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Modeling Spread of COVID-19 in Pakistan and Policy Interventions to Mitigate its Spread

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ABSTRACT

COVID-19 has been a pandemic, a communicable disease that presented as atypical pneumonia with an unclear clinical spectrum. The first case in Pakistan was reported on February 26, 2020. Sind provincial government showed seriousness in initiating the containment measures. The outbreak progression was multiplying day by day. Fear and spread were dominating the areas increasing the number of detected infections and cumulative deaths. The demand for serious containment measures was increasing and highlighting the issues regarding public health capacity. This paper aims the development an epidemic model using the system dynamic architecture. The research aims to unveil the underlying structure that caused the spread of this contagious disease and identify the containment measures as policy levers to mitigate the spread of this deadly novel corona. Experimentation with the model highlighted that the model performed better in replicating the detected infections and cumulative deaths than the recovered people. Simulation results for varied simulation lengths under the combination of policy levers exactly traced the future trajectory of infected and dead people. Horrible numbers of future predictions demanded seriousness from the public and the government to mitigate its emerging outbreak with rational and plausible policies.

Keywords

COVID-19, Epidemic model, System dynamics, Policy design, Pakistan.

Article history

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1. Introduction

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is the pathogen that causes COVID-19 infection. COVID-19 is a leading cause of death worldwide due to a lack of preparedness and scarcity of health care capacity around the globe. Researchers and epidemic modeling experts are exploring the implicit strategies to reduce its transmission rate and effectively manage the disease burden. In this battle with COVID-19, all human and technological resources are being consumed, and global economic activity has completely ceased, which has stressed the global economy, which is expected to experience an unprecedented recession alleviating poverty, creating hunger, and lowering employability. In order to lessen the drastic effects of this disease, there is a dire need to explore a set of policies that can reduce the accelerated blowout of this disease.

In our research, the standard dynamic epidemic model (SIR) provides the foundation stone of our model while capturing the structures grounded in experiential information and real-life setting (Bostanudin, et al., 2020). Our model is developed in simulation-based software STELLA; professional version 1.1.2 using system dynamics modeling framework (Cori et al., 2013). In our study, our simulated model (SIDIRD) is a policy regime tool that not only predicts the trajectory of this disease in Pakistan in the upcoming time but also establishes different policy levers that can flatten the curve of this disease and can dramatically reduce its spread and disease mortality. It also illustrates a list of possible limitations halting the productiveness of these policies and proposes an action plan to limit not only the infection rate of this disease but also the fatality rate associated with it.

2. Literature review

On December 31, 2019, an epidemic of atypical pneumonia (Forrester, 1968) was reported to WHO in Hubei, a city of Wuhan in China. An intensive investigation program was initiated in china which revealed the novel Coronavirus, SARS-CoV-2, as the causative agent, and the disease was afterward named on February 11, 2020, by the world health organization as COVID-19. It is a zoonotic disease with human-to-human transmission. Based on transmission dynamics, numerous policies were introduced in China, not only for local people but for health care workers as well. Owing to its exponential spread and global outbreak world health organization declared it a public health emergency of international concern on January 31, 2020. On February 26, 2020, the rate of increase in infected patients in other countries superseded China. A significant increase in infected cases was noticed in Italy, Iran, and many other countries. Till March 1 2020, WHO had confirmed 87137 cases of COVID-19 globally.

By March 11, 2020, this disease had affected 113 countries and territories, with the number of infected cases reaching 118162, the number of deaths reaching 4990, and the WHO had declared it a Pandemic due to a thirteen-fold increase in cases in two weeks. The basic reproduction number for Coronavirus is estimated to be around 2.2 (range from 1.4 to 6.5) (Ghaffarzadegan and Rahmandad, 2020).

Based on published data from the Chinese center for disease control and prevention, the case fatality rate for COVID-19 is 3.64. Since many infected patients are asymptomatic carriers, the number of confirmed cases is just the tip of the iceberg, and these officials are not a reliable gauge to estimate the extent of the disease.

Pakistan is a developing country with a population of 197 million people as per the national census survey report 2017 in the country. Pakistan is a close friend of China, and there are many travelers from Pakistan to China and vice versa. The outbreak started in Wuhan city, and its spread was so fast that it got jet momentum covering 178 countries worldwide. The progression of COVID-19 was astonishing; the rapid rise in reported cases in many countries dimmed the hopes of containing the contagion at the origin.

The problem is multi-faceted in nature. The nature of the epidemic is not properly detected, the virus mutates quickly, and many mutations have been observed by virologists'; unlike other viruses, it is resistant to temperature partially (Lane, 2007), and no one has a clue about its vaccination. Pakistan, being a CPEC stakeholder, has strong ties with China, and Chinese products have flooded the Pakistani market with a good share. Price fluctuation in many products is the outcome of anything that happens in China. The Pakistani government, the business community, and even the common man have an eye on the news of COVID-19, especially concerning China and neighboring countries like Iran, Afghanistan, and India. Iran is the second neighboring country affected by COVID-19 after China and Pakistan have a close religious tie with the Iranian people (Qudrat-Ullah, 2012).

Table 1. Information related to the events of different periods of COVID-19

Time Period	Event Description
Period 1	The first case of the Coronavirus was highlighted in Sind Province at Taftan Border people coming from Iran.
Period 2	Till March 15, 53 cases were reported in Pakistan, and an awareness campaign has been started in all media houses.
Period 3	Educational institutes, schools, colleges, and universities have been closed till the next order.
Period 4	For the first time, two deaths were reported in Sind Province.
Period 5	The infection Fatality rate was one person died out of 151 infected people
Period 6	The government enforced two and a half days partial lockdown due to a rise in infected people
Period 7	The government enacted a full lockdown for the next 15 days
Period 8	The government extended the lockdown duration for the next 15 days to exert pressure on lockdown effectiveness and social distancing, etc.

During that timeframe, the paper "Hell is coming: here is a mathematical proof" by Dogan (2020a), (2020b) got the attention while mentioning that by April 15, 2020, 2 million Americans will be infected. Another article was written by Khan (2020), published in Business Recorder on March 27, 2020, sharing the horrifying findings like 90 million Pakistani will get infected in the next 40 days (Till May 6, 2020). Both researchers claim that mathematical modeling is the science behind these calculations. The odds are stacked against us, and it is a ticking time bomb. There was a motivation to develop the system dynamics model to understand the true magnitude of the epidemic. The information in Table 1 provides data for researchers to know how far this epidemic will go and what policies should be implemented to push down the infection rate and flatten the curve. What have policy levers been deployed to mitigate the spread of contagious diseases and lower the death toll?

Alarming news and a rising number of cases around the globe may be underestimating the actual size of the pandemic. Errors in data reporting and limiting health capacity in testing and screening lead to underestimation of its exponential growth. The patient's types are broadly classified as symptomatic and asymptomatic. It is said that at least 80% of the cases have symptoms not very different from common cold or flu (Novel Coronavirus Pneumonia Emergency Response Epidemiology 2020) (Ghaffarzadegan and Rahmandad, 2020). The following statistics show the ratio of deaths to those recovered at the beginning of March was 6.3% (Worldmeters 2020). However, most reports put the death rate at lower rates, indicating that approximately 70% of cases go undetected (Forrester, 1968).

3. Methodology

System Dynamics is a computer-aided simulation technique that addresses the complex, non-linear, time-delayed, feedback-dominant, and dynamic models of various disciplines (Raouf and Yusuf, 2011). System Dynamics masterly attempts to combine the key concepts like feedback controls, mutual causality, non-linearity in the functions, cybernetics, complexity, counterintuitive behavior, deviation correcting and deviation amplifying processes like goal-seeking, external resource production process, and many more to the organizational systems (Richardson, 2011).

Disease epidemiological modeling is an interesting research domain for modelers and researchers. Most of the mathematical and simulation models are grounded in the well-known epidemiological model SIR (Susceptible, Infected, and Resolved). Fiddaman's (2020) work on COVID-19 added another variable and renamed the SIR model as SEIR (Susceptible, Exposed, Infectious and Recovered). Lazovic-Lønningen (2020), inspired by Tom Fiddaman, has

adopted his model to the community of Serbia. The results of this study indicate an inextricable link between implementation of combined policy of masks and social (physical) distancing and control of infection transmission, thus – total deaths caused by the infection. COVID-19 simulator by Eberlein (2020) is an abstract model generic in nature and valuable input in the epidemic research area, but all these models and simulators are not replicating the spread of the epidemic in Pakistan. There is a dire need to develop the simulated dynamic epidemic model to understand the mechanics of the spread of infectious disease and gain insight into the effectiveness of the measures adopted by the government to reduce its spread. The followings are the research questions:

1. What are the underlying structures that cause the undesirable spread of the infectious disease Covid-19?

2. What are the policy interventions that can reduce the spread of the virus and generate plausible outcomes?

3.1. Model structure

Stock and Flow diagram of Epidemic Model is shown in Figure 1. Saturation loop **(S)**, reinforcing loop **(R)** and balancing loops **(B)** are in play simultaneously. Their interactions generate the model behavior. The model consists of these loops.

As the transmission rate increases due to an increase in infected people, there is a decline in susceptible people (people who are healthy but are at risk), and it is going to saturate till all the susceptible persons become infected people.

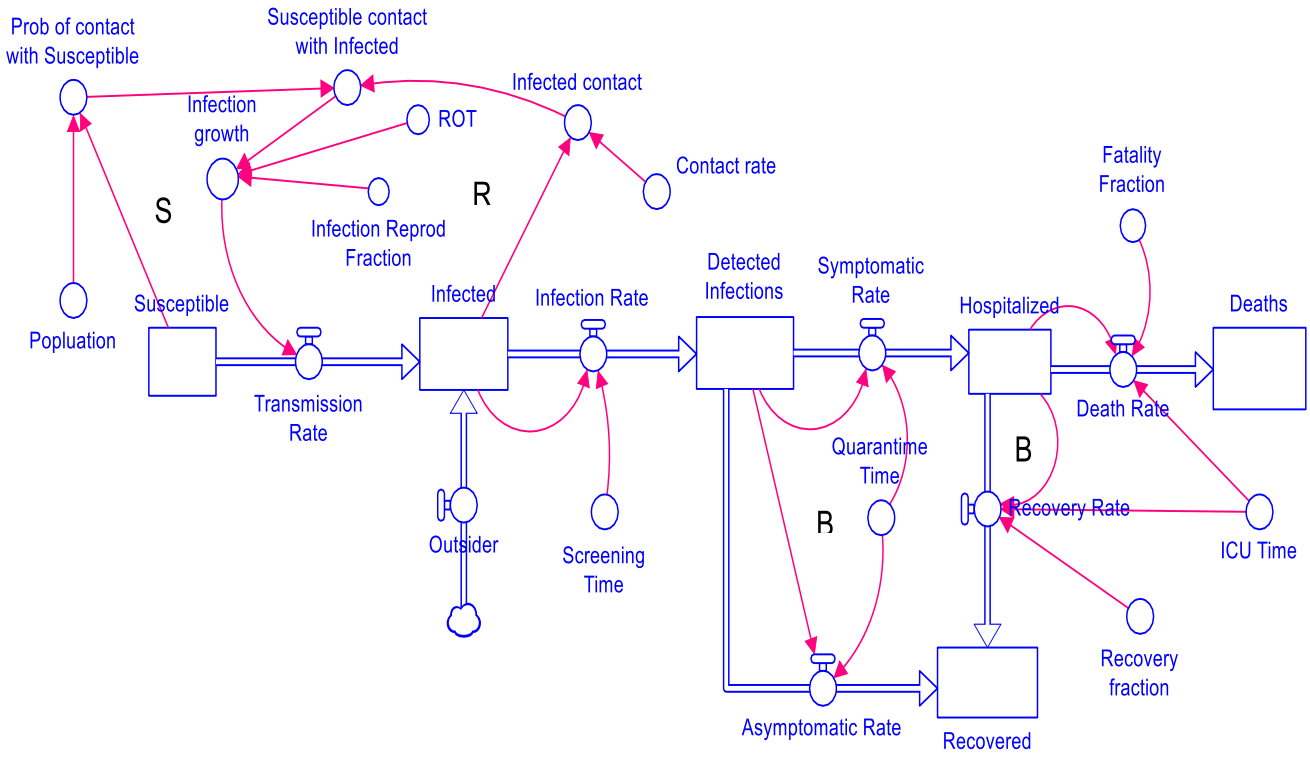


Figure 1. Simplified representation of the epidemic model

The reinforcing loop regulates the spread of disease. The susceptible are in contact with the infected people. They give exponential growth from susceptible to infected people, who are ultimately considered part of the stock of detected infections (Richardson and Pugh, 1981). Practically, it is impossible to test and screen all the infected people. Detected infections depend upon the availability of kits, quality of testing kits, and testing and screening to be conducted daily. The infected persons are quarantined for 14 days in quarantine centers.

Around 65 % of the infected are asymptomatic and stay in quarantine centers and become part of the stock of recovered persons. The other 35 % are symptomatic and can be categorized as symptomatic by mild, symptomatic by moderate, and the last category is symptomatic by severe. See details in Table 2.

Table 2. Types of patients and level of treatment

Patient Type	Description	Treatment
Type I	Asymptomatic and contagious	Isolation and staying in Quarantine
Type II	Contagious and Symptomatic by mild	Isolation and basic medicine
Type III	Contagious and Symptomatic by moderate	Isolation, medicine, and oxygen, having breathing difficulty
Type IV	Contagious and Symptomatic by severe	Isolation, medicine, and oxygen, ventilator, and plasma treatment

Type I patients are all recovered and stay alive. Type II, type III, and type IV patients either recover or die. The recovered persons become part of the stock of recovered patients, and the

people who die become part of the death stock. Type II, III, and IV patients require hospitalization and sometimes an Intensive care unit (ICU), depending upon the symptom. It is empirically observed that type II, III, and IV patients are hospitalized for around 7 days, so the total resolution time is approximately 21 days. Special cases do not prove the rule, and resolution times slightly vary in various parts of the country. The resolution period varies from 21 days to 30 days. The model is the seventh-order differential equation with associated flows (Saeed, 1992). The order of the model depends upon the number of levels and the number of delays (Saeed, 2017). In our epidemic model, there is no delay function, so the number of levels decides the order of the model. Lockdown duration, social distancing, awareness campaigns, and government policies are non-linear and vary as the days pass. The number of infected persons and deaths in different parts of the country and world news about the spread of the Coronavirus is the added controller to regulate and control people's behavior. These non-linearities are captured through graphical functions. Graphical functions have been used in the model to translate the ground realities based on secondary sources of data and researcher empirical information (Saeed et al., 2018).

The range of the different variables in the graphical functions and their curvilinear patterns are discussed and approved by the domain experts. Interactions of the positive and negative feedback loops generate behavioral patterns. The system consists of major positive and negative feedback loops (Sterman, 2000). Model structure and interactions of dynamic variables generate multiple patterns that are understandable, interesting, and surprising for some variables. The dominance of the polarity and its shift from positive to negative and negative to positive adds complexity; the mechanisms of change from one pattern to another can be searched through experimentation (Sushil, 1993).

The simulation experiments conducted with our model are designed to understand the behavioral patterns arising out of the model structure rather than point prediction of future deaths and recoveries (Sweeney and Sterman, 2007). Figure 2 demonstrates the stock and flow diagram of the model showing all the policy levers.

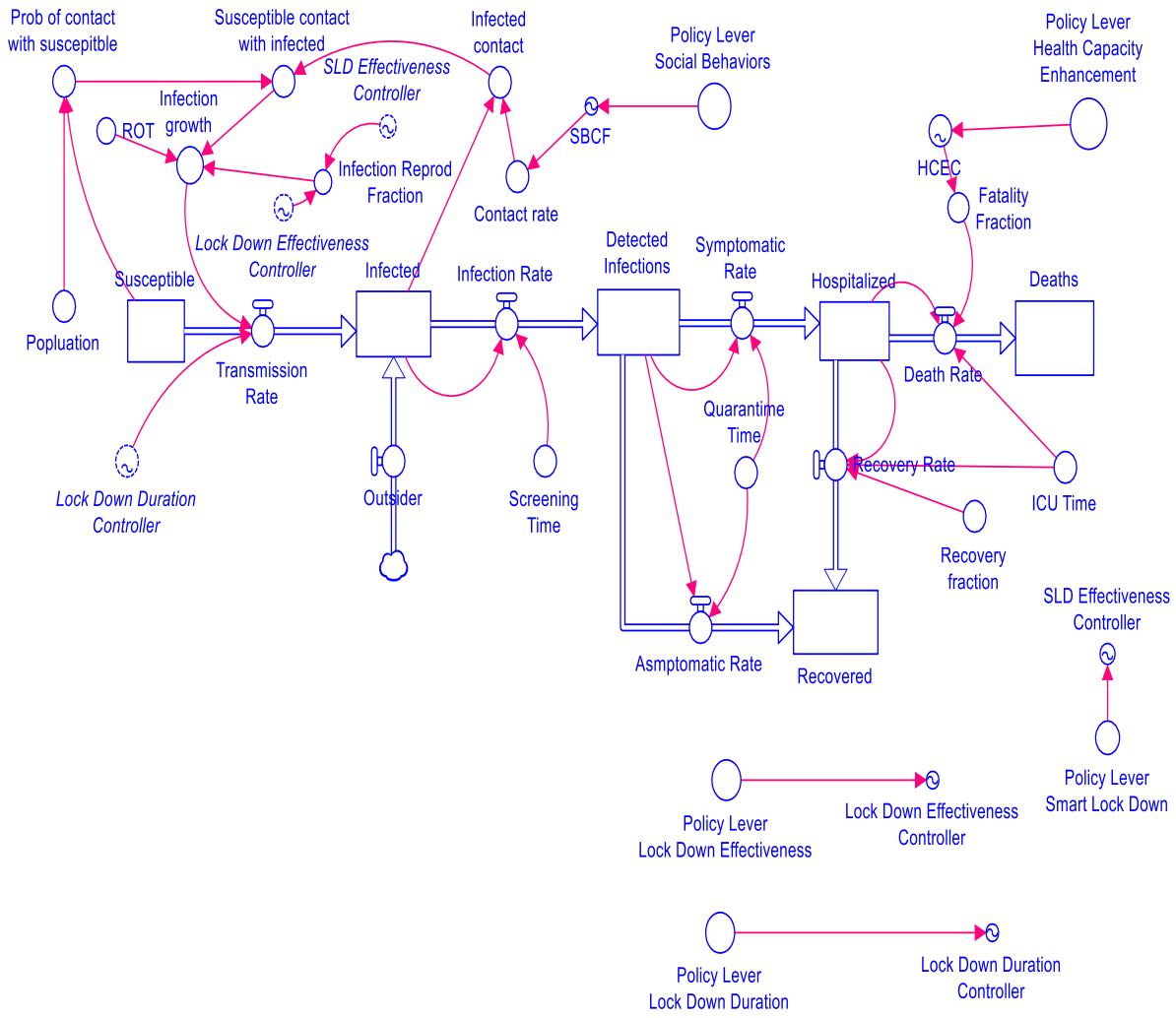


Figure 2. Stock and flow diagram of COVID-19 model

3.1.1. Base line model equations

Our baseline model has seven integral equations 1 to 7.

Susceptible = INTEGRAL (- Transmission rate) * dt (1)

Infected = INTEGRAL (Transmission rate – infection rate + outsider inflow) * dt (2)

Detected Infections = INTEGRAL (Infection rate – symptomatic rate – asymptomatic rate) * dt (3)

Hospitalized = INTEGRAL (symptomatic rate – death rate) * dt (4)

Deaths = INTEGRAL (Death rate) * dt (5)

Recovered = INTEGRAL (Recovery rate + Asymptomatic rate) * dt (6)

Annual COVID Death rate = INTEGRAL (Daily deaths – Deaths info discard) * dt (7)

Transmission rate = Infection growth (8)

Infection growth = Infection reproduction fraction * susceptible contract with infected / Reproduction Time (ROT) (9)

Susceptible contact with infected = prob of contact with susceptible * infected contact (10)

Infected contact = Contact rate * Infected (11)

Prob of contact with susceptible = Susceptible / population (12)

Infection rate = Infected / screening time (13)

Outsider Inflow = One person per day (Constant) (14)

Asymptomatic rate = 0.65 * Detected Infections / quarantine time (15)

Symptomatic rate = (1-0.65) *Detected Infections / quarantine time (16)

Death rate = fatality fraction * Hospitalized / ICU Time (17)

Recovery rate = Hospitalized / ICU Time * Recovery fraction (18)

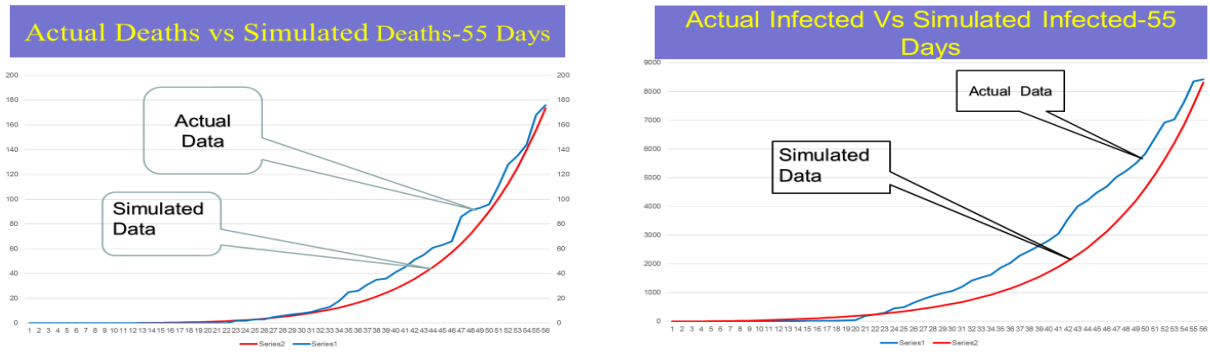
Daily deaths = Death rate (19)

Death info discard = Annual COVID Death rate / Time of info residence (20)

3.2. Model assumptions

Dynamic balance (Sweeney and Sterman, 2007) in this model prevails; the summation of all the stock and rates is equal to the total population. The person who is part of a healthy population lies somewhere in the system, either part of flow or stock. There are a few assumptions that have been taken into consideration while developing the model, which is as under:

1) There is no information about the immunity loss period.
2) An infected person is not to be infected again.
3) The Serio type of virus in Pakistan is less dangerous, or here the people have healthy immunity systems.
4) COVID-19 is temperature resistant; hot weather has no impact
5) Post-mortem testing is not allowed.



a. For deaths b. For detected infections

Figure 3. Actual and simulated data source:www.covid.gov.pk and www.worldometers.info/coronavirus

Table 3. Base case values of policy levers and model calibration

	Days since first case reported 55 Days					
			Detected Infections		Deaths	
Policy Levers	**Base Case Values**	**UOM**	**Actual**	**Simulated**	**Actual**	**Simulated**
Social Distancing	15	%				
Lockdown Duration	30	Days				
Lockdown Effectiveness	30	%				
Health Capacity Enhancement	15	%				
Smart Lockdown	0	%	8418	8400	176	174

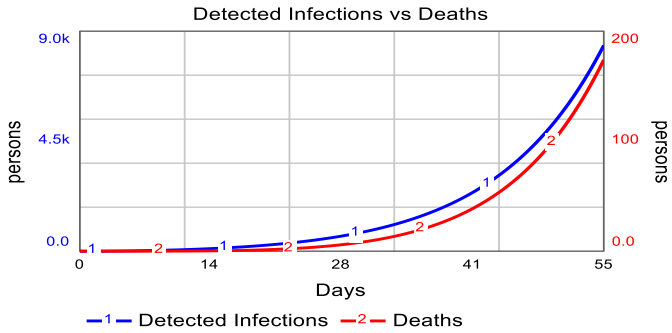
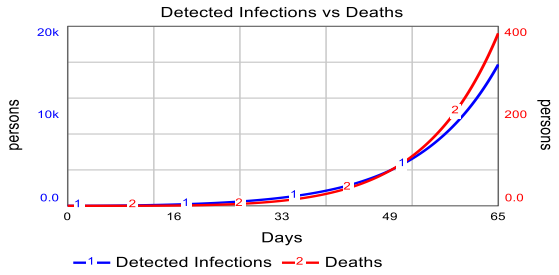


Figure 4. Detected infections and deaths for a simulation length of fifty-five days source:www.covid.gov.pk and www.worldometers.info/coronavirus

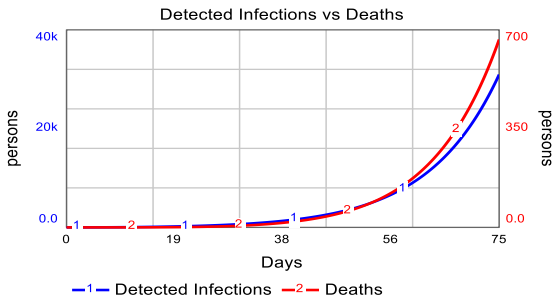
Experimentation with the model not only allows us to understand the diversity of patterns (Wu and McGoogan, 2020) of detected infections and deaths under the influence of policy interventions and various combinations of the policies as shown in Table 4 and Figure 5 .

Table 4. Tracing the detected infections and deaths with a mix of proposed values

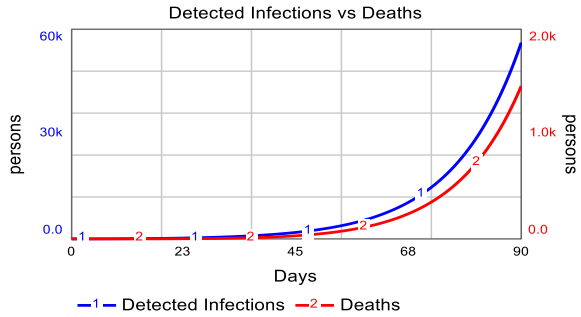
Policy Levers	**UOM**	**65 Days**	**75 Days**	**90 Days**	**180 Days Period of Six Months Duration**
		Mix of Proposed Values	**Mix of Proposed Values**	**Base Case Values**	**Base Case Values**
Social Distancing	%	35	35	39	39
Lockdown Duration	Days	40	50	65	65
Lockdown Effectiveness	%	45	50	40	40
Health Capacity Enhancement	%	25	85	90	90
Smart Lockdown	%	0	10	30	30
Detected Infections	**Actual**	16817	30334	56349	Not Known
	Simulated	16000	31000	56000	5.9 Million
Deaths	**Actual**	385	659	1167	Not Known
	Simulated	384	666	1400	648,000



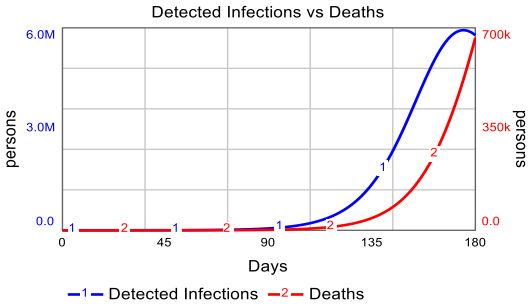
a. simulation length of sixty five days days



b. simulation length of seventy-five days days



b. simulation length of seventy-five days days



a. simulation length of next ninety days days

Figure 5. Detected infections and deaths

3.3. Model behavior

On the basis of the actual time series data, unofficial medical community estimates and the literature support providing building blocks of the SIR modeling paved the path for developing the system dynamics model to capture the true picture of COVID-19 spread in Pakistan. The model is calibrated, having a time series data of fifty-five days highlighted in Figure 3, considering the government measures shown in Table 3 and Figure 4.

Other model parameters like contract rate, infection fatality ratio, and the infection growth derived from the time series data and world statistics on COVID-19 and tracing the behavioral pattern for various simulation periods validated the estimations. We analyze the model for the future trajectory of the disease up to 90 days of actual data of detected infections and deaths with the simulated pattern having a mix of policy measures offered by the government.

Experimentation with the model has highlighted several scenarios**,** which are as under:

1) A positive change in social behaviors reduces the transmission of susceptible people into infected people (Tuite et al., 2020).
2) Infected people have a direct link with the Detected infections. The more infected people are prone to appear in testing and screening,
3) Lockdown effectiveness reduces the speed of spread of infectious disease, causing reduced detected infections and reduced deaths.

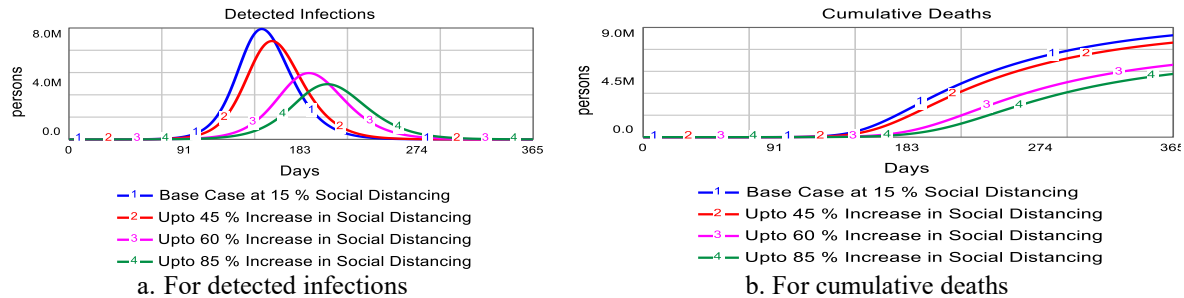
4) Enhancement in health care capacity lowers the death rate.
5) Lockdown duration just shifts the peak creating economic recession and having no effect on the reduction in infected people and deaths. An embedded reality is that lockdown duration has an effectiveness of almost less than half percent per day (estimation).

These scenarios are translated into policy measures that can change the model's behavior. A combination of various policy measures generates the various modes of behavioral patterns at different periods. These policies are guidelines for policymakers and government officials to reduce the spread of infectious diseases.

4. Results

4.1. Testing the scenarios

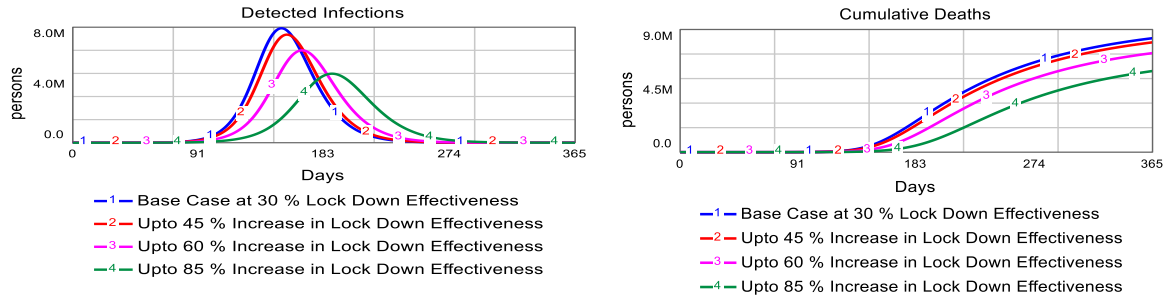
Social Distancing is a non-pharmaceutical prevention policy intervention that relates to people's behavior and attitude (Wang et al., 2020). Knowledge, understanding, and attitude of medical students (Waris et al., 2020) about health issues play a vital role in educating people around them. Education, religious beliefs, social norms, and awareness campaign are the deciding factors in lowering the detected infections and deaths. Figure 6 depict the same story.



a. For detected infections b. For cumulative deaths

Figure 6. Testing scenario social distancing

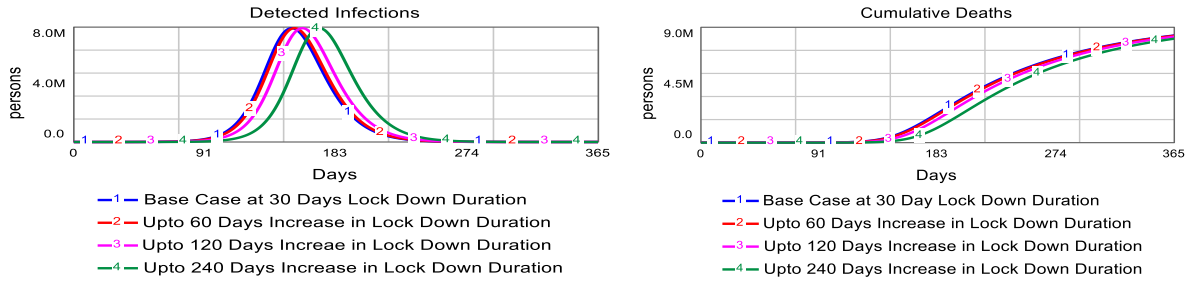
Lockdown effectiveness is the outcome of law enforcement agencies. How masterly do they go for Lockdown of the shops, shopping malls, hotels, restaurants, and other market places, get-togethers, official meetings, marriage parties, and funerals? Government has to enforce the effectiveness of the closure of factories and all public places. Figure 7 indicate the power of Lockdown effectiveness in lowering the spread of infectious disease.



a. For detected infections b. For cumulative deaths

Figure 7. Testing scenario lockdown effectiveness

Lockdown duration just shifts the peak and does not contribute to reducing deaths and detected Infections. They just announced that the province is in a Lockdown state and everyone is free to move as the Punjab government did in her first Lockdown, and they openly declared, "It is not curfew, so people are free to move". No doubt that the Lockdown duration created fear about infectious disease and created awareness of social distancing while closing the offices and public places see the behavioral pattern in Figure 9.



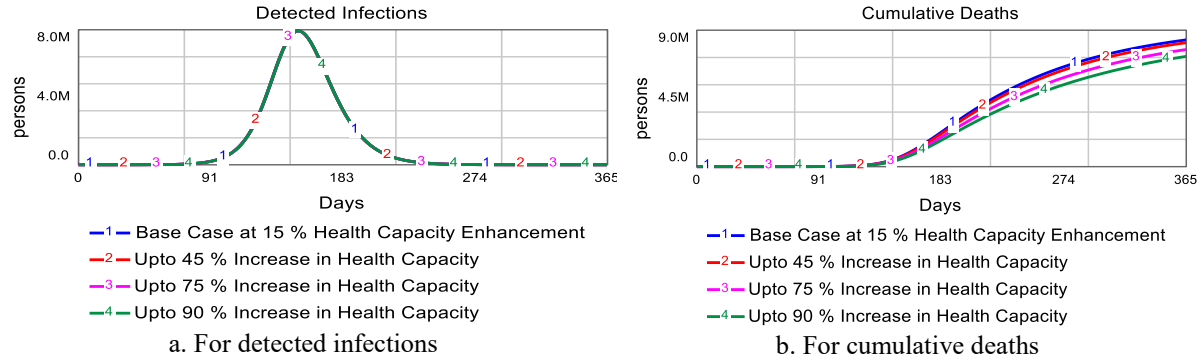
a. For detected infections b. For cumulative deaths

Figure 8. Testing scenario lockdown duration

Currently, the health capacity of the country is around thirty thousand beds, including all the quarantine centers and public hospitals. The government of Pakistan has progressively established metropolitan-wide quarantine centers (non-healthcare facilities) (Wu et al., 2020) all over the country. Expo centers, hotels, and schools are the key places for the quarantine centers. In the beginning, the detected person was forced to go quarantine center even though he was asymptomatic and seemed to be quite normal and healthy. Nowadays government is encouraging people to home isolation due to the scarcity of beds. The unclear clinical spectrum of disease and testing capacity with quality issues is still a question mark.

Ventilators are very limited, and private hospitals are charging so high that even the upper-middle-class family cannot afford to stay there. Enhancement in health capacity has no contribution to detected infections shown in Figure 9 (a) but reduces the death toll shown in Figure 9 (b). Figure 9 indicates that only health capacity cannot be reduced much unless we

strengthen it with other policy levers, like Lockdown effectiveness, social distancing, and Lockdown duration.



a. For detected infections b. For cumulative deaths

Figure 9. Testing scenario health capacity enhancement

The term smart Lockdown was borrowed from Sweden Model. The idea was brilliant. It can reduce poverty alleviation, job unemployment, and lay off of people from companies.

Smart Lockdown means opening every shop, public place, restaurant, factory, and intuitions in compliance with strict standard operating procedures (SOPs). Ensure effective contact tracing and territorial Lockdown where ever the case is reported. The outcome is very encouraging, as shown in Figure 10. But the hindrance point is awareness of the SOPs, the degree of seriousness of the people for its implementation, and passion for adhering to SOPs. It was observed that as the shops were opened near the Eid festival, women were there with small kids, ignoring the corona effect.

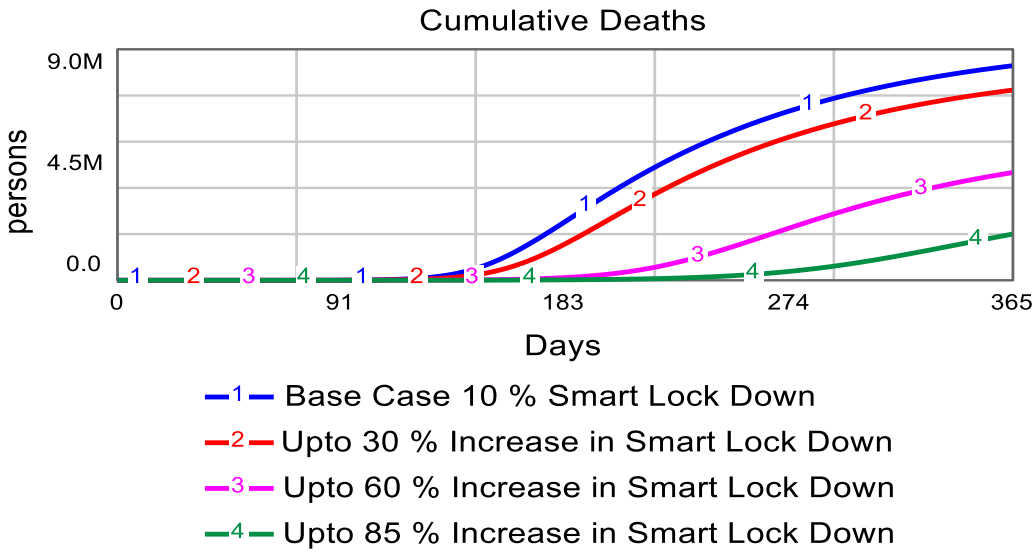


Figure 10. Testing scenario smart lockdown for cumulative deaths

The figures above clearly demonstrate the benefits of social distancing, the effectiveness of the Lockdown, Lockdown duration, enhancement in health capacity, and smart Lockdown. The role of law enforcement agencies in the effectiveness of the Lockdown seems harsh but helps to avoid a complete collapse of healthcare infrastructure.

5. Conclusion

Experimentation with the model (Yusuf and Azhar, 2018) and usage of various policy levers have given the guidelines for policymakers to mitigate the spread of Coronavirus. Lack of implementation of the policy lever not only builds up the stock of detected infections but as well the cause of the rising death toll. It is indispensable to keep on monitoring the data and playing with the policy levers to reduce the spread. Government should keep on working to enhance the health capacity and screening capacity. Contact tracing and territorial Lockdown effectiveness can contribute to its reduction and lower the pressure on health care services. Exploring the underlying feedback system structure for organizing the explicit and tacit knowledge about the system (Saeed et al., 2018) opens up other policy interventions to control this deadly communicable disease. Social distancing, Lockdown duration, Lockdown effectiveness, Health care capacity, and Smart Lockdown are the few control measures that were opted for in various countries depending upon their ground realities. There was a need to study these measures and foresee the impact in terms of reduction in infected and deaths as an outcome of these policies. Social distancing (based on education and literacy rate of the country) showed more impact than Lockdown effectiveness (Lockdown effectiveness depicts supremacy of the law enforcement agencies). Lockdown duration just shifted the peaks; otherwise, there was no impact while reducing the infected and deaths. Health care capacity seems to be very good in developed countries as compared to developing countries, but the model indicates that its impact is not significant, as shown in Figure 9. The initial focus was on the policies developed that should be used in Pakistan. Nevertheless, the results are so generic that they can be implemented in various countries as a control measure to mitigate the spread of COVID-19.

Disclosure statement

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

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Supply Chain Redesign: Strategic Decision Framework for Competitive Advantage

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ABSTRACT

This paper presents a framework to prioritize the supply chain strategies (SCS) according to all involved criteria, including objectives, process characteristics, product types, and environmental and demand conditions, to gain competitive advantages. This process has been done for the entire SC and upstream, downstream companies, and the focal companies of SC separately. Literature review and nominal group technique were used to identify customized criteria and SC strategies. Fuzzy Multiple Criteria Decision-Making techniques, including FDEMATEL and FANP, were used to structure the causal diagram and prioritize the entire and each section of SC. The case study is an industrial electronic supply chain (ESC) that produces condition monitoring devices. This is the first study on SC strategies for the entire SC and each section separately and implemented in an ESC. In addition, this is one of the few studies on flexibility requirements evaluation in supply chain strategies.

Keywords

Supply chain strategy, Agile supply chain, Supply chain flexibility, FMCDM model, Strategic decision framework.

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1. Introduction

The Supply Chain Strategies (SCSs) that managers consider are interactive with the company's operations and will affect the competitive advantage of SC partners (Hilletofth, 2009; Razmi et al., 2011; Naim et al., 2011). It is not enough to employ a traditional "one-size-fits-all" SCS. Since companies nowadays offer a wide range of products and services in various business environments, no SCS applicable to all types of products and markets. Regarding this fact, every part of SC, including upstream and downstream companies and the focal company of SC, can have different strategies and more than one strategy with different importance weights (Naylor et al., 1999; Olhager, 2003).

Previous studies have an emphasis on the necessity of research on identifying the criteria and factors involved in SC and the different weights of each criterion in SCSs model (Mason-Jones et al., 2000; Zhou et al., 2014; Nag et al., 2014) and Setting the flexibility requirements for types of SCSs. Also, using the decision support models and study on the SCSs in new industry sectors, including healthcare, monitoring, and construction, are suggested (Naim et al., 2011).

A Supply Chain (SC) is a set of added value activities that connect upstream and downstream entities to the customers (Basu et al., 2010). Supply Chain Design (SCD) is defined as: "identifying the desired strategic outcomes for the firm and developing, implementing and managing the resources, processes, and relationships (within the firm and across the supply chain) that seek to make the attainment of such desired outcomes inevitable over time". In today's turbulent world, one of the most critical tools available to managers is SCD and redesign (Melnyk et al., 2014, Huang et al., 2022). The first step in SCD and one of the most important issues in SC studies is to develop competitive strategies between the network partners (Cuthbertson et al., 2012; Ayers, 1999; Wang et al., 2004).

Selecting strategies is a multi-criteria decision, and many internal and environmental criteria should be considered for this decision. There is no consensus on the characterizations and criteria which are effective and differentiate SCSs (Kisperska-Moron et al., 2011). However, these criteria, in general, are distinguished by three decisive factors which determine the strategy of an SC: Demand, Supply, and the general environment (Cuthbertson et al., 2012).

This study provides an analytical approach and a model for managerial decision-making. We selected industrial electronic SC and separately examined strategies for the upstream, downstream, focal company, and entire supply chain. Condition monitoring devices (CMD) supply chain support sensitive equipment to prevent damage, including temperature, pressure, vibration sensors, and other detectors (Lorite et al., 2017; Ing et al., 2013). In the last decade,

condition monitoring (CM) industries have been impressed by important structural changes (Lorite et al., 2017; Stetco et al., 2018). Especially Iran's electronic industry with economic conditions by sanctions and the limitations of the budget; that lead them to the restructuring and redesign of their SC, consequently, strategies assessment for the achievement of the best economic and competitiveness situation (Taleizadeh et al., 2017; Lu et al., 2018).

We will examine the literature review in two areas to determine and select the appropriate SCSs to gain a competitive advantage. At first, the typology of SCSs will review and identify the most popular ones (section 2). Second, comprehensive decision criteria that are affecting and determinative in choosing the best strategy will be identified and characterized (section 3). Then we will use the MCDM, including a hybrid of FANP and FDEMATEL techniques, in a case study of the Electronic Industry Supply Chain (EISC) (section 4). Finally, a discussion, managerial implications, and conclusions in Section 5 are presented.

Based on the information we gathered, no study has done this by first suggesting an effective hybrid fuzzy MCDM method by considering all possible details to select appropriate strategies in EISC parts separately and second, examination of SC's criteria (including flexibility requirements) in every type of EISCSs. Also, in the literature, there are some works by these paper hybrid methods (Herat et al., 2012; Ho et al., 2011; Chang et al., 2011). However, there are few and rarely researches that integrate fuzzy set theory, ANP, and DEMATEL. To eliminate expert subjective judgment problems involving complex hierarchical relationships among SCSs selection criteria (Büyüközkan, 2012; Tseng, 2011).

2. Literature review

Since Porter's generic strategies (1985) were introduced for a company to pursue competitive advantage, each company tried to choose and implement the most appropriate competitive strategy according to its situation. Due to the complexity of today's business environment and its constant changes, individual businesses just compete as SCs, not as stand-alone entities (Basu et al., 2010). Several classifications have been proposed for SCSs that have common definitions and principles

Fisher (1997) proposed an 'efficient SC' for functional products and a 'responsive SC' for innovative products. Based on the degree of integration, Frohlich and Westbrook (2001) define five SCSs cluster including inward facing, periphery-facing, supplier-facing, customer-facing, and outward-facing.

Lee (2002) has identified four SCSs, including efficient, responsive, agile, and Risk-hedging. Katz et al. (2003) have suggested three distinct strategies for an SC, including innovating, modularizing, and appending SCs.

Supply chain council (SCC) (2010), in the Supply Chain Operations Reference model (SCOR), identifies five core SC performance attributes as its strategic orientations, which include reliability, responsiveness, agility, cost management, and asset management.

Parallel to the strategies mentioned, 'Sustainable and green' SCSs with emphasized environmental issues, social responsibility, and conservation of resources for future generations (Srivastava, 2007; Zhu, 2008) and 'resilience' SCS due to the volatility and turbulence in the market (Azevedo et al., 2011; Blackhurst et al., 2011), also presented.

By extension, Naylor et al. (Naylor, 1999) introduced 'Lean' and 'Agile' paradigms as SCSs; For the first time, they combined these two strategies in one SC and raised 'Leagile' or 'Hybrid' SCS. Since their work, lots of studies with different purposes have been done, with the acceptance of this typology for SC (Kisperska-Moron et al., 2011; Agarwal et al., 2006; Goldsby et al., 2006; Christopher et al., 2006; Vonderembse et al., 2006; Carvalho et al., 2011; Rahiminezhad Galankashi et al., 2016; Mittal, 2017).

Other types of SCSs mentioned have common and similar characteristics to the Lean, Agile, and Leagile classifications. Studies have stated that characteristics of 'green SC' (Carvalho et al., 2011; Dües et al., 2013; Larson et al., 2004) and 'resilience SC' (Christopher, 2004) can be implemented respectively with some changes in the ideal forms of the lean and agile SCs. In the following, each of these SCSs will discuss.

Lean SC requires predictable market demand, low product variety, and a long product life cycle. This strategy needs to compress lead time, eliminate all Muda, and develop a value stream to achieve level production (Naylor et al., 1999; Olhager, 2003). Agile SC developed to flexible and quick response to volatile customer's needs. This strategy uses market knowledge and a virtual corporation to exploit portable opportunities in a volatile marketplace. Leagile SC is the amalgam of the lean and agile strategies within an entire SC by positioning the decoupling point to the best suit that needs responding to a fugacious demand downstream yet providing level scheduling upstream from the marketplace (Van Hoek et al., 2001).

Identifying and selecting the most suitable strategy in SC have been examined in some studies, which are summarized and shown in Table 1, according to their techniques and findings.

Table 5. Literature review on SCSs selection

Author(s)	Method and techniques	Findings
Hallgren et al., (2009)	literature review, a software with Visual Basic language	Answers of the firm's manager to 15 questions about the product attributes of one SC, A software will select the most suitable SCS
Herat et al., (2012)	literature review and case study analysis	A framework proposed to select between lean, agile, and leagile SCs, according to the Introduction, Growth, Maturity, and Death lifecycle of products types (functional, innovative, and hybrid)
Chen et al. (2011)	literature review and case study analysis	Proposed a 2×2 matrix according to the demand characteristics (predictable and not predictable) and supply characteristics (lead time conditions) to select between lean, agile, and leagile SCSs and tested in a case study of retail in England
Agarwal et al., (2006)	ANP in FMCG business	According to the network, models and experts determined which supply chain performance criteria should be given priority over others. They also identify that leagile SC is the proper SCS to adopt for their products
Pettit et al., (2010)	AHP and Fuzzy Topsis	According to the quantitative and qualitative attributes selecting the leagile SCS as the best in a case study while the expert opinions of one manufacturing company just have considered
Stetco et al., (2018)	Define hypotheses about the four strategies of SC. Clustering analysis of 125 different companies and The ANOVA test	Choosing and grouping companies between four SCS clusters (lean, agile, hybrid, none of them) based on the alignment between the level of effective supply chain practice and the level of information quality in a 2×2 matrix. In addition, differentiation of business performance measures in each cluster.
Narasimhan et al., (2006)	Cluster analysis and Case analysis	Grouping US manufacturing industries into the four status SCS according to the degree of the material and goods stocks. An industry shows low or high in mentioned inventories depending on its products, processes, and the dynamics of all forces described in the Five Forces Model.
Rahiminezhad et al., (2016)	Nominal Group and AHP Techniques	A framework to evaluate the operational activities of Leagile supply chain strategy. Operational activities of Leagile SCS were determined and categorized with regard to supply chain drivers, and the activities were ranked using an AHP before being categorized using a cycle view of the supply chain.
Mittal et al., (2017)	Entropy approach, VIKOR analysis, and Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) method	Determination of Ten enablers for Lean-Green-Agile Manufacturing System (LGAMS). The influence of these enablers and prioritizing the facilitating capacity of each enabler have been done.
Tirkolaee et al (2020)	Hybrid FANP and FDEMATEL, TOPSIS and Weighted Goal Programming (WGP)	Addressed a sustainable SCS, supplier selection, and order size identification method, and it was tested in a case study of the LED lamps SC
Khan et al., (2022)	interval-valued q-rung orthopair fuzzy combinative distance-based assessment	Five types of green SCSs were investigated and evaluated for food SC, including risk-based, efficiency-based, resource-based, innovation-based, and closed-loop strategy
Tundys & Wi´sniewski (2021)	critical analysis of the literature and simulation methods	Select the most appropriate SCSs to reduce greenhouse gases emissions

By examining these researches, several things were identified: 1) No research evaluates and selects lean, agile, and leagile SC strategies in the electronic industry SC, and the needed flexibility dimensions of throw entire SC have not been prioritized. 2) Past studies have not

selected comprehensive criteria for choosing the SCSs; each one depending on their goals, just select only two-three criteria. Functional goals include cost, quality, service level, and lead time. No research has considered environmental conditions and dimensions of flexibility, especially return flexibility, in their models. Finally, 3) the selection of SCSs is a multi-critical decision-making issue with the complexity and high communication between variables.

3. The methodology of SCSs selection

Selecting between SCSs according to the criteria is an MCDM problem with lots of complexity and relationships between criteria. According to these relationships and due to ambiguity in decision-making, we used a literature review, Nominal Technique Group (NTG), and a hybrid of Analytical Network Process (ANP) and Decision Making Trial and Evaluation Laboratory (DEMATEL) with fuzzy values. Figure 1 shows the general view of the research process and methodology.

Briefly, after setting the decision goal, creating a team of experts, specifying the alternatives, and setting the customized decision criteria for evaluation with EISC experts' opinions, we have seven clusters each with a different amount of elements (criteria) inside it. Then we determine the network structure and clusters connections model using the FDEMATEL. After that, we calculate and obtain each cluster's priority vectors of criteria (elements) with inner interdependencies by FDEMATEL; then, we establish outer dependencies and their priority vectors using the FANP. Finally, we construct an unweighted supermatrix based on the interdependencies in the network for every part of SC and the entire SC.

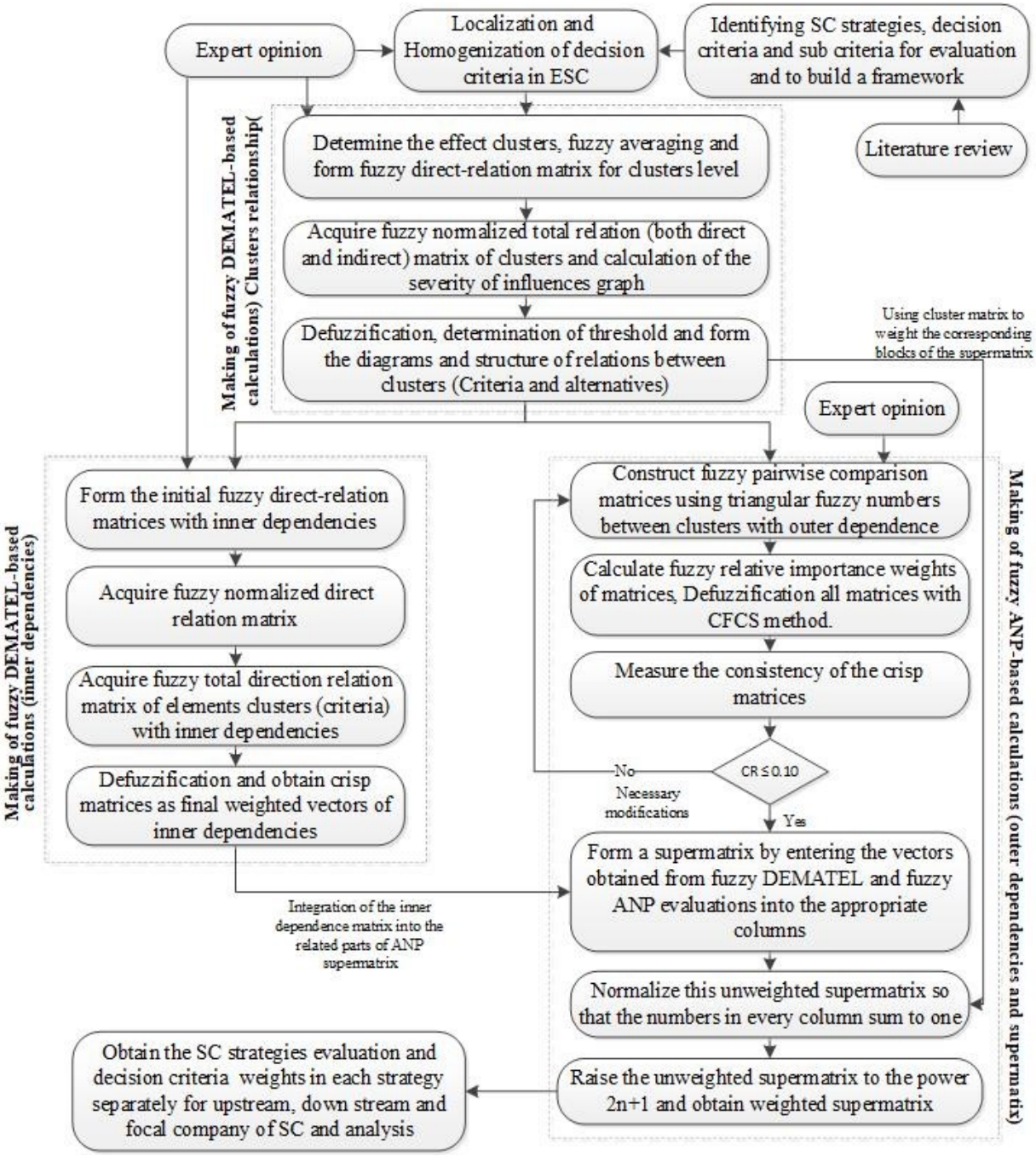

Figure 11. Methodology of SCSs selection

3.1. The FDEMATEL technique

The DEMATEL method originated from the Geneva Research Centre of the Battelle Memorial Institute as a kind of systemic modeling for a problem. When measuring a problem, it can see the cause-effect connections of criteria (Chen-Yi et al., 2007). Although DEMATEL is a good technique for evaluating problems, the crisp values are not enough in the real world. The human judgments with distinctions in decision-making are often uncertain and rigid to guess by accurate numerical values, causing the fuzzy logic requirement (Lin et al., 2004).

Thus, fuzzy theory (Zadeh, 1965) is applied to the DEMATEL technique for answering such an MCDM subject. FDEMATEL method is used in the literature (Büyüközkan et al., 2012; Chang et al., 2011; Lin et al., 2004). In this paper, the steps of group FDEMATEL is according to the Lin and Wu (2004) research.

3.2. The FANP technique

ANP is a general form of the Analytical Hierarchy Process (AHP) that considers the dependence between the elements. Instead of a hierarchy, the ANP-based system is a network that replaces single-direction relationships with dependence and feedback (Saaty, 2008). The ANP uses a reciprocal pairwise comparisons scale.

A network has clusters (categories) of elements (criteria), with the elements in one cluster being connected to elements in another cluster (outer dependence) or the same cluster (inner dependence). An arc denotes the interactions between two clusters, and a loop indicates the inner dependence of elements within a cluster.

As mentioned that human decisions about priorities are often unclear and rigid to guess by crisp values; again, fuzzy values are indispensable for considerate subjects structured by ambiguity. Therefore, using a combination of fuzzy set theory and ANP for SCSs assessment. In the literature, many researchers, such as [Liu et al., 2009; Vinodh, 2011] applied FANP to several research fields. In this paper, the steps of FANP is according to the Buyukozkan and Cifci (2012), Saaty (2008), and Zhou (2012) researches.

3.3. Decision criteria of the SCSs selection framework

To find and define the decision criteria for SCS selection, we examined studies from scientific databases (e.g., EBSCO, Scopus, Google scholar); with keywords including 'SCS', 'SCD', 'lean, agile, leagile SCs', 'green, sustainable, resilience SCs', 'SC performance' and with an emphasis on industrial electronic SCs.

Although wide studies on lean, agile, and leagile SCSs have been done, there is no consensus on the criteria of SCSs. But all studies' criteria are in three general categories, including 'Supply characteristics', 'Demand characteristics', and 'Environmental conditions' of SC. Supply characteristics have three subcategories: ' Objectives of supply', 'Process characteristics of supply', and 'Product characteristics of supply' (Basu et al., 2010).

After literature review and extracting all the possible criteria in each category, experts' opinions of the case study have been taken through the NGT (Delbecq, 1986) to customization and specialization of decision criteria for the electronic industry. Each criterion was evaluated

in terms of 'related or not', 'overlapping' or 'common concept' with another, 'need to change the title', 'very low importance', 'hierarchy of categorized', and 'adding new one'. Finally, some criteria were eliminated, some were changed, some were merged, and some new ones were added. Table 2 shows the final decision criteria of the research, with their sources, definitions, and categories. These criteria will be used to develop the framework of SCSs selection.

Table 6. Literature review of decision criteria on EISCS selection

Category (cluster)	Criteria	Sources	abbrev
Supply characteristics-Objectives-(GSC)	Cost	Wang et al., (2004); Pooya et al., (2017); Liu et al., (2010)	CO
	Profit	Harrison et al., (2008); Rimienė (2011); Frohlich et al., (2001)	PR
	Customer satisfaction	Ho et al., (2011); Fisher (1997)	VCS
	Efficiency	Niosi et al., (1992)	EF
	Quality	Porter (1985); Naylor (1999)	QT
	Speed and Swiftness	Stetco et al., (2018); Swafford (2006)	SD
	Responsiveness	Razmi et al., (2011); Delbecq (1986)	RS
	Market sensitive and Alertness	Hilletofth (2009); Bruce (2004)	MS
	Lead time	Gunasekaran et al., (2001); Thornton (2012)	LT
	Adaptability	Agarwal et al., (2007); Christopher and Jüttner (2000)	AD
	Certainty	Goldsby et al., (2006); Brun et al., (2017)	UC
	Reliability	Christopher and Jüttner (2000); Hilletofth (2009)	RE
	Service level	Büyüközkan (2012); Christopher and Jüttner (2000)	SL
	Innovation	Chang et al., (2011); Christopher (2004)	IN
Supply characteristics-Flexibility-(FSC)	Operation and system flexibility	Vonderembse et al., (2006); Rimienė (2011)	PFL
	Supply flexibility	Carvalho et al., (2011); Dües (2013); Chien et al., (2007)	SFL
	Delivery flexibility	Namulanda et al., (2018)	DFL
	Return flexibility	Christopher and Jüttner (2000)	RFL

Category (cluster)	Criteria	Sources	abbrev
Supply characteristics-process- (PSC)	Customization	Vinodh et al., (2011); Stetco et al., (2018)	CU
	Strategic Stock	Azevedo et al., (2008)	SS
	Decisiveness	Gunasekaran et al., (2008); Huang et al., (2002)	DE
	Postponement	Christopher and Jüttner (2000)	PP
	Surplus capacity	Chang et al., (2018); Stetco et al., (2018)	CS
	Process integration	Taleizadeh et al., (2017);	PIG
	IT integration and accessibility	Van et al., (1983)	ITIG
	Virtual Networking	Hallgren et al., (2009)	VN
	Alliances and Cooperation	Christopher and Jüttner (2000); Hilletofth (2009)	PA
	Waste eliminating	Thornton (2012); Chang et al., (2018)	WE
	Smooth operation flow	Harrison et al., (2008)	SOF
	Continuous Replenishment	Christopher and Towill (2001)	CR
	Employees skills	Gunasekaran et al., (2001)	HR
Supply characteristics-Product- (OSC)	Innovative product	Srivastava (2007); Chen et al., (2011)	IP
	Standard and Functional product		SP
	Hybrid product		HP
Demand characteristics (DC)	Stable and predictable	Gabus et al., (1973)	SPD
	Variable and unpredictable		VD
Environmental conditions (ECC)	New foreign threats	Opricovic et al., (2003); Lorite et al., (2017); Research expert opinions.	FNT
	International sanctions	Research expert opinions.	IS
	Environmental problems	Zhu et al., (2008)	EP
	government regulations	Zadeh (1965); Research expert opinions.	RR
	Electronic industry budget	Zadeh (1965); Research expert opinions.	DDB
	National security conditions	Zadeh (1965); Research expert opinions.	SC

4. Application of the SCSs selection in EISC

In nature, electronic industries have high investment, high levels of knowledge and technology, knowledge base human resources, equipment with a long lifecycle, and high maintenance costs and are more expensive than other industries. Trial and error in the design of this industry's SC result in high costs, and missed opportunities will be significant (Thornton, 2012).

Nowadays, electronic industries have faced structural changes in condition monitoring, which include: Notice of the latest status of equipment in the form of online, controlling equipment hazards in the workplace, uncertainty in demand and sensitive equipment needs in terms of speed and variety, transformation in infrastructures, industrial and research capabilities (Lorite et al., 2017, Stetco et al., 2018), intense activities of electronic industries competitors including China, India, USA, and European Union through investment to development CMD production and exports (Stetco et al., 2018), in addition, changes in Iran I.R. economic conditions and the limitations of the budget. The total environment changes indicate that the current structures of the electronic industry need a change to achieve the required competitive advantages. Evaluation previous studies shown that to cope with these changes, electronic industries of other countries have examined restructuring and redesigning their SCs (Liu et al., 2010; Lu et al., 2018; Chien et al., 2007).

Ministry of Energy (MOD) of IRI is responsible for planning, supporting, producing, and developing facilities and electronic equipment of relative companies by its affiliated organizations. One of the main organizations affiliated with this ministry is Iran Electronics Industries (IEI). IEI works on producing different kinds of electronic products, including electrical boards and components, instrumentation, PLC, and controllers. According to the expert's opinions, SC of individual small monitoring devices and their instrumentations in the electronic industry has the strategic and unique position that serves all rotary and static equipment (pumps, compressors, turbines, tanks, valves and etc.), a wide variety of products from standard to innovative and multiple suppliers that shown the priority to redesign and assessing and selecting the most appropriate strategies in this industry section. The network of SC and upstream, focal company, and downstream of the case study ESC is shown in Figure 2.

Decision makers were 10 people, including managers and top advisers of the firms of the selected SC, separately, four people from upstream companies of SC, four people from downstream companies of SC, and two from a focal company of SC, according to the research objectives. Due to the order fulfillment (Opricovic et al., 2003; Huang et al., 2002), the focal

company was the central company of the SC that concentrates on assembly and key components manufacturing (Chiu et al., 2009).

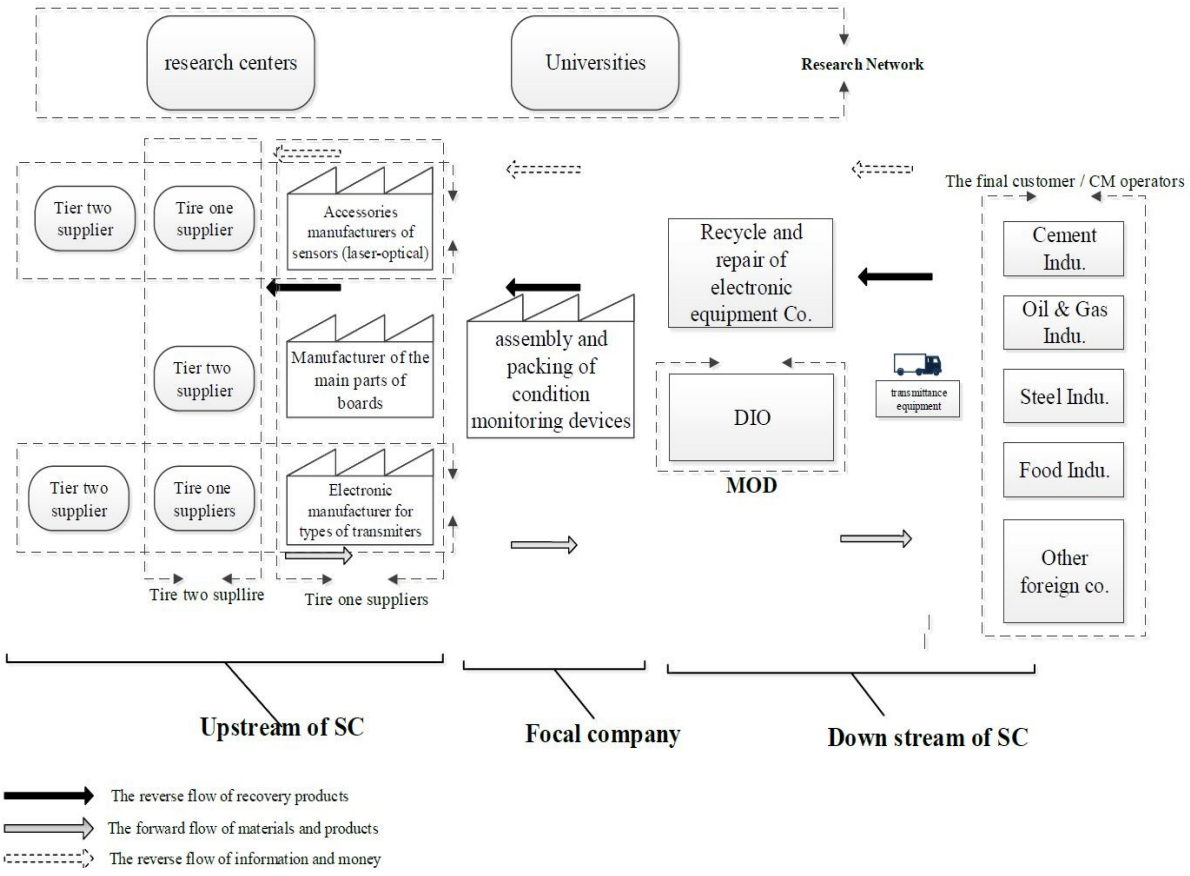

Figure 12. The general view of the ESC case study

4.1. The steps of the EISCSs selection and formulations

According to the previous sections, after setting the decision goal, create a team of experts, specify the alternatives, and set the customized decision criteria for evaluation with EISC expert's opinions; in this study, we have seven clusters that each have a different amount of elements (criteria) inside it. The following steps are as below:

Step 1. Determination of the network structure and clusters connections model: this step uses the FDEMATEL according to the sub-steps and equations below:

Step 1.1: Acquire fuzzy direct-relation matrices. Experts make sets of pairwise comparisons according to the linguistic terms and equivalent positive triangular fuzzy values scale in the study of Lee (2002) regarding influence and direction between clusters.

So obtained 10 fuzzy 7×7 matrices$\widetilde{Z^1}$, $\widetilde{Z^2}$…$\widetilde{Z^{10}}$, for example, the matrix $\widetilde{Z^1}$ for expert No. 1; Where $\widetilde{Z_{ij}^1}$ = (lij, mij, uij) are triangular fuzzy numbers. Elements $\tilde{Z}_{ii}$ (i = 1, 2… n) will be regarded as a triangular fuzzy number (0, 0, 0) whenever it is necessary. Then acquired average

fuzzy matrix $\tilde{Z}$ according to the fuzzy arithmetic rules (Lee, 2002). Fuzzy matrix $\tilde{Z}$ is called the initial direct-relation fuzzy matrix.

Step 1.2: Acquire normalized fuzzy direct-relation matrix. On the base of the direct-relation matrix$\tilde{Z}$, the normalized direct-relation matrix $\tilde{X}$ can be obtained through the linear scale transformation (Eq.1).

$$\tilde{a}_i = \sum_{j=1}^{n} \check{Z}_{ij} = \left(\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij}\right), \quad r = \max_{1 \le i \le n} \left(\sum_{j=1}^{n} u_{ij}\right)$$
$$\tilde{x}_{ij} = \frac{\check{Z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right) \tag{1}$$

Step 1.3: Acquire a fuzzy total-relation matrix. As soon as the normalized direct-relation matrix $\tilde{X}$ is obtained, the total-relation matrix $\tilde{T}$, can be acquired by using the following formulas (Eq. 2) according to the proof of Lin & Wu (Lin, 2004) and the rules of Lee (Lee, 2002), Kuafman and Gupta (1991), and Laarhoven & Pedrycz (Laarhoven et al., 1983), in which the I is denoted as the identity matrix (Eq.2).

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \dots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \dots & \tilde{t}_{2n} \\ . & . & \dots & . \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \dots & \tilde{t}_{nm} \end{bmatrix} \tag{2}$$
$$\tilde{t}_{11} = (l'_{ij}. m'_{ij}. u'_{ij})$$

All fuzzy calculations in these steps were done through the EXCEL. Inverse matrix and matrices multiplications were done by the Matrix Calculator Pro Ver. 3.5 software.

Step 1.4: Defuzzification and acquire the causal diagram. We apply the CFCS method by Opricovic and Tzeng (2003) for the defuzzification of the fuzzy values of the matrix $\tilde{T}$ and obtain the total relation definite matrix T (Table 3). The CFCS method has many advantages over other means (Lin et al., 2004). Then the causal diagram is constructed with the horizontal axis ($\tilde{D}_i$+$\tilde{R}_i$) def. named 'Prominence' and the vertical axis ($\tilde{D}_i$-$\tilde{R}_i$) def. named 'Relation' (columns nine and ten of Table 3). In the SC case study, it is clear that 'Environmental conditions', 'Demand characteristics' and 'Product characteristics' clusters are the cause group, and 'Strategies alternatives', 'Process characteristics', 'Flexibility types', and 'Objectives' clusters are in the effect group. From this point of view, 'Environmental conditions' has the highest impact on the 'Strategies alternatives', 'Objectives', and 'Flexibility types'.

Table 7. The total relation crisp matrix T and the values of $(\widetilde{D}_i+\widetilde{R}_i)^{def.}$ and $(\widetilde{D}_i-\widetilde{R}_i)^{def.}$

T	ASC	GSC	FSC	PSC	OSC	DC	ECC	$(\widetilde{D}_i+\widetilde{R}_i)^{def.}$	$(\widetilde{D}_i-\widetilde{R}_i)^{def.}$
ASC	0.30	0.42	0.44	0.39	0.40	0.22	0.22	5.03	-0.28
GSC	0.37	0.25	0.38	0.33	0.35	0.16	0.16	4.65	-0.55
FSC	0.39	0.39	0.29	0.38	0.37	0.17	0.16	4.97	-0.62
PSC	0.43	0.43	0.45	0.30	0.42	0.23	0.21	5.03	-0.06
OSC	0.35	0.34	0.39	0.36	0.25	0.20	0.16	4.67	0.01
DC	0.40	0.37	0.42	0.40	0.40	0.16	0.19	3.83	0.91
ECC	0.47	0.47	0.50	0.45	0.46	0.29	0.20	4.24	1.49

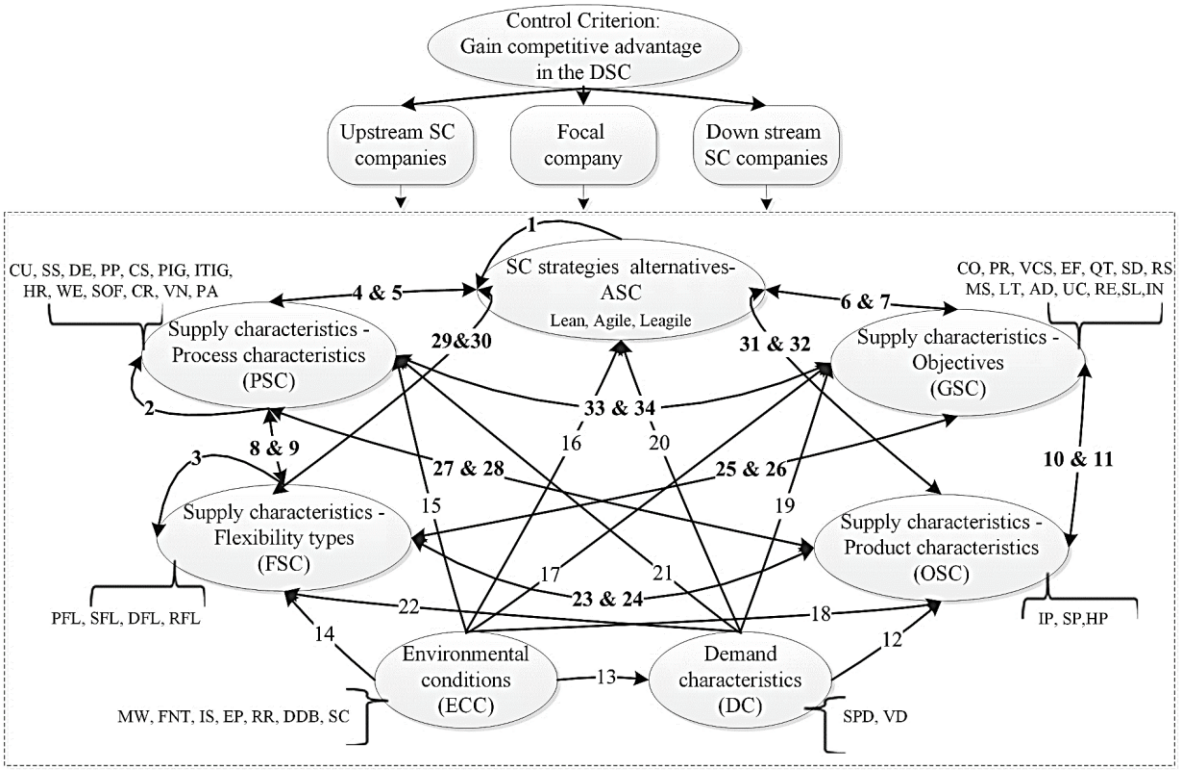

Figure 13. The detailed diagram structure and relations between clusters to SCSs selection

Step 1.5: set a threshold value and develop the structural model and diagram of relations. In practice, if all the information from matrix T converts to the diagram, the map would be too complex to show the indispensable information for decision-making. To reduce the complexity of the diagram, the decision-maker sets a threshold value 'α' for the influence level: only factors whose influence value in matrix T is higher than the threshold value can be chosen and converted into the diagram. The threshold value can be decided through the brainstorming of experts. When the threshold value and relative diagram have been decided, the diagram can be shown (Yang et al., 2008; Huang et al., 2010). In this paper, the threshold value is 0.29

according to the expert's opinions, and matrix T_α was obtained by filtering the minor effects denoted by the factors of matrix T. According to the matrix T_α, we can form the diagram of relationships between clusters, shown in Figure 3.

From the next step until the end, all calculations will have done separately for three parts of SC experts, including the focal company and upstream and downstream companies.

Step 2: Calculate and obtain each cluster's priority vectors of criteria (elements) with inner interdependencies by FDEMATEL. According to Figure 3, there are three clusters with inner dependencies that experts have answered to a set of pairwise comparisons to determine the effect of criteria X1 to X2 of each cluster element for SC to gain competitive advantages. All sub-steps of this step are the same as the first four substeps of step one. Due to abound of data, results were just shown for one cluster with inner dependency and for one part of SC; other calculations just did in the same way. Table 4 (columns 1 to 4) shows the fuzzy values matrix sample, completed by the expert of downstream SC, for flexibility types of SC cluster. Columns 5 to 8 show the defuzzified normal total relation sample matrix for mentioned cluster and then the inner dependencies of all three total relation matrices, as the priority vectors, can be obtained to locate in the unweighted supermatrix of ANP afterward; and can be seen in Figure 4 as matrices '1', '2' and '3' of the supermatrix.

Table 8. The fuzzy values matrix sample for flexibility types of SC cluster

Cn.No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	$\widehat{Z}^1{}_3$				$\widehat{T}_3^1$				**AG**	
	PFL	**DFL**	**SFL**	**RFL**	**PFL**	**DFL**	**SFL**	**RFL**	**Fuzzy weights** $\widetilde{W}_3^1$	**Final weights** W_3^1
PFL	(0,0,0.25)	(0.5,0.75,1)	(0,0.25,0.5)	(0.5,0.75,1)	0.19	0.29	0.27	0.31	(0.18,0.23,0.30)	0.24
DFL	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.25,0.5,0.75)	0.10	0.09	0.11	0.18	(0.54,0.62,0.69)	0.63
SFL	(0.5,0.75,1)	(0.5,0.75,1)	(0,0,0.25)	(0.25,0.5,0.75)	0.34	0.30	0.21	0.29	(0.05,0.04,0.07)	0.04
RFL	(0.5,0.75,1)	(0.5,0.75,1)	(0.5,0.75,1)	(0,0,0.25)	0.36	0.32	0.41	0.23	(0.07,0.09,0.12)	0.09

Step 3: Establish outer dependencies and their priority vectors using the FANP. In this step, 202 matrices were completed according to the outer dependencies between clusters and related criteria in Figure 3 for every expert.

Step 3.1: Distributing and collecting pairwise comparison questionnaires. In this step, a pairwise comparison was made according to the fuzzy linguistic scale of Zhou (2012), in which experts compared the influence of criteria in a cluster on criteria in another cluster with respect to a control criterion.

Step 3.2: Compute the respective importance weight vectors. The priority vectors for each pairwise comparison matrix must fill the various supermatrix submatrices. Approximate triangular fuzzy priorities $\widetilde{W_k}$, where k = 1, 2. . . , n, from the opinion matrix. After averaging related fuzzy matrices of each part of SC; such as the example, the fuzzy weight is obtained by applying Equation 3 calculations on the averaged fuzzy matrix of the FSC cluster with respect to agile SCS, as the 9th column of Table 4. The logarithmic least-squares method can calculate these weights (Eq.3) (Büyüközkan, 2012).

$$\widetilde{W_k} = (w_1^k . w_k^m . w_k^u) \quad k = 1, 2, \ldots, n$$

$$w_s^k = \frac{(\prod_{i=1}^{n} a_{kj}^s)^{1/n}}{\sum_{i=1}^{n}(\prod_{i=1}^{n} a_{ij}^m)^{1/n}} . s \in \{l. m. u\} \tag{3}$$

Then the CFCS method (Kauffman et al., 1991) was applied for the defuzzification of the fuzzy values, and defuzzified weights were obtained according to the 10th column of Table 4.

With respect to the other SCSs and obtaining weighted vectors, the result of this evaluation will form matrix '30' of supermatrix, which can be seen in Figure 3. Other evaluations for all matrices separately for all parts of SC are calculated similarly.

Step 3.3: Calculate the consistency ratio of all matrices. In order to control the result of the method, The Consistency Ratio (CR) is used to directly estimate the stability of the pairwise comparisons and should be less than 0.10. Then it will be tolerable comparisons (Saaty, 2008). In this study, the inconsistency ratios for all the comparison matrices were calculated according to the Büyüközkan et al. (2012) research.

For needed adjustments to improve the consistency of the matrices with inconsistency, the related matrix with highlighted values that caused inconsistency returned to the related decision maker, and this process continued until all matrices were consistent.

Step 4: Construct an unweighted supermatrix based on the interdependencies in the network for every part of SC and the entire SC. The supermatrix is a partitioned matrix in which each submatrix is composed of a set of inner (FDEMATEL) and outer (FANP) relationships between dimensions and attribute-enablers in the graphical model. All weighted vectors insert in Super Decision software to form an unweighted supermatrix for each part of SC. The unweighted supermatrix of the entire SC was calculated by averaging the unweighted supermatrix of three parts, including $W_f{}^1 . W_f{}^2$ and $W_f{}^3$ (Eq.4) (Yang et al., 2008).

$$W_f = \frac{1}{3}W_f^1 + \frac{1}{3}W_f^2 + \frac{1}{3}W_f^3 \quad (4)$$

A total supermatrix is shown in Figure 4, with the attention representing the several connections from Figure 2; for instance, '30' is the submatrix that shows the influence relationship among FSC types (elements) and SCSs with respect to the competitive advantages as control criteria. Blank sections of the supermatrix mean they had no relationships and calculations.

	ASC	GSC	FSC	PSC	OSC	DC	ECC
Supply chain strategies alternatives (ASC)	1	7	29	4	32	20	16
Supply chain objectives (GSC)	6		25	33	11	19	17
Supply chain flexibility (FSC)	30	26	3	8	24	22	14
Supply chain process characteristics (PSC)	5	34	9	2	28	21	15
Supply chain product characteristics (OSC)	31	10	23	27		12	18
Supply chain demand characteristics (DC)							13
Supply chain environmental conditions (ECC)							

Figure 14. General priority vectors submatrix notation for supermatrix

Step 4.1: Acquire the weighted supermatrix for each part of SC and the entire SC. Saaty (2008) stated that to obtain the weighted supermatrix, paired comparisons on the clusters perform as they influence each cluster to which they are connected with respect to the given control criterion. The derived weights are used as weights of the elements of the corresponding column blocks of the supermatrix. Assign a zero when there is no influence. Thus, obtain the weighted column stochastic supermatrix. In this paper, the normalized cluster weights matrix (T_α) was obtained by FDEMATEL in sub-step 1.4, according to Yang et al. (2008). Then, they are normalized and entered into super decision software to calculate the weighted supermatrix of each part of SC (${W^1}_w$,${W^2}_w$ ${W^3}_w$) and the entire SC (W_W).

Step 4.2: Limit the weighted supermatrix by raising it to a sufficiently large power k and extracting results. Overall weights of the criteria and strategies of each part of SC and entire SC were obtained by multiplying the related weighted supermatrix by itself until the values of each row converge to the same value for every column of the supermatrix. In this case, the supermatrix is raised to power 96. Then limited priorities values normalized to one. We choose any column from the stable limit supermatrices as the final weights of interdependency indicators, as shown in Table 5. The limit-normalized supermatrices are given separately for downstream companies(${W^1}_T$), upstream companies(${W^2}_T$), the focal company (${W^3}_T$) and entire (W_T) SC.

5. Results and discussion

The main goal of this study is to suggest an effective hybrid fuzzy MCDM approach with considering all possible details to select appropriate strategies and evaluation related criteria in each strategy, especially flexibility types of an SC. Based on the literature review and expert confirmation, possible SCS criteria were described, and a new systemic model was prepared.

Table 9. Final results of normalized limited priorities separately for parts and entire of SC

Clusters (categories)	Criteria	Entire SC(W_T)	Focal company of SC ($W^3{}_T$)	Upstream companies of SC ($W^2{}_T$)	Downstream companies of SC ($W^1{}_T$)
ASC	Lean	0.0607	0.059	0.078	0.043
	Agile	0.0770	0.064	0.057	0.108
	Leagile	0.0794	0.096	0.076	0.062
GSC	CO	0.0073	0.008	0.008	0.004
	PR	0.0069	0.009	0.006	0.003
	VCS	0.0229	0.028	0.024	0.018
	EF	0.0105	0.009	0.012	0.009
	QT	0.0141	0.013	0.018	0.011
	SD	0.0112	0.016	0.009	0.009
	RS	0.0189	0.015	0.017	0.026
	MS	0.0121	0.011	0.012	0.013
	LT	0.0096	0.008	0.009	0.011
	AD	0.0167	0.014	0.014	0.023
	UC	0.0091	0.010	0.010	0.006
	RE	0.0139	0.015	0.016	0.011
	SL	0.0129	0.013	0.010	0.015
	IN	0.0153	0.015	0.010	0.022
FSC	PFL	0.0838	0.084	0.074	0.089
	DFL	0.0530	0.048	0.052	0.058
	SFL	0.0424	0.034	0.055	0.038
	RFL	0.0541	0.058	0.053	0.050
PSC	CU	0.0172	0.013	0.017	0.024
	SS	0.0093	0.010	0.011	0.006
	DE	0.0123	0.010	0.014	0.014
	PP	0.0208	0.026	0.019	0.022
	CS	0.0115	0.013	0.011	0.012
	PIG	0.0163	0.017	0.014	0.018
	ITIG	0.0184	0.017	0.019	0.023
	VN	0.0146	0.013	0.017	0.015
	PA	0.0174	0.018	0.018	0.017
	WE	0.0129	0.015	0.016	0.010
	SOF	0.0095	0.012	0.013	0.005
	CR	0.0117	0.011	0.014	0.013
	HR	0.0187	0.016	0.019	0.022
OSC	IP	0.0649	0.055	0.055	0.080
	SP	0.0430	0.050	0.048	0.030
	HP	0.0700	0.075	0.072	0.063

For the secondhand goal of the study, we consider SC strategies of DI. For national supply, electronic industries must be able to compete with threatened countries and gain competitive advantages over them. In this regard, selecting the right strategies and implementing the appropriate policies are inevitable necessities for them.

Based on our information, no research has been done on such subjects in ESC by comprehensive techniques with DEMATEL and ANP in a fuzzy environment. The presented system can be used to further MCDM subjects and case studies.

According to the result of this study in Table 6, we developed the flexibility requirements of lean, agile, and leagile in the EISCs, which was a gap in the literature research (Naim et al., 2011).

Table 10. Flexibility requirements of lean, agile and leagile of EISCs

Flexibility types		Leagile	Lean	Agile
Operation and system flexibility	PFL	M	L	H
Delivery flexibility	DFL	M	M	H
Supply flexibility	SFL	M	H	L
Return flexibility	RFL	H	M	M
	H=high		M=medium	L=low

5.1. Discussion on the industrial electronic SC results

Hilletofth (2009) has argued that companies must use several SC solutions concurrently (i.e., develop a differentiated SCS) to stay competitive in today's fragmented and complex markets. Results of this study show that the 'leagile' strategy is applied to the entire EISC and focal company, but there are considerable weights for other strategies too. Downstream of SC select 'Agile' SCS as the first, and upstream of SC select 'Lean', and very close it leagile as the first. This study addresses employing several SCSs concurrently with different weights of criteria to consider, that can develop and manage these multiple SCSs.

Brun et al. (2017) expressed that after 'readiness' and 'responsiveness' for EISC, according to the budget restriction, 'Cost' control is critical. In this study, 'Cost' is not recognized as a very important criterion in each level of SC. It may be because of governmental companies in SC that have no problem with financing and funding. Privatization may help this SC to assess its financial situation with more concern.

Operation and system flexibility in every part of SC has the highest priority, but in agile SC, the weight differences between each part are more essential. Return flexibility is at the next level of priority in EISC. In electronic industrial SCs dealing with security issues, flexibility in returned repair parts and used equipment is indispensable. Delivery flexibility has an

approximately equal priority with return flexibility, and supply flexibility is at the end of the priority. The electronic industry has a closed loop SC with special products regarding the high-security level of information, high technology, technical knowledge, and the need for high investment. In this situation, the ability and permission to enter a supplier in this SC are not easy (Stetco et al., 2018). Especially, Iran is under sanctions pressure which caused few foreign supplier connections, so supply flexibility in EISC has the lowest priority.

5.2. Limitations and future research suggestions

The limitation of this research is the number of decision-makers in the EISC. This research proposes all proven models of the hybrid of two techniques in a fuzzy environment to reduce the number of pairwise questionnaires and remove restrictions of ANP. But many criteria and their connections in this framework need the decision maker's cooperation.

This framework can be used in other multi-tier and more complex SCs. Future research offers opportunities for SCSs in return process remanufacturing material flow in a closed loop or other kinds of SCs in which SC partners have different strategies as a reverse SC. Also, according to the variety and types of products, especially for upstream companies of SC, there are multi-decoupling points that can be determined.

Disclosure statement

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

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Comparison Between the Performances of Pull and Push Systems Using Discrete Event Simulation

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ABSTRACT

This study considers push and pull strategies to control production systems with random processing times for multistage manufacturing inventory systems. In this paper, the behavior of push and pull production systems is examined to explain the superior performance of push systems. On the production system, the phrases "push" and "pull" have been defined to explain a variety of production and distribution environments. To some, the difference refers to an important attribute that can be defined by observing the methods for managing material flow on the production lines. To others, pull and push can be considered in phrases as a special method for managing production schedules. This paper considered the push and pull systems and developed a framework to compare multistage production systems based on work-in-process (WIP) and throughput (TP) tradeoffs. In this paper, according to the way of defining the systems and the desired criteria in evaluating the efficiency, the push system is a better option. Finally, the proposed model with generated different examples is simulated in Arena software to analyze the model performance. The results obtained from models and simulation proved the push system is the suitable method for this problem. The pull system also appears more general in its applicability than traditional pull systems.

Keywords

Job shop, Pull system, Push system, Buffer.

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1. Introduction

In production systems, products are very different, so there may be two modes of intermittent production. The first case is that most products have a fixed production sequence, and the production equipment is also established based on this method. This state of the system is called the production flow process. In the other case, the production method varies in a wide dimension compared to the products, and the equipment and machinery are established according to the machine's performance. This state of periodicity is called job shop production, which has more management problems than the first method. In this case, production is done in a small volume and a wide range of products. The production unit needs highly flexible production capability to make different products. Hence, flexible equipment and skilled labor are needed to perform various activities (Ndayisaba et al., 2020).

Production systems are divided into two general categories: pull and push. In push systems, the stations are working as long as the resources are available, the main focus is on the system's output, and the buffer is infinite. In this system, the entire product or inventory may not be used during the manufacturing process due to demand rate changes, demand content, seasonal changes, etc. However, in the pull system, production begins after receiving a signal based on customer demand, and the limited buffer means that the inventory in the construction process is low (Hirakawa, 1996). In this paper, we have proposed a new model for the push-pull manufacturing system and introduced some parameters and variables to compare two systems, like buffers, which have not been presented in the literature.

In a production process controlled by a push system, items are produced at times determined by a certain schedule. In this system, when a station prepares its parts according to the program, it pushes it to the next station. Sometimes push systems are considered synonymous with systems such as material requirements planning (Puchkova et al., 2016).

In a production process controlled by a pull system, an item is produced only when a signal is received from the customer. Pull systems, which are assumed to be synonymous with just-in-time production methods, fundamentally differ from push systems. In this case, the main production driver is no longer planning, but the signal is reaching the system from the customer. In practice, a final assembly program based on customer orders follows the parts and products during the production process. Only the last station is given a copy of the final assembly schedule. This station fulfills its requirements by itself. In the same way, with the help of cards, empty containers, or empty squares carved on the floor of the factory, the information related to the requirements is transferred to the first station in a backward manner. The need for less

production planning and production reports is only one of the benefits of pull systems (Yeboah et al., 2021).

Companies that have used push systems to pull systems have reported that there has been a significant reduction in inventory costs, production, and lead times, and at the same time, the level of quality and customer satisfaction has increased. There are many potential benefits of traction systems, but practically many companies do not use them. The reason is that creating the right environment for a traction system may take years, and in some cases, it seems almost impossible. The main prerequisites of a pull system are:

(1) The possibility of equipment failure should be very low.

(2) The quality of manufactured parts and products must be very high.

(3) Setup times should be very short for the economic production of small batches.

(4) The quality of raw materials and purchased parts must be very high. Suppliers must also be able to deliver required items in small quantities as soon as requested.

Most of the systems that exist are a combination of pull and push systems; these systems take advantage of both. For example, the fixed inventory system is one of the combined systems with a fixed amount of inventory in the production line, and as soon as a product is completed and exits the line, inventory immediately enters the line to make a product (Betterton and Cox, 2009).

A buffer is different from work in process inventory. The buffer is not a physical inventory but a period during which the volume of the inventory can be brought to the assumed value. For this reason, it is called a time buffer in the theory of constraints. In production scheduling based on the theory of constraints, buffers are used at two points of the production line: Before the bottleneck and at the end of other lines where there is no bottleneck (before assembly).

The built-in buffer before the bottleneck ensures that the bottleneck will not remain idle due to possible disturbances of the stations behind it. The buffer at the end of other lines also considers the safety that we will have an output equal to the number of pieces processed in the bottleneck, and the amount of output will not decrease due to defects in other non-bottleneck lines. The amount of these buffers also determines the volume of materials entering the system and the rate at which materials are injected into the system (Grosfeld-Nir and Magazine, 2002).

Push and pull are approaches both designed to gain control of production planning. In this paper, we have two defined systems within a Pull environment to assign the best production policy to the parts within the production lines. This paper aims to develop the chance of using flexibility in simulation to cope with the different product varieties by defining a Push/Pull

production for internally produced parts. The novelty of the research is represented by the proposed simulation model to properly set the Push or Pull policy for each part to minimize work-in-process and maximize throughput. A key element of the proposed paper is the similar element in both simulation models.

The purpose of the research is to compare the effect of the implementation of two push and pull systems on the performance criteria of output and inventory during construction in the job shop production system. This production system has three products and five workstations. The results show that in the proposed system, the performance criteria of the push system are more favorable than the pull system.

2. Literature review

In pull systems, the stations start working according to the signals received from the next station, while in the push systems, the stations work until they have parts to produce and do not wait for the signals from the next stations. Güçdemir and Selim (2018) compared two types of pull and push systems and considered the level of available inventory and output as performance criteria to make the two systems comparable. They first simulated the pull system and the output obtained from it, and they considered it an input to the push system. In other words, in the pull system, they controlled the inventory during construction, and in the push system, they did the opposite, and in both cases, they compared the output and the inventory level as performance criteria. They performed the simulation on different lines and with different numbers of machines, from three to fifteen. In order to get more reliable answers, the way of entering the material into the line was selected as deterministic, probable, or with different distributions. They concluded that for lines with seven or greater cars, the push system and for lines with less than seven cars, the traction system performs better according to the criteria considered. Silva et al. (2022) considered the impact of the push-pull system on the basic pests and natural enemies in brassica crops. They resulted that the plants applied to compose the diversification method are better for composing the pull-push policy in brassica crops. The buffers in the line also affect the system's performance; Determining the size of buffers in the system is difficult. Radovilski (1998) defined the buffer as the number of products waiting in the queue and determined the size of the buffer in a system that has one product. To solve the problem, he took help from queuing theory, and since his chosen production line produced a single product, he considered the system as a single server. To determine the size of the buffer, the balance between the amounts of income obtained from determining a certain amount for the buffer and the operational and inventory costs resulting from it was considered.

He defined the system as M/M/1/K and considered K as the number of input pieces, the same as the buffer size. His goal was to determine the buffer behind the bottleneck in the simulation. He assumed the output rate to be lower than the input rate to have a stable system. He tested the answers obtained on different systems and finally concluded that determining the right value for the buffer affects the system's profit. Liu et al. (2020) applied a two-stage push-pull system in a make-to-order production environment. They considered a decision model to define the optimal stock of the work-in-process product and the best lead time for the completed products. The study result is useful for managers to choose the best inventory and lead time to cope with production variability.

Rammer and Rennings (2012) examined the role of simulation in different production systems. They stated that a simulation is an important tool for analyzing and designing production systems. Smith performed simulations for various discrete or continuous production. He concluded that in the design of a production system, the simulation execution time is not very important because this operation is done only once, but the production processes must be examined in the analysis of a system. This operation is repeated during the simulation execution time. Construction is important. Also, Lin et al. (2022) evaluated the dynamic treatment of a hybrid system in which manufacturing elements occur simultaneously to generate the same serviceable inventory for customer orders. They considered the bullwhip effect and evaluated it under push-and-pull remanufacturing systems. The nonlinear control theory was applied in their model with discrete-time simulation, and the result showed the bullwhip efficiency of pull and pushed controlled hybrid systems. Lin et al. (2022) simulated a job shop production system that had ten production stations and ten products to produce. The purpose of the study was to divide the production process of products into similar production processes with the aid of the simulation technique, so that joint processes can be carried out consecutively and without interruption. The result showed that less time is needed for production, and the system is improved. The simulation was repeated for seven different types of queuing systems for fifty weeks and ten times, and one of the main performance criteria of this simulation was to calculate the maximum time for making each piece. The results showed that in the investigated system, the first-in, first-out queuing system was the minimum manufacturing time for parts.

3. The problem modeling

In push systems, products are produced by a pre-prepared program, so the buffer in these systems is assumed to be infinite. Each station that completes its piece pushes it to the next station. In this system, blocking does not happen, although starvation may occur due to the products not arriving from the previous station. In the pull system, where the buffer is limited, production occurs when each station's buffer allows the product's production. In this way, if the nth station's buffer is full, the n-1st station will not generate until it receives a signal from the nth station that the buffer is empty. Therefore, in this system, in addition to starvation, blocking also occurs due to the limited buffer. Since the buffer in the pull system is limited, the work in the construction process is less in this system. While in the push system, the output is more because the production takes place continuously and regardless of the buffer. Although the inventory costs in this system increase.

3.1. Simulation

Table 1 demonstrates some general information and the input data of processing time and precedence of the tasks. The proposed system consists of 5 workstations: parts cutting, turning, CNC with high flexibility to perform various operations, hardening operations. Finally, the assembly station. It is assumed that the machines of each station are completely identical. The parts that the system can produce are of two models, each of which accounts for a certain percentage of the total demand, and each has a specific production sequence that is defined using the sequence module. Each piece's preparation time and process time at each station are defined as an attribute in its sequence. Each workstation with any number of machines has an operator who places the part before the machine starts working, and because of the short time of placing, it can support several machines.

Table 11. The input data of processing time and precedence of the tasks

Task no.	Model 1	Model 2	precedence
1	4	2	-
2	3	-	-
3	-	-	2
4	2	3	3
5	-	6	3,4
6	1	4	5
7	6	5	6
8	5	3	7

The operator of the cutting station works on the piece at the same time as the machine. Each part entered into the system also includes ready parts that must be assembled. After entering

the parts into the system, the part is copied using a separate module. The original part goes through its production process; they are permanently batched using the internal software attribute and finally exit the system after assembly process.

A transporter with a capacity of one is used to transfer the parts between the stations. The loading time and imagination in the system are variable with a constant value. The parts are batched before being transferred to the next station, the size of which is assumed to be constant with all stations, considering that it is assumed that the parts of a batch are processed one after the other. After the parts arrive at each station, the preparation time for all the batch parts is done, and the parts are separated and enter into the process (Figure 1).

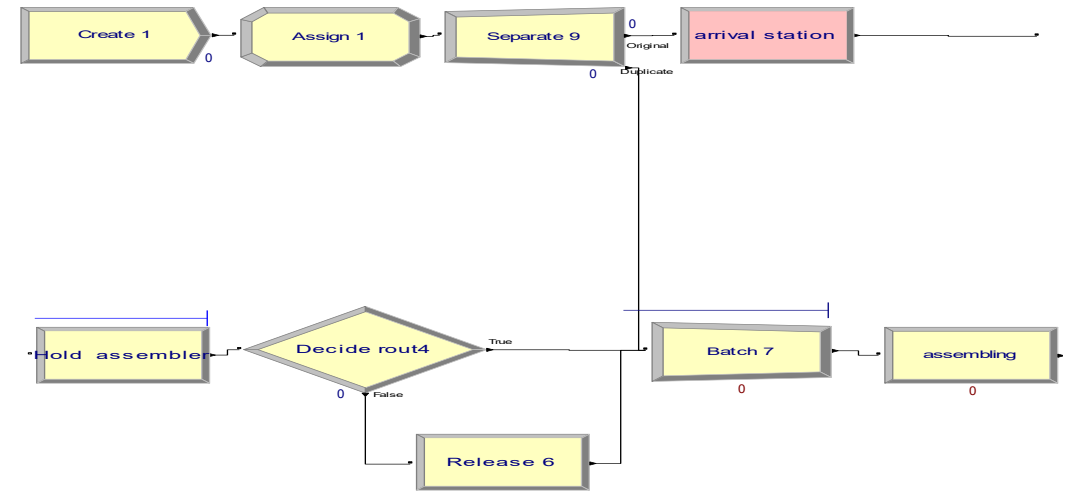

Figure 15. Using the separate module to separate the main part and parts ready for assembly

In the traction system, the buffer size is limited, and the part is allowed to leave the current station if the buffer of the next station has an empty capacity. In this system, the buffer size in the whole model is a variable with a fixed value. For further explanation, let's assume that part one is at the cutting station, and the destination station is turning (Figure 2).

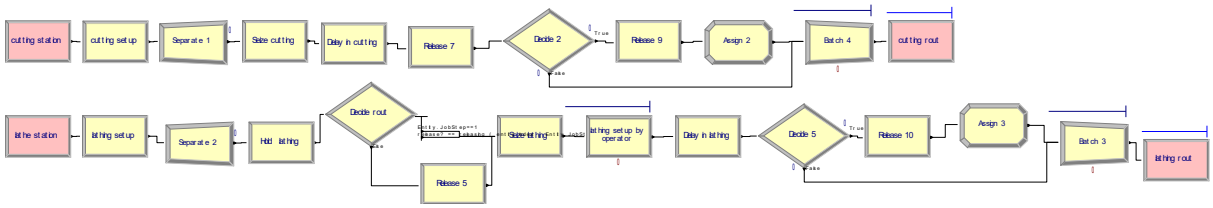

Figure 16. Cutting and turning station

In the initial modeling of the system, we assumed that the part entered the turning machine before leaving the cutting machine. In the Hold module, it remains in the queue related to this part until the turning machine queue has an empty capacity for this part (waiting queue according to the type of part as a set is defined). The problem, in this case, was that the parts

that entered the cutting station could not catch the machine, and the queue was extremely long. To solve the problem of checking the buffer of the next station and releasing the machine, every station is performed at the same station. First, the buffer of the turning station is done at the current station (cutting), and if the buffer has an empty capacity, the turning machine is abandoned, and the attribute value of Entity.JobStep is assigned in its sequence (Figure 3).

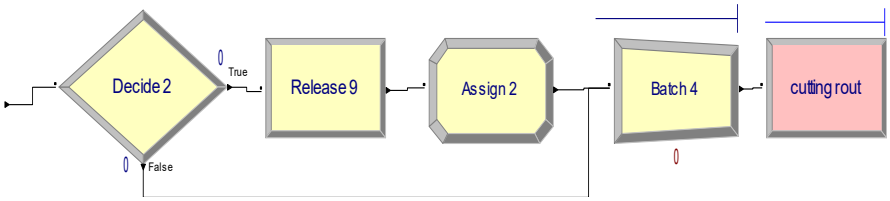

Figure 17. Checking whether the car will be left at the current station or not?

Otherwise, this machine is kept at the lathe station in the Hold module. Of course, until the queue of this part in the lathe has the capacity and if the cutting machine has not been abandoned at the origin station. (Figure 4).

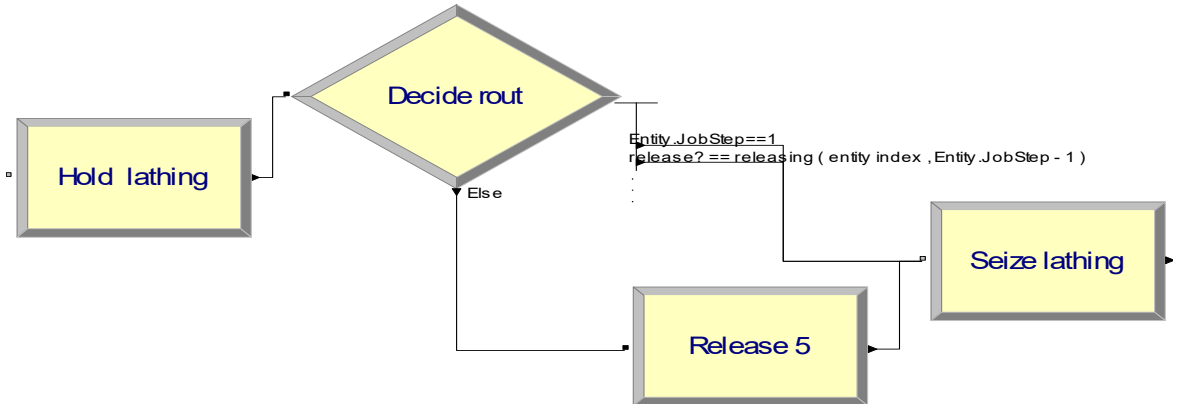

Figure 18. Checking whether the car of the previous station was left at the same station or not?

In this system, it is assumed that each system applies a fee proportional to the time of its presence in the system, and the selling price of the piece is already known. Therefore, the profit obtained from the sale of parts is equal to: sales profit = {number of parts leaving the system * (selling price of the part * time the part is in the system - the cost of the part being in the system per unit of time)}

To compare this system with the push system, there is no need to have limited buffers in the system. We released the buffers we had defined in the queue and set them to infinity. The hold and decide modules related to receiving signals to release resources from the system. To make the two systems comparable, we defined the process times, costs, and related issues in the two systems.

4. The simulation results

Considering that the basis of the comparisons is based on the traction system. We first determined the model repetitions for this system. For this purpose, we ran the system for 20 repetitions and examined two evaluation criteria of waiting time and work in process. The value of these results was recorded for 20 repetitions, and the average and standard deviation of the results were calculated. The results are shown in Table 2.

Table 12. The results of running the pull model for 20 iterations

No. replication	Waiting time(min)	WIP
1	206.5	58.9137
2	209.36	48.0289
3	201.89	52.5545
4	226.33	55.5182
5	239.29	63.361
6	215.68	55.2005
7	240.47	53.6088
8	216.86	46.2414
9	204.91	52.1742
10	217.48	53.4045
11	214.67	46.1574
12	221.7	50.3895
13	219.73	52.9149
14	193.01	52.4658
15	229.41	54.5159
16	211.25	45.3365
17	221.23	40.324
18	202.67	52.2584
19	223.96	49.6284
20	202	54.2195
m	**215.92**	**51.8608**
s	**12.46203498**	**5.070019**

The value of half-width was calculated using the formula 1,2, 3, and the result is as follows:

HW calculation for waiting time:

$$HW=2.093\frac{12.462}{\sqrt{20}}=5.832 \quad (1)$$

Calculate HW for work in process:

$$HW=2.093\frac{5.07}{\sqrt{20}}=2.372 \quad (2)$$

The optimal number of repetitions according to work-in-process:

$$n=20\ \frac{2.3728^2}{2^2}=28.151\approx 29 \quad (3)$$

The maximum calculated values were selected for the number of iterations to perform calculations in both pull and push systems. In the pull system, two variables, batch size and

buffer size, affect the work in the construction process. To choose the best value for these variables according to the least work in the construction process, 10 scenarios were defined, and the best answer for the work in the construction process per batch size And the buffer size was equal to 5 and 6, respectively. Three modes were considered for the batch size value in all the scenarios defined for the pull system. In the push system, because the buffer is infinite, only three scenarios were defined for these batch size values, and in this case, the batch size of 5 was the best answer. The scenarios defined for these two systems can be seen in Figures 5 and 6.

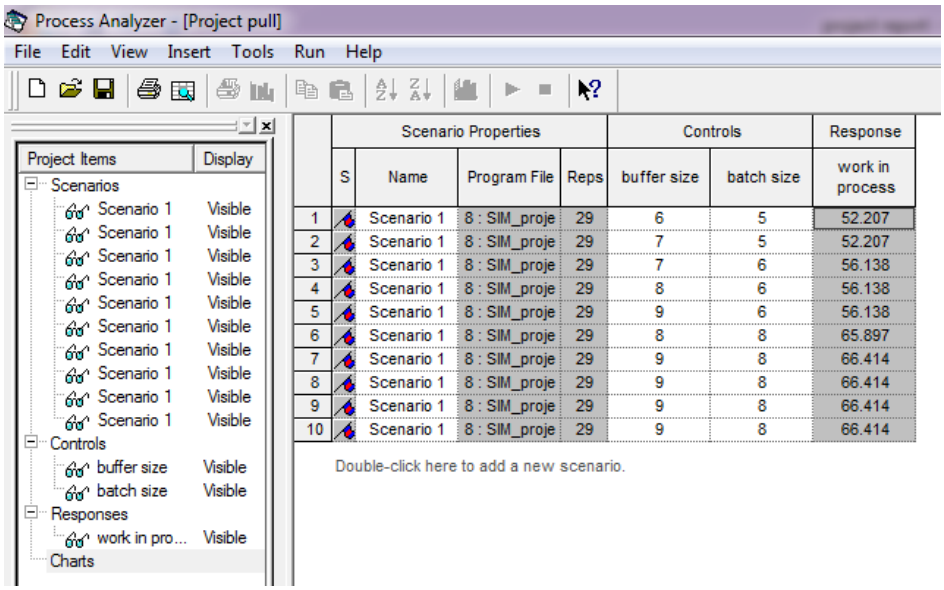

Figure 19. Defined scenarios for the pull system

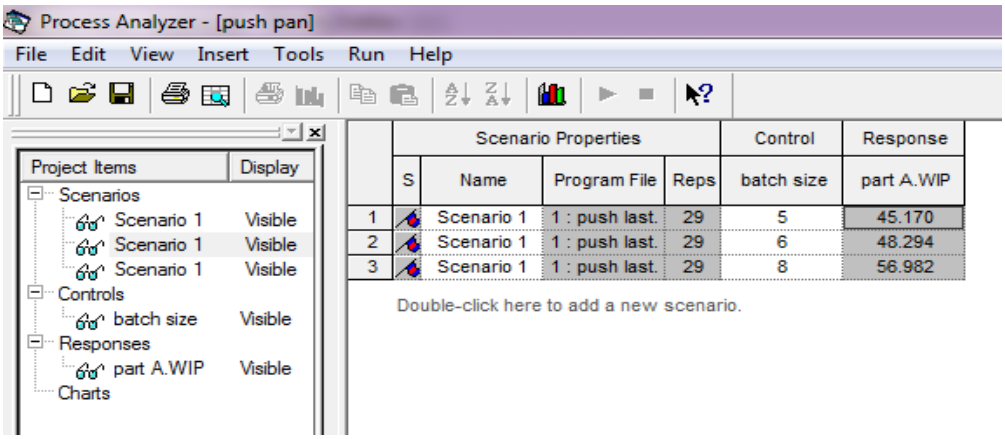

Figure 20. Defined scenarios for the push system

Therefore, for the batch size equal to 5 for both systems and buffer size = 6 for the push system, and the number of repetitions equal to 29, the results table of the important criteria for comparing the two systems is shown in Table 3:

Table 13. The results of running the model for two pull and push systems

	Total Time	WIP	throughput	Cost	Income	Profit
Push system	117.84	45.1697	75	176760	375000	198240
Pull system	136.41	50.9458	70	190974	350000	159026

In order to check the ability of the two proposed simulation models, an experiment is conducted using some self-made test problems, and comparing the pull solution with the push solution indicates that the push system performs well in problems. As seen in the table, the output in the push system is more than the pull system and the total time in the model is less for the push system. The cost applied to the system is also less, and as a result, the profit of the push system is more than the pull system.

For managers in production systems that supply a family of products for customers, the key issue is to find the best lead time to satisfy customer demands and also to maximize the throughput. We proposed a decision model for the pull and push systems with similar elements and evaluated the buffer effect in manufacturing systems. According to the results obtained from models and simulation, the push system proved to be the suitable method for this problem. The pull system also appears more general in its applicability than traditional pull systems. So the study result is useful for managers to choose the best production policy and lead time to cope with production variability with attention to the manufacturing situation.

5. Conclusion

In this paper, according to the way of defining the systems and the desired criteria in evaluating the efficiency, the push system is a better option. Of course, this result is true in this system, and if the conditions change, including the number of machines in each station, the sequence of product operations in each station, the processing time, as well as the desired criteria for evaluating efficiency, the pull system can be more suitable than the push system.

There is some suggestion for this study that could be useful for future investigation. Applying a mixed pull push simulation model with a similar element is fantastic and comparing it with only a pull or push system. Furthermore, pricing and setup time are key factors for managing production lines that can be considered in future studies. In future research, except for the buffer discussion mentioned in this paper, we can also pay attention to issues such as customer orders and customer orientation in the model. It is also possible to use other comparative evaluation factors, such as product delivery time to compare the two systems.

Disclosure statement

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

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An Extended LRFMP Model for Customers Segmentation by Using Two-Step SOM: A Study of Aesthetic and Dermatology Center

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ABSTRACT

To recognize customers, organizations use a scale to measure the importance of different customers. In the present study, the customer segmentation is done in the aesthetic and dermatology center in an Islamic country based on the extended LRFMP model. For attaining the purpose, this study used clustering by Two-Step SOM and data gathered from 220 patients of aesthetic and dermatology center in an Islamic country. Due to selecting the optimal number of clusters, is adopted the Davies-Bouldin index. In the first step, the number of clusters is calculated by Lehman's rule, and then by the SOM method, the analysis was repeated for three, four, and five clusters and through the Dunn index compared the results. Also, for more understanding, the type of patients has selected the label for the clusters by using Marcus's customer value matrix as the foundation. Considering the value of the Dunn index, the triple cluster is the favorite cluster. The status of LRFMP indices was shown in the triple cluster, and selected the labels for each cluster as "Loyal customers", "Potential loyal customers" and "Uncertain customers". Regarding the nature of the labels and the literature, this study recommended marketing strategies. The investigation of the kinds of the literature showed that segmentation in the aesthetic and dermatology center in an Islamic country was not performed with LRFMP indices by SOM in an aesthetic and dermatology center.

Keywords

Customer segmentation, LRFMP model, Customers clustering, Two-Step SOM.

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1. Introduction

Customer relationship management (CRM) was introduced in the early 1980s and includes four dimensions: customer recognition, customer attraction, customer retention, and customer development. Through CRM, the firms can manage their interaction with customers (current and potential), and it cusses opportunities for the companies to gain competitive superiority in a competitive environment. Vincent (2016) believed three crucial decisions should be made in strategy development: segmentation, positioning, and target market selection. Market segmentation has enticed the considerations during the last 50 years. Smith (1956) proposed the definition of market segmentation for the first time (Boejgaard and Ellegaard, 2010). Besides, Buttle and Maklan (2015) mentioned that customer data is trapped in the organization's pockets and not operational to potential users. Right customer recognition in competitive markets has become vital to any business. Segmentation is when a company categorizes its customers within a market into similar groups by considering specified characteristics, desires, and needs (Hunt and Mello, 2014).

On the other hand, customer segmentation is a way that an organization can recognize the customers better, and ultimately resource allocation is optimized. As Vincent (2016) believes, a marketing mix (Price, Product, Place, and Promotion) helps understand the customers' needs and provide the value to determine the particular actions. By segmentation, marketing managers and marketers respond to customers better and present proper marketing strategies for each group of customers. Judging the customer's value on one aspect gives an imprecise report of the customer base and lifetime value. A more in-depth comprehension of the customers has accredited the importance of focusing on them. It is accepted that it expenses about five times more to reach a novel customer than to retain an existing one and ten times more to get a discontent customer back (Massnick, 1997). In addition, Reichheld (1996) believed that five-point growth in customer retention could accelerate incomes by more than 25%. According to Marcus (1998), small- to mid-sized businesses are better at creating excellent customer relationships. Focusing on direct marketing allows organizations to allocate their marketing resources to gain more return on investment and compete more effectively to retain their customers. In this way, they can develop and grow their business, which causes good customer relationships. Also, Marcus (1998) believed that for small and mid-sized self-governing businesses, it is better to focus their marketing program on local relationship marketing due to actively using their competitive advantage. Pooya et al. (2020)

mentioned that effective organizations gain customer satisfaction. Customer retention in the long term is more profitable than attracting new customers. So, the retention strategy for loyal customers involves finding and understanding how the customers are satisfied. This article investigates the kinds of literature in two directions: the research of segmenting and its indices, and the second, the methods of segmenting and clustering.

In the first direction, there are many methods for segmenting customers. The most popular method for segmenting the customers is RFM, proposed by Hughes in 1996. The RFM (recency, frequency, monetary) model is a marketing technique that ascertains quantitatively that customers are the desirable ones by analyzing how recently a customer has bought (recency), how many times they bought (frequency), and how much the customer pays out (monetary). There have been numerous efforts to improve segmentation variables, and additional variables have been added to each industry. For example, Yeh et al. (2009) proposed an expanded RFM model by adding two parameters, time since first purchase and lost Customer probability. By utilizing the Bernoulli sequence in probability theory, they discovered the formula that estimated the likelihood that a customer buys and the total number of times a customer comes back to buy. They examined a blood transfusion service to note that their methodology has precise predictive accuracy compared to the traditional RFM approaches. According to Reinartz and Kumar's (2000)'s study, the RFM model cannot determine the length of time a customer is related to the organization (short or long term); they introduced customers' relationship length in their research. Also, they examined the effect of customer loyalty and profitability, and finally, they completed the RFM model by the Loyalty index by presenting the LRFM model.

Wei et al. (2012) used the developed LRFM model in Taiwan. They segmented patients (according to the patient profile, such as gender, membership number, birth date, and visit frequency). Also, another research on Customer Relationship Management in the Children's Dental Clinic used the Two-Step Algorithm. Finally, the customers are divided into loyal, new, and lost Customers. Chiang (2018) extended the RFM model to the RFMDT model (D variable is the abbreviation of discount; T variable is the abbreviation of the shopping times in six months). The case of Chiang's study was online shoppers in Taiwan. Moreover, Peker et al. (2017)'s opinion; is that people tend to visit various sectors like hotels, clinics, and hair salons more frequently, which advances the level of variation in their visiting patterns, which is essential in explaining their purchasing behavior.

In the second direction, various customer or retailer segmentation studies utilize the clustering model, such as taxonomy models and SOM. Pooya and Faezirad (2017) presented a study to distinguish the taxonomy of manufacturing strategies from manufacturing competitive precedents and the taxonomy of production processes in a developing country. Also, they adopted SOM to identify common patterns. The relationship between production processes and manufacturing strategies was studied using Crosstabs and the chi-square test. Khajvand et al. (2011) researched customer lifetime value estimation based on RFM analysis of customer purchasing behavior. They used customer lifetime value (CLV) to segment a customer in a health and Beauty Company using two extended RFM and RFM approaches by Count Item. The results showed that Count Item did not make any difference in customer clustering. Wei et al. (2012) conducted the application of the LRFM model on the segmentation of the dental clinic market, which aimed to recognize customers; and exceptionally loyal customers. For this purpose, they studied 2258 patients, and the monetary value variable was considered constant due to the provision of government support services. Their research shows that three clusters are above the average LRF values. Peker et al. (2017) proposed LRFP for classifying customers in the grocery retail industry and segmentation. Li et al. (2011) surveyed customer characteristics of a textile factory by a two-stage clustering method based on the LRFM model. The Ward index determined the optimum number of clusters, segmented customers into five clusters using K-means, and analysis of each cluster's attributes using the LRFM scoring method. Alizadeh Zoeram and Karimi Mazidi (2018) proposed a new approach for customer clustering by integrating the LRFM model and the Fuzzy Inference System. They attempted to provide a systematic method for analyzing the characteristics of customers' purchasing behavior to improve the operation of the customer relationship management system. For this purpose, the extended model of LRFM was used that would be proper for analyzing the customer lifetime value.

The results of their study are five different customers group that they named high-contribution loyal customers", "low-contribution loyal customers", "uncertain customers", "high spending lost customers", and "low-spending lost customers". Parvaneh et al. (2014), in their study, utilized data mining due to segment the retailers of hygienic manufacturers. They proposed the LRFMP model for retailer segmentation. Their study results are ten retailer clusters using the K-means algorithm with K-optimum. Also, the weighted sum of LRFMP values by the AHP technique. Alipour Sarvari and Takci (2016) investigated that the customers segmented by attention to the RFM model by utilizing artificial intelligence

methods, including k-means clustering, Apriori association rule mining (ARM), and neural networks. Their study noted demographic factors because they wanted to present different scenarios due to improved factors for segmenting the customer.

Hammer (1983) mentioned that grown competition prompted many physicians to consider serious attention to how they can utilize modernized marketing methods to enhance the flow of patients to their clinics. By examining studies in clinics, studies in this field (Aesthetic clinics and other clinics) show that clinics cannot succeed in utilizing marketing methods as worthy. The studies in clinics such as Kamagahara et al. (2016) focused on dental clinic management in Japan, where the service quality enormously influences the clinic's outcome. Also, Van et al. (2010), in their study, developed a marketing strategy for engaging at-risk individuals with Internet-based depression inhibition interference in primary care by targeting essential attitudes.

As mentioned, various types of research on the segmentation of customers according to the RFM model (and extended of it) through utilizing the multiple methods in the different industries. This study has proposed the LRFMP model and segmented the customers using the self-organizing mapping method (SOM), a neural network-based clustering method. The Self-Organized Mapping Network can perform the learning process on complex and multidimensional data. This method helps extract a visible cluster set (Kohonen, 1998). In fact, to our knowledge, no research has been done on customer clustering concerning the LRFMP indices by Self-Organized Mapping Network in an Aesthetic & Dermatology Center, so this is one of the innovations of the present study. The Aesthetic & Dermatology Center provides various aesthetic & dermatology services to patients. These centers are customer-oriented firms, and the people who visit these centers, like their age or any reason, see different ups and downs in their appearance. They worried about it increasingly because of various reasons. Therefore, each segment of customers helps better recognize the customers for providing customer service. This recognition leads to customer relationship targeted, marketing management, and appropriate resource allocation. On the other hand, help Aesthetic & Dermatology Centers provide professional and complimentary consultation before and after the services. This paper is organized as follows: research method, finding, discussion, cluster labeling, conclusion, and theoretical and practical implications.

2. Methodology

By examining the background of the research and interviewing organizational experts, attention was paid to the LRFMP indices, and all the indices have the same importance. So, this study aims to evaluate and cluster the Aesthetic & Dermatology Center customers based on the LRFMP model indices. This article has been done on customer segmentation in one of Mashhad's Aesthetic & Dermatology Centers. The center has been operating since 2011, and this study gathered data from 220 patient samples from 2018 until 2020; they have come to the clinic for any service. Data collected included the age, the date of the first and last visit, the number of visits, patterns that the patient came to the clinic, and the time and cost of paying. The L index, which represents the length of time a patient related to the clinic (or the patient's loyalty), was calculated by comparing the first and the last visit dates. The maximum of the L index is 84 months (84 months are the clinic's age till now). The R index represents the more recent patient visits, calculated by subtracting the last time the patient visited from the end of 2019.12.22. The maximum of the R index is 458 days.

The F index is defined as the number of times the patient has visited the clinic, and the M index shows the total cost spent on the clinic by the patients, which these data were recorded on their profile cards. The P index represents the patterns the patient came to the clinic (or Periodicity) extracted from the customer database. The operational steps of the research method of this study are as Figure1.

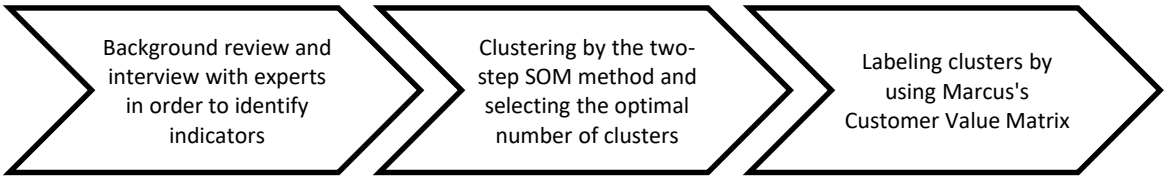

Figure 21. Operational steps of the research method

The clustering in this study was done by the two-step SOM method. Clustering is one of the most important data mining methods, especially in marketing research. Many methods have been developed for data clustering; one is the SOM or Kohonen map. It is a neural network-based clustering method that is an unsupervised learning model. In other words, the SOM presents a mapping from a higher-dimensional input space to a lower-dimensional map space. Placing a vector from data space onto the map is to detect the node with the vector of the closest weight to the data space vector (Ultsch and Siemon, 1990). It is fundamentally a method for dimensionality reduction, and it maps a higher-dimensional input to a lower-dimensional discretized representation (Kohonen, 1998). Due to selecting the optimal number

of clusters, one of them is the Davies Bouldin index, the silhouette width, or the Dunn index. In this study was used the Dunn index (1).

$$DI = \min_{1\le i\le k}\{\min_{i+1\le j\le k}\{\frac{d(C_i.C_j)}{\max_{1\le l\le k} diam(C_l)}\}\} \quad (1)$$

Where $d(C_i.C_j)$ denotes the distance between the cluster *i, j,* and $diam(C_l)$ represents the diameter of cluster l. Each of these two parameters is computed using equations (2) and (3):

$$d(C_i.C_j) = \min_{x\in C_i.y\in C_j} d(x.y) \quad (2)$$

$$diam(C_l) = \max_{x.y\in C_l} d(x.y) \quad (3)$$

The diameter of a cluster (equation (3)) is the maximum distance between two cluster members, and the distance between two clusters (equation (2)) is the distance closest to the two members. Therefore, the more the Dunn index value helps ensure well-separated and compacted clusters. Lehman (1979) suggested that the number of clusters is between n/30 and n/60, where n is the sample size. Therefore, in the first step, the number of clusters is calculated by Lehman's rule between three and five clusters, and then by the SOM method, the analysis was repeated for three, four, and five clusters. After that, the Dunn index compared the results and determined the best number of clusters. Also, for more understanding, the type of patients has selected the label for the cluster. Labeling clusters was done using Marcus's Customer Value Matrix as the foundation. According to Marcus (1998), the Customer Value Matrix requires primary customer and buying data.

3. Findings

3.1. Results of the clustering by two-step SOM method

As mentioned in this study, data was gathered from 220 samples of patients from 2018 until 2020 that have come to the clinic for any service, then the clustering of customers was analyzed through the SOM method. For this purpose, due to the five LRFMP properties, the number of neurons was considered once 3, once 4, and once 5. As a result, three, four, and five clusters are achieved.

The three clusters. The position of clusters, their neighborhood status, and the number of members in each cluster are illustrated in Figure 2:

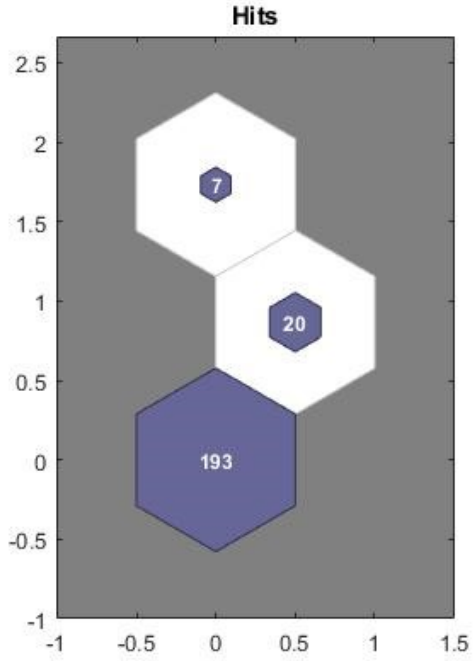

Figure 22. The three cluster

Table (1) shows the coordinates of the centers of each of the three clusters. The coordinates of each center are specified for each of the five dimensions of the LRFMP. The value of the Dunn index for these clusters is 0.044.

Table 14. The centers' coordinates of three clusters

	L	**R**	**F**	**M**	**P**
The first cluster	18.77	49.78	2.33	465.69	0.22
The second cluster	28.11	43.74	5.74	4018.42	0.37
The third cluster	13.60	15.60	9.40	7780	0.60

The four clusters. The position of clusters, their neighborhood status, and the number of members in each cluster are shown in Figure 3:

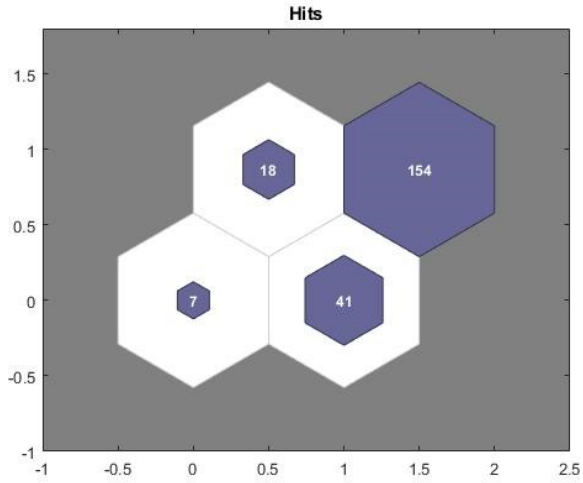

Figure 23. The four clusters

Table (2) illustrates the coordinates of the centers of each of the four clusters. The coordinates of each center are specified for each of the five dimensions of the LRFMP. The value of the Dunn index for these clusters is 0.0058.

Table 15. The centers' coordinates of four clusters.

	L	R	F	M	P
The first cluster	13.60	15.60	9.40	7780.00	0.60
The second cluster	22.30	44.35	3.46	1284.59	0.46
The third cluster	29.39	34.44	6.17	4091.67	0.37
The fourth cluster	15.37	49.39	1.97	268.72	0.18

The five clusters. The position of clusters, their neighborhood status, and the number of members in each cluster are illustrated in Figure 4:

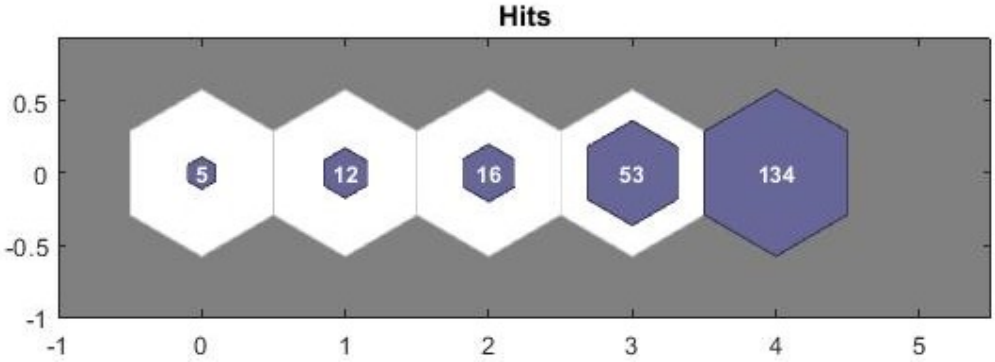

Figure 24. The five clusters

Table (3) shows the coordinates of the centers of each of the five clusters. The coordinates of each center are specified for each of the five dimensions of the LRFMP. The value of the Dunn index for the five clusters is 0.0061.

Table 16. The centers' coordinates of five clusters

	L	R	F	M	P
The first cluster	13.333	15.33	10.66	8466.66	1
The second cluster	23.33	14.50	6.25	5016.66	0.33
The third cluster	29.33	62.66	4.73	2643.33	0.27
The fourth cluster	19.98	27.78	3.29	902.15	0.52
The fifth cluster	17.41	57.18	1.86	225.54	0.12

3.2. The final clustering

Considering the value of the Dunn index in the status of the three clusters is the highest in comparison to the other type of clusters. Therefore, the proposed final clustering with the three clusters can be considered. As mentioned, the data of the LRFMP indices were gathered from 220 patients. Table 4 shows the average of each LRFMP indices for all patients:

Table 17. The average of the LRFMP indices of all patients

	L	R	F	M	P
The average	19.54	46.69	2.79	1028.72	0.26

Table 5 illustrates more information about triple clustering.

Table 18. The information of triple clustering

Cluster	The number of patients	The average of L	The average of R	The average of F	The average of M	The average of P	The average of age	More than average
3	7	32	58	8.42	8557.14	0.53	29	LFMP
2	20	23.9	27.05	5.55	3877.5	0.34	35.9	R
1	193	18.63	48.31	2.29	460.46	0.23	33.78	-
Average		19.54	46.7	2.78	1028.7	0.2579		

4. Discussion and cluster labeling

As shown in Table 5, the L index represents the length of time a patient interacts with the clinic (or the patient's loyalty); the third cluster has the highest rank compared to the other clusters. The third cluster has the highest rank in the F index, which showed the number of times patients came to the Aesthetic & Dermatology Center. Furthermore, the third cluster has the highest rank in the M index, offering the patients' total cost spent on the clinic despite the lowest number. The P index represents the patterns in which the patient came to the clinic. The win of the third cluster in most indices belongs to 29 years, but the age of almost 36 years that got soon to the Aesthetic & Dermatology Center belongs to the second cluster. Although the third cluster has the highest score in most indices, the lack of an R index is worrying. The paucity of R index means some patients did not visit recently, so the Aesthetic & Dermatology Center lost their big spender and frequent customers, or some of the patients used specified services. Finally, the R index representing the more recent patient visits is calculated by subtracting the last time the patient visited from 2019.12.22. Therefore, the best R index is a cluster with a lower value, so the second cluster is the winner in the R index. The winner in the R index, while the second cluster is the loser in the other indices, means the newcomers are in the second cluster. As observed in Table 5, although the first cluster is the highest number of patients (approximately 87% of the total patients but 39% of the total revenue), this cluster is the misfit cluster because it could not get a proper position in any LRFMP indices. In Table 5, the "More than average" column was utilized to select the cluster label according to Marcus's (1998) article.

The third cluster is exalted in the LFMP. It means the loyal patients, the patients who frequently go to the center, the big spenders, and the periodic patients who came to the clinic but did not visit recently belong to this cluster. So was assigned the Loyal Customers as a label to the third cluster. Also, the potential loyal customers as the label were selected as the second cluster related to fresh customers. Finally, the first cluster is the highest in the patient numbers, but all the indices' loser was assigned Uncertain Customers as the label.

5. Conclusion

This study aimed to segment the Aesthetic & Dermatology Center customers on LRFMP indices through the SOM method. This paper used the two-stage SOM method for customer clustering with due attention to the LRFMP model in the Aesthetic & Dermatology Center. In the first step, the number of clusters is calculated by Lehman's rule (1979) between three and

five clusters, and then by the SOM method, the analysis was repeated for three, four, and five clusters. After that, the Dunn index compared the results and determined the best number of clusters. The result of the Dunn index showed that the triple cluster is the best number of clusters. The label selected the cluster for more understanding types of patients according to their characters in their cluster. The label of clusters was named "Loyal customers", "Potential Loyal Customers" and "Uncertain Customers". The findings show that each Aesthetic & Dermatology Center customer segment should be adopted different behavior. Following presented Theoretical implications and Practical implications.

5.1. The theoretical implications

The findings of this study have implications not only for the study of the Aesthetic & Dermatology industry but also for each service-oriented business due to the importance of Loyalty, Frequency, Monetary, Periodicity, and Recency indices for service-oriented businesses. Most researches focus on the LRFM model for segmenting customers (Reinartz and Kumar (2000), Yeh et al. (2009), Khajvand et al. (2011), Wei et al. (2012)). There are some studies that these studies extended the LRFM model by adding the Periodicity index (Peker et al. (2017)) and the Discount index (Chiang (2018)).

By reviewing the literature, few studied the service-based market segmentation according to LRFMP model indices by SOM or other models. For practical directing and operational usage of the customer data instead of trapping them in pockets within the organization, the literature was perused to propose the appropriate marketing strategies by considering specified characteristics. However, to our knowledge, no studies match the nature of the Aesthetic & Dermatology services. Given the less academic concern in the concept of this study's purpose, this study can contribute to the existing literature by providing valuable insights.

5.2. The practical implications

The finding also has practical implications for service-based firms. According to the developed Peker et al. (2017)'s model, the LRFMP model was adopted to segment the customers to recognize them better and keep a productive relationship with them in the Aesthetic & Dermatology Center. For more understanding, the type of patients has selected the label for the cluster. The label of clusters was named "Loyal customers", "Potential Loyal Customers" and "Uncertain Customers". Each type of customer in the triple clusters follows specific marketing strategies.

Customer retention is vital for any business that creates frequent purchases due to a growth in customer retention that can accelerate incomes (Massnick, 1997; Reichheld, 1996). According to Marcus (1998), small- to mid-sized businesses are better at creating excellent customer relationships. Focusing on direct marketing allows organizations to allocate their marketing resources to gain more return on investment and compete more effectively to retain their customers. In this way, they can develop and grow their business, which causes good customer relationships. Whereas the Aesthetic & Dermatology Center is categorized as small and mid-sized self-governing, it would better focus on retaining and local relationship marketing. Maintaining the customer that belongs to the third cluster (Loyal customers) is vital, as they guarantee business survival. As Pooya et al. (2020) mentioned, effective organizations gain customer satisfaction. Customer retention in the long term is more profitable than attracting new customers. So, the retention strategy for loyal customers involves finding and understanding how the customers are satisfied.

The Aesthetic & Dermatology Center should show in its treatment that loyal customers are worthy. For example, it should consider privileged discounts (for New year) and hold events that loyal customers relate together and the center. Loyal customers should feel they are different from the center, which can be done by sending birthday cards. They are an excellent resource for reinforcing the LFMP indices. A and have the potential to increase the R index.

In their study, Wei et al. (2012) proposed that to increase the number of patient visits, the clinic could serve more after-medical care activities and provide gifts. Parvaneh et al. (2014) mentioned when the firms did the segmentation of customers in their article. They should implement a proper marketing strategy for each cluster. They propose Cross-selling, loyalty programs, and Strong anti-attrition. By doing Cross-selling, sellers increase their income from their customers.

Focusing on patients who have previously visited the center minimized the marketing costs, but they increased the expense of promotion programs. Whereas Loyal customers are big spenders who spend lots of money on the clinic, the fit strategy increases their purchase frequency. Loyal customers have demonstrated loyalty due to the frequency of purchases; the beneficent strategy is to accelerate their purchases; in other words, the functional level strategy could be Push Marketing Strategy. Due to the purchasing behavior of Potential Loyal Customers, they also buy from competitors. By tactic of discounts of regular and periodic visits for these types of customers and tactic of discounts on services due to increasing the variety of purchased services, the center could hope that they become loyal customers and so that the

monetary value and frequent purchases will increase. Therefore, the best strategy is to focus the marketing activity on newcomers or depend on a specified service type. The center should try to get these customers away from their competitors with a stair-step volume discount policy; eventually, the Uncertain Customers be converted to another cluster. The monetary value and frequent purchase determine their purchasing pattern and the likelihood that loyal customers increases. Wei et al. (2012) suggested that patients with lower values in the length, recency, and frequency index can be ignored, and the resources should be allocated to valuable customers. However, the Uncertain Customers are the largest group, representing approximately 87% of the total patients but 39% of total revenue.

5.3. Limitations and future research

This study has limitations. The lack of an existing marketing strategy for each type of service the Aesthetic & Dermatology Center provided imposed hardships on recognizing the attribute of the cluster in the initial phase of the study. Also, the unspecific gender of patients on the profile card constrained us from building a clear image of the customer's mind map. The other characteristics of patients should be attention (like educated level and date of birth) that help segment the customer and design a proper marketing strategy. Another limitation is the lack of precise approaches to the marketing mix (especially Price and Promotions) of the Aesthetic & Dermatology Center. It also imposed difficulty for proposing improvement marketing strategy suggestions for each cluster. This article presents the marketing suggestions implicitly. An experimental study helps to understand the marketing strategy's effectiveness better. For example, an investigation can examine which marketing strategy is better and how each cluster's customer behavior is affected. As we know, the marketing strategy belongs to the functional strategy level. So, each business should ensure that the strategy at the practical level aligns with the corporate strategy. The business lives on a different scale, so they should adjust their marketing activity by having a cost advantage and logistics.

Disclosure statement

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

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How Does the Earthquake Affect Economic Growth with System Dynamics Approach (Case Study of Tehran)

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ABSTRACT

Natural disasters affect economic growth, and due to the location of Tehran, as the capital of Iran, on the Rey fault, Masha, and North of Tehran, the present research was conducted to investigate the effect of earthquakes on the Rey fault on the economic growth of Iran. The economic growth of Iran has been simulated for 40 years, starting from 2013, and through cause and effect cycles, the long-term economic effects of a possible earthquake have been simulated. The innovation of the current research is the economic growth model is designed in terms of product production, knowledge production, production of intermediate energy goods, and the performance of the insurance industry as a part of the financial sector. Also, the influence channels of the earthquake on Roemer's endogenous economic growth model have been simulated using the system dynamics method. The results show that causalties will lead to a reduction in human resources and, as a result, a slight decrease in Iran's economic growth in the long-term. Secondly, the destruction will lead to the reduction of physical capital and, as a result, the reduction of economic growth in the long term. Thirdly, reconstruction costs will have a negative effect on economic growth, which will diminish in the long run.

Keywords

Economic growth, Earthquake, System dynamics, Physical capital, Human capital.

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1. Introduction

One of the policymakers' most important economic goals is to achieve high economic growth. Many economists have tried to analyze the issues of economic growth and design their policies based on growth-inhibiting and growth-accelerating factors. Natural disasters are among these factors. Countries that have frequently experienced natural disasters have lower growth rates Benson and Clay (2004). Loayza et al. (2012) believe that natural disasters affect the economic growth of countries and this effect is more severe for developing countries. If the severity of natural disasters is high, they will have a negative effect on economic growth (Cavallo and Noy, 2011).

The importance of the present issue is due to the fact that Iran is located on one of the two earthquake-prone belts in the world. The city of Tehran is located on the Rey fault, the Masha fault, and the North Tehran fault, so a huge earthquake is likely. And due to the accumulation of many physical and human capitals in Tehran, in the event of an earthquake, these capitals will be damaged, and the activities of government bodies, organizations, and industrial and commercial sectors, including Tehran's Grand Bazaar, will be disrupted. Therefore, it is likely that the country's economic growth will be affected. Kirigia et al. (2004) shows that the death of each person due to natural disasters has reduced the gross domestic product of countries by one dollar. Also, Deng, et al. (2022), Noy et al. (2017), Isoré (2018), Rajapaksa et al. (2017), Hallegatte et al. (2016), Joseph, I. L. (2022), Hsiang and Jina (2014), Okuyama and Santos (2014), Barone and Mocetti (2014), Shahzad (2014), Cavallo et al. (2013), Fisker (2012), Rodriguez et al. (2013), Benali, N. (2022), Loayza et al. (2012), Kellenberg and Mobarak (2011) have investigated the effect of natural disasters on the economic growth of countries.

Chang-Richards (2018), Phonphoton and Pharino (2019), Potirakis, et al. (2013), Kachali et al. (2012), Bagheri et al. (2010), Ramezankhani and Najafiyazdi (2007), and Ho et al. (2006) have simulated the various effects of earthquakes through the system dynamics method.

Most of the studies show the negative effects of natural disasters on economic growth. In this study, the effects of earthquakes on economic growth have been investigated using the system dynamic method, which has provided the possibility to test the hypotheses. In the present study, Romer's endogenous economic growth has been simulated using the system dynamics method, which has made it possible to comprehensively examine economic growth and consider the knowledge production sector, goods production, energy, and the performance of the insurance industry at the same time.

The main purpose of this research is to simulate and investigate the long-term and short-term effects of an earthquake in the Ray fault in Tehran on the economic growth of Iran. Therefore,

Romer's endogenous economic growth model is simulated in terms of a knowledge production function, goods production function, energy production function, and insurance industry for Iran. This model will be prepared for 40 years, starting from 2011. Then, the possible earthquake that occurred in 2019 in the Rey fault is entered into the model. So that physical capital and labor decrease. Then changes in the production function are investigated. The main contribution of this study is the construction of the economic growth simulation model in terms of good production, knowledge, production of intermediate energy, and the performance of the insurance industry as a symbol of the financial sector. Also, the further innovation of the present research is identifying the channels of earthquake influence on economic growth through the dynamic examination of economic cause and effect relationships.

2. The theoretical principles

Endogenous growth theories investigate the forces that cause growth and their dynamics. Endogenous growth theories were created by developing economic growth models and, consequently, endogenous technological changes by Romer (1986) and Lucas (1988).

In the second generation of endogenous growth models, Romer (1990), Grossman and Helmpman (1991) consider innovations as the basis of the economic growth process. In these models, innovations are the result of research and development activities in firms, and the overflow of international knowledge due to international trade and research and development are the main determinants of economic growth rate.

In this paper, the endogenous economic growth of Romer is considered. Production of goods (Y) is assumed as a function of human capital (H), physical capital (K), technology (a), and energy (E). The pattern has a continuous time. Labor and capital are employed in three parts of goods production, research and development production, and intermediate goods of energy production. Insurance performance indirectly improves economic growth through its impact on capital. Economic growth also affects insurance performance through the amount of public and private sector spending on premium payments.

In this model, the ratio θ_1 of the workforce is used in the final product manufacturing sector. θ_2 of the labor force is used in the intermediate goods production sector of energy. ($\theta_3 = 1 - \theta_1 - \theta_2$) of the labor force is used in the research and development(R&D) sector. η_1, η_{21}, and (η_3=1-η_1-η_2) are the share of capital in the final product manufacturing sector, intermediate goods production sector of energy, and the share of capital in the R&D sector. All three sectors

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use the whole knowledge inventory because knowledge in one sector does not prevent its usage in other sectors. Therefore, the function of the product is at the time (t) is according to Eq.1.

$$\mathrm{Y(t)} = B_2[(\eta_1)\mathrm{K(t)}]^{\beta_1}[(\theta_1)\mathrm{H(t)}]^{\beta_2}[E(t)]^{\beta_3}[A(t)]^{\beta_4} \quad (1)$$

In this model, knowledge production is a function of the share of physical capital and the share of human resources and knowledge inventory as follows:

$$\dot{\mathrm{A}}(\mathrm{t}) = B_1\mathrm{A(t)}[(1-\eta_1-\eta_2)\mathrm{K(t)}]^{\alpha_1}[(1-\theta_1-\theta_2)\mathrm{H(t)}]^{\alpha_2}$$
$$\mathrm{B} > 0 \quad , \quad \alpha_1, \alpha_2 \geq 0 \quad (2)$$

It assumes that increasing the current knowledge inventory leads to improving new discoveries directly. Therefore, the knowledge inventory appears in the above equation exponent 1. The energy production function is considered according to Eq.3, which is a function of the share of physical capital and human resources, knowledge inventory, and primary energy supply.

$$\mathrm{E(t)} = B_3[(\eta_2)\mathrm{K(t)}]^{\Upsilon_1}[(\theta_2)\mathrm{H(t)}]^{\Upsilon_2}[A(t)]^{\Upsilon_3}[IES(t)]^{\Upsilon_4} \quad (3)$$

The capital function is as Eq.4:

$$\dot{\mathrm{K}}(\mathrm{t}) = \mathrm{sY(t)} - \delta\mathrm{K(t)} \quad (4)$$

We consider population growth as endogenous and assume no negative population growth exists (Eq.5).

$$\dot{\mathrm{L}}(\mathrm{t}) = \mathrm{nL(t)} \qquad \mathrm{n} \geq 0 \quad (5)$$

It should be noted that in eq.2, the parameters α_1, α_2 are the elasticity of knowledge growth relative to the physical and human capital, and in Eq.3, the parameters Υ_1, Υ_2, Υ_3, and Υ_4 are energy production elasticity relative to the physical capital, workforce, Knowledge level, and basic energy levels.

Schumpeter (1911) and Hicks (1969) studied the importance of the financial sector in support of economic growth for the first time. King and Levine (1993), Berg and Schmidt (1994), Soo (1996), Arena (2008), and Pietrovito (2009) confirmed the effect of financial development on economic growth by endogenous growth models.

3. Methodology

We use system dynamic methodology to analyze the rescue team's impact of earthquakes on Iran's economic growth. Effective decision-making and learning in a world of dynamic complexity growth force us to be system thinkers to expand the mental model's boundaries and limits. In the system dynamic, the long-term effects of the decisions acquire experience and speed up learning (Sterman, 2001).

The system dynamics is based on control theory and nonlinear dynamics modern theory. So, there is an exact mathematical foundation for theory and models, and it is also a technical tool that policymakers can solve problems in societies. In this method, as shown in figure 1, the model is formulated after expressing the problem and defining dynamic hypotheses. After testing and validating the model, policies are designed and evaluated.

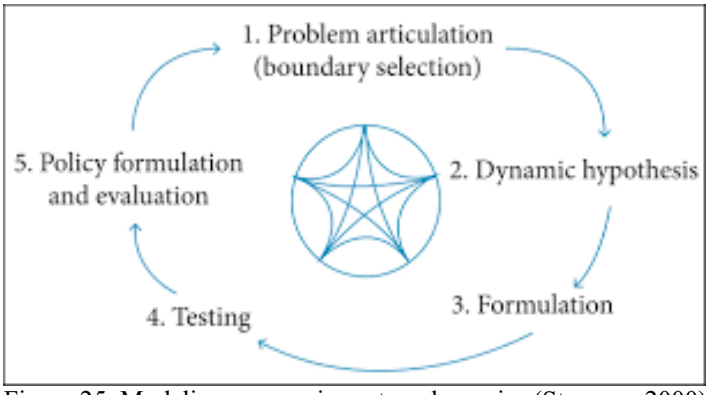

Figure 25. Modeling process in system dynamics (Sterman, 2000)

Table 1 shows study variables and the source of relationships and data extraction. It should note that the model start time is 2012, and the earthquake occurrence in 2020 is simulated. Therefore, the data related to economic growth relate to 2012.

Table 19. Introducing model variables

Symbol	Variable name	Kind of variable	Variable unit	Formula , amount	source
dA	growth of knowledge level	flow	Billion Rials/year	$(\dot{A}(t)/year) = (B_1 A(t)[(1-\eta_1-\eta_2)K(t)]^{\alpha_1}[(1-\theta_1-\theta_2)H(t)]^{\alpha_2})/year)$	Hadian and Ostadzad (2016)
At1	Knowledge inventory	Stock	Billion Rials	$A(t) = A(t-1) + \dot{A}(t)$ *2144*	Hadian and Ostadzad (2016)
A	Initial knowledge inventory	Covariate	Billion Rials	lookup	Hadian and Ostadzad (2016)
α1	Elasticity of knowledge growth to capital	Covariate	-	0.042	Hadian and Ostadzad (2016)
α2	Elasticity of knowledge growth to workforce	Covariate	-	0.049	Hadian and Ostadzad (2016)
B1	Coefficient of knowledge function	Covariate	-	0.0197	Hadian and Ostadzad (2016)
B2	Coefficient of produce function	Covariate	-	0.731	Hadian and Ostadzad (2016)
β1	power of capital on produce function	Covariate	-	0.301	Hadian and Ostadzad (2016)
β2	power of workforce on produce function	Covariate	-	0.246	Hadian and Ostadzad (2016)

Symbol	Variable name	Kind of variable	Variable unit	Formula , amount	source
β3	power of knowledge on produce function	Covariate	-	0.221	Hadian and Ostadzad (2016)
β4	power of energy on produce function	Covariate	-	0.123	Hadian and Ostadzad (2016)
dY	Growth of total production	flow	Billion Rials/year	$(\frac{Y(t)}{\frac{rial^2}{year}}) = B_2[(\eta_1)K(t)]^{\beta_1}[(\theta_1)H(t)]^{\beta_2}[E(t)]^{\beta_3}[A(t)]^{\beta_4} /(\frac{rial^2}{year})$	---
Y	Gross domestic production	Stock	Billion Rials	1605453	Central Bank of Iran
dE	Energy production changing	flow	Billion Rials/ye	$(\frac{E(t)}{rial^2}) = (B_3[(\eta_2)K(t)]^{\gamma_1}[(\theta_2)H(t)]^{\gamma_2}[A(t)]^{\gamma_3}[IES(t)]^{\gamma_4}$ /rial^2)	---
E	Energy production	Stock	Billion Rials	550984	Iran Energy Balance Sheet
B3	other variables on energy production function	Covariate	-	0.300	Hadian and Ostadzad (2016)
E1	Primary energy supply	Covariate	Billion Rials	289467	Iran Energy Balance Sheet
ϒ1	Elasticity of energy production to capital	Covariate	-	0.223	Hadian and Ostadzad (2016)
ϒ2	Elasticity of energy production to workforce	Covariate	-	0.037	Hadian and Ostadzad (2016)
ϒ3	Elasticity of energy production to knowledge level	Covariate	-	0.0247	Hadian and Ostadzad (2016)
ϒ4	Elasticity of energy production to ESTI	Covariate	-	0.8589	Hadian and Ostadzad (2016)
irate	Investment rate	Covariate	-	0.25	World bank data
I	investment	flow	Billion Rials/ye	I(t)= irate*Y(t)	---
K	Physical capital	Stock	Billion Rials	PULSE(0, 8)*(I+nonlife loss+zi-est)+PULSE(8, 1)*(I+nonlife loss+zi-est-destruction1-destruction2)+PULSE(9, 32)*(I+nonlife loss+zi-est(7770050	Amini and Neshat (2005)
est	Depreciation	flow	Billion Rials/ye	Estrate*k	Amini and Neshat (2005)
estrate	Depreciation rate	Covariate	-	0.05	Amini and Neshat (2005)
pop	population	Covariate	Thousand people	U15+(15-65)+m65	---
b	birth	flow	Thousand people/year	br*pop	---
br	Birth rate	Covariate	-	0.016	World bank data
d	death	flow	Thousand people/year	dr*pop	---
dr	Death rate	Covariate	-	0.005	World bank data
hh	Workforce	Covariate	1	H*15-65*hhh	Central Bank of Iran
h	Active population ratio to 15-64	Covariate	-	lookup	Central Bank of Iran
U15	Population under 15	Stock	Thousand people	PULSE(0, 8)*(b-d1-mian)+PULSE(8, 1)*(b-d1-mian-casualties1-casualties2-casualties3)+PULSE(9, 32)*(b-d1-mian) 17561000	Statistical Center of Iran
15-65	Population 15 -64	Stock	Thousand people	PULSE(0, 8)*(mian-d2-salm)+PULSE(8, 1)*(mian-d2-salm-casualt1-casualt2-casualt3)+PULSE(9, 32)*(mian-d2-salm) 53244000	Statistical Center of Iran
M65	Population more than 65 years old	Stock	Thousand people	PULSE(0, 8)*(salm-d3)+PULSE(8, 1)*(salm-d3-casual1-casual2-casual3)+PULSE(9, 32)*(salm-d3) 4343000	Statistical Center of Iran
salm	Elder rate	flow	Thousand people/year	(15-65/64)/year	---
mian	Middle-aged rate	flow	Thousand people/year	(U15/15)/year	---
year	year	Covariate	year	1	---
rial	rial	Covariate	Billion Rials	1	---
C	consumption	Covariate	Billion Rials	0.45*Y	Statistical Center of Iran

Symbol	Variable name	Kind of variable	Variable unit	Formula , amount	source
G	government expenditure	Covariate	Billion Rials	0.11*Y	Statistical Center of Iran
cul	Percent of insurance expenditure	Covariate	--	۰/۰۲	Central insurance of IR Iran data
pre	premium	Covariate	Billion Rials	cul*(C+G)	Central insurance of IR Iran data
pr rein	Reinsurance premium	Covariate	Billion Rials	0.24*pre	Central insurance of IR Iran data
life premium	Life premium	Covariate	Billion Rials/ye	pre-pr rein))/year*(0.2	Central insurance of IR Iran data
nonlife premium	Nonlife premium	Covariate	Billion Rials/ye	pre-pr rein))/year*(0.8	Central insurance of IR Iran data
other revenue	Other revenue of insurance	Covariate	Billion Rials/ye	1821	Central insurance of IR Iran data
insurance	Insurance performance	Covariate	Billion Rials	life premium+nonlife premium+other revenue-life loss-nonlife loss-other expenditure 2112	Central insurance of IR Iran data
life loss	Life loss	Covariate	Billion Rials	((0.69* life premium)-(0.69* life premium *loss rein))	Central insurance of IR Iran data
nonlife loss	nonlife loss	Covariate	Billion Rials	((0.84*nonlife premium)-(0.84* nonlife premium *loss rein))	Central insurance of IR Iran data
other expenditure	Other insurance costs	Covariate	Billion Rials/ye	(0.24*pre)/year	Central insurance of IR Iran data
loss rein	Percentages of reinsurance losses	Covariate	--	0.25	Central insurance of IR Iran data
haghomr	aanonlife premium	Covariate	Billion Rials/ye	0.12*life premium	Central insurance of IR Iran data
lossomr	nonlife loss	Covariate	Billion Rials/ye	0.11*life loss	Central insurance of IR Iran data
zakhire riazi	Mathematical reserves	Covariate	Billion Rials	haghomr-lossomr 1800	Central insurance of IR Iran data
zi	Mathematical reserveson year	Covariate	Billion Rials/ye	zakhire riazi/year	---
destruction1	earthquake destruction	flow	Billion Rials/ye	1833440	JICA (2000)
Destruction2	fire destruction after earthquake	flow	Billion Rials/ye	(em2(rescue teams))/(year)	Sadeghian et al. (2016)
Casual1	Casualties1(more than 65 year)	flow	Thousand people/year	(emd*(0.15*m65))/(people*year)	JICA (2000) Sadeghian et al. (2016)
Casual2	Injured Casualties (more than 65 years)	flow	Thousand people/year	t2*((people*aaa*(0.15*m65))+(emd1*(0.15*) (m65))))/(2*year*people^2	Amini et al. (2012)
Casual3	Patient Casualties (more than 65 years)	flow	Thousand people/year	((t33*(tal3))/(year*people)	Ramezankhani and Najafiyazdi (2007)
Tal3	Number of patients (more than 65)	Covariate	Thousand people	0.45*0.11*0.15*m65	Ramezankhani and Najafiyazdi (2007)
casualt1	Casualties1(15 -64)	flow	Thousand people/year	(emd*(0.17*"15-64"))/(people*year)	JICA (2000) Sadeghian et al. (2016)
casualt2	Injured Casualties(15-64)	flow	Thousand people/year	t2*((people*aaa*(0.17*"15-) 64"))+(emd1*(0.17*"15-(64"))))/(2*year*people^2	Amini et al. (2012)
casualt3	Patient Casualties(15-64)	flow	Thousand people/year	(t33*tal2)/(people*year)	Ramezankhani and Najafiyazdi (2007)
Tal2	Number of patients (15-64)	Covariate	Thousand people	0.45*0.11*0.17*" 15-64"	Ramezankhani and Najafiyazdi (2007)
casualties1	Casualties1(under15)	flow	Thousand people/year	(emd*(0.12*u15))/(people*year)	JICA (2000) Sadeghian et al. (2016)
casualties2	Injured Casualties(under15)	flow	Thousand people/year	t2*((aaa*(0.12*u15)*people)+(emd1*(0.12*u) (15))))/(2*year*people^2	Amini et al. (2012)
casualties3	Patient Casualties (under 15)	flow	Thousand people/year	(tal1*t33)/(year*people)	Ramezankhani and Najafiyazdi (2007)
Tal1	Number of patients (under15)	Covariate	Thousand people	0.45*0.11*0.12*" u14"	Ramezankhani and Najafiyazdi (2007)

4. Results and discussion

In order to simulate Romer's endogenous economic growth model, the first causal loop diagram was drawn (Figure 2), and based on that, the Stock and flow diagrams were drawn (Figure 3). In this model, the damages caused by the earthquake are shown in the form of the destruction of physical assets and secondary damages due to fires after the earthquake. Part of the deaths caused by the earthquake is due to the death due to debris, another part is the death of the injured, and the next part is the death due to infectious diseases after the earthquake, which is drawn separately for each age group. Then, simulation was done using relevant data and information. The parameters are extracted from previous studies or data from Central Bank, World Bank, Iran Statistics Center, and Energy Balance Sheet.

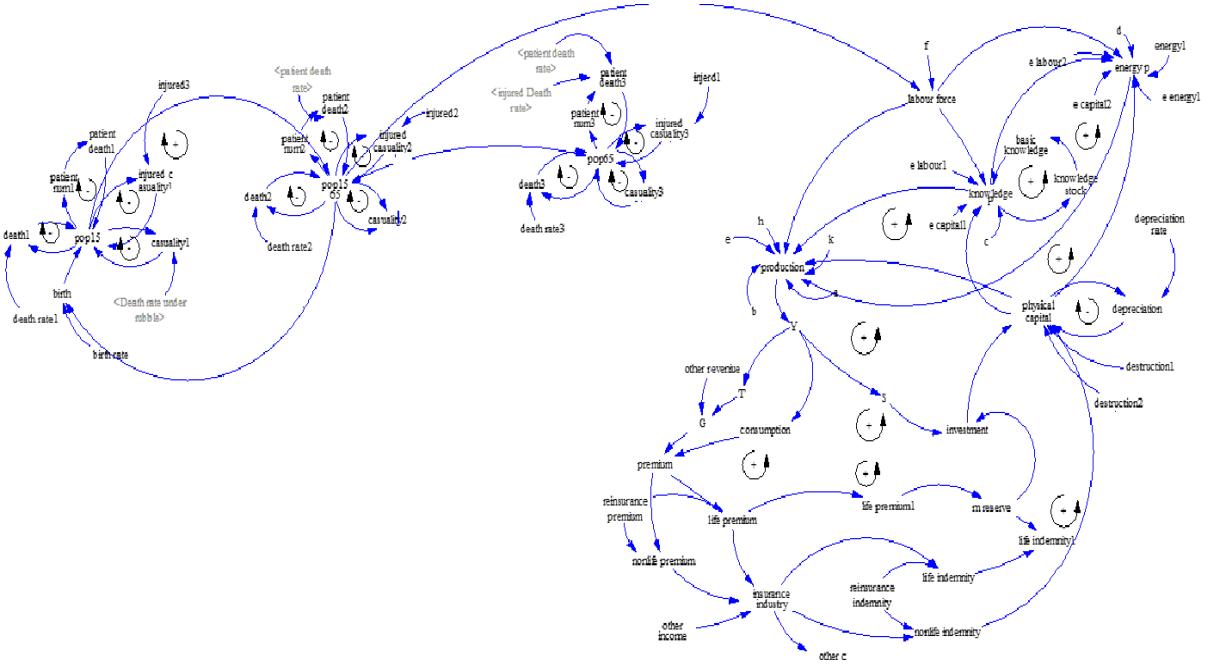

Figure 26. Causal loop diagram

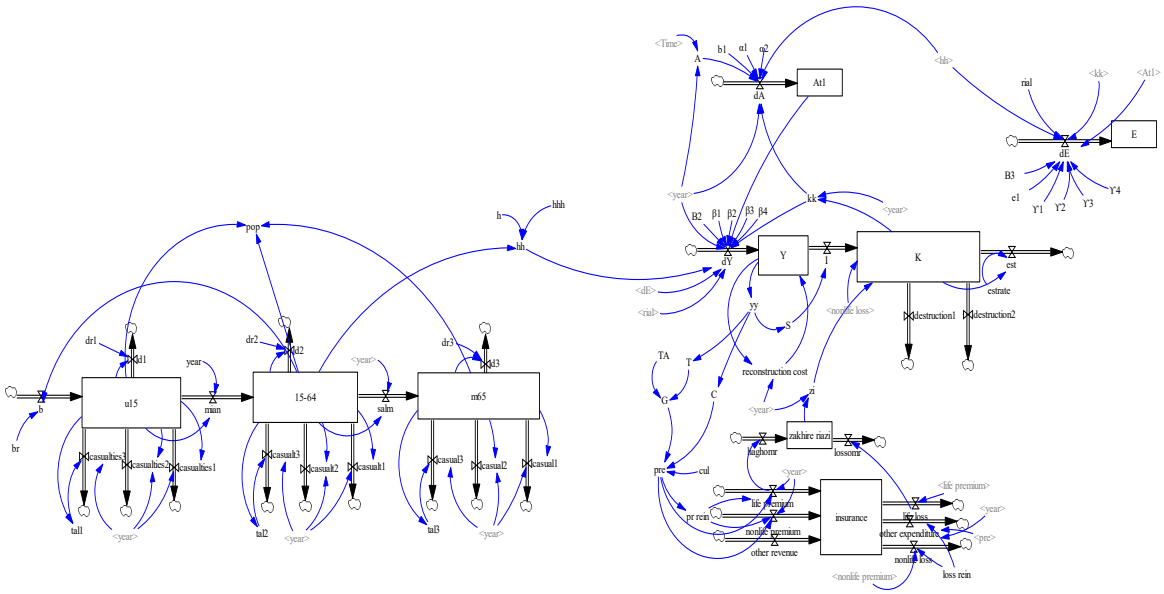

Figure 27. Stock and flow diagram

The following tests are performed to test the model validity:

a) **Behavior reproduction test:** To assess the model validity, we studied the model from 1996 to 2013 in comparison with the actual data extracted from the Central Bank of Iran and the Statistics Center of Iran. According to Figure 4, with a close approximation, we reached the results close to reality.

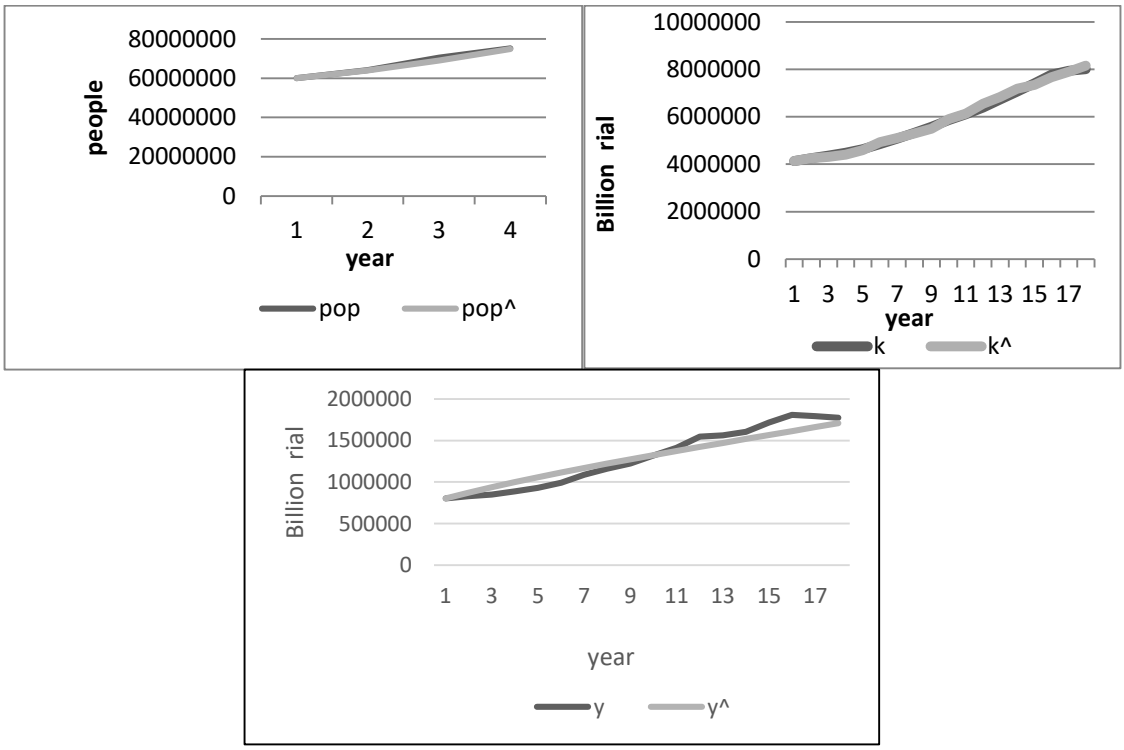

Figure 28. Comparison of the values calculated by the model (y^) with real values (y)

b) **Boundary-adequacy test:** We formulated all the variables needed to examine endogenous economic growth according to theoretical principles and existing literature, including physical and human capital and the knowledge production function. The values assigned to the variables are determined based on their real values. They can provide a proper approximation of the behavior of the gross domestic product (GDP) and economic growth of Iran.

c) **Structure verification test:** A review of model matching with reality in the decision-making process shows that the behavior of defined variables and their impact on model behavior in the critical stages is perfectly in accordance with reality. This is confirmed due to the model's behavior in this situation and by the survey of experts.

d) **Dimensional test:** This test is performed to determine the unit of variables and coordinate them with the reality that is performed on the model's variables, which indicates that the unit of variables is in accordance with reality.

e) **Extreme policy test:** In this section, the behavior of variables has been investigated in a limit state. Non-negativity of the state variables and the direction of the movement of information and materials based on model assumptions are among the issues discussed in this section, and the behavior of variables confirms this situation. Also, in order to prevent irrational behavior of variables in the limit state, infinite capacities are defined for variables of state and rate. For example, the behavior of the variable in the production of goods and capital is shown in Figures 5 and 6 in the event of an increase in depreciation rates of up to 90%. The lower curve represents changes in capital and production in the case of an increase in the rate of depreciation, in which the capital variable is close to zero over the next two years, and the production of goods will fall sharply after two years, too. Figures 7 and 8 show the behavior of the production variable and the population in the case of declining birth rates up to 0.001. The lower curves indicate the behavior of variables in the case of declining birth rates. As it is seen, the population under 15 years of age is rapidly decreasing, and after a while, this decline is transferred to the population aged 15-64. Following a decline in the population aged 15-64, labor and, consequently, the output will be reduced.

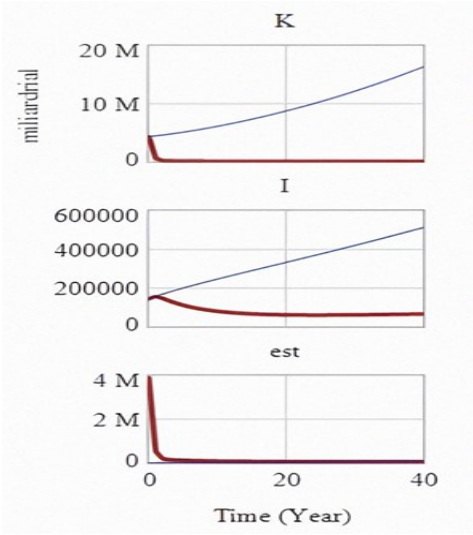

Figure 29. The behavior of the capital variable

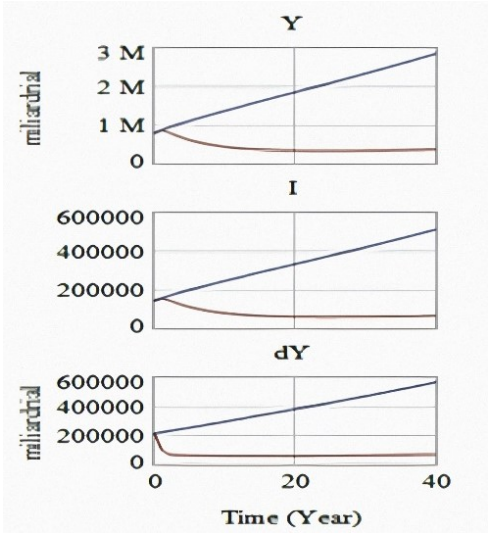

Figure 30. The behavior of the production variable

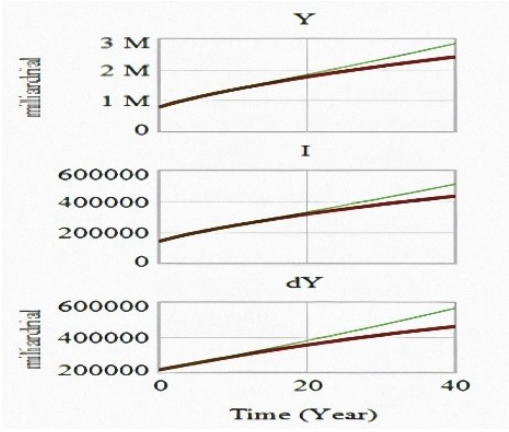

Figure 31. The behavior of the production variable

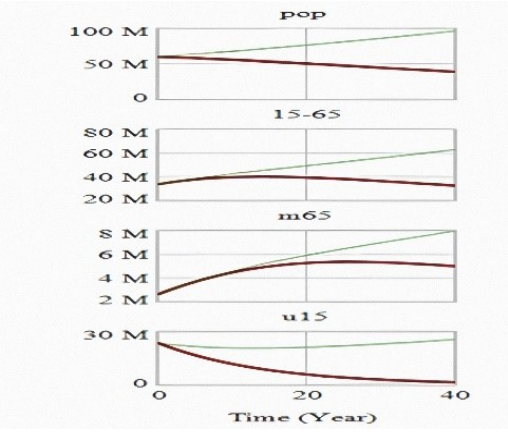

Figure 32. The behavior of the population variable

In the following, three hypotheses are examined:

Hypothesis 1: In case of an earthquake in Tehran, due to the dead, disabled and injured, part of the country's human resources will be lost and will lead to a decrease in the production of goods and the economic growth of Iran.

Hypothesis 2: In the event of an earthquake, residential houses, commercial, industrial and administrative units will be destroyed, and machines and commercial capital, and infrastructures of the region will be damaged. Therefore, reducing physical capital will lead to a decrease in economic growth, and physical capital will decrease again.

Hypothesis 3: In the event of an earthquake, savings are diverted from productive investments to damage reconstruction. Therefore, reconstruction costs will have a negative effect on economic growth.

We analyze rescue operations' impact on reducing the Tehran earthquake's devastating effects on Iran's economic growth with the origin of 2012 and assume that the earthquake happened in 2020. Required information on the severity, mortality rate, and possible damage of earthquakes in each case are derived from JICA (2001). It should note that in all scenarios, causalities were considered about the number of causalities at night. Information on possible earthquakes is shown in Table 2.

Table 20. Rey fault information (JICA, 2001)

		Ray Fault model
Length (km)		26
Width (km)		16
Moment Magnitude (Mw)		3.5
Origin	N (degrees)	35.8255
	E (degrees)	51.7392
Azimuth (Clockwise from North) (degrees)		263
Dip angle (degrees)		75
Depth of upper edge (km)		5

In the event of an earthquake in the Rey fault, the number of causalities under the debris, deaths due to injury and disease, and fires after the earthquake are shown separately in each age group, as shown in the Figures (9) to (12). The amount of labor and physical capital of the country will decrease, which will lead to a decrease in the gross domestic product. Curve 1 shows the state of Iran's gross domestic product without the occurrence of an earthquake until 2051. Curve 2 shows the effect of the reduction of labor, and curve 3 shows the effect of the destruction of physical capital due to an earthquake. Curve 4 simultaneously shows the effect of the reduction of human resources and physical capital and the reduction of production due to the cost of post-earthquake reconstructions.

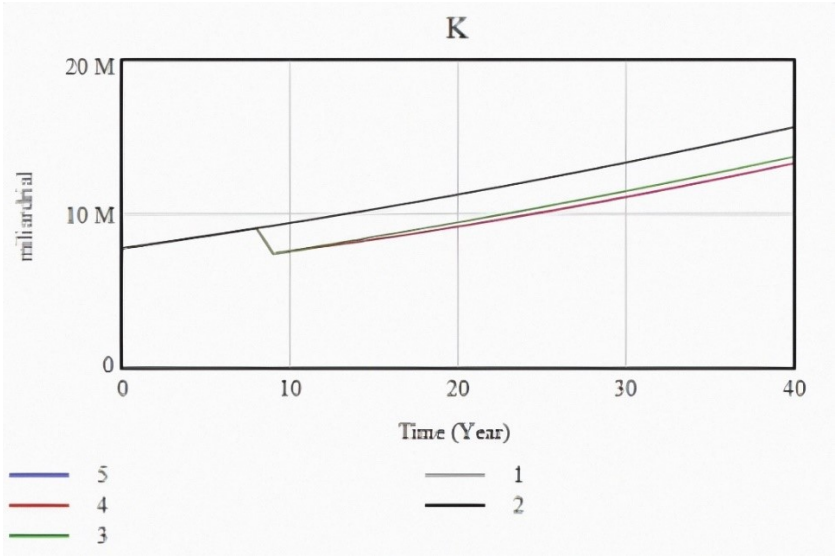

Figure 33. Behavior of physical capital in the event of rey fault earthquake

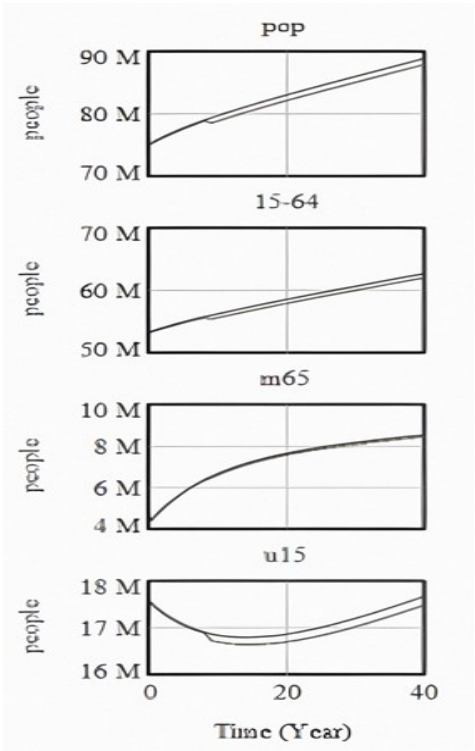

Figure 34. Behavior of the population in the event of rey fault earthquake

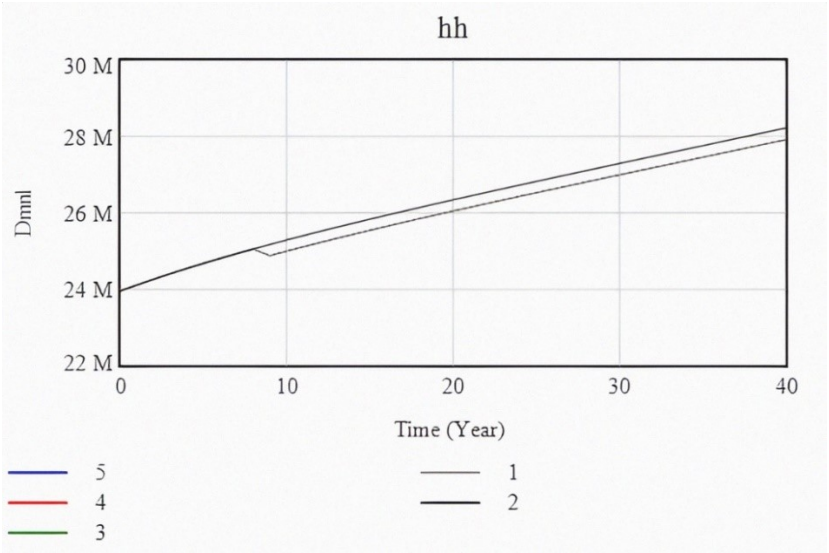

Figure 35. Behavior of labor in the event of rey fault earthquake

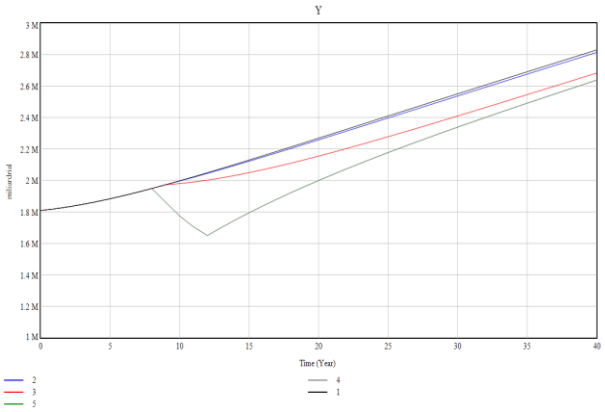

Figure 36. Behavior of economic growth in the event of rey fault earthquake

The changes made after the earthquake in physical capital, human power, population, and GDP for two scenarios are listed in the Table 3 to analyze the possible effects of the Tehran earthquake on Iran's economic growth. It should be noted that the numbers presented in the table 3 indicate the status of the variables two years after the earthquake and thirty-two years after the earthquake.

Table 21. Changes in model variables in each scenario

Variable scenario	**Population (person)**		**Labor (person)**		**physical capital (Billion Rials)**		**GDP (Billion Rials)**	
Year	2021	2051	2021	2051	2021	2051	2021	2051
No earthquake	81225300	89963800	27294200	29249500	9429480	15674400	1998240	2829450
earthquake	78972200	87991200	25699000	28601700	7573210	13274300	1775730	2625970

5. Conclusion

This study investigated the effects of a possible earthquake in Tehran's Rey fault on Iran's economic growth. The limitations of this study are assuming the stability of other conditions such as investment rate, knowledge production, birth rate, etc. Also, the Tehran earthquake's effect on the economic growth of Iran has been investigated. Therefore, the results cannot be generalized to other cities in Iran. The results show that the country's economic growth rate will decrease after the earthquake, and the negative effects of the earthquake will continue in the long term. This result is in line with research, including the study of Cavallo and Noy (2011). Due to the existence of traditional and old fabric in the south of Tehran city, the initial destruction caused by the earthquake will be severe in the Rey fault. On the other hand, rescue and relief operations will also be very difficult, so the number of causalities and damages will increase.

In this study, the occurrence of a possible earthquake affects economic growth in three ways. According to Figure 10, the population decreases due to death under debris, injuries, or the spread of infectious diseases after the earthquake. According to Figure 11, the death of the

population leads to a decrease in the active human resources of the country. According to chart 6, physical assets are also reduced due to the destruction caused by the earthquake or the fires after the earthquake. Also, in the early years after the earthquake, part of the savings are diverted towards reconstruction. Therefore, economic growth decreases. According to Figure 12, curve 2 shows human causalities, which alone do not have a significant effect on the reduction of economic growth, but its effects, along with the destruction of physical capital and reconstruction costs, will be significant on the reduction of GDP, as shown by curve 5. Therefore, all three hypotheses are confirmed. The decrease in labor caused by the earthquake in the Ray's fault will reduce the GDP by 12,000 billion Rials in 2031 and 17,810 billion Rials in 2051. The reduction of physical capital caused by the earthquake in Ray's fault will reduce the GDP by 101,900 billion Rials in 2031 and by 128,680 billion Rials in 2051. The reconstruction costs caused by the earthquake in Ray's fault will reduce the GDP by 154,880 billion rials in 2031 and by 56,980 billion rials in 2051.

Therefore, it can be concluded that the occurrence of a severe earthquake in Tehran will have a negative effect on Iran's economic growth. The results show that these negative effects will continue long-term within 30 years after the earthquake. In the early years after the earthquake, the gross domestic product will decrease by about 300 thousand billion rials, and this decrease will continue in the long term, but it will be adjusted over time. For example, 30 years after the occurrence of an earthquake, the reduction of GDP will be about 100 thousand billion rials compared to the condition of no earthquake. Therefore, paying more attention to preventive measures, risk management, and crisis management is suggested.

Disclosure statement

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

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Hypermarket Segmentation based on Lifestyle Criteria of VALS, to Identify the Customers' Requirements Using Kano Model and Prioritize Their Motivational Needs Using DANP (DEMATEL and ANP) Case Study: Daily Chain hypermarket

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ABSTRACT

The purpose of this research is to segment the hypermarket market according to the lifestyle of VALS and identify their needs. In this research, hypermarket customers were first classified according to the VALS lifestyle model; in the second step, the needs of each of the lifestyle categories were determined according to the Kano model; and in the last step, to determine the dominant lifestyle needs of store managers, the motivational needs of the dominant group were prioritized and weighted according to the three indicators of customer satisfaction, customer dissatisfaction, and implementation cost using the combination of DEMATEL and ANP techniques. To carry out the work, after identifying the needs of the customers of the store based on the theoretical basis and the opinions of the customers, two types of questionnaires were designed, and according to Cochran's formula, 400 questionnaires were distributed among the customers of the Daily Market store and 210 items were collected. In the final step, a questionnaire was given to store managers to implement the motivational needs of dominant customers so that they could prioritize the implementation of each need according to the store's facilities. The results indicated that the dominant group in this hypermarket has a hardworking lifestyle, that the features of product arrangement, appropriate behavior of employees, and clean environment are among the basic needs; diversity, quality, the performance of cashiers, the level of information of employees and neatness are among the functional needs and discounts, paper envelopes, online sales, having parking and courier are among the motivational needs for them. Also, according to the facilities and infrastructure of the store and the opinions of its managers, it was determined that the need to have a courier is one of the most important motivational needs that should be prioritized to implement and implement so that more audiences will have the desire to buy from this store.

Keywords

Market segmentation, Lifestyle, VALS model, Kano model, Customer satisfaction, DEMATEL, ANP.

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1. Introduction

Nowadays, paying attention to customers' needs and fulfilling their wishes are undeniable facts of today's business and competition world; Therefore, to earn profits and increase income, companies are forced to correctly understand the behavior of consumers and the factors that influence their buying behavior. In any market, buyers differ from each other in their needs, resources, attitudes, and buying habits. Through market segmentation, companies can achieve products and services that meet their unique needs with greater efficiency and effectiveness by dividing large and homogeneous markets into smaller categories. Market segmentation reveals the opportunities available in the company's market segmentation and is done to develop appropriate strategies for each market segment (Dehdashti and Pourhosseini, 2012). Segmentation is a tool that groups people based on their distinct needs to determine which types of consumers will be most receptive to a particular product or marketing message. These groups form a consumption model. To develop models, marketers categorize consumers based on specific sets of criteria, usually starting from demographic and geographic variables.

More complex models include psychological and behavioral variables, including attitudes, lifestyle, values, ideology, risk aversion, and decision-making patterns. Therefore, it is necessary to determine the target market of customers by identifying their lifestyles. Many companies that operate in the market research and advertising sector have presented a specific typology of style segmentation. In this division, the best and most well-known approaches and models are: activities, interests, opinions (AIO), values, attitudes and lifestyle system (VALS), and value list (LOV). In this research, considering the unique frameworks in the VALS lifestyle, this model has been used (Bakhshizadeh Borj et al., 2015).

In today's organizations, customer satisfaction is very important because customer satisfaction is the main factor and the organization's survival. For this reason, examining consumer behavior is considered very important. Paying attention to customer satisfaction and trying to improve it to create loyal customers who are responsible for promoting the business as promoters and a free marketing tool and are considered brand ambassadors. If organizations do not care about the satisfaction of their customers, they should not expect them to show interest and attention to their services and products. Providing quality services can capture the hearts and souls of customers and differentiate the brand from others. Therefore, companies must identify features of products or services that provide them satisfaction or happiness to the customer, and not providing them causes dissatisfaction in the customer. Since expectations vary from one customer to another, the features of the product or service that cause delight and those that only

prevent dissatisfaction need not be the same across market segments. Therefore, it is important to analyze the contribution of a specific product or service features to customer satisfaction or happiness on a market level (Kazemi et al., 2014). This study tries to segment a part of the hypermarket's target market using the psychological variable of lifestyle first according to the VALS model and to use the Kano model to determine the requirements of each of these segments and to implement the motivational needs. The dominant group of customers they were ranked. Therefore, at the end of this research, the following questions will be answered:

1- According to the geography of the store, what kind of lifestyle do the majority of customers of the Daily Market hypermarket have?

2- In which categories of the Kano model requirements are customers' expectations in each of the eight styles of VALS?

3- What is the prioritization of the motivational needs of the dominant group of customers for implementation?

2. Theoretical foundations and research background

2.1. Market segmentation

Segmentation is a management philosophy derived from the theory of microeconomics and the tendency towards customer requirements. Market segmentation is one of the basic principles of modern marketing. This concept was presented more than half a century ago by Smith (1956) (Mortazavi et al., 2009). Market segmentation is a wide range of methods. These methods can be divided into two main groups. The first group is based on known or observable characteristics, and the groups are selected from a community in advance and are considered as sections (such as socio-demographic characteristics, etc.); on the other hand, in the second group, post-hoc methods, multivariate analysis is used to identify sectors. To identify the segments, respondents are clustered based on their similarities on multivariate profiles. These methods include different attitudes and behavioral or personality characteristics (Hanafizadeh and Mirzazadeh, 2011).

Marketers need to better understand their customers based on their requirements and desires. Psychological is a subject that can be related to different types of customers with their differences and similarities. From the point of view of marketing, it means how, when and where people spend their money. For this purpose, market segmentation can be done based on psychological variables to gain better customer knowledge. As a marketing strategy, psychological segmentation can divide customers into different social segments and predict people's future requirements and desires. There are main variables for market segmentation,

such as geographic, demographic, psychological and expected benefits, lifestyle, etc., which will be briefly explained below:

1. Geographical Segmentation: The market is classified geographically into different regions in geographic segmentation. The company can operate in one or more geographical areas (Kotler, 2001).
2. Demographic Segmentation: In this segmentation, it means dividing the market into different groups, such as age, gender, income, occupation, and nationality. Demographic factors are the most common criteria for dividing the market into groups of different customers because often, the demands and requirements of each customer show a noticeable change due to the change in demographic variables (Kotler and Armstrong, 2005).
3. Psychological Segmentation: In this segmentation, buyers are divided into different groups based on their way of thinking, personality, or lifestyle. People in the same demographic group exhibit very different psychological characteristics (Kotler, 2001).
4. Market Segmentation based on expected benefits: Segmentation based on expected benefits focuses on the specific features of products and services that buyers consider in their purchases (Peltier and Schribrowsky, 1992).

Among the various variables that are the basis of market segmentation, some mentioned above, lifestyle is the variable used more in marketing and segmentation studies. This study's market segmentation has been done based on this variable, which will be discussed further.

2.2. Lifestyle

The concept of "lifestyle" was first used by a sociologist named Max Weber and a psychoanalyst named Alfred Adler (Cockerham, 2006). In 1960, Adler emphasized the uniqueness of people and stated that there are known similarities between people and their lifestyles (Matzler et al, 2004). In 1963 Laser introduced the concept of lifestyle to marketing (Füller Matzler, 2008) and it is based on the fact that people have specific life patterns that may affect their motives for buying products and brands (Xu and Ren, 2010). Past research has usually defined lifestyle by examining consumer attitudes, interests, and opinions. In fact, lifestyle is a psychological concept that can be presented by individual activities, way of thinking, type of life and life cycle, and functions in response to environmental stimuli, and also lifestyle can be a set of behaviors that reflect concerns individual psychological (internal beliefs) and sociological consequences (external stimuli) are defined (Yu, 2011). In general,

lifestyle can show consumers' characteristics and purchasing behavior. Also, lifestyle includes activities that spend money and time, people's interests, and opinions, including the customer's view of the surrounding environment and the world. Therefore, the lifestyle variable is related to the individual's knowledge that allows him to combine his characteristics with his behaviors (Gonzalez and Bello, 2002). In this segmentation, the best and most well-known approaches and models are Activities, Interests, and Ideas (AIO), VALS Psych mapping Lifestyle (VALS), and list of values (LOV) (Kotler and Armstrong, 2005). Segmentation (AIO) measures how people spend their time, interests, opinions, income, education, and where customers live. In VALS's method, consumers are defined based on their personality characteristics and use psychology to classify people with distinct personality traits. According to the LOV method, people have a list including nine values: self-respect, security, warm relationships with others, sense of achievement, success, sense of belonging, to be respected they observed, pleasure and happiness in life, and excitement (Afjeh and Bakshizadeh Borj, 2007). Considering the unique frameworks in the VALS lifestyle, this model has been used in this research.

2.2.1. VALS lifestyle

VALS stands for "values, attitudes, and lifestyle". As the first psychographic system based on theory, it was depicted to integrate social values into people's lives. The basic principle in VALS is that people express their personality through their behavior. VALS specifically defines consumer segments based on personality traits that influence market behavior. Eight features of the VALS model are summarized in Table 1.

Table 22.Personality classification based on VALS personality models

Row	The part	Lifestyle characteristics	Psychological characteristics	User profile
1	Innovators	Successful personal growth, Broad intellectual interests	Optimistic, extroverted, developmental, changeable, Confident	Welcome to new products Being pessimistic about advertising
2	Thinkers	Valuing travel and education, relatively active in society and politics	mature, satisfied, intelligent, To value Order and knowledge	Looking for value and durability, highly educated
3	Believers	Predictable, family-oriented, politically conservative	Traditional, cautious, ethical	Has an average income Looking for a deal
4	Achievers	Opposing too much change, formal social relations,	Goal-oriented, formal, controlled, conservative	Attracting superior products, interest in reading publications
5	Strivers	Limited interests, somewhat isolated, careless about health and nutrition, interest in new purchases	Disaffected, active, fun, looking for imitation	Buying without thinking beforehand, they prefer watching TV to reading, they usually have low education

Row	The part	Lifestyle characteristics	Psychological characteristics	User profile
6	Experiencers	Interested in sports and socializing, they like power and fame	Extroverted, active, energetic, and enthusiastic	They spend a lot of money on clothes and food, they are interested in fashion, the youngest group
7	Makers	Spending free time with family and friends.	Constructive, committed, satisfied Importance of self-sufficiency	They are not affected by sentences
8	Survivors	Their interests and activities are limited, their most important concern is safety and security, they have health problems and spend most of their time alone.	Conservative, traditional, risk-averse, and powerless	They trust advertisements, they spend most of their time watching TV, they use the Internet the least, have the lowest income, and are the oldest

2.3. The Kano model

Dr. Noriaki Kano, a professor at Rika University in Tokyo and one of the most prominent experts in the science of quality management, proposed a model that is used in most customer satisfaction models today. The Kano model develops the Traditional thinking of Quality Services. This model is useful for understanding customers' needs by identifying and classifying the quality attributes. He proposed the concept of Kano's two-dimensional quality model and a new idea with attractive and essential quality. This Model includes the four quarters and five categories. Must-be (M), One-Dimensional (O), Attractive (A), Indifferent (I), and reverse (R), which we will discuss below. The Kano Model is used to classify the features of products or services and is used as a way to fulfill the needs of customers (Tang et al., 2021).

a) Must-be factors: These are the first requirements provided in the product. Failure to approve them in the product will lead to user dissatisfaction

b) one-dimensional factors: these factors lead to satisfaction in the case of high efficiency and dissatisfaction in the case of low efficiency.

c) Attractive factors: These factors surprise the user and arouse his enthusiasm.

d) Indifferent factors: These are features that do not affect customer satisfaction.

e) Reverse factors: These features lead to customer dissatisfaction (Mamghani and Izadpanah, 2012).

Figure 1 shows kano's model and its factors. The vertical axis shows the level of customer satisfaction, and the horizontal axis shows the level of providing the quality requirements desired by the customer. The highest and lowest points of the graph's vertical axis represent customer satisfaction and customer dissatisfaction. The intersection of the horizontal and vertical axis represents the place where the customer is in a state of balance in terms of

satisfaction and dissatisfaction. The right side of the horizontal axis indicates the place where the expected quality requirement is fully supplied, and the left side of the horizontal axis is the point of providing a product that does not have the expected quality characteristics. The desired quality requirement is not included in the product or service in any way. (Lai et al., 2004).

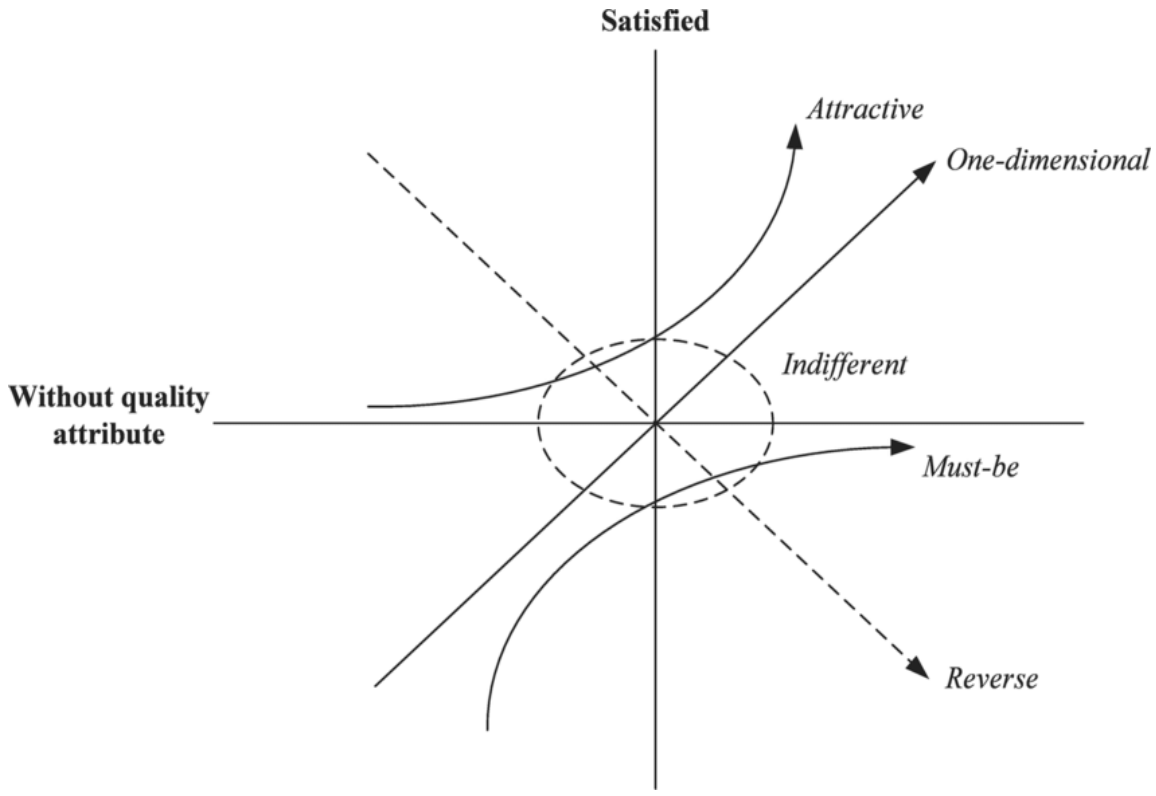

Figure 37. Kano's diagram

One of the most effective factors in prioritizing the customer's requirements is Kano's categories. (Xu et al., 2009) add about this, the ultimate goal of customer need analysis is to provide decision support for product (service) design. Although Kano's categories may improve designers' understanding of customer needs, they are not true decision-making criterion.

Therefore, Kano's classification to facilitate decision-making in product or service design priorities seems insufficient. Since decision-makers, whether they are customers or managers of the organization, are unaware of the scientific and theoretical assumptions of Kano's model, so their competence to determine the importance of Kano's main categories is questionable; moreover, in academic and scientific studies such as (Tan and Pawitra, 2001) and (Li et al., 2009) do not have the same opinions about the existence of inherent superiority among Kano's main categories. Therefore, counting the factors that enable managers based on the main business strategies seems necessary for the work of their organization to determine their importance weights. On the other hand, the importance of factors such as customer satisfaction

and dissatisfaction in prioritizing customer requirements in many studies (Berger et al., 1993), (Matzler and Hinterhuber, 1998), (Lai et al., 2004), and (Yang, 2005) has been specified and used. In addition, satisfaction and dissatisfaction factors are derived from the first dimension of Kano, which is the customer satisfaction axis. But the important factor considered in the study of Shan, Ton, and Shan is innovation in the product (service). They stated that based on the Kano model, attractive features must be implemented in the product or service to achieve an innovative product (service) (Shen et al., 2000)

2.4. Previous studies

Mortazavi et al. (2008) in their research, called the Market Segmentation of Mashhad Banks based on the Expected Benefits of Customers, examined factors such as the bank's reputation and fast and efficient service, etc. and directed them in different directions, focusing on their efforts exactly on the customers who have the highest chance to meet their expectations and demands. Kazemi et al. (2014) called laptop product market segmentation according to the segmentation based on lifestyle; VALS placed customers in seven groups of innovators, conscientious, believers, achievers, hard workers, experiencers, and creators. According to Kano's model, motivational, functional, and basic needs were determined in each group, and the level of satisfaction and dissatisfaction with each factor was also determined. Baghernjad (2019) divided travelers into seven categories, world-class, luxury relaxers, religious travelers, businessmen-professors, corporate travelers, easy Nature hunters, and adventurers. Raj and Sait (2015) divided consumers into eight VALS groups and identified their needs. This study attempts to assess a snapshot of the differences and similarities of smartphone users in a defined sample of the population and provide a glimpse into the early stages. Kim et al. (2020) divided consumers into 5 categories, fun, relaxed, inactive, prejudiced, and meditation. Target from this study use from data secondary to identification sections consumption doer older was that patterns similar from activities particle for direct object to subscription they put. Myun Kim and Kim (2020) have divided the elderly into 4 groups. Those who travel for education and those who travel for health, economic status, and marriage. Taraoktavia and Indravati (2021) divided consumers into 3 categories, quality hunting consumers, non-committed consumers, and loyal consumers. This study was conducted with the aim of analyzing the distribution of crunchy almond products in Pawanko. Ozdenerol and Seboli (2021) by evaluating market segmentation systems, divided lifestyle into 5 categories, people from the city, rural outposts., the birthplace of scientists and patriots, bachelors of middle cities, and senior styles. The

purpose of this study is to describe the relationship between lifestyle characteristics and the death rate of covid-19 in the United States and the impact of covid-19 in different cases.

According to the research background, it can be said that few studies in the field of hypermarkets have focused on segmenting the market based on the lifestyle of the waltz and identifying the requirements of customers accordingly. Also, in the studied models, the performance indicators of the studied needs have not been counted. However, first, this study tried to segment the hypermarket market based on the lifestyle of the VALS, and in order to identify the needs of the dominant groups of customers, the Kano model was used. To list the needs of customers that make them happy, implementation indicators are considered and according to them. The motivational needs of the dominant group of customers are ranked and weighted using the DANP technique (ANP method based on DEMATEL).

3. Methodology

The current research is applied in terms of purpose and survey-analytical in terms of method. Customers of one of the branches of Daily Market in Mashhad with an average purchase volume located in Elahia 7 street in 1400-1401 were selected for the statistical population. To estimate the sample size from Cochran's formula with an estimation accuracy and confidence level of 0.95, the sample size was determined to be 371 people. Due to the prediction of non-return of several questionnaires, 400 questionnaires were randomly distributed among customers, and 210 questionnaires were returned. Finally, 200 qualified questionnaires were used in the analysis process. The decision algorithm in this research is the market segmentation of hypermarket customers based on their lifestyle and determining the most important requirements of the dominant customer groups and includes the following four major steps:

1. Extracting the needs of the store's customers and checking the lifestyle of the customers according to the lifestyle of VALS
2. Investigating the relationship between customers' lifestyles and classifying their needs in the form of the Kano model
3. Determining the indicators affecting the implementation of the requirements of the dominant group of customers
4. Ranking the motivational requirements of the dominant group of customers based on the combination of DEMATEL and ANP (DANP) techniques.

Finally, the implementation steps of the proposed research process according Figure 2 are:

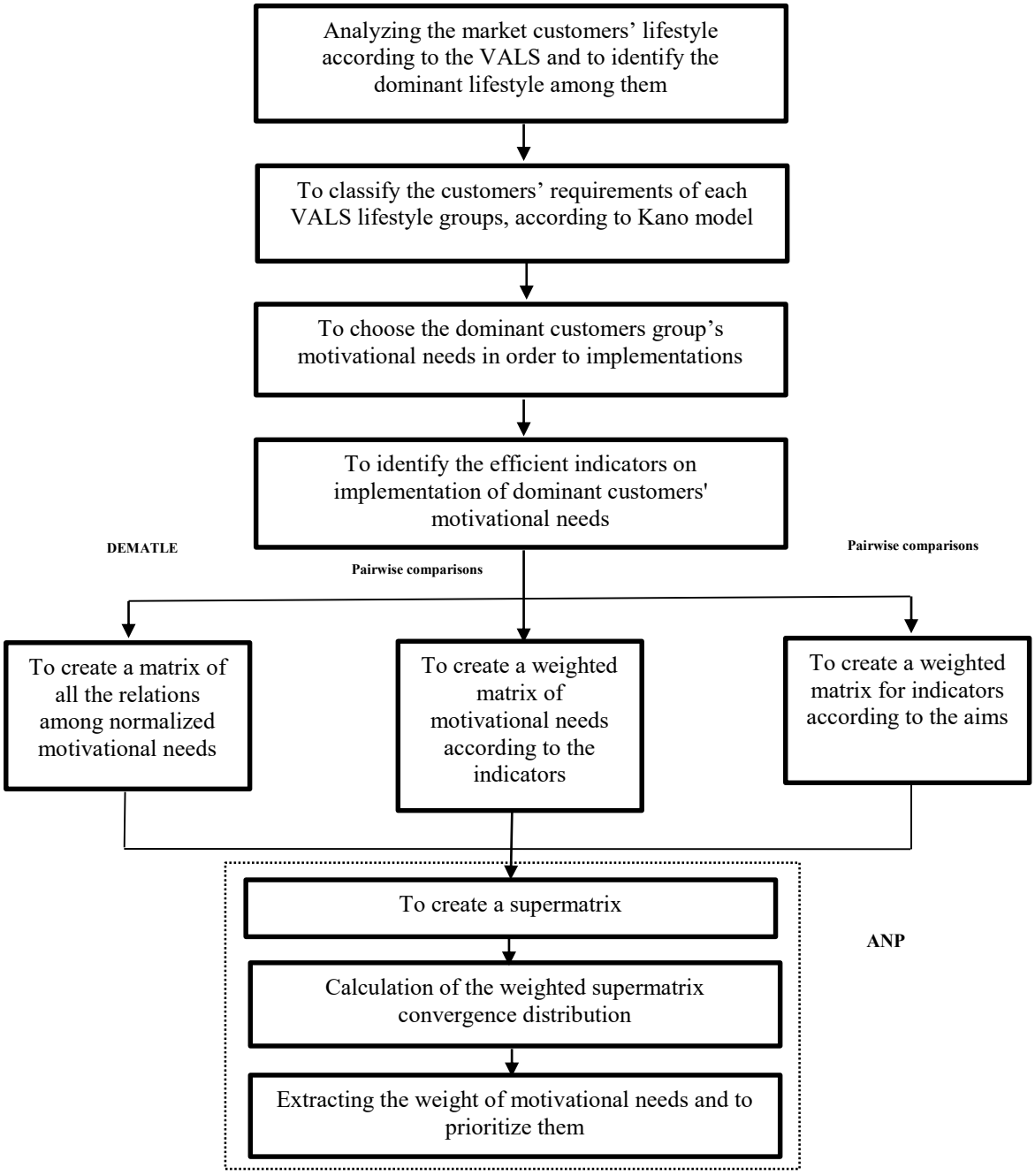

Figure 38. Research model

4. Research findings

4.1. The first stage: extracting the needs of the store's customers and checking the lifestyle of the customers according to the lifestyle of VALS

In the first step of the research, based on the theoretical foundations of studies and field research, customers' demands from a hypermarket were extracted. Then, based on the needs obtained on theoretical bases, a questionnaire was designed and given to the customers of the store, and they were asked to express the impact of these needs on repeat purchases and their

satisfaction. The needs that gained the most frequency from the point of view of the consumers of different lifestyles were extracted and became the basis of the third stage questionnaire. 15 experts and Cronbach's alpha were also used for the validity and reliability of the consumer requirements questionnaire. The list of needs identified in this step is shown in Table 2.

Table 23. Recognized needs in field research

Row	Requirement name	Row	Requirement name
1	discount	9	Arrangement of products
2	variety	10	monthly draws
3	quality	11	Having a parking lot
4	Use of paper envelope	12	employee behaviour
5	Cashiers' performance	13	Grooming of staff
6	levels of employee information	14	Having a courier
7	price	15	clean environments
8	Internet sales		

In the continuation of this step, it was determined what kind of lifestyle each customer has according to the Valls Psych mapping questionnaire and its distribution among the customers of the store. According to this classification, customers are placed in eight types of lifestyles. But because the decision to implement store programs is targeted to plan for the future actions of the most frequent lifestyle among customers, it was chosen as the target market and became the basis of decisions. VALS's questionnaire was localized to be used in the context of Iranian society using the method of translation-back-translation. To ensure face validity, this questionnaire was given to experts after translation, all of whom confirmed its validity. Therefore, it was enough to standardize the questionnaire to perform reliability and validity. Based on the obtained results, it was found that the people studied in this research were placed in seven groups of the eight categories of VALS.

Table 24. Frequencies related to the VALS category

The name of the group	Hardworking	Experiencers	Makers	Innovators	Believers	Achievers	Thinkers
Abundance	78	73	12	19	6	8	4
Percentage	39%	36.5%	6%	9.5%	3%	4%	2%

Table 3 shows the frequencies of each type of lifestyle. The results showed that in the studied subjects, the highest frequency is related to the hardworking group and the analyzing group, and the lowest frequency is related to the conscientious group.

4.2. The second stage: investigating the relationship between customers' lifestyles and classifying their needs in the form of the Kano model

At this stage, based on the output of the questionnaire from the previous stage, the Kano questionnaire (two forms of functional and non-functional needs) was developed. The customers who had completed the questionnaire of the previous stage and their lifestyle was determined, their needs were classified according to the Kano model, and the needs of the customers of each type of lifestyle were determined according to the Kano model. An analysis was done to find out the desired needs of each group, the results of which are given in tables 4 to 6.

Table 25. Classification of factors for the group of hard workers, experiencers, makers

Store features	Hardworking group	Level dissatisfaction	Level Satisfaction	Experiencers group	Level Dissatisfaction	Level Satisfaction	Makers group	Level dissatisfaction	Level Satisfaction
Mitigation	Attractive	-0.192	0.6944	Attractive	-0.414	0.6	Attractive	-0.414	0.6
Variety	One-dimensional	-0.747	0.587	One-dimensional	-0.694	0.5416	Must-be	-0.818	0.5454
Quality	One-dimensional	-0.872	0.525	Must-be	-0.79	0.4657	One-dimensional	-0.916	0.5833
Paper envelope	Attractive	-0.389	0.590	One-dimensional	-0.440	0.5932	One-dimensional	-0.444	0.7777
The performance of cashiers	One-dimensional	-0.714	0.5714	Must-be	-0.718	0.4084	Must-be	-0.909	0.4545
Level of employee information	One-dimensional	-0.658	0.5657	Must-be	-0.718	0.3239	Must-be	-0.75	0.5833
Price	Reverse			Reverse			Reverse		
online sale	Attractive	-0.432	0.6621	Indifferent			Indifferent		
Arrangement of products	Must-be	-0.628	0.4871	Must-be	-0.722	0.4583	Must-be	-0.833	0.4166
Monthly lottery	Indifferent			Indifferent			Indifferent		
Parking	Attractive	-0.372	0.5256	Attractive	-0.438	0.4931	Attractive	-0.333	0.75
Employee behavior	Must-be	-0.808	0.4615	Must-be	-0.821	0.3013	One-dimensional	1-	0.5454
Grooming	One-dimensional	-0.558	0.5324	Must-be	-0.708	0.3888	One-dimensional	-0.75	0.6666
delivery	Attractive	-0.387	0.6533	One-dimensional	-0.422	0.4507	Attractive	-0.363	0.6363
Clean environment	Must-be	-0.885	0.4615	Must-be	-0.875	0.3472	Must-be	-0.818	0.4545

The results of the table 4 show that for the first group, there are five factors in the group of functional needs, three factors in the group of basic needs, and five factors in the group of motivational needs of the Kano model. For this group, one factor was classified as indifferent needs, and one was classified as reverse needs. The column of satisfaction coefficients also shows that the "discount" factor with a coefficient value of 0.69 has the highest satisfaction coefficient (close to one) for this group, and on the contrary, the two factors, "employee

behavior" and "clean environment" have the lowest values. It has a positive coefficient (close to zero) of 0.461, which indicates the least impact on customer satisfaction if this feature is presented. The results of the customer dissatisfaction column show that the "clean environment" factor, with a value of -0.885, has the most negative number (close to negative one), which indicates that the lack of this feature has the greatest impact. It will affect the dissatisfaction of customers, and on the other hand, the "discount" factor has the lowest negative coefficient with an amount of -0.192. For the second group, there are three factors in the group of functional needs, seven factors in the group of basic needs, and two factors in the group of motivational needs of the Kano model. For this group, two factors were categorized as indifferent needs and one as inverse needs. The column of satisfaction coefficients also shows that the "discount" factor with a coefficient value of 0.6 has the highest satisfaction coefficient for this group.

On the contrary, the "employee behavior" factor has the lowest positive coefficient value of 0.3, which indicates the lowest the effect on customer satisfaction is if this feature is provided. The results of the customer dissatisfaction column show that the "clean environment" factor has the most negative number with a value of -0.875, which indicates that not providing this feature will have the greatest impact on customer dissatisfaction, in contrast to the factor "discount" has the lowest negative coefficient with -0.414. For the third group, there are four factors in the functional needs group, five factors in the basic needs group, and three factors in the motivational needs group of the Kano model. For this group, two factors were categorized as indifferent needs and one as inverse needs. The column of satisfaction coefficients also shows that the "paper envelope" factor with a coefficient value of 0.77 has the highest satisfaction coefficient for this group, and on the contrary, the "product arrangement" factor has the lowest positive coefficient value of 0.41, which indicates the least impact. It is in the satisfaction of customers if this feature is provided. The results of the customer dissatisfaction column show that the "employee behavior" factor has the most negative number with a value of -1, which indicates that not providing this feature will have the greatest impact on customer dissatisfaction, in contrast to the "parking" factor. It has the lowest negative coefficient, with -0.333.

Table 26. Classification of factors for the group of innovators, believers, and achievers

Store feature	The group of Innovators	Level dissatisfaction	Level Satisfaction	The group of believers	Level dissatisfaction	Level Satisfaction	Achievers group	Level dissatisfaction	Level Satisfaction
Mitigation	Attractive	-0.473	0.6842	Must-be	-0.75	0.25	Must-be	-0.5	0.25
Variety	Must-be	-0.947	0.4210	Must-be	-0.6	0.4	One-dimensional	-0.75	0.75
Quality	One-dimensional	-0.894	0.5789	Must-be	-0.8	0.2	One-dimensional	-0.875	0.5
Paper envelope	Indifferent			One-dimensional	-0.75	0.75	Indifferent		
The performance of the cashier	Must-be	-0.789	0.2631	Must-be	-0.6	0.2	Must-be	-0.857	0.1428
Level of employee information	Must-be	-0.789	0.3157	Must-be	-0.5	0.25	Must-be	-0.75	0.125
Price	Reverse			Reverse			Reverse		
online sale	One-dimensional	-0.473	0.5789	Indifferent			Must-be	-0.625	0.5
Arrangement of product	Must-be	-0.789	0.3684	Must-be	-0.6	0	Must-be	1-	0.125
Monthly lottery	Indifferent			Attractive	0	0.6	Indifferent		
Parking	Must-be	-0.5	0.45	Attractive	-0.4	0.6	One-dimensional	-0.5	0.625
Employee behavior	Must-be	-0.947	0.4736	Must-be	-0.8	0.2	Must-be	1-	0.125
Grooming	Must-be	-0.736	0.3684	Indifferent			Must-be	1-	0.125
Delivery	Attractive	-0.578	0.6315	Attractive	-0.166	0.5	Must-be	-0.5	0.375
Clean environment	Must-be	-0.944	0.4444	Must-be	-0.833	0.3333	Must-be	1-	0.1428

The results of the table 5 show that for the first group, two factors are in the functional needs group, eight factors are in the basic needs group, and two factors are in the motivational needs group of the Kano model. For this group, two factors were classified as indifferent needs and one factor as reverse needs. The column of satisfaction coefficients also shows that the "discount" factor with a coefficient value of 0.68 has the highest satisfaction coefficient for this group, and on the contrary, the "cashiers' performance" factor has the lowest positive coefficient value of 0.26, which indicates the least impact. It is in the satisfaction of customers if this feature is provided. The results of the customer dissatisfaction column show that the two factors, "variety" and "employee behavior", have the most negative number with a value of -0.947, which indicates that the lack of this feature will have the greatest impact on customer dissatisfaction. Compared to the two factors "discount" and "online sales" with the amount of -0.47, it has the lowest negative coefficient. For the second group, there is one factor in the functional needs group, eight factors in the basic needs group, and three factors in the motivational needs group of the Kano model. For this group, two factors were classified as indifferent needs and one as reverse needs. The column of satisfaction coefficients also shows that the "paper envelope" factor with a coefficient value of 0.75 has the highest satisfaction

coefficient for this group. On the contrary, the "product layout" factor has the lowest positive coefficient value of zero, which indicates the least impact. It is in the satisfaction of customers if this feature is provided.

The results of the customer dissatisfaction column show that the "clean environment" factor has the most negative number with a value of -0.833, which indicates that the lack of this feature will have the greatest impact on customer dissatisfaction, in contrast to the factor "monthly lottery" has the lowest negative coefficient with zero. For the third group, there are three factors in the functional needs group and nine factors in the basic needs group of the Kano model. For this group, two factors were categorized as indifferent needs and one factor as inverse needs. The column of satisfaction coefficients also shows that the "variety" factor with a coefficient value of 0.75 has the highest satisfaction coefficient for this group, and on the contrary, the four factors "employee information level", "product layout", "employee behavior" and "decoration" It has the lowest positive coefficient value of 0.125, which indicates the least impact on customer satisfaction if this feature is provided. The results of the customer dissatisfaction level column show that the four factors "arrangement of products", "behavior of employees", "decoration" and "clean environment" have the most negative number with a value of -1, which indicates the lack of provision. This feature will have the greatest impact on customer dissatisfaction and has the lowest negative coefficient compared to the three factors "discount", "parking", and "peak" with a rate of -0.5.

Table 27. Classification of factors for the thinkers group

Store features	A group of Thinkers people	Level of dissatisfaction	Level of Satisfaction
Mitigation	Must-be	-0.6666	0.3333
Variety	Must-be	-0.5	0.25
Quality	One-dimensional	-0.5	0.75
Paper envelope	Attractive	0	1
The performance of cashiers	One-dimensional	-0.75	0.5
Level of employee information	One-dimensional	-0.75	0.75
Price	Indifferent		
Online sale	Indifferent		
Arrangement of products	One-dimensional	-1	0.75
Monthly lottery	Attractive	-0.25	0.75
Parking	Attractive	-0.5	0.75
Employee behaviour	One-dimensional	-0.75	1
Grooming	One-dimensional	-0.6	1
Delivery	Attractive	0	0.75
Clean environment	One-dimensional	-1	1

The table 6 results show that for this group, there are seven factors in the group of functional needs, two in the group of basic needs, and four in the group of motivational needs of the Kano

model. For this group, two factors were classified as indifferent requirements. The column of satisfaction coefficients also shows that the four factors "paper envelope", "employee behavior", "neatness", and "clean environment" with a coefficient value of 1 have the highest satisfaction coefficient for this group. On the contrary, the "variety" factor It has the lowest positive coefficient value of 0.25, which indicates the least impact on customer satisfaction if this feature is presented. The results of the customer dissatisfaction column show that the two factors "arrangement of products" and "clean environment" with a value of -1 have the most negative number, which indicates that the lack of this feature will have the greatest impact on customer dissatisfaction. And on the other hand, the two factors "paper envelope" and "courier" have the lowest negative coefficient with a value of zero.

4.3. The third stage: determining the indicators that affect the implementation of the requirements of the dominant group of customers

In the second stage, where the results of the customers' needs were analyzed in the Kano model, it was determined how much each of the requirements affected the satisfaction and dissatisfaction of the customers. At this step, the indicators affecting the implementation of customer needs were calculated according to the opinion of store managers (experts). In this regard, three indicators of customer satisfaction, customer dissatisfaction, and the cost of achieving each need were considered. But since the store was in its introduction stage and needed to attract more customers, the research team decided to consider the motivational needs of the majority of the store's customers and, according to the indicators of implementing these needs, prioritize to implement so that the store can identify the needs that make the customer happier and put them in priority for implementation.

4.4. The fourth stage: ranking the attractive requirements of the dominant group of customers based on the combination of DEMATEL and ANP techniques

In the final step, to prioritize the implementation of each of the motivational needs of the dominant group (hardworking), the DANP method was used. Based on the nature of the problem, customers' needs are not completely independent from each other, and there are connections between them; Therefore, it is necessary to pay attention to the connections between these indicators based on a network structure. On the other hand, the DEMATEL technique has been used to determine the relationships and effective weights of each dimension and criterion.

The final output of this method is a matrix that expresses all direct and indirect relationships between indicators and motivational needs. The output of the final step of the research

determines for the store managers which requirements to prioritize based on the considered indicators that have the greatest benefit for the store. To rank the requirements of the dominant groups of customers according to the DANP model, the following actions were taken:

4.4.1. The first step: creating a network structure

According to the output of the second stage of the research, the motivational requirements of the hardworking group include discounts, paper envelopes, online sales, parking, and courier. Also, the indicators of implementing these requirements were identified with the titles of customer satisfaction, customer dissatisfaction, and the cost of implementing the requirement. Table 7 shows the symbols of motivational needs and the indicators of implementing these needs, and Figure 3 shows the structural model of the related problem.

Table 28. Symbols of indicators and motivational needs of hard workers

Symbol	**Indicator**
C_1	Satisfaction The level of
C_2	The level of dissatisfaction
C_3	Implementation cost
Symbol	**Motivational needs**
A_1	Discount
A_2	Paper envelope
A_3	Online sale
A_4	Parking
A_5	Delivery

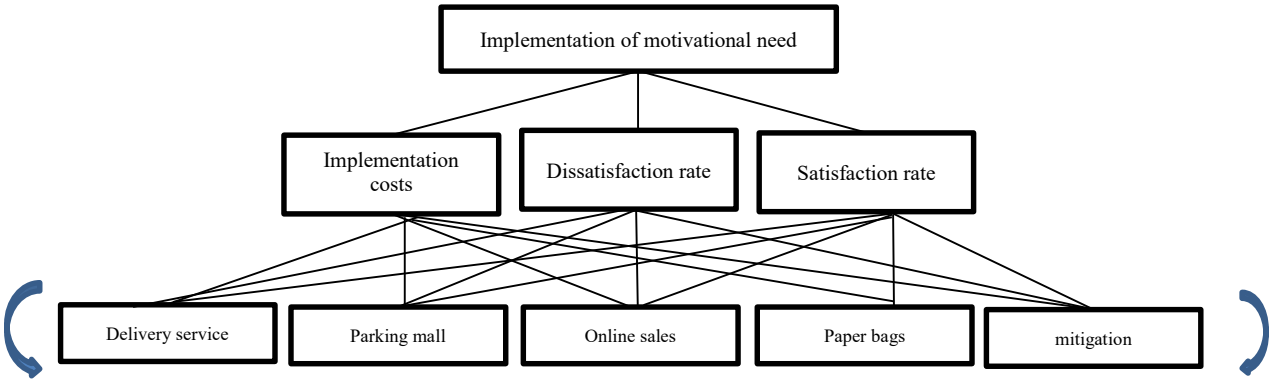

Figure 39. Attractive requirements of a hardworking group

4.4.2. The Second step: determining the overall relationships between the requirements using DEMATEL

Next, direct relationships between Attractive requirements were surveyed by store managers as experts. Then the obtained matrix was normalized, and at the last stage, the T matrix was

obtained, which indicates the intensity of direct and indirect relationships between Attractive requirements.

$$T = \begin{matrix} A_1 \\ A_2 \\ A_3 \\ A_4 \\ A_5 \end{matrix} \begin{bmatrix} 0 & 0 & 0.271 & 1.400 & 0 \\ 0 & 0 & 0.088 & 0 & 0 \\ 0.473 & 0.121 & 0 & 0 & 0.456 \\ 0.280 & 0 & 0 & 0 & 0 \\ 0.252 & 0.283 & 0.408 & 0 & 0 \end{bmatrix}$$

Table 8 shows different analyses extracted from the entire relations in the matrix. The total of rows of the elements of this matrix represents the effectiveness of each requirement, and the total of columns of the elements represents the effectiveness of each requirement. Based on the obtained results, it was found that the mitigation is the most effective, and the parking lot is the most effective. On the other hand, the mitigation item has the highest correlation with the relation (C-R).

Table 29. Determining the degree of relationship and impact of requirements

D	R	D-R	D+R
1.6712755	1.0058763	0.6653992	2.6771517
0.0881438	0.4044245	-0.316281	0.4925683
1.0508123	0.7673695	-0.2834428	1.8181818
0.2799862	1.3999309	-1.119945	1.679917
0.9436571	0.4562738	0.4873833	1.3999309

In Figure 4, the influence-relationship map (IRM) is also shown. This diagram graphically shows the relationships between different motivational needs. According to the value of C-R in the vertical axis of the diagram, it can be said that the needs for discounts, online sales, and having a courier are in the group of reasons (with a positive value of C-R), and other requirements are in the group of disabilities (with a negative value of C-R).

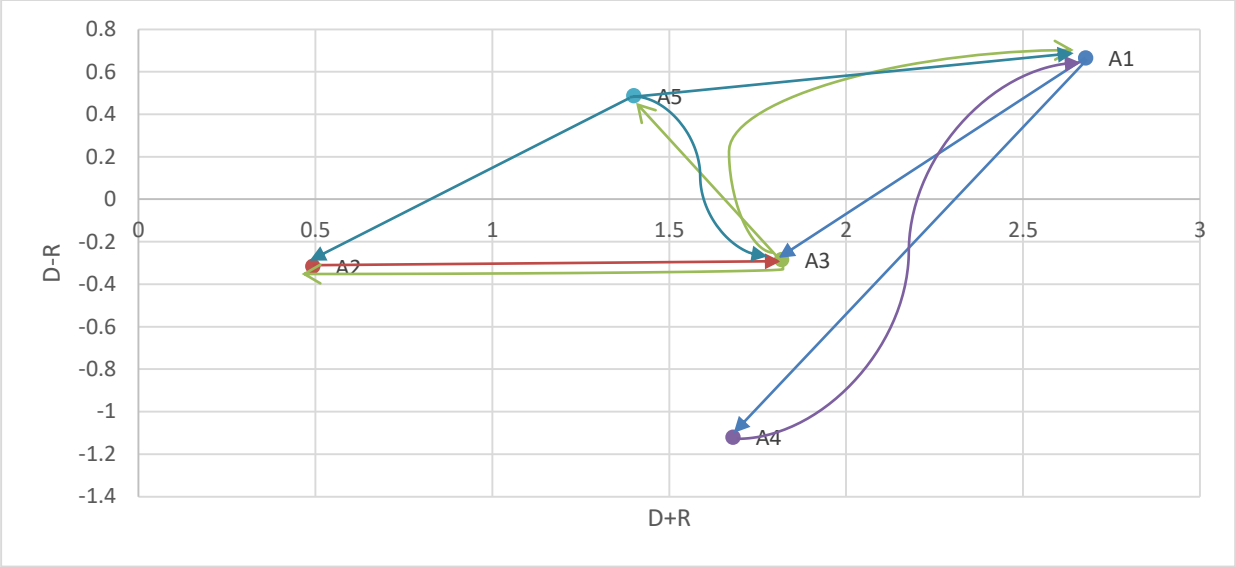

Figure 40. DEMATEL impact relationship diagram for requirements

4.4.3. The third step: forming the supermatrix

To use the total matrix of relationships in the supermatrix related to the problem, the obtained matrix T is normalized (by dividing each element by the sum of the elements of the corresponding column). Table 9 represents the supermatrix related to the structure of the problem, in which the matrix of the relative weights of the indicators based on the goal, the matrix of the total relations between the normalized requirements, and the matrix of the relative weights of the requirements relative to the indicators are specified next to each other.

Table 30. Initial supermatrix

	Goal	C_1	C_2	C_3	A_1	A_2	A_3	A_4	A_5
Goal	0	0			0				
C_1	0.107	I			0				
C_2	0.776								
C_3	0.117								
A_1	0	0.621	0.341	0.061	0	0	0.354	1	0
A_2		0.053	0.053	0.027	0	0	0.115	0	0
A_3		0.224	0.458	0.205	0.471	0.300	0	0	1
A_4		0.037	0.088	0.474	0.278	0	0	0	0
A_5		0.064	0.061	0.233	0.251	0.701	0.531	0	0

Since the sum of the elements of the columns of the supermatrix, in some cases, is more than one; Therefore, in table 10, each element is divided by the total of the corresponding column.

Table 31. Normalized supermatrix

	Goal	C_1	C_2	C_3	A_1	A_2	A_3	A_4	A_5
Goal	0	0	0	0	0	0	0	0	0
C_1	0.107	0	0	0.5	0	0	0	0	0
C_2	0.776	0	0.499	0	0	0	0	0	0
C_3	0.117	0.500	0	0	0	0	0	0	0
A_1	0	0.311	0.170	0.0305	0	0	0.354	1	0
A_2	0	0.0265	0.0264	0.0135	0	0	0.115	0	0
A_3	0	0.112	0.228	0.1025	0.470	0.300	0	0	1
A_4	0	0.018	0.0439	0.237	0.279	0	0	0	0
A_5	0	0.032	0.0304	0.116	0.251	0.700	0.531	0	0

Finally, the weighted supermatrix is brought to power until its normal distribution reaches convergence. As it is clear from the following relation, the convergence of the weighted supermatrix has been established in the sixteenth power. Table 11 shows the results of this supermatrix.

Table 32. Convergent weighted supermatrix

	Goal	C_1	C_2	C_3	A_1	A_2	A_3	A_4	A_5
Goal	0	0	0	0	0	0	0	0	0
C_1	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418	0.0418
C_2	0.249	0.249	0.249	0.249	0.249	0.249	0.249	0.249	0.249
C_3	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
A_1	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176	0.176
A_2	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
A_3	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144	0.144
A_4	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064
A_5	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229

4.4.4. The fourth step: extracting the weight of requirements and ranking

The weights related to attractive requirements can be extracted based on the final matrix obtained. As shown in Table 12, having a courier has the most weight and importance for the customers of this store. Other priority requirements include mitigations, online sales, parking, and paper envelopes.

Table 33. Prioritization of attractive indicators and requirements

Attractive requirements	Rank
A1	2
A2	5
A3	3
A4	4
A5	1

5. Discussion and conclusion

In this research, 15 characteristics were investigated in general, and 10 factors were obtained through field research, which include discounts, variety, cashiers' performance, employee behavior, online sales, product layout, quality, parking, courier, and clean environment. Five factors were also obtained through library studies which include monthly lottery, paper envelope, price, level of information of employees, and grooming of employees. In the following, the customers of this store were classified according to the VALS lifestyle pattern, and according to the results, more than 75% of them have a hardworking or disintegrating lifestyle.

In the next step, all the needs of customers with different lifestyles were examined, and their needs were determined according to the Kano model. In the end, to meet the needs of the dominant customers, three indicators of the level of customer satisfaction, the level of customer dissatisfaction, and the cost of implementing each need were set as indicators considered by the store managers, and based on these indicators, the needs of the dominant customers were ranked (hard lifestyles). It should be mentioned that due to the new nature of the store and the need to attract the attention of its customers, only the motivational needs of the hardworking group, who were among the dominant customers of the store, were evaluated and ranked using the combination of DEMATEL and ANP techniques. The results of this ranking indicate that having a motor courier has the greatest effect on making the customers of this store happy and willing to buy. Other motivational needs include discounts, online sales, parking, and paper envelopes. According to the obtained results, in the first stage, managers should set up a courier for the store to have the greatest impact on sales growth. Also, because the dominant style of the customers is hard workers, paying attention to all the basic and functional needs of this type of customer should be prioritized in the store's executive plans.

In this research, in addition to the fact that the needs of the customers have been calculated, attention has also been paid to the level of implementation and the priority of their implementation, which has not been paid attention to in other studies. The results of this study can help store management to go through its growth phase as quickly as possible and attract more customers.

Disclosure statement

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

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