Evaluating the Effectiveness of Bank Advertising According to the Advertising Characteristics and Audience Involvement Using the AISDALSLOVE Model. *Journal of Business Administration Researches, 8*(15), 185-209.

Sarmad S, S., & Jamshidian, M. (2014), Investigating the Effect of Internal Marketing on Markets and Functioning of Service Organizations. Marketing Management, 19,131–31.

Shamloo, M.(2014). *Marketing and Customer Orientation in Bank*. Andishe Mana.

Tarkhani, A., Nazari, A., & Niloofar, P.(2020). Investigating Effective Factors on The Efficiency Of Iranian Banking Industry (Simar And Wilson' S Two-Stage Method). *Journal of Quantitative Economics (Quarterly Journal of Economics Review), 17*(2), 1-41. https://doi.org/10.22055/jqe.2019.14838**.**

Tabibi, S., Nasiripour, A., Ayubian, A., Bagherian MahmoodAbadi, H. (2012). The Relation between Information Mechanisms and Medical Tourist Attraction in Hospitals of Tehran, Iran. *Health Information Management, 9*(3), 416-423.

Van Esch, P., Stewart Black, J., Franklin, D., & Harder, M. (2021). Al-enabled biometrics in recruiting: Insights from marketers for managers. *Australasian Marketing Journal, 29*(3), 225–234. https://doi.org/10.1016/j.ausmj.2020.04.003.

Weinreich, N. (2010). *Hands-On Social Marketing: A Step-by-Step Guide to Designing Change for Good* (2nd ed). Sage Publications.

Wong, L. W., Tan, G. W., Hew, J. J., Ooi, K. B., & Leong, L. Y. (2022). Mobile social media marketing: A new marketing channel among digital natives in higher education. *Journal of Marketing for Higher Education,* 32(1), 113-137.

Wu, A. (2017). A supportive pricing model for suppliers with purchase order financing. *International Journal of Production Research, 55*(19), 5632–5646. https://doi.org/10.1080/00207543.2017.1327727.

Wymer, W., & Samu, S. (2009). The Influence of Cause Marketing Associations on Product and Cause Brand Value. *International Journal of Nonprofit and Voluntary Sector Marketing, 14*(1), 1–20. https://doi.org/10.1002/nvsm.348.

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Providing a Model of Knowledge Management of Customer Experience and Its Effectiveness Evaluation in The Fintech Ecosystem

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ABSTRACT

According to the studies conducted in the field of knowledge management and experience management and the undamentals of customer experience management approach provided by Jaziri in 2019, the paper was conducted with two purposes:1. Providing a model of knowledge management of customer experience model in Fintech field and 2. its effectiveness evaluation in the Fintech ecosystem from the experts' perspective. The research is a descriptive and analytic survey type. The research method is Grounded Theory. In order to achieve the first purpose, 48 articles were selected, studied, and opinionated by purposefully sampling people. After reading and analyzing articles, customer knowledge experience concepts were extracted and categorized based on the phenomena, context, cause, intervention, strategy, and consequence. Then, the relationship between the concepts was designed as a model. Based on those propositions, the knowledge management of customer experience model was provided, and the fitting test was tested and approved. In order to achieve the second purpose, a questionnaire was designed based on four components, including 1- Understanding the importance of knowledge management of customer experience, 2- the role of tacit knowledge in customer experience, 3- the effectiveness of customer experience knowledge, and 4- Applying knowledge of customer experience. The results showed that from the point of view of experts, the effectiveness of knowledge management of customer experience in the Fintech ecosystem leads to improving marketing performance, better management of products and services, and increased customer satisfaction.

Keywords

Fintech, Theory building, Customer experience, Knowledge management, Grounded theory, CEKM Approach .

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1. Introduction

The studies show that the knowledge of customer experience in Fintech is a topic that has not been addressed much. Transforming customer experience into knowledge and using it optimally to increase customer satisfaction, improve service and product delivery to Fintech customers, and improve marketing performance for Fintech companies shows the necessity and importance of the research (Rahmani et al., 2022; Jaziri, 2017). Customer experience management is a kind of knowledge management but with repetition conditions. This iteration is the concept of the customer life cycle, which begins with identifying sources containing the experience; experiences are extracted, edited, stored, and transferred to the right person or people (Jaziri, 2017). After evaluation, this knowledge transfer is either confirmed or rejected, and, in any situation, it may be estimated as useful and applicant (Schneider, 2009). The consumer experience is a lived, subjective which can be transformed knowledge resulted from physical, praxiological and rhetoric dimensions, all are integrated under a dynamic interaction between the consumer, the object and the situation (Jaziri, 2019, p.14). The concept of customer experience is multidimensional and is analyzed from different perspectives, with distinct capacities, and in different industries (Barbu et al., 2021). Identifying aspects that result in a service experience being vividly memorized by the customer and subsequently relived is important for service businesses because it influences consumer behaviors such as word of mouth and repeat purchasing (Kim et al., 2022). The acquired experience can only be reused when the last stage of experience management (sharing) is also done effectively (Schneider, 2009). Knowledge Management of customer experience is an organized effort to use customer knowledge to improve the organization's performance (Teran-Bustamante et al., 2021). According to the customer knowledge literature, there is a consensus that customer knowledge is classified into three types of knowledge: "knowledge for", "knowledge about," and "knowledge from" (Desouza et al., 2005 in Jaziri, 2019). Research during the last few decades shows that tacit knowledge, which is the knowledge obtained from experience (Jaziri, 2019), is the basis of all other forms of knowledge, which allows the interpretation and logical application of knowledge at its highest level to the concept of wisdom (Sanzogni et al., 2017). In this regard, Jaziri (2019) conceptualized the customer experiential knowledge management approach (CEKM) as the association of knowledge management process with the customer service experience in order to enhance the future customer service experience or to create an experience offer. CEKM is based on the tacit knowledge related to the whole of customer experiential knowledge (Jaziri, 2019, p.11). The purpose of knowledge management is not the management of all knowledge but the management of that knowledge, which includes the collective knowledge and the ability of all knowledge-oriented employees of the organization, customers, and stakeholders. That knowledge increases the organization's performance and achieves specific goals, which can differentiate products and services and help meet customer needs (Alryalat et al., 2008). In this regard, Jaziri (2019) conceptualized the customer experiential knowledge management approach (CEKM) as the association of knowledge management process with the customer service experience in order to enhance the future customer service experience or/and to create an experience offer. CEKM is based on the tacit knowledge related to the whole of customer experiential knowledge (Jaziri, 2019, p.11). Digital transformation in business processes has led to the emergence and development of initiatives such as financial technology, which provide numerous services such as payment and e-commerce, e-insurance, and cryptocurrencies such as Bitcoin (Suryono et al., 2020). Fintech is the innovative use of technology in providing financial services to customers and users who previously used traditional ways to do financial operations (Anshari et al., 2018). For example, Fintech lenders can compensate for financial and credit deficiencies in areas where bank offices are less accessible (Jagtiani et al., 2018). Fintech is the future of banking and finance, easily available to financial service providers (same source). Fintech can be any innovative idea that improves financial services processes by providing technological solutions according to various business conditions (Suryono et al., 2020). The advancement of financial technologies has led to innovation in this field and, subsequently, the development of banking and payment services in the Fintech ecosystem (Zhang et al., 2020). Part of the motivation for Fintech is that information technology has made everything cheaper and more functional, from computers to cars., However, the unit cost of financial intermediation has not changed much in the last century. Therefore, one of the Fintech's promisesFintech is to unveil cheaper ways to overcome financial contractions and cost reduction of financial services to improve consumer welfare (Thakor, 2019). Also, Fintech markets have received widespread attention from researchers, research institutes, and public or private organizations (Anshari et al., 2018). It should be noted that most knowledge is stored in the human brain, regardless of the production or flow of knowledge; this is the performance of people, which is the basis of evaluation (Zhou et al., 2020). As founded by Jaziri (2019) through CEKM approach and customer experiential knowledge management competence construct (CEKMC), the customer experience can be identified as an indicator for discovering, extracting, and exploiting knowledge in the form of a new knowledge management model. This study seeks to provide a model in the field of knowledge management and customer experience research and customer experience research in Fintech field while measuring the effectiveness of this model in the Fintech ecosystem through the review of existing studies. The main questions of this research are:

RQ1: What are the main components of the customer experience model based on knowledge management based on knowledge management in the fintech field ?

RQ2: What are the performance effects of customer experience management based on knowledge management in the financial technology ecosystem?

In order to answer these questions, customer's comments in the field of financial technology were analyzed, and new concepts, models, and theories were presented. In the end, the limitations and contributions of the study were discussed.

2. Literature review

Due to rapid business changes, knowledge has become the primary source of increasing competitive advantages for organizations. In the meantime, customer knowledge has gained particular importance. The salient and main points of developing the customer knowledge management process include three parts: 1- the knowledge process about the customer, 2- the knowledge process for the customer, and 3- the knowledge process from the customer (Alryalat et al., 2008). Related activities to customer experience are categorized into seven steps:1- Collecting experience from sources, 2- modeling (finding the appropriate method to provide reusable experience and shaping it, if needed), 3 - Storing experiences, 4- Reusing (use of previous experience to solve a new problem), 5- Evaluating (evaluation of experience during re-use in terms of suitability of selected experience), 6- Checking correctness and accuracy of recovered experience and 7- Maintaining (updating experience) (Bergmann, 202). Figure 1 presents the need to provide new models of Fintech , ML and customer experience (Rahmani et al., 2022). Customer experience research started in the early 2000s, creating value for customers and financial technology companies (Addis et al., 2001).

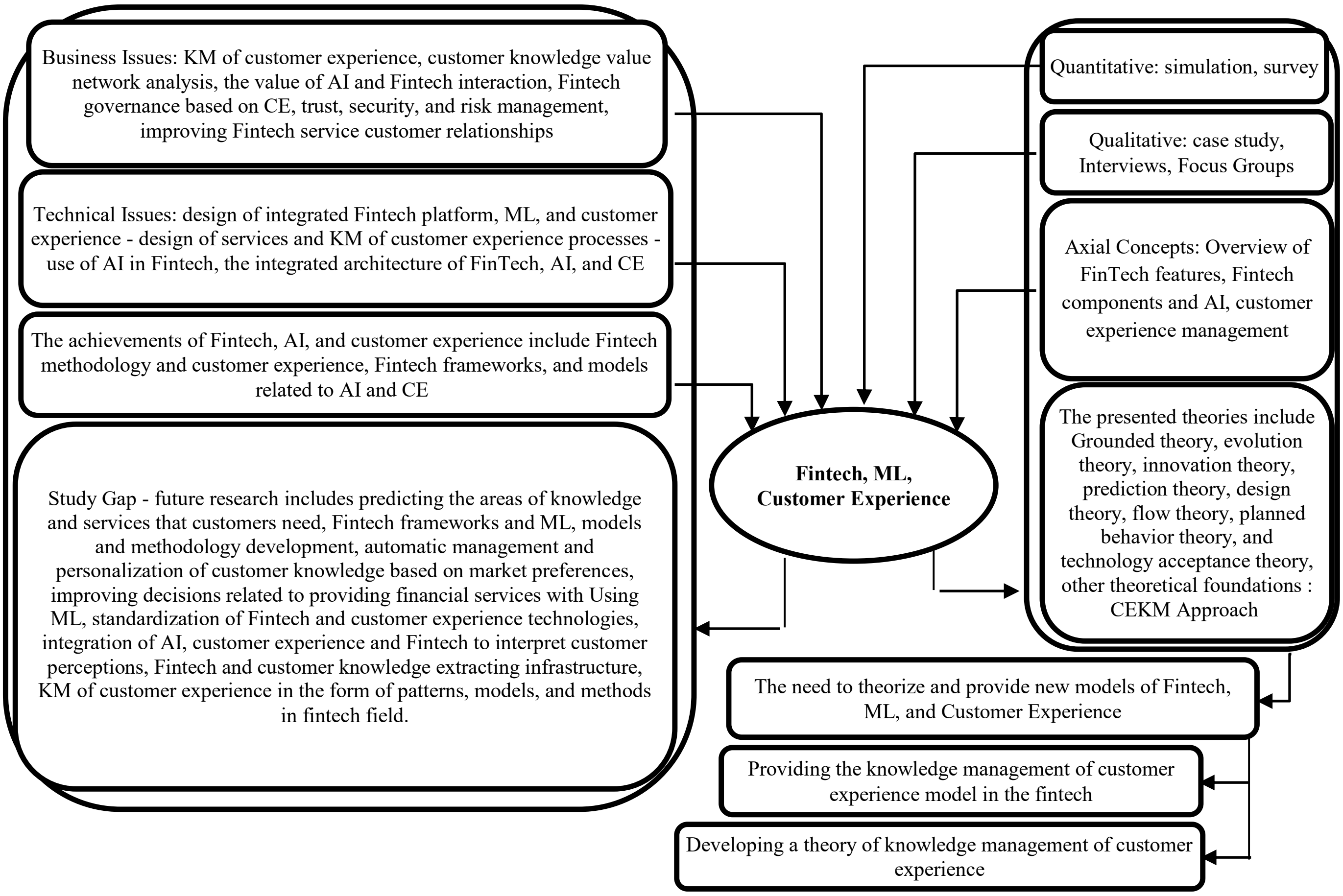

Figure 1. A framework based on the research in fintech, machine learning, and customer experience for future studies (Adapted from Rahmani et al., 2022).

The necessity and need for customer experience management and its management in various digital channels and networks, including financial technologies for business success, has made investing in customer experience lead to effective results in businesses (Izogo et al., 2018). Customer experience measurement is very complicated because the experience does not include all dimensions, and it is the responsibility of the researcher to determine which characteristics and dimensions exist inside or outside the person or organization that affect the customer experience. which of these features is the most important (Maklan and Klaus, 2011). The Fintech industry's growth accompanied the financial crisis of 2008, as consumers faced difficulties accessing traditional financial services (Knight et al., 2020). The concept of customer experience faces new capacities in new technologies, especially those that lead to Fintech development Fintech (Hoyer et al., 2020). Fintech companies create new value for consumers by focusing on technology-based customer experience (Rangaswamy et al., 2022). Customer experience is a psychological construct that includes a mental response to a customer's interaction with a company, its brands, services, or products (Rose et al., 2012).

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Customer experience defines a cognitive and emotional state resulting from concepts' production in a cultural context (Waqas et al., 2021). More coordination with customers positively influences business customer experience, and Customer engagement positively influences business customer experience (Ruiz-Alba et al.,2023). Customer experience is a multidimensional structure formed based on the customer's cognitive, emotional, behavioral, sensory, and social responses to a company's offers over time (Lemon et al., 2016). Customer experience is a set of a customer's cognitive, emotional, social, physical, and sensory responses after interacting with an organization, its products, and its brands (Keiningham et al., 2017). Customer engagement is interrelated with relationship marketing, resulting in an active conceptualization of the customer that co-creates the value of engaging customers in co-creation activities amongst service ecosystems (Rather et al., 2022). Cognitive experience indicates how customers think; emotional experience shows how they feel; social experience refers to customer interactions with others, and physical experience shows interactions with tangible products or contact points. Also, sensory experience refers to customer responses perceived through the senses (Ameen et al., 2021). Customer experience is a mental action formed from activity in a specific context for each person. It is affected by socio-cultural elements, education, expectations, and skills in using Fintech applications (Hollebeek et al., 2011). Fintech usually implements solutions to meet customer needs by leveraging emerging technologies to create a comprehensive and advanced customer experience by gathering different services on a single platform (Riemer et al., 2021). Fintech companies enrich the customer experience by providing access to automated and streamlined processes (Vasiljeva et al., 2016). When using Fintech services, customers do not want to waste time learning how to use the service or even waiting for the service to be completed, so ease of use is an important element in the technology-based financial environment for customers (Lee, 2009). CEM it is the foundation of CEKM but CEKM is the approach that can convert to experiential knowledge (Jaziri, 2019). Customer experiential knowledge management approach is the fundamental theoretical framework that advanced the conversion of customer experience data in customer experiential knowledge (CEK) (Jaziri, 2019). Tacit knowledge, which is the knowledge obtained from experience (Jaziri, 2019), is the basis of all other forms of knowledge, which brings the possibility of logical interpretation and application of knowledge to the highest level, the concept of wisdom (Sanzogni et al., 2017). Knowledge management guarantees competitive advantages when intellectual capital is considered perceivable knowledge that can be converted into value extraction and creation (Teran-Bustamante et al., 2021). A knowledge management framework consists of five main processes: 1) Transfer of knowledge from one person to another, 2) storing knowledge in the database, applying knowledge and exploiting it to innovate processes to create competitive advantage, 3) Creating knowledge through internalization, 4) composition, externalization, and socialization through interview with experts, and 5) acquiring knowledge from the out -of -organization environments such as receiving customer experience, competitors or other suppliers (AlGhanem et al., 2020). Common challenges in Fintech, include investment management, customer management, laws and regulations, integration of information technology, privacy and security, and risk management (Lee et al., 2018). Fintechis considered a distinct level that mainly describes the financial technology sectors in a wide range of operations for companies or organizations and is often associated with improving information technology applications (Gai et al., 2018). Customer experience is increasingly recognized as an important phenomenon in managerial practice, which has many implications for establishing customer relationships (Andreini et al., 2019). Regarding the concept of customer experience, conducted studies have emphasized the importance of customer experience and organizations' opportunities to use a strong and long-term customer experience (Lemon et al., 2016). Companies' interactions with customers or their offers lead to customer experiences, which determine how the customer will react to the company in the future (Brakus et al., 2009). Based on customer experience management studies, It was found that in the ranking of use, the Flow-Theory is highest. Respectively, stimulus-organism-response framework theory, service governance theory, technology acceptance model theory, and theory of planned behavior, justice theory, reconstruction memory theory, interaction-symbolic theory, theory of optimal experience are the next theories used in research. While it is usually borrowed from other theories for emerging fields, such as artificial intelligence in financial technology (Murray et al., 1995). Studies that lead to borrowing and extending the theory have developed the maturity of the original field, while the scope of application may be immature (Leong et al., 2017). An item that is rarely seen in studies is the connection between artificial intelligence and customer experience. At the same time, conversational AI models can positively impact these aspects of the customer experience. However, more research is needed to understand the specific factors that influence the impact of conversational AI models on customer experience (Abdelkader, 2023).

Table 1. Important journals in the field of fintech in science direct and elsevier (Rahmani et al, 2022)

Row	Journal Name	Reason For Importance	QTY	Present
1	Dublin Business School	St Ireland 2021	1	5%
2	Energy / ScienceDirect	IF = 7.147	1	5%
3	Computer Standards & Interfaces/ Elsevier	IF =2.487	1	5%
4	Research in International Business and Finance	IF=4.091	1	5%
5	Kelley School of Business Business Horizons Journal /ScienceDirect	Ranked 25th in the world in 2021	1	5%
6	Network and Computer Applications	IF = 6.363	1	5%
7	High Technology Management Research	Rank 6 among 108 computer magazines in the world	1	5%
8	Economics and Business	IF=4.076	1	10%
9	Borsa _Istanbul Review/ ScienceDirect	IF = 3.94	1	5%
10	Banking and Finance	IF = 3.348	1	5%
11	International Journal of Information Management	Rank 1 out of 86 technology fields and IF = 18. 958	1	5%
12	Journal of Financial Economics	IF = 6.988	1	5%
13	IATSS Research	IF=2.86	1	5%
14	International Journal of Engineering & Technology	IF = 1.27	1	5%
15	Federal Reserve Bank of Philadelphia	The central bank- Ranks 18	1	5%
16	Bank of England	The central bank won the GO 2020 global award	1	5%
17	Procedia Computer Science	IF =3.0	1	5%
18	Journal of Business Economic	IF = 2.39	1	5%

In the studies carried out for this research and subsequently the general look at the research in the field of financial technology regarding the distribution of publications, references, and other matters, Table 1 shows the distribution and number of articles published in prestigious journals.

Table 2. The important subjects in fintech research (Rahmani et al., 2022)

Subjects in Fintech	Axial coding	Open Coding
1- Economic issues and business strategy	FintechNetwork Analysis/ Creating Common Value/ Fintech governance and legal issues/ Trust, Risks, and Security/ Knowledge development, sharing, and management/ Fintech strategies and process management/ Fintech Strategy/ Fintech Price Analysis/ Fintech Digital Marketing	Knowledge development and sharing/Impact of technology platforms/Fintech governance and regulatory stability/Trust and Risk Determination/Fintech value creation strategies and competitive advantage/Business requirements/ Disruptive transformation, business intelligence/Resource sharing, organizational agility/Intranet competition, better performance, Fintech adoption, Process Management, FintechGlobal competition
2- Technical and technological issues	FintechPlatform Design, Design of Fintech Services and Processes, FintechTechnologies, Fintech Architecture, Integration and Interoperability of FintechSystems, FintechIoT, FintechSmart Payment, FintechDecision System, The use of AI in Fintech	Process Management of Technical Issues, Fintech Platform Design Process, FintechComponents, Fintech Infrastructure Support, Service Oriented Architecture, Organizational Architecture, Innovation
3- Conceptualization of Fintech	Development and Management of Fintech, Fintech Projects, The Origin and Characteristics of Fintech, Creation of Fintech Society	Fintech Conceptualization, FintechOverview, Fintech Implementation, FintechProject Management, Fintech Development and Evolution, New Concepts of Fintech
4- Fintech Achievements	Fintech Methodologies, Fintech Frameworks, FintechModels, Fintech Applications	Fintech Applications, Fintech Products and Services, Process Interoperability Framework, Fintech Formation Methodology, Fintech Integration Framework, Simulation Framework, Dynamic Integration Framework, Coordination Model, Fintech Business Modeling
5- Political orientation and start-up issues	Fintech Policies	Fintech start-up, Financial consolidation system

In order to theorize, Reviewing the topics, issues, and content of the articles in the Fintech area is a significant step. For this purpose, Table 2 was examined. In the table, the issues of business, economy, technical and technological strategy, new concepts in Fintech, the latest achievements, political orientations, and policy-making for Fintech startups have been researched. As shown in Table 2, financial technology research can be classified into 5 main topics, and 2 axial codes and open codes are considered for core and applied topics in the articles, respectively. The main topics include business, economics and strategy, technical issues, financial technology conceptualization and achievements, political orientations, and startups. The subject of business, economy, and strategy includes 18 open codes and 11 Axial codes, and 13 open codes and 9 axial codes are seen in the technical subject. The conceptual subject of financial technology has 6 open codes and 4 axial codes, and financial technology achievements include 9 open codes and 4 axial codes. Finally, political orientation and start-up topics include 2 open codes and 1axial code.

Table 3. Important journals in the field of customer experience (Rahmani et al., 2022)

Row	Journal Name	Index	Impact Factor	QTY
1	Journal of Marketing	JCR	9.462	4
2	Journal of Marketing Management	Scopus	6.96	2
3	Journal of Operations Management	JCR	6.97	2
4	Journal of Product and Brand Management	Scopus	4.355	2
5	Journal of Promotion Management	SJR	2.357	2
6	Journal of Relationship Marketing	SJR	1.781	1
7	Journal of Retailing	Scopus	5.245	6
8	Journal of Retailing and Consumer Services	Scopus	7.135	5
9	Journal of Services Marketing	SJR	4.466	2
10	Journal of Service Research	SJR	10.667	1
11	Journal of Strategic Marketing	Scopus	3.602	1
12	Journal of the Academy of Marketing Science	JCR	9.481	5
13	Journal of Travel Research	Scopus	5.169	1
14	Marketing Science	JCR	2.490	1
15	Marketing Theory	Scopus	4.343	2
16	Psychology and Marketing	JCR	2.23	1
17	Journal of Brand Management	Scopus	3.500	10

To ensure that the selected customer experience articles were extracted from authentic publications, refer to Table 3. The table includes the journal names, Index, impact factor, and the number of articles studied in the present research.

Table 4. Selection articles on customer experience management based on keywords.(Waqas et al., 2021)

A selection of customer experience articles based on the keywords below	The number of retrieved articles From 1998 to 2022	The Number of stored Articles from1998 to2022
Experience Management	25	20
Customer Experience	23	19
Consumer Experience	13	13
Online/Web/Internet Experience	12	10
Brand Experience	33	32
Product /Service Experience	8	7
Shopping Experience	10	9
Experience	11	9
Total	135	119

As Table (4) indicates, the keywords based on which articles in the field of customer experience management were searched, selected, included, referred to, and exploited.

Here, the need to examine the theories used in customer experience management research became more important. Customer experience is increasingly recognized as an important phenomenon in managerial performance, which has many implications for creating customer relationships (Andreini et al., 2019). Many articles and research literature have been published about customer experience. Studies indicate the importance of customer experience and the opportunity for organizations to use the development of a strong and long-term customer experience (Lemon et al., 2016). Among the theories used in customer experience management research, the studies show that flow theory ranks highest with 8 cases, stimulus-organism-response framework theory with 5 cases, service governing theory with 4 cases, and technology acceptance model theory with 3 cases. The used case is the theory of planned behavior with 2 cases, and theories of justice, restorative memory theory, interaction-symbolic theory, and theory of optimal experience are used in 1 case each.

3. Methodology

For studying and reviewing articles, it is necessary to draw the processing steps (Petersen et al., 2015). So, first, the process map of selection and review of sources for the research was designed (Figure 2).

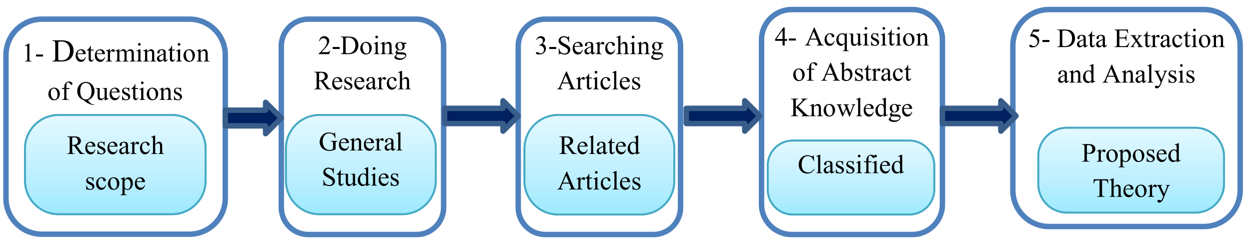


Figure 2. Process map of selection and review of articles

Based on the CEKM approach's foundations in service business research (Jaziri, 2019), the current research aims to provide a knowledge management of customer experience model in Fintech. The research method is Grounded Theory with an analytical and qualitative approach. Also, using the GT method helps us to find the answers to the research questions. First, The components of the knowledge management of customer experience model should be determined. Including requirements analysis and the necessity of theorizing in the field of knowledge of customer experience, there is the customer experiential knowledge (CEK construct, conceptualized by Jaziri, 2013 till 2022), Correct selection of informational and knowledge-based resources in the field of knowledge management of customer experience, Identifying and determining the concepts of knowledge management of customer experience, Classification of common content concepts related to knowledge management of customer experience, Classification of related concepts to the knowledge management of customer experience based on the phenomenon, the context, the cause, the interventionist, the strategy, and the consequence. They are also determining the hypotheses resulting from the relationship between the phenomenon, context, cause, interventionist, strategy, and consequences to realize the knowledge management of customer experience model and Goodness-of-Fit Test of the knowledge management of customer experience model in Fintech field. Second, The measure of the significance of improving marketing performance, the effect on better management of products and services, and increasing customer satisfaction in the Fintech ecosystem should be investigated. In order to collect data, the descriptive method and review of previous articles have been used. In response to the second question of the research, which is to measure the effectiveness of the knowledge management of customer experience model in the Fintech Ecosystem, a survey of connoisseur experts was conducted and investigated. These two approaches focus on four key issues, i.e., sampling, creativity, reflection, and accuracy, as the basis for using Grounded Theory (Cutcliffe, 2000). So, to reach comprehensive research literature, the correct extraction of concepts and the relationship between the variables were investigated and analyzed because applying the Grounded Theory is in search of pointing to the meaningful relationships between the variables (Wolfswinkel et al., 2013).

According to these approaches to a more detailed review and choosing the correct articles, Silva's 2015 research for articles choosing process was used. A systematic review process that includes the following steps:

1. Identifying and extracting articles from scientific databases and removing duplicate records used for this research through the keywords Fintech, financial technology, customer

experience management, knowledge management of customer experience, presenting knowledge management models and theories in financial technology research.

2. Screening by reading the titles and abstracts of the extracted articles, selecting relevant articles, and removing unrelated articles.
3. Re-screening and studying the introduction and conclusion of the articles screened in the previous stage, selecting relevant articles, and removing unrelated articles.
4. Final evaluation of the extracted articles from the previous stage by studying them and considering the research objectives and,
5. final selection of articles (Silva, 2015). The nature of methods and methodologies in Fintech area research are shown in Table 2. For instance, descriptive statistics have been used in the research of comparisons between banks, shadow banks, and Fintech companies (Buchak et al., 2018).

In some cases, hypothesis suggestions, empirical analysis, and regression have been used to compare the features and regulations of financial innovations (Knyazeva, 2019). The research was studied and reviewed 75 high-quality sources regarding the index and impact factor of scientific publications and authoritative magazines. Finally, 48 articles were selected for analysis. In the analysis stage, articles with open codes with the highest semantic load and more similar to Axial code in knowledge management of customer experience concepts and terms of methods, theories, and future study gaps were used. In the second stage, the opinions of 20 Fintech experts, including 5 Business development managers, 7 Knowledge managers, 4 Sales and marketing managers, and 4 Business analysts, all senior financial and e-commerce experts with more than ten years of experience and expertise, were used. Accordingly, two targeted sampling methods, i.e., 1) the method of maximum difference of characteristics and dimensions of knowledge management of customer experience phenomenon according to the selected samples and 2) the criterion-based method, were used in order to select a clear criterion (Lindlof, 2011). For this purpose, a questionnaire with 20 questions in the form of a four-level spectrum and the options "very little", "low", "moderate", "much" and "very much" were used. The components, including the importance of knowledge management of customer experience, the role of hidden knowledge in customer experience, the effect of knowledge of customer experience, and the application of knowledge of customer experience were graded and measured from 0 to 4, respectively. The questionnaire content validity was evaluated and classified in the three-part Likert scale by qualified experts through the content validity ratio using three items ("it is necessary", "it is useful, but not necessary" and "it is not necessary"). Experts considered more than 80% of the questions necessary, and the content validity was confirmed. The usefulness was evaluated to ensure the questionnaire's reliability by receiving the opinions of 15 Fintech experts and estimating Cronbach's alpha equal to 85%. In terms of quantitative data analysis, the results were obtained using multivariate analysis of covariance and smart-Pls software. In continue, the Composition of Questionnaire Questions, Cronbach's Alpha, and CR Values is shown in Table 5.

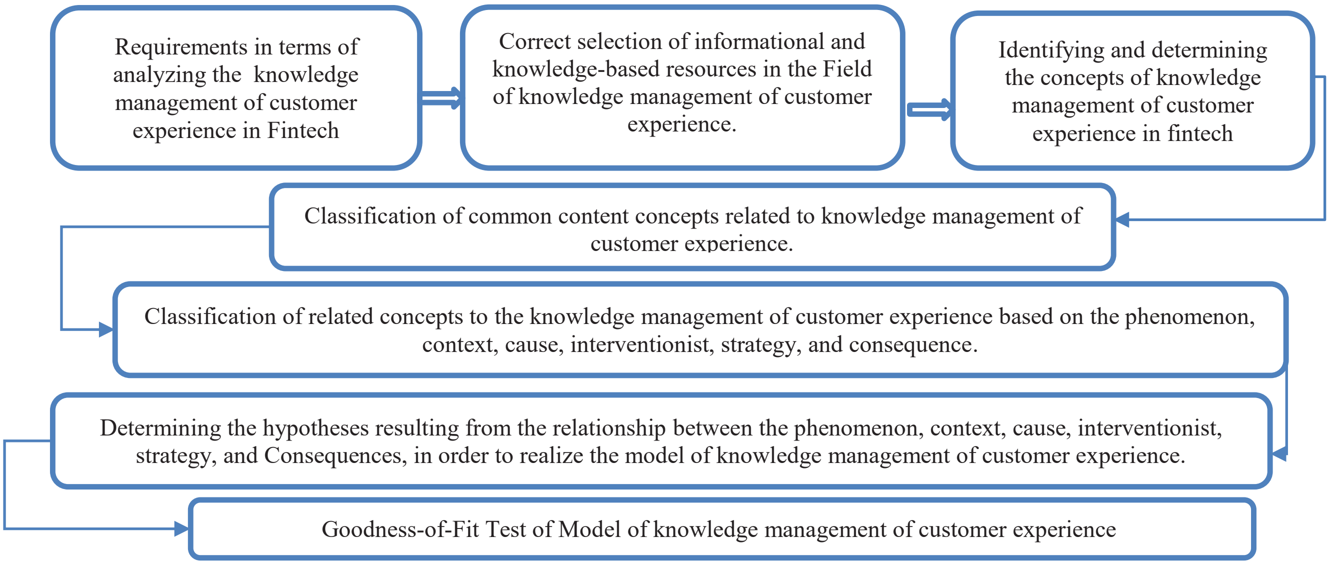
Table 5. The composition of questionnaire questions, cronbach's alpha, and cr values

	Construct	Questions NO	Cronbach's alpha	CR	Total
Knowledge management of customer experience	Understanding of the importance of knowledge management of customer experience	1 to 4	0.753	0,864	**80%**
	The role of hidden knowledge in customer experience	5 to 10	0.902	0.921	
	The effect of knowledge of customer experience	11 to 15	0.822	0.896	
	The application of knowledge of customer experience	16 to 20	0.793	0.801	

4. Results

First, in order to provide the model of knowledge management of customer experience, 6 main stages were identified and designed. In this way, the means of the main question of the research identifying the main components of the model of knowledge management of customer experience was answered. Following, The Main Stages and components of developing the model of knowledge management of customer experience in fintech are shown in Figure 3.

Figure 3. The main stages, and components of the developing the model of knowledge management of customer



experience in fintech

As shown in Table 6, in the first stage, needs analysis and the necessity of theorizing in the field of customer experience are examined. The studies show that This necessity is presented as a framework (Rahmani et al., 2022). In the second stage, the correct selection of articles and publications in Knowledge Management, Customer Experience, and the Fintech ecosystem were identified, selected, and reviewed. The third stage, which includes open coding, in order to determine the related concepts to knowledge management of customer experience in fintech domain by analyzing the content of selected articles, related concepts to experience issues, knowledge management, and knowledge management of customer experience were extracted.

In the fourth stage, for classifying the related features to knowledge management of customer experience in terms of common contents, the second stage of open coding was done.

In the last stage doing the Axial coding, the concepts, and features corresponding to the subject of the phenomenon, which in the current study is the knowledge management of customer experience, were classified based on the following components: The Context, cause, or necessity of paying attention to the customer experience knowledge management, intervention including barriers and facilities which could have negative or positive effects on implementation to use of this model in the Fintech ecosystem, strategy, and providing practical solutions for the knowledge management of customer experience in Fintech ecosystem and the consequences, which is the results of applying or not applying the strategies.

Table 6. Open coding, and axial coding of the components of knowledge management of customer experience components

Category	Concept
1. The phenomenon of attention to knowledge management of customer experience	Understanding the importance of knowledge management of customer experience, the role of tacit knowledge in customer experience, the impact of knowledge of customer experience, and the application of knowledge of customer experience in fintech.
2.The reasons, necessity, and, paying attention to the knowledge management of customer experience.	The market needs knowledge of customer experience, business development needs knowledge of customer experience, knowledge of customer experience as a data analysis training tool, tacit knowledge of every customer experience, the appropriateness of effective knowledge with the level of customer experience, and using customer experience as applied knowledge.
3. Contexts of knowledge management of customer experience	knowledge of customer experience is acquired, knowledge of customer experience is citable, knowledge of customer experience is transferable, and knowledge of customer experience can be learned, knowledge of customer experience is endless.
Strategies to create knowledge management of customer experience	To create knowledge of customer experience, Discover knowledge of customer experience, Store knowledge of customer experience, Share knowledge of customer experience, Apply knowledge of customer experience, Refine knowledge of customer experience, Cultivate knowledge of customer experience, and Select the best-experienced and knowledge-owner customers.
Negative intervention - effective barriers to applying strategies of knowledge management of customer experience	Using the knowledge of wrong customers' experience, Cultivating knowledge from the unprincipled customer experience, Citation to knowledge derived from emotional customers experiences.
Positive intervention - effective facilitators to applying strategies of knowledge management of customer experience	Having quality knowledge from repeated experiences
The consequences of applying the strategies of knowledge management of customer experience	Increasing awareness and focusing on the real needs of customers, Identifying the right experience from the wrong experience, the opportunity to create new knowledge from customer experience, and increasing wisdom from valid knowledge.
Consequences of not applying strategies of knowledge management of customer experience	Applying knowledge from the wrong experience, Lack of wise decision-making from successful customer experiences. Applying immature experience, Sharing unprincipled knowledge of customer experience as effective knowledge.

The axial coding stage aims to create a relationship between the components of the phenomenon, context, cause, interventionist, strategy, and consequences, which leads to the model. On the other hand, selective coding, which is based on axial coding, answers the hypotheses and knowledge management of customer experience model, and the result is the knowledge management of customer experience model. Figure 4 shows how the phenomenon is created from causal conditions. How does it lead to carrying out strategies by the influence of the contexts and interveners, and what consequences will be obtained?

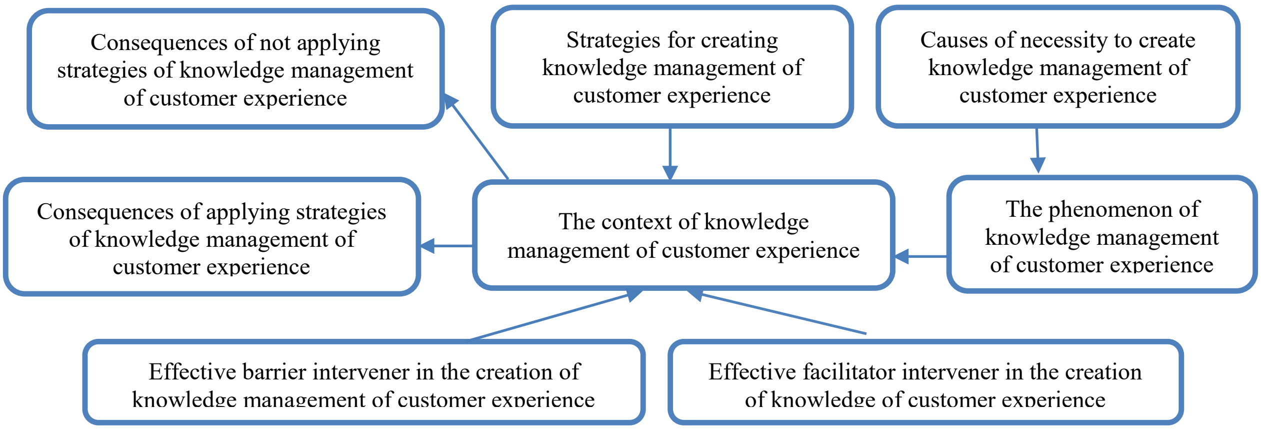


Figure 4. The axial coding paradigm of knowledge management of customer experience
the research achievement: providing a model of knowledge management of customer experience in fintech field

By examining the governing theorems on the internal relationships between components (Table 6), which is based on selective coding, the model of knowledge management of customer experience was developed.

Theorem 1. The causes and necessity are effective in paying attention to the phenomenon of knowledge management of customer experience.
Theorem 2. Paying attention to the phenomenon of knowledge management of customer experience is effective in developing efficient strategies for creating this phenomenon.
Theorem 3. Contexts of knowledge management of customer experience effectively create knowledge management of customer experience strategies.
Theorem 4. Barrier intervention factors disrupt the creation of strategies for knowledge management of customer experience.
Theorem 5. Facilitator intervention factors help to create strategies for knowledge management of customer experience.
Theorem 6. Applying the strategies of knowledge management of customer experience has positive results.
Theorem 7. Not applying the strategies of knowledge management of customer experience have negative consequences.

4.1. Model Fitting

In order to ensure the accuracy of the findings of the model, the validity of the process of each concept and category was measured by six experts in the field of KM and Fintech. Also, the

Kappa index was calculated to determine the coefficient of agreement between the researcher and KM experts. The Kappa index showed 72% in the stage of extracting concepts and 81% in the stage of categorizing concepts. Considering that both values are in the range of 61% to 80%, the level of agreement is acceptable and has good reliability.

Regarding process validity measurement, the content validity ratio was calculated based on %99 for six experts in KM and customer experience management. In Table 7, the ratio values of the content validity show that more than 95% of the experts considered the concepts of knowledge management of customer experience essential in the Fintech ecosystem. Therefore, the model of knowledge management of customer experience was recognized as valid.

Table 7. Validation of model of knowledge management of customer experience

Category	CVR	Concept	CVR
The phenomenon of attention to knowledge management of customer experience	1	Understanding the importance of knowledge management of customer experience	1
		The role of tacit knowledge in customer experience	1
		The effect of knowledge of customer experience	1
		Applying knowledge of customer experience	1
The reason and necessity to attention to the knowledge management of customer experience	1	The market needs to knowledge of customer experience	1
		Business development needs to knowledge of customer experience	1
		Knowledge of customer experience as an educational tool for data analyzing	99%
		Tacit knowledge in every customer experience	1
		The ratio of effective knowledge to the level of customer experience	1
		Using customer experience as applied knowledge	1
Contexts of knowledge management of customer experience	1	the knowledge of customer experience is to be acquired.	1
		Knowledge of customer experience is endless.	1
		Knowledge of customer experience is Citable.	1
		Knowledge of customer experience is transferable.	1
		Knowledge of customer experience could be learned.	1
Strategies for creating knowledge management of customer experience	1	knowledge creation of customer experience	1
		Selecting the best experienced and knowledgeable customers	1
		Discover knowledge of customer experience	1
		Storage knowledge of customer experience	1
		Sharing knowledge of Customer experience	1
		Applying knowledge of customer experience	1
		Refining knowledge of customer experience	1
		Cultivating knowledge of customer experience	1
Effective barrier intervener conditions in applying strategies of knowledge management of customer experience	1	Applying knowledge of the wrong customer experience	1
		Cultivating knowledge from the unprincipled customer experience	99%
		Relying on knowledge acquired from customers' emotional experience	1
Effective Facilitator intervener conditions in applying strategies of knowledge management of customer experience	1	The possibility of having high-quality knowledge acquired from repeated experiences	1
The consequences of applying strategies of knowledge management of customer experience	1	Awareness promotion and focusing on the real needs of customers	1
		Distinguishing the right experience from the wrong experience	1
		Opportunity to create new knowledge from customer experience	1
		Wisdom promotion from credible knowledge	1
The consequences of not applying strategies of knowledge management of customer experience	1	Applying knowledge of the wrong experience	99%
		lack of wise decision-making from a successful customer experience	1
		Applying immature experience	1
		Sharing unprincipled knowledge of customer experience as an effective knowledge	1

In order to investigate the effectiveness of the knowledge management of customer experience model in the Fintech ecosystem, a questionnaire that includes 20 questions focusing on the four main components of knowledge management of customer experience was designed. The questionnaire includes 1- Understanding the importance of knowledge management of customer experience, 2- The role of tacit knowledge in customer experience, 3- The effeteness of knowledge of customer experience, and 4- Applying knowledge of customer experience was provided to 25 experts of Fintech. The answers were received and then analyzed through a multivariate analysis of variance.

The findings show that knowledge management of customer experience significantly leads to improved marketing performance (F=04.74, P>50.5), improved product and service management (F=94.19, P>50.5), and increased customer satisfaction (F=26/11, P>50/5).

Therefore, it can be concluded that knowledge management of customer experience has an effect on Fintech marketing processes based on:

1. Real customer needs, product and service selection
2. Real customer expectations
3. Customer satisfaction, and finally, will lead to a transformation in the management development of Fintech ecosystems.

5. Discussion and conclusion

The research was conducted to develop the knowledge management of customer experience model and its effectiveness evaluation in the Fintech ecosystem. For this purpose, first, related articles were selected from authoritative publications as references. The knowledge management of customer experience was classified into eight categories using both open and axial coding (table 6). In this regard, the four first categories have been incorporated into the foundations of the CEKM approach (Jaziri, 2013, 2019). As a result, the analysis builds on the foundations of the CEKM approach (Jaziri, 2019) in the fintech sector, offering a specific model in this subject. Four main components include 1- Understanding the importance of knowledge Management of customer experience,3- The role of tacit knowledge in customer experience, 3- The effectiveness of knowledge of customer experience, and 4-Applying knowledge of customer experience from within the contents were extracted. Then, the relationships between the components were discovered and analyzed. The developed model of the research was provided in a new and combined form compared to other theories in the field of Fintech. Finally, based on the opinion of experts, the model was confirmed in terms of reliability and validity.

The components of the model of knowledge management of customer experience finding were determined including requirements analysis and the necessity of theorizing in the field of knowledge of customer experience, correct selection of informational and knowledge-based resources in the field of knowledge management of customer experience, identifying and determining the concepts of knowledge management of customer experience, classification of common content concepts related to knowledge management of customer experience, classification of related concepts to the knowledge management of customer experience based on the phenomenon, context, cause, interventionist, strategy, and consequence, determining the hypotheses resulting from the relationship between the phenomenon, context, cause, interventionist, strategy, and consequences, in order to realize the model of knowledge management of customer experience, and Goodness-of-Fit Test of model of knowledge management of customer experience. The second finding was the significance of improving marketing performance, better management of products and services, and increasing customer satisfaction in the Fintech ecosystem. The study's results could lead to a transformation in managing the development of Fintech ecosystem businesses through the acquired knowledge from the customer experience. The research developed a model of knowledge of customer experience in Fintech field which is the research contribution. It is suggested that other researchers investigate the effectiveness of this model in a different business environment or through quantitative methods. As a limitation of the research, the focus was on the Fintech ecosystem, so focusing on payment channels, the results will probably be more specialized.

Disclosure statement

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

References

Abdelkader, O.A., 2023. ChatGPT's influence on customer experience in digital marketing: Investigating the moderating roles. *Heliyon*, *9*(8). https://doi.org/10.1016/j.heliyon.2023.e18770.

Addis, M. and Holbrook, M.B., 2001. On the conceptual link between mass customisation and experiential consumption: an explosion of subjectivity. *Journal of Consumer Behaviour: An International Research Review*, *1*(1), pp.50-66. https://doi. org/10. 1002/cb. 53.

AlGhanem, H., Shanaa, M., Salloum, S. and Shaalan, K., 2020. The role of KM in enhancing AI algorithms and systems. . *Advances in Science, Technology and Engineering Systems Journal*, *5*(4), pp.388-396. https://dx.doi.org/10.25046/aj0504245.

Alryalat, H. and Al Hawari, S., 2008. Towards customer knowledge relationship management: integrating knowledge management and customer relationship management process. *Journal of Information & Knowledge Management*, *7*(03), pp.145-157. https://doi.org/10.1142/S0219649208002020.

Ameen, N., Tarhini, A., Reppel, A. and Anand, A., 2021. Customer experiences in the age of artificial intelligence. *Computers in Human Behavior*, *114*, p.106548. https://doi.org/10.1016/j.chb.2020.106548.

Andreini, D., Pedeliento, G., Zarantonello, L. and Solerio, C., 2019. Reprint of" A renaissance of brand experience: Advancing the concept through a multi-perspective analysis". *Journal of Business Research*, *96*, pp.355-365. https://doi. org/10. 1016/j. jbusres. 2018. 05. 047.

Anshari, M., Almunawar, M.N., Masri, M. and Hamdan, M., 2019. Digital marketplace and FinTech to support agriculture sustainability. *International Conference on Power and Energy Systems Engineering*, 2(156), pp.234-238. https://doi. org/10. 1016/j. egypro. 2018. 11. 134.

Barbu, C.M., Florea, D.L., Dabija, D.C. and Barbu, M.C.R., 2021. Customer experience in fintech. *Journal of Theoretical and Applied Electronic Commerce Research*, *16*(5), pp.1415-1433. https://doi.org/10.3390/jtaer1605008.

Bergmann, R. ed., 2002. *Experience management: foundations, development methodology, and internet-based applications*. Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/3-540-45759-3 .

Brakus, J.J., Schmitt, B.H. and Zarantonello, L., 2009. Brand experience: what is it? How is it measured? Does it affect loyalty?. *Journal of marketing*, *73*(3), pp.52-68. https://doi. org/10. 1509/jmkg. 73. 3. 52.

Buchak, G., Matvos, G., Piskorski, T. and Seru, A., 2018. Fintech, regulatory arbitrage, and the rise of shadow banks. *Journal of financial economics*, *130*(3), pp.453-483. https://doi.org/10.1016/j.jfineco.2018.03.011.

Cutcliffe, J.R., 2000. Methodological issues in grounded theory. *Journal of advanced nursing*, *31*(6), pp.1476-1484. https://doi. org/10. 1046/j. 1365-2648. 2000. 01430. x.

Desouza, K.C., Awazu, Y., Desouza, K.C. and Awazu, Y., 2005. Engaging with customer knowledge management. *Engaged Knowledge Management: Engagement with New Realities*, pp.116-144. URL: http://sumin.in.ua/books/DVD/Desouza_K.C.,_Awazu_Y._Engaged.

Gai, K., Qiu, M. and Sun, X., 2018. A survey on FinTech. *Journal of Network and Computer Applications*, *103*, pp.262-273. https://doi.org/10.1016/j.jnca.2017.10.011.

Hollebeek, L.D., 2011. Demystifying customer brand engagement: Exploring the loyalty nexus. *Journal of marketing management*, *27*(7-8), pp.785-807. http://dx.doi.org/10.1080/0267257X.2010.500132.

Hoyer, W.D., Kroschke, M., Schmitt, B., Kraume, K. and Shankar, V., 2020. Transforming the customer experience through new technologies. *Journal of interactive marketing*, *51*(1), pp.57-71. https://doi.org/10.1016/j.intmar.2020.04.001.

Izogo, E.E. and Jayawardhena, C., 2018. Online shopping experience in an emerging e-retailing market. *Journal of Research in Interactive Marketing*, *12*(2), pp.193-214. https://doi.org/10.1002/cb.1715.

Jagtiani, J. and Lemieux, C., 2018. Do fintech lenders penetrate areas that are underserved by traditional banks?. *Journal of Economics and Business*, *100*, pp.43-54. https://doi. org/10. 1016/j. jeconbus. 2018. 03. 001.

Jaziri-Bouagina, D. and Triki, A., 2013, September. Customer experiential knowledge management (CEKM)-concept proposition and research framework development. In *European Conference on Knowledge Management* (p. 307). Academic Conferences International Limited.

Jaziri-Bouagina, D. (2017). The tacit knowledge through the customer experience: Conceptualization, externalization methods, and use application to Tunisian thalassotherapy centers. In *Handbook of research on tacit knowledge management for organizational success* (pp. 1-29). IGI Global.

Jaziri, D., 2019. The advent of customer experiential knowledge management approach (CEKM): The integration of offline & online experiential knowledge. *Journal of Business Research*, *94*, pp.241-256. https://doi.org/10.1016/j.jbusres.2018.05.029.

Jaziri, D. and Rather, R.A., 2022. Customer Experiential Knowledge-Process Competence in Driving Experience-Based Innovation: An Ethnography Lens in Well-Being Tourism. In *Contemporary Approaches Studying Customer Experience in Tourism Research* (pp. 107-130). Emerald Publishing Limited.

Ruiz-Alba, J.L., Quero, M.J. and López-Tenorio, P.J., 2023. Institutions and business customer experience: the role of interfunctional coordination and service co-design. *European Research on Management and Business Economics*, *29*(1), p.100213. https://doi.org/10.1016/j.iedeen.2022.100213.

Keiningham, T., Ball, J., Benoit, S., Bruce, H.L., Buoye, A., Dzenkovska, J., Nasr, L., Ou, Y.C. and Zaki, M., 2017. The interplay of customer experience and commitment. *Journal of Services Marketing*, *31*(2), pp.148-160. https://doi.org/10.1108/JSM-09-2016-0337.

Kim, Y., Ribeiro, M.A. and Li, G., 2022. Tourism memory, mood repair and behavioral intention. *Annals of tourism research*, *93*, p.103369. http://dx.doi.org/10.1016/j.annals.2022.103369.

Maklan, S. and Klaus, P., 2011. Customer experience: are we measuring the right things?. *International Journal of Market Research*, *53*(6), pp.771-772. http://dx.doi.org/10.2501/IJMR-53-6-771-792.

Knight, E. and Wójcik, D., 2020. FinTech, economy and space: Introduction to the special issue. *Environment and planning A: economy and space*, *52*(8), pp.1490-1497. . https://doi.org/10.1177/0308518X20946334.

Knyazeva, A., 2019. Financial innovation in microcap public offerings. *Journal of Banking & Finance*, *100*, pp.283-305. https://doi. org/10. 1016/j. jbankfin. 2018. 06. 012.

Lee, M.C., 2009. Factors influencing the adoption of internet banking: An integration of TAM and TPB with perceived risk and perceived benefit. *Electronic commerce research and applications*, *8*(3), pp.130-141. https://doi.org/10.1016/j.elerap.2008.11.006.

Lee, I. and Shin, Y.J., 2018. Fintech: Ecosystem, business models, investment decisions, and challenges. *Business horizons*, *61*(1), pp.35-46. https://doi.org/10.1016/j.bushor.2017.09.003.

Lemon, K.N. and Verhoef, P.C., 2016. Understanding customer experience throughout the customer journey. *Journal of marketing*, *80*(6), pp.69-96. https://doi. org/10. 1509/jm. 15. 0420.

Leong, C., Tan, B., Xiao, X., Tan, F.T.C. and Sun, Y., 2017. Nurturing a FinTech ecosystem: The case of a youth microloan startup in China. *International Journal of Information Management*, *37*(2), pp.92-97. https://doi. org/10. 1016/j. ijinfomgt. 2016. 11. 006.

Lindlof, T.R. and Taylor, B.C., 2017. *Qualitative communication research methods*. Sage publications. http://dx.doi.org/10.21018/rjcpr.2015.3.164.

Murray, J.B., Evers, D.J. and Janda, S., 1995. Marketing, theory borrowing, and critical reflection. *Journal of Macromarketing*, *15*(2), pp.92-106. https://doi.org/10.1177/027614679501500207.

Petersen, K., Vakkalanka, S. and Kuzniarz, L., 2015. Guidelines for conducting systematic mapping studies in software engineering: An update. *Information and software technology*, *64*, pp.1-18. https://doi.org/10.1016/j.infsof.2015.03.007.

Rahmani, A., Sorouri, M., Radfar, R. and Alborzi, M., 2022. Systematic Review Focusing on Financial Technology Machine Learning and Customer Experience and Providing Framework for Future Research. *Business Intelligence Management Studies*, *10*(39), pp.329-356. http://dx.doi.org/10.22054/ims.2022.61447.200.

Rangaswamy, A., Moch, N., Felten, C., Van Bruggen, G., Wieringa, J.E. and Wirtz, J., 2020. The role of marketing in digital business platforms. *Journal of Interactive Marketing*, *51*(1), pp.72-90. https://doi.org/10.1016/j.intmar.2020.04.006.

Rather, R.A., Hollebeek, L.D. and Rasoolimanesh, S.M., 2022. First-time versus repeat tourism customer engagement, experience, and value cocreation: An empirical investigation. *Journal of Travel Research*, *61*(3), pp.549-564. http://dx.doi.org/10.1177/0047287521997572.

Riemer, K., Hafermalz, E., Roosen, A., Boussand, N., El Aoufi, H., Mo, D. and Kosheliev, A., 2017. The Fintech Advantage: Harnessing digital technology, keeping the customer in focus. University of Sydney, Business School and Capgemini. http://hdl.handle.net/2123/16259.

Rose, S., Clark, M., Samouel, P. and Hair, N., 2012. Online customer experience in e-retailing: an empirical model of antecedents and outcomes. *Journal of retailing*, *88*(2), pp.308-322. https://doi.org/10.1016/j.jretai.2012.03.001.

Sanzogni, L., Guzman, G. and Busch, P., 2017. Artificial intelligence and knowledge management: questioning the tacit dimension. *Prometheus*, *35*(1), pp.37-56. https://doi.org/10.1080/08109028.2017.1364547.

Schneider, K., 2009. *Experience and knowledge management in software engineering* (Vol. 235). Berlin: Springer Science & Business Media. https://doi.org/10.1007/978-3-540-95880-2_6.

Silva, M., 2015. A systematic review of Foresight in Project Management literature. *Procedia Computer Science*, *64*, pp.792-799. https://doi. org/10. 1016/j. procs. 2015. 08. 630.

Suryono, R.R., Budi, I. and Purwandari, B., 2020. Challenges and trends of financial technology (Fintech): a systematic literature review. *Information*, *11*(12), pp.590-610. http://dx. doi. org/10. 3390/info11120590.

Teran-Bustamante, A., Martínez-Velasco, A. and Dávila-Aragón, G., 2021. Knowledge management for open innovation: Bayesian networks through machine learning. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(1), pp.40-58. https://doi.org/10.3390/joitmc7010040.

Thakor, A.V., 2020. Fintech and banking: What do we know?. *Journal of Financial Intermediation*, *41*, p.100833-100879. https://doi.org/10.1016/j.jfi.2019.100833.

Vasiljeva, T. and Lukanova, K., 2016. Commercial banks and FINTECH companies in the digital transformation: Challenges for the future. *Journal of Business Management*, *11*, pp. 25–33. https://doi.org/10.3390/su13042032.

Waqas, M., Hamzah, Z.L.B. and Salleh, N.A.M., 2021. Customer experience: a systematic literature review and consumer culture theory-based conceptualisation. *Management Review Quarterly*, *71*, pp.135-176. https://doi.org/10.1007/s11301-020-00182-w.

Wolfswinkel, J.F., Furtmueller, E. and Wilderom, C.P., 2013. Using grounded theory as a method for rigorously reviewing literature. *European journal of information systems*, *22*(1), pp.45-55. https://doi: 10. 1057/ejis. 2011. 51.

Zhang-Zhang, Y., Rohlfer, S. and Rajasekera, J., 2020. An eco-systematic view of cross-sector fintech: The case of Alibaba and Tencent. *Sustainability*, *12*(21), pp.8907-.8932. https://doi.org/10.3390/su12218907.

Zhou, Z., Liu, Y., Yu, H. and Ren, L., 2020. The influence of machine learning-based knowledge management model on enterprise organizational capability innovation and industrial development. *Plos one*, *15*(12), p.e0242253. https://doi. org/10. 1371/journal. pone. 0242253.

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

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