Analysis of the sharing economy effect on sustainability in the transportation sector using Fuzzy cognitive mapping[1]

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ABSTRACT

Along with the significant growth of the sharing economy in recent years, its effect on the economy, society, and the environment at the level of governments, academic communities, and researchers has been widely discussed. One of the main debates is identifying the side or negative effects of the sharing economy as well as its positive effects. Studying the cause-effect relationship of the variables affecting sustainability in the sharing economy context can provide valuable results for firms. For this purpose, fuzzy cognitive maps have been used. Based on the literature review, the sharing economy's essential variables that affect sustainability were identified, and using the Fuzzy Delphi method, these variables were localized. Snapp and Tap30 were selected as two of the largest platforms in the Iranian transportation sector. Fuzzy cognitive maps based on aggregated opinions of experts were inputted to the Mental Modeler online software to drawn the cognitive map of this research. The degree of centrality index, i.e., the summation of input and output degree, was used to identify the most relevant sustainability variables. Consequently, the incentives to make a greater use of the platform, the income of drivers, the monopoly power of platforms, the price of services, the higher service quality of platforms, the use of private vehicles by passengers, and the change of traffic in cities were identified as variables with the greatest effect on stability. Four positive loops and one negative loop were identified among these seven variables in the cause-effect analysis. In the final section, some suggestions are presented based on each loop.

Keywords: Sustainability, Sharing economy, Transportation sector, Fuzzy Delphi Method, Fuzzy Cognitive Mapping

1- Introduction

Sharing is not a new phenomenon emerging in recent years. Throughout history, commodities and assets have always been shared with family, friends, and neighbors. The new sharing concept is the development Information and Communication Technology (ICT) infrastructures and consequently the formation of digital platforms which allows sharing goods and services between people who do not know each other and are at different locations (Pouri and Hilty, 2018; Sabitzer

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et al., 2018). The sharing economy facilitated peer-to-peer interaction to share resources and assets by developing new technologies such as open-source software and Web 2.0, which has now thrived in many countries. A host of successful emerging startups have adopted this new economic model and established huge businesses with significant revenues in an unexpectedly short period (Hasan & Birgach, 2016). By 2025, sharing economy-based businesses are projected to account for $335 billion of the global revenue. This is mainly because some traditional businesses are being replaced by new business models in the context of the sharing economy (Muñoz & Cohen, 2017).

The sharing economy has changed how products and services are used by substituting ownership with the idea of access (Ciulli and Kolk, 2019; Martin et al., 2019; Paundra et al., 2020). From the business model perspective, the sharing economy refers to business models in which interactive platforms facilitate activities. These platforms create an open market that grants individuals temporary access to offered goods or services (Murillo et al., 2017). The sharing economy helps expand the utilization of durable assets by recirculation (Ranjbari et al. 2018), and the redistribution of resources and assets, which might not be frequently used to their full potential by swapping access with the ownership for consumption (Bartenberger & Littner, 2013). Also, the sharing economy has been introduced as an infrastructure to serve all capacities and resources available in the economy and businesses (Hasan & Birgach, 2016) by sharing and co-using underutilized, idle, and untapped resources (Muñoz & Cohen, 2017; Laczko et al., 2019; Zheng and Song, 2019; Grondys, 2019; Yu et al., 2020). According to different definitions of the sharing economy, some essential characteristics can be identified. Some of these characteristics include non-ownership of products or assets, peer-to-peer exchange, temporary access by borrowing or renting, optimized use of the idle or underutilized capacity of physical assets, online platforms for sharing, and network-based activities based on trust (Ma et al., 2019; Liu and Chen, 2020).

Sustainable development, as a macroeconomic concept, is a process that, along with economic growth, aims to ensure sustainable development beyond economic development. At the microeconomic level, from the mid-twentieth century, there has been a mounting pressure on large organizations to pay attention to sustainability and accountability for the overall performance outcomes that are beyond financial performance (Lee & Saen, 2012; Heydari et al., 2021; Kannan, 2021). Sustainability is defined as creating a conscious balance between economic development, environmental protection, and social justice at both organizational and macroeconomic levels (Carter & Rogers, 2008). One of the common approaches to describing sustainability concept is the Triple Bottom Line (TBL) approach, which encompasses three economic, social, and environmental aspects (Muñoz et al., 2019). TBL, introduced by Elkington (1997), uses the terms *profit*, *people*, and the *planet* to describe the three pillars of sustainability. In addition to this term, a number of similar terms such as dimensions, components, aspects and perspectives have also been proposed in the literature. Some studies have also considered other institutional, cultural, and technical dimensions for sustainability (Purvis et al., 2019). This study uses the TBL approach and the term dimension to describe sustainability factors at economic, social, and environmental dimensions. Our review of related articles suggests that divergent use of the term sustainability in most of studies. For example, many studies have only focused on environmental or social dimension, while others have considered social and economic dimension together (Carter & Rogers, 2008; Alhaddi, 2015; Govindan et al., 2021). The TBL approach considers all three dimensions in a balanced manner by attaching the same importance to all of them. In light of the above, the TBL approach has been adopted in our research. Sustainability, as a way of exploiting resources without risking the needs of future generations for such resources, is associated with the idea of sharing economy that replaces access with ownership (Cohen and Munoz, 2016).

As the sharing economy expands in sectors such as transportation, its complexity and impact on society, economy, and environment have undergone changes (Ma et al. 2019). Most studies have addressed the positive effects of sharing economy on the economy, workforce, society, the organizational stakeholders, and the environment. It can be posited that the sharing economy offers new alternatives for existing consumption models (Pouri and Hilty, 2018) and promotes a sustainable consumption model (Ciulli and Kolk, 2019; Curtis and Mont, 2020). Sustainable consumption minimizes adverse environmental impacts so that today's needs of humans are met along with the needs of the future generations. The positive effects of sharing economy have been explored in the literature but scant attention has been paid to its negative effects. Curtis and Mont (2020) noted that the sharing economy is not sustainable per se, and it is a proper business model design that ensures its sustainability. For instance, by the sharing economy growth, free monetary capitals can be redistributed in the society by reducing the sum of money spent on the asset ownership. The distribution of these monetary resources can increase the consumption of services and assets shared in the sharing economy and therefore decrease the economy's resources (Geissinger et al., 2019).

Based on the literature review, we identified the following research gaps. 1) Some articles have discussed positive or negative effects of the sharing economy on sustainability separately, but an inter-related analysis of these effects has not been performed. 2) There is a lack of research on the causal relationship of sustainability variables with Fuzzy Cognitive Mapping (FCM). 3) In most articles, only a single sustainability dimension, such as environmental or economic dimensions, has been considered, and few studies have addressing the three dimensions of the sustainability simultaneously.

The causal relationships of variables in each of these three dimensions could be positive or negative. It means that a variable can exert only positive effects on each dimension, but at the time induces negative effects by considering its cause-effect relationships with other variables. For instance, in the transportation sector, the sharing economy may increase employment rate (positive effect) and the rate of car access for passenger transportation (positive effect). On the other hand, it can reduce travelers' motivation to use public transportation (negative effect), which will increase traffic in cities (negative effect) and therefore exacerbate environmental pollution (negative effect).

In light of the identified research gaps, it can be concluded that the main contributions of this study are identifying variables, which in the context of the sharing economy in the transportation sector, have a positive or negative effect on economic, social, and environmental dimensions of sustainability. In addition to identifying these variables in Iranian transportation sector, we will discuss their negative or positive cause-effect relationships, which to the best of our knowledge, has not been addressed in the literature. Identifying the causal relationships and consequently the essential variables that wield considerable impacts on other variables a can help business managers for tackle and control these variables to maximize the level of sustainability in this industry. For this purpose, to identify the key variables and their place in the transportation sector of Iran, the Fuzzy Delphi Method (FDM) has been used. Moreover, FCM has been used to identify the cause-effect relationships

Based on the research contribution, the main research questions are as follows:

- What are the variables that can positively or negatively affect sustainability in the sharing economy within the transportation sector?
- What are the causal relationships between the economic, social, and environmental dimensions of these variables in the sharing economy within the transportation sector?
- What are the most critical variables that can significantly influence sustainability in the transportation sector within the sharing economy context?

The rest of the study is structured as follows. In Section 2, the related literature is reviewed to identify the major positive and negative effects of the sharing economy on sustainability in the transportation sector. The research methodology, including the explanation of FDM and the FCM, is presented in Section 3. In Section 4, the results of the FDM and the FCM implementation are explained. Finally, Section 5 concludes by discussing the results and their managerial applications as strategies to maximize sustainability in the transportation sector. The steps of this research are shown in Fig. 1.

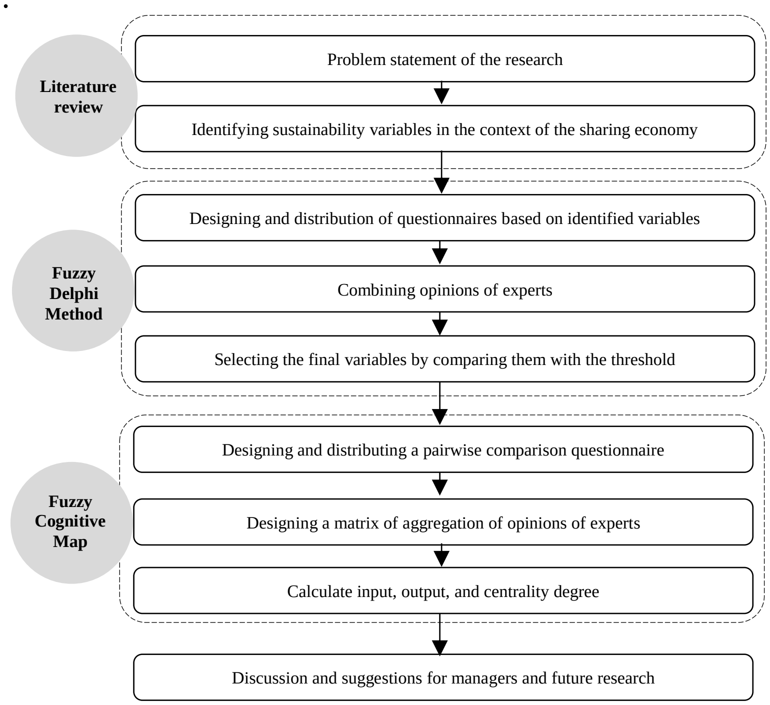

Figure 1. The steps of this research

2- Literature Review

The relationship between the sharing economy and sustainability in recent years has been the subject of considerable academic debate (Sabitze et al., 2018; Curtis and Mont, 2020; Liu and Chen, 2020; Paundra et al., 2020). The literature review suggests that this relationship could be classified into positive and negative effects of the sharing economy on sustainability, as described below.

2-1- Sharing economy's positive effects on sustainability

The positive effects of sharing economy on sustainability have been well documented in the relevant literature. The studies that have investigated sharing economy from an environmental perspective stress its positive environmental effect owing to a variety of reasons, including extended span of utilizing assets, buying the access rather than the product and exploiting the idle capacity of existing assets (Paundra et al., 2020). On the other hand, due to the reduced need for new products and hence shrinking production, the sharing economy can reduce energy consumption and consequently decrease greenhouse gas emissions (Hamari et al., 2016).

From an economic standpoint, the sharing economy can decrease the waste of resources and promote maximum economic efficiency by replacing ownership with the possibility of access and redistribution of resources that are not usually exploited to their full capacity (Ganapati and Reddick, 2018; Jin et al., 2018; Ciulli and Kolk, 2019; Leung et al., 2019; Liu and Chen, 2020;). The growth of sharing economy will cultivate prosperity in entrepreneurial activities (Ciulli and Kolk, 2019; Leung et al., 2019). Such growth can bolster local economy and improve wealth distribution (Miller, 2016; Verboven and Vanherck, 2016). Other positive socio-economic effects of the sharing economy include strengthening the purchasing power of consumers, decreasing the transaction and information costs, facilitating efficient supply and demand coordination in the market (Verboven and Vanherck, 2016; Jin et al., 2018), expanding the product life cycle (Rong et al., 2018), providing greater flexibility for users and customers (Leung et al., 2019) improving the service quality (Pouri and Hilty, 2018; Govindan et al., 2020), fostering trust in society and creating social values (Ciulli and Kolk, 2019).

2-2- Sharing economy's negative effects on sustainability

It is noteworthy that the sharing economy also has some unintended negative effects (Verboven and Vanherck, 2016; Sabitzer et al., 2018; Martin et al., 2019; Govindan et al., 2020; Liu and Chen, 2020; Paundra et al., 2020). These unintended negative effects are named the "sustainability paradox" or the "paradox of sustainable development" (Verboven and Vanherck, 2016). The sharing economy creates "unregulated markets" characterized by unfair competition, risk transfer, and tax evasion (Martin, 2016). The sharing economy can also be disruptive for its traditional competitor. Most of the sharing economy services were previously provided by traditional competitors, creating intense competition within businesses operating in the sharing economy and traditional businesses (Demailly and Novel, 2014; Miller, 2016). Miller (2016) pointed out that the blue ocean market established on the sharing economy platform will spontaneously turn toward a red ocean with fierce competition when the legal adaptation and acceptance of platform businesses occur. In addition to the direct negative effects of the sharing economy, its indirect negative effects should be considered. For instance, in the transportation sector, increasing the purchasing power of people can create more demand for using the sharing transportation services, and this factor can increase the demand for more extensive use of cars, which leads to more greenhouse gas emissions (Schor, 2016). Furthermore, the increasing growth of ridesharing can cause traffic congestion in the cities and, consequently, increase the pollution rate and cause lower public transportation utilization by travelers (Martin et al., 2019).

2-2- The industry studied in this research

The industry studied in this research is the transportation sector, which according to Petropoulos (2017), is one of the four main areas of the sharing economy. Also, the main focus in the transportation sector is passenger transportation. Passenger transportation in one categorization can be classified into two groups based on the ownership or non-ownership of the assets. In the first group, businesses own the assets such as cars, motorcycles, bicycles, and scooters and provide short-term rental services for passengers. Examples of these businesses are Zipcar, EasyCar, Car2go. The second group are the businesses that operate as intermediaries to help people share their assets with others without owning any of those assets. BlaBlaCar, Lyft, and Uber are examples of these businesses (Ambrosino et al., 2016; Casprini et al., 2019; Ćurlin et al., 2019). Based on this categorization, the organizations considered in our study are from the second group. For businesses in the passenger transportation sector that operate in the sharing economy, different titles such as car sharing, ride-sharing, ride hilling, and carpooling have been used in the literature. In this research, the authors considered the ride-sharing model with Uber as one of its most well-known examples. We define ride-sharing as follows; the ride-sharing model matches passengers who need transportation services with drivers who use their personal vehicles in the form of a website or app (Kooti et al., 2017; Long et al., 2018).

2-3- Review of the past studies

The effects of the sharing economy business model on society, economy, environment and stakeholders have been studied in the literature. In a simple classification, the literature on sharing economy and sustainability can be classified into two categories. The first category are the studies that have concentrated only on the positive effects of the sharing economy, while the second category are the papers that have simultaneously paid attention to both positive and negative effects. Following studies belong to the first category. Heinrichs (2013) stated that the sharing economy is a new route that leads to sustainability. In order to evaluate and create values for the business models of the sharing economy and to examine their sustainability effects, Bocken et al. (2014) provided a framework in which they listed indicators such as minimizing energy and water consumption, maximizing social and environmental benefits instead of prioritizing economic growth, and adopting a closed-loop approach. Verboven and Vanherck (2016) and Miller (2016) mentioned some positive effects and recognized features such as increasing purchasing power for consumers, reducing costs of the transaction, strengthening social interactions, and creating positive emotions due to consumers' help for each other. Some of the other positive effects are excellent adaptation of market supply and demand, higher life cycle of the products, greater flexibility for customers, improved service quality and growth and revival of the local economy for sharing economy. Amatuni et al. (2020) regarded car sharing as one of the approaches that can reduce greenhouse gas emissions in the transportation sector. Therefore, they proposed a comprehensive forecasting model based on Life Cycle Analysis (LCA) to estimate the total change in annual greenhouse gas emissions after implementing the car-sharing model in selected cities.

In the second category, some other researchers, such as Martin (2016), have spoken skeptically about the impacts of the sharing economy and have presented several negative effects for these newly formed business models. Problems related to work license, unclear accountability of employees and the parties in the platform businesses, regulations related to fixed and variable wages of employees and the method of its calculation, lack of transparency in accountability, low employment quality of employees and staff are some of the significant challenges related to the social dimension of the sharing economy (Miller, 2016; Verboven and Vanherck, 2016). Pouri and Hilty (2018) employed life cycle analysis and the model for structural impacts to investigate the sharing economy's sustainability potentials. Liu and Chen (2020) asserted that it would not necessarily have positive environmental results despite the sharing economy's very high flexibility. They accentuated the need for the government's attention to legislation to maximize the positive effects of the sharing economy on sustainable development. They also offered some suggestions for legislation in each supplier and consumer section and the platforms' operating activities to make the business models as sustainable as possible. Sabitzer et al. (2018) examined the conflicts created in a community that has experienced sharing models and proposed some strategies and solutions, suggesting that government laws can reduce these conflicts. Using a system dynamic modeling approach, Luna et al. (2020) investigated the impacts of implementing the e-car sharing scheme on carbon emissions. They also mention that the role of the government in e-car sharing schemes is essential. Paundra et al. (2020) asserted that car-sharing platforms at the initial entry to a market have positive environmental impacts because access-based consumption reduces traditional car ownership. They believed that the effect of "access-induced ownership" will replace with the effect of "access-replaces-ownership" and create an overall negative environmental impact in the long run. Cui and Aziz (2019) conducted a case study on the Uber platform in which they examined the advantages and disadvantages of the sharing economy, considering both supplier and consumer dimensions in the platform. Among the identified positive effects, the efficiency of resources and assets were identified as the most critical positive factors, and security and regulatory issues were identified as two of the most important negative factors.

Table 1 is extracted from the literature on sustainability and sharing economy from 2015 to 2020, which was reviewed. Based on this, 33 variables were identified. These variables were classified into three economic, social, and environmental categories, based on Carter and Rogers (2008).

Table 1
Sustainability variables extracted from the literature review in sharing economy context

Dimensions of sustainability	Variables	Article

1	Economic dimension	Creating monopoly power by platforms	Leung et al. (2019); Pouri and Hilty (2018); Schor (2016); Verboven and Vanherck (2016)
2		Competitiveness of traditional competitors against platforms	Gurău and Ranchhod (2020); Acquier et al. (2019); Ma et al. (2019); Leung et al. (2019); Ganapati et al. (2018); Pouri and Hilty (2018)
3		The income of drivers that work in the platform	Schor (2016); Ganapati et al. (2018); Leung et al. (2019); Ciulli and Kolk (2019); Govindan et al. (2020)
4		Price of services provided by platforms compared to traditional competitors	Gurău and Ranchhod (2020)
5		Transportation costs in the portfolio of households using platform services	Daunorienė et al. (2015)
6		Higher service quality of platforms than traditional competitors in the passenger transport industry	Daunorienė et al. (2015); Schor (2016); Verboven and Vanherck (2016); Pouri and Hilty (2018); Leung et al. (2019); Govindan et al. (2020); Gurău and Ranchhod (2020);
7		Ease of entering into the labor market for drivers	Hasan and Birgach (2016); Acquier et al. (2017); Ciulli and Kolk (2019); Leung et al. (2019)
8		Creating jobs in the economy and reducing the unemployment rate	Leung et al. (2019)
9		Strengthening the local economy due to job creation	Miller (2016); Verboven and Vanherck (2016); Leung et al. (2019)
10		The flexibility of work for drivers	Hasan and Birgach (2016); Verboven and Vanherck (2016); Pouri and Hilty (2018); Ciulli and Kolk (2019); Leung et al. (2019)
11		Improving access to transportation in low-density areas	Jin et al. (2018)
12		More efficient use of existing assets (car in this research)	Ganapati et al. (2018); Ciulli and Kolk (2019); Mi and Coffman (2019); Gurău and Ranchhod (2020)
13		Increasing the life cycle of assets (car in this research)	Verboven and Vanherck (2016); Rong et al. (2018)
14		Lack of a clear mechanism for collecting taxes from platforms in the transportation sector	Verboven and Vanherck, (2016); Ganapati and Reddick (2018); Acquier et al (2019); Gurău and Ranchhod (2020)
15		Disrupting of existing regulations of the passenger transport industry	Ganapati and Reddick (2018)
16		The inefficiency of current laws in the transportation sector	Verboven and Vanherck, L. (2016); Acquier et al (2019); Leung et al. (2019); Govindan et al. (2020)
17	Social dimension	Low job security for drivers	Verboven and Vanherck (2016); Ciulli and Kolk (2019); Leung et al. (2019)
18		Feeling of job instability for drivers	Leung et al. (2019)
19		Lack of medical support and unemployment insurance for drivers	Hasan and Birgach (2016); Ganapati and Reddick (2018)
20		lack of drivers' legal rights and classification of workers under labor law coverage	Verbove and Vanherck (2016); Bajwa et al. (2018)
21		Excessive working and burnout of drivers	Wood et al. (2019)
22		No job promotion for drivers	Bajwa et al. (2018)
23		Social interactions at the community level	Hasan and Birgach (2016); Schor (2016); Verboven and Vanherck (2016); Pouri and Hilty (2018); Rong et al. (2018); Ciulli and Kolk, 2019; Leung et al. (2019)
24	Environment dimension	Motivation to make more use of the platform	Ganapati et al. (2018); Jin et al. (2018); Pouri and Hilty (2018); Hasan and Birgach (2016); Schor (2016); Verboven and Vanherck (2016); Ciulli and Kolk (2019); Gurău and Ranchhod (2020)
25		Public transport use	Jin et al. (2018); Pouri and Hilty (2018)
26		Traffic rate in cities due to reduced use of public transport	Acquier et al. (2019)
27		Demand for cars to enter the platform	Gurău and Ranchhod (2020)
28		More usage of transportion industry because of improving security for passenger	Jin et al. (2018)
29		Reducing the negative effects on the environment due to the reduction of new car production and consumption of raw materials at the macro level	Daunorienė et al. (2015); Ganapati et al. (2018); Ma et al. (2019); Mi and Coffman (2019); Amatuni et al. (2020); Govindan et al. (2020); Luna et al. (2020);
30		Demand for buying new cars by passengers due to the use of the platform	Jin et al. (2018); Sabitzer et al. (2018)
31		Reducing waste production due to less car production	Sabitzer et al. (2018)
32		change of traffic rate in cities and thus the effect on pollution	Hasan and Birgach (2016); Acquier et al. (2019)
33		The use of private cars by passengers	Hasan and Birgach (2016)

3- Research methodology and design

3-1- Fuzzy Delphi Method (FDM)

The Delphi Method (DM) was developed by Dalkey and Helmer (1963) based on the opinions of experts survey method (Ocampo and et al., 2018). In 1950, DM was initially used for technological forecasting at the Rand Corporation (Ahmad and Wong, 2019). The crisp number cannot be accurately represented to quantitative values due to the vagueness and imprecision of the real-world and human preferences' subjective nature in many decision-making situations (Kannan et al., 2014, Chen et al., 2021). Fuzzy Delphi Method (FDM) is a compound of the DM and Fuzzy Set Theory (FST) developed by Ishikawa et al. (1993). Zadeh (1965) introduced the FST to respond to the vagueness of human judgment and preferences in complex decisions making situations. The FST can be used in uncertain situations and cases where human language cannot accurately describe or measure that situation to resolve the problem successfully (Geramian et al., 2018; Ocampo et al., 2018).

One of the FDM's most common uses in various fields is to select appropriate variables among the available variables (Lee and Seo, 2016) and to validate the results from the study conducted in the past (Ahmad and Wong, 2019). In this research, FDM has been used to select the essential sustainability variables identified from the literature review in the transportation sector based on the opinions of experts in Iran. Based on Bouzon and et al. (2016), we use the following three steps to implement FDM in this research.

- *S1:* identifying research variables by using a systematic literature review and theoretical foundations of the last researches
- *S2*: gathering and aggregating the opinions of decision-making experts. In this step, after identifying the research variables, the opinions of experts are collected using a designed questionnaire by the researchers. Based on this, linguistic variables will be used to collect each variable's importance, presented in Table2 and Fiq2.

Table 2
Language variables and Triangular Fuzzy Number (TFN) used in FMD

Linguistic Variables	TFN
Without any importance	(0, 0, .25)
not important	(0, .25, .5)
Moderate	(.25, .5, .75)
Important	(.5, .75, 1)
High Important	(.75, 1, 1)

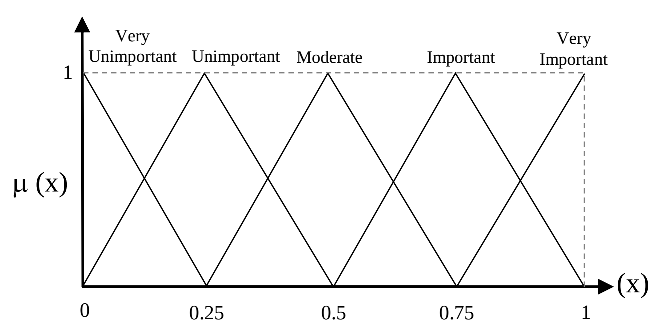

Fig 2. Triangular fuzzy membership function

- *S3:* This step is done by comparing each variable's acquired value with the threshold value (Z). The threshold value is determined by the mental inference of decision-makers and will directly affect the number of variables selected. After receiving each expert's opinion, language variables will be converted to fuzzy numbers using triangular fuzzy membership functions (Eq.1). Since opinions of a group of experts have been used, we used the average of their opinions for each variable. For this purpose, Eq.3 has been used. Since the threshold value (Z) is a crisp number, we need to define crisp numbers for each variable's weight to identify if each variable acquired a value within the acceptable threshold range. For this purpose, we have used Eq.4 for the defuzzification step. After defuzzification of each fuzzy number, if the final weight of each variable (A_j) is greater than or equal to the threshold value ($A_j \geq Z$), the desired variable is selected, and if the final weight of a variable is less than the threshold value ($A_j < Z$) The desired variable will be rejected.

$$\mu(x) \begin{bmatrix} x - a/b - a \ , \ \ a \leq x \leq b \\ c - x/c - b \ \ , b \leq x \leq c \\ 0 \qquad \text{Otherwise} \end{bmatrix} \quad (1)$$

(a, b, c) are the fuzzy triangular numbers.

$$A_{ij} = (a_{ij}, b_{ij}, c_{ij}) \text{ for } i = 1, 2, 3, \ldots, n \text{ and } j = 1, 2, 3, \ldots, m \quad (2)$$

In Eq.2, *n* gives the number of experts and, *m* denotes the number of variables.

$$A_{average} = (a_j, b_j, c_j) = (1/n \sum_{i=1}^{n} a_{ij},\ 1/n \sum_{i=1}^{n} b_{ij},\ 1/n \sum_{i=1}^{n} c_{ij}) \quad (3)$$

$$\text{Crisp } (A_{average}) = (\frac{a_j + 2b_j + c_j}{4}) \quad (4)$$

3-2- Fuzzy Cognitive Mapping (FCM)

Researchers have developed numerous methods to encounter the complexity, vagueness, and uncertainty aspects of the real-world data. FCM is one of these methods proposed by Kosko (1986) based on Cognitive Mapping (CM). FCM is a cause-effect relationship knowledge-based method for modeling complex decision-making systems of humans that consist of interrelated variables and are described by unavailable or lack of data (Carlucci et al., 2018). It emerges from a combination of Fuzzy logic and artificial neural network (Nasirzadeh et al., 2020).

FCM is a graphical diagram that includes some nodes (variable or concept) (C_i, C_j) and their cause-effect relationships (Pereira et al., 2020). Each interconnection between two variables or the concept of C_i and C_j in cause-effect relationships has a weight. This weight, denoted by W_{ij}, indicates the strength of the cause-effect relationship between the variables C_i and C_j. In other words, W_{ij} shows how strongly the variable C_i affects C_j. Based on the value of the W_{ij}, three types of cause-effect relationships between C_i and C_j can be considered. If $W_{ij} > 0$, it means that there is a positive (straight) causal relationship between the variables C_i and C_j, i.e., increasing/decreasing the value of the variable C_i results in increasing/decreasing the value of the variable C_j (positive causality). If $W_{ij} < 0$, then there is a negative (inverse) causal relationship between the variables C_i and C_j, meaning that increasing the value of the variable C_i leads to decreasing the value of the variable C_j, and decreasing the value of the variable C_i increases the variable C_j (negative causality). Finally, $W_{ij} = 0$ means that there is no relationship between the variables C_i and C_j (zero causality) (Carlucci et al., 2018). W_{ij} is extracted based on opinions of the experts using linguistic variables and then converted to fuzzy numbers with fuzzy membership functions. These fuzzy numbers will be converted to crisp numbers between -1 and +1 using the given defuzzification methods.

FCM could be used for both static and dynamic analysis (Özesmi & Özesmi, 2004; Olazabal et al., 2018; Nasirzadeh et al., 2020). In static analysis, only cause-effect relationships between the variables will be identified. Static analysis can also be used to identify the essential variables of a system, which presents the state of the system in a general framework. For static analysis, indicators such as input, output, and centrality are used (Yaman & Polat, 2009; Nyaki et al., 2014; Shukla et al., 2018; Morone et al., 2019; Nasirzadeh et al., 2020, Shahvi et al., 2021). In dynamic analysis, the effect of a change in the value of each variable on the map will be considered and also the variable of time will be added to the problem, and different scenarios will be simulated over time based on the different values of the variables (Nasirzadeh et al., 2020). Accordingly, the value of A_i for each variable C_i during each period (t) is calculated using Eq.5.

$$A_i^{(t+1)} = f\left\{A_i^{(t)} + \sum_{\substack{i \neq j \\ j=1}}^{n} A_j^{(t)} . wij\right\} \quad (5)$$

$A_i^{(t+1)}$ and $A_i^{(t)}$ are the activation level of variable C_i at the time $(t+1)$ and time t, respectively. As it is mentioned above, W_{ij} is the weight of the interconnection between variables C_i and C_j. In Eq.4, *f* denotes the activation or the threshold function. (Mazlack, 2009). Two of the most popular activation functions are the Hyperbolic tangent function (Eq. 6) and the Sigmoid function (Eq. 7) (Carlucci et al., 2018; Pereira et al., 2020).

$$f(x) = tanh(\lambda x) = \frac{e^{\lambda x} - e^{-\lambda x}}{e^{\lambda x} + e^{-\lambda x}} \quad (6)$$

$$f(x) = \frac{1}{1+e^{-\lambda x}} \quad (7)$$

In this study, we aim to conduct a static analysis and the aim of our study is not to test different scenarios. One of the purposes of our static analysis is to provide a tool for analyzing causal relationships and complex interactions to identify the most important variables affecting sustainability. For our static analysis, in addition to the three indicators of input, output, and centrality degree, a density indicator was used, which indicates the complexity of the map.

Özesmi and Özesmi (2004) stated that due to the FCM method's exploratory nature and the long duration of data collection, it is impossible to use high-volume samples. Moreover, since the FCM deals with exploration and not a generalization, there is no need for sampling Iran's transportation sector in the FCM implementation stage.

Based on the existing literature, data collection in the FCM method is done in three Methods. *1) Questionnaire method*: Based on this method, first, by reviewing the literature on the subject under study, the desired variables are extracted. According to the extracted variables, a questionnaire was designed, and the respondents are asked to determine the negative or positive effect of the variables or their lack of effect on each other and also the amount of this effect if there is a negative or positive effect (Hossain and Brooks, 2008). *2) Fuzzy comparison matrix method*: In this method, the identified variables affecting a phenomenon are written on the rows and columns of a matrix. Respondents are asked to compare the variables' effectiveness in the rows with the variables in the columns in pairs (Doostmohammadi et al., 2012). *3) Interview method*: In this method, the interviewees are asked to draw each of the problem's variables with a circle on a white paper. They are also asked to connect variables that have positive or negative cause-effect relationships using an arrow. In addition to the direction of these relationships, the intensity of these relationships is also determined. In this study, the first method based on a questionnaire was used.

4- Methods application and result

4-1- Implementation of FDM to identifying the essential sustainability variables

In this study, FDM was used to identify the essential sustainability variables in Iran's transportation sector in the sharing economy context among the variables extracted from the literature review. FDM implementation is based on the three steps introduced in the research methodology section.

- *S1:* As stated in the third section, 33 variables in three economic, social, and environmental dimensions were extracted from reviewing the literature as variables affecting the sustainability in the sharing economy context in the transportation sector, shown in Table 1.
- *S2:* As mentioned above, in the second step, a questionnaire designed by the researcher collects the opinions of experts. Experts' selection was based on judgmental sampling and criteria such as professional skills and background, practical experience and knowledge, working in a professional firm in the transportation sector, and high academic education. In addition to the above, the desire to participate in the study was another essential sample selection criterion (Ocampo et al., 2018; Ahmad and Wong, 2019). Different viewpoints have been presented about the number of experts required for FDM, between at least seven to 60 experts (Bozon et al., 2016; Ahmad and Wong, 2019; Petrudi et al., 2020). Ocampo and et al. (2018) pointed out that there is no significant correlation between the expert's number and the quality of decisions. For this study, 18 experts from universities and industries have been selected. Demographic information about these experts is given in Table 3.

Table 3
Demographic information about these experts

		Number	Percentage
Gender	Female	5	0.28
	Male	13	0.72
Organization	University	5	0.28
	Snapp	7	0.39
	Tap30	6	0.33
Organization level	Top-level	5	0.28
	Middle-level	9	0.50

	Lower level	4	0.22
Work Experience	Less than 1 year	2	0.12
	Between 1 and 3 years	8	0.44
	More than 3 years	8	0.44

After selecting the panel of experts, the designed questionnaire was distributed among them. As stated in the research methodology section, the linguistic variables listed in Table 1 were used in this study. After distributing and collecting the questionnaires, the average of the opinions of experts was obtained using Eq.3, which is shown in Table 4. This table also shows the crisp value of the average opinions of experts.

- *S3:* In this step, to select the essential sustainability variable, the value obtained for each of the variables in Table 5 was compared with the threshold value (Z) considered in this study. Different approaches have been introduced in the literature to determine the threshold value. The simple average value of the opinions of experts was calculated based on the crisp values obtained in Table 3, which was equal to 0.607 and was named z_1. The 18 experts in the study were asked to set their proposed threshold value between two numbers, 0.063 and 0.938, which are the crisp values of two triangular numbers (0, 0, .25) and (75., 1, 1) by using Eq.4. The simple average of the opinions of experts for the threshold was 0.589, which was named z_2. Finally, 0.598 for Z was obtained based on the mean of z_1 and z_2. Table 4 shows the comparison of average opinions of experts and the rejection or acceptance of each variable.

Table 4
Average opinions of experts and comparison with the threshold

Dimensions of sustainability	Variables	a	b	c	Crisp	A/R
Economic dimension	Creating monopoly power by platforms	0.50	0.75	0.94	0.736	Accept
	Competitiveness of traditional competitors against platforms	0.56	0.81	0.99	0.788	Accept
	The income of drivers that work in the platform	0.36	0.61	0.86	0.611	Accept
	Price of services provided by platforms compared to traditional competitors	0.47	0.72	0.94	0.715	Accept
	Transportation costs in the portfolio of households using platform services	0.33	0.58	0.82	0.580	Reject
	Higher service quality of platforms than traditional competitors in the passenger transport industry	0.57	0.82	0.99	0.799	Accept
	Ease of entering into the labor market for drivers	0.49	0.74	0.94	0.726	Accept
	Creating jobs in the economy and reducing the unemployment rate	0.32	0.57	0.82	0.569	Reject
	Strengthening the local economy due to job creation	0.26	0.51	0.76	0.514	Reject
	The flexibility of work for drivers	0.58	0.83	1.00	0.813	Accept
	Improving access to transportation in low-density areas	0.35	0.60	0.83	0.594	Reject
	More efficient use of existing assets (car in this research)	0.47	0.72	0.94	0.715	Accept
	Increasing the life cycle of assets (car in this research)	0.31	0.56	0.79	0.552	Reject
	Lack of a clear mechanism for collecting taxes from platforms in the transportation sector	0.28	0.53	0.76	0.524	Reject
	Disrupting of existing regulations of the passenger transport industry	0.31	0.54	0.76	0.538	Reject
	The inefficiency of current laws in the transportation sector	0.39	0.64	0.85	0.628	Accept
	Low job security for drivers	0.21	0.44	0.68	0.444	Reject

Social dimension	Feeling of job instability for drivers	0.15	0.40	0.64	0.399	Reject
	Lack of medical support and unemployment insurance for drivers	0.32	0.57	0.79	0.563	Reject
	lack of drivers' legal rights and classification of workers under labor law coverage	0.36	0.61	0.83	0.604	Accept
	Excessive working and burnout of drivers	0.36	0.61	0.85	0.608	Accept
	No job promotion for drivers	0.38	0.61	0.83	0.608	Accept
	Social interactions at the community level	0.36	0.61	0.85	0.608	Accept
Environment dimension	Motivation to make more use of the platform	0.53	0.78	0.94	0.757	Accept
	Public transport use	0.47	0.72	0.93	0.712	Accept
	Traffic rate in cities due to reduced use of public transport	0.28	0.53	0.78	0.528	Reject
	Demand for cars to enter the platform	0.29	0.54	0.79	0.542	Reject
	More usage of transport industry because of improving security for passenger	0.54	0.79	0.94	0.767	Accept
	Reducing the negative effects on the environment due to the reduction of new car production and consumption of raw materials at the macro level	0.24	0.47	0.72	0.476	Reject
	Demand for buying new cars by passengers due to the use of the platform	0.10	0.35	0.60	0.347	Reject
	Reducing waste production due to less car production	0.14	0.38	0.63	0.378	Reject
	Change of traffic rate in cities and thus the effect on pollution	0.38	0.63	0.86	0.622	Accept
	The use of private cars by passengers	0.43	0.68	0.92	0.677	Accept

4-2- Implementation of FCM to identifying cause-effect relationships

In order to implement FCM, the following steps have been utilized.

- ***S1: Identify the problem variables:*** The first step in implementing FCM is to identify the problem variables. By use of the FDM in the previous step, 18 of the essential variables were recognized based on opinions of experts in Iran's transportation sector, shown in Table 5. Among these 18 variables, nine variables related to the economic dimension, four variables related to the social dimension, and the remaining five variables related to the environmental dimension.
- ***S2: Gathering and aggregating opinions of experts:*** As mentioned in the research methodology section, in this research, the questionnaire method has been used for gathering opinions of experts to implement FCM. For this purpose, using a judgmental sampling method, 13 senior and middle managers in the Iranian transportation sector in Snapp and Tapsi were selected as experts in this study that is shown in table3. These two companies are among the most critical players in the transportation sector in Iran. Before distributing the FCM questionnaire among the experts, FDM variables and how to complete the questionnaire were explained in face-to-face meetings. The effect of each of the research variables on each other was measured using this questionnaire. Opinions of experts were then collected by linguistic variables. In the next step, these language variables are converted to a fuzzy triangular number. After collecting the opinions of 13 experts, the average of their opinions was obtained using Eq.3. The language variables and fuzzy triangular numbers are used listed in Table 1. An example of a questionnaire question is below.

Creating monopoly power by platforms has *[No•] [very low • low • medium • high• very high•] [positive• /negative•] effect on* ***competitiveness of traditional competitors against platforms.***

Table 5
final essential variables based on FDM

Dimensions of sustainability	Variables	Abbreviation
	Creating monopoly power by platforms	EC1

Economic dimension	Competitiveness of traditional competitors against platforms	EC2
	The income of drivers that work in the platform	EC3
	Price of services provided by platforms compared to traditional competitors	EC4
	Higher service quality of platforms than traditional competitors in the passenger transport industry	EC5
	Ease of entering into the labor market for drivers	EC6
	The flexibility of work for drivers	EC7
	More efficient use of existing assets (car in this research)	EC8
	The inefficiency of current laws in the transportation sector	EC9
Social dimension	lack of drivers' legal rights and classification of workers under labor law coverage	SO1
	Excessive working and burnout of drivers	SO2
	No job promotion for drivers	SO3
	Social interactions at the community level	SO4
Environment dimension	Motivation to make more use of the platform	EN1
	Public transport use	EN2
	More usage of transport industry because of improving security for passenger	EN3
	change of traffic rate in cities and thus the effect on pollution	EN4
	The use of private cars by passengers	EN5

- ***S3: Creating the matrix of average opinions of experts:*** At this stage, the matrix of average opinions of experts was created based on the aggregated opinions of experts. Each of the numbers in this matrix indicates the power and direction of the effect of each of the row variables on the column variables. The numbers in this matrix are converted to crisp numbers using Eq.4. These numbers demonstrated the weights of the connections between nodes shown in Table 6.

Table 6
Interactive Matrix of average opinions of experts

Variables	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9	SO1	SO2	SO3	SO4	EN1	EN2	EN3	EN4	EN5
EC1		-0.65		0.42	0.62					-0.70								
EC2	-0.70				0.38													
EC3	0.43	-0.69		-0.63	0.71		0.74				0.70							
EC4	-0.77	0.54												-0.73	-0.78		-0.74	0.67
EC5	0.70	-0.77												0.73	-0.57	0.62		-0.64
EC6	0.48	-0.43	0.66				0.78										0.81	
EC7		-0.54	0.57			0.63					0.45						0.55	
EC8			0.65	-0.42													-0.62	0.33
EC9	-0.65	-0.60								0.70							-0.35	
SO1	-0.63										-0.55	0.42						
SO2																	0.54	
SO3																		
SO4																		
EN1	0.58	-0.58	0.70	-0.70	0.56			0.73			-0.74		0.57		-0.73		0.57	-0.53
EN2			-0.58											-0.58			-0.55	
EN3		-0.65			0.73								0.73					
EN4																		
EN5			-0.74	-0.65				-0.73					-0.38	-0.40	0.42		0.78	

- ***S4: Drawing the cause-effect diagram:*** Based on the matrix of average opinions of experts, the cause-effect diagram of the variables was implemented using the Mental Modeler software. This diagram is given in Figure 3. Each of the nodes shown in Figure 3 represents one of the research variables. Based on the causal relationships obtained, each node can be classified into three categories. The first category are nodes that are not influenced by other nodes and only influence other nodes that called transmitter or driver nodes. Accordingly, only the inefficiency of current laws in the transportation sector variable (EC9) falls into the category of transmitter variables. This variable can also be observed in Figure 3, where all the arrows have gone from this variable to other variables, and no arrows have been entered. The second category are nodes that do not influence other nodes and are only influenced by other nodes, called receiver nodes. According to Table 7, no job promotion for drivers (SO3), social interactions at the community level (SO4) and change of traffic rate in cities and thus the effect on pollution (EN4) variable falls into this category. Variables that fall into this category are only influenced by other variables and can have no influence on other variables and consequently, it is not easy to manage these variables. Nodes that both influence on and influenced by other nodes are called ordinary nodes. Other variables are in the category of ordinary variables.

- ***S5: Analysis of the fuzzy cognitive mapping evaluation indicators****:* Each node's power of influence can be determined by the two concepts of each variable's input and output degree. The node's input degree is the absolute summation of the nodes' weights that influence that node (summation of values in each column in Table 6). Also, the node's output degree is the absolute summation of that node's influence on other nodes (summation of values in each row in Table 6). The degree of centrality of each node is obtained from the summation of two input and output degrees. Table 7 shows the input, output, and centrality degrees of each variable.

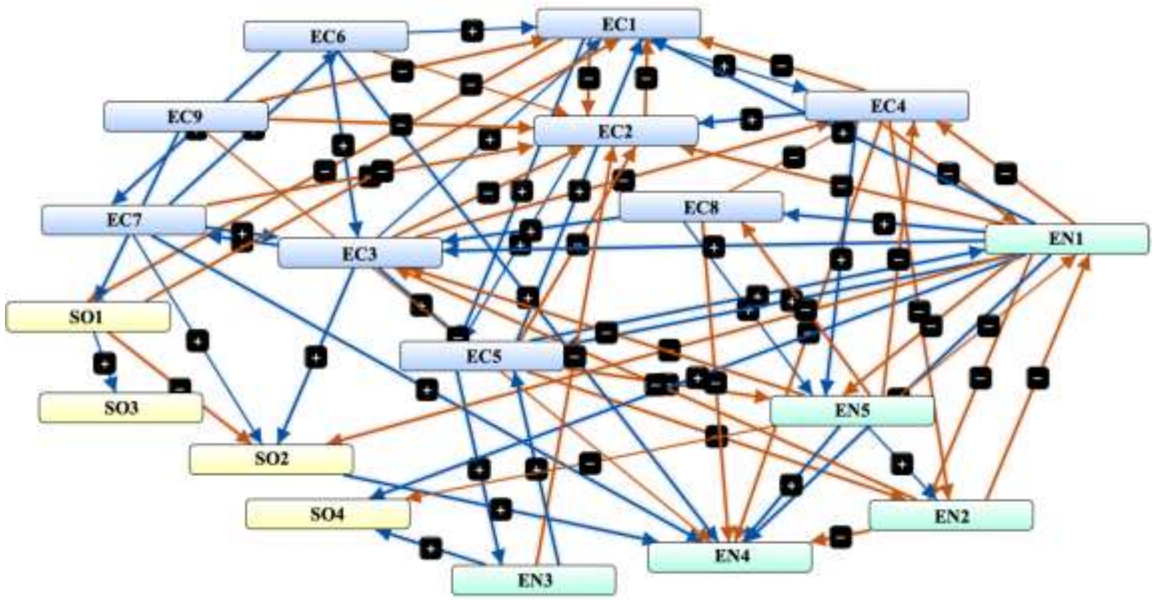

Figure 3. Cause-effect diagram of 18 research variables (output of Mentalmodeler online software)

Based on the results achieved in Table 7 and Figure 3, the variable EN1 has the highest output degree among the variables. Next to this variable are the variables EC4, EN5, and EC5, respectively. Also, SO3, SO4, and EN4 are three variables that their output degree is zero and have the least possible influence. Based on the input degree, the variables that are most influenced by other variables are EN4, EC2, and EC1, respectively. Also, the variable EC9 has an input degree of zero, which means that other variables do not affect it. Centrality degree, which is the sum of output and input degree, indicates the importance of a variable in the cause-effect relationship. In other words, the higher the centrality degree of a variable, the more interaction this variable has in the cause-effect diagram. Accordingly, the variable EN1 has the highest value of the Centrality degree. EC3 variables and EC1 have the highest values, respectively. Figure 4 shows the comparison between Input, output, and centrality degree for each variable simultaneously.

Another indicator for evaluating fuzzy cognitive maps is their density, which shows how well the map components are connected or separated from each other. Density indicates the number of all possible paths on the map (Özesmi & Özesmi, 2004). According to Figure 3, there are 18 components (research variables) in this research. Based on these 18 components, 306 connections will be possible in total. Considering that the number of connections in the map is 70, the ratio of connections to the total possible connections is 0.228, which indicates the density of the causal map. Also, connections per component are 3.88, which is the ratio of existing connections to the total number of components.

Table 7
Input, output, and centrality degree of each variable

Variables	Output degree	Input degree	Centrality degree	Type of variable
EC1	2.38	4.94	7.31	Ordinary
EC2	1.07	5.45	6.52	Ordinary
EC3	3.89	3.90	7.79	Ordinary
EC4	4.23	2.81	7.04	Ordinary
EC5	4.02	3.00	7.02	Ordinary
EC6	3.16	0.63	3.78	Ordinary
EC7	2.74	1.51	4.25	Ordinary
EC8	2.01	1.45	3.46	Ordinary
EC9	2.30	0.00	2.30	Transmitter
SO1	1.59	1.40	2.99	Ordinary
SO2	0.54	2.44	2.98	Ordinary
SO3	0.00	0.42	0.42	Receiver
SO4	0.00	1.68	1.68	Receiver
EN1	7.00	2.44	9.44	Ordinary
EN2	1.72	2.50	4.22	Ordinary
EN3	2.12	0.62	2.73	Ordinary
EN4	0.00	5.51	5.51	Receiver
EN5	4.08	2.85	6.94	Ordinary

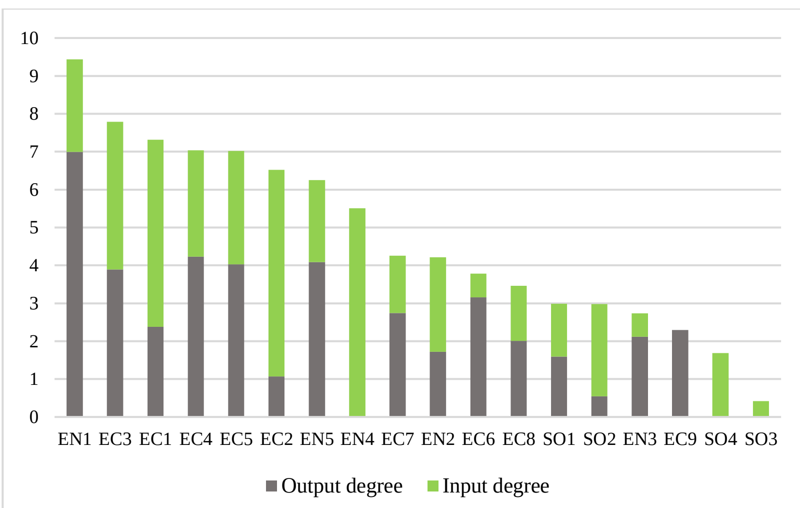

Figure 4. Comparison of Input, output, and centrality degree of each variable

It is essential to determine which variables should be focused on to obtain higher sustainability performance levels (Kiraz et al., 2020). For this purpose, Figure 5 was drawn using the input and output degrees, which helped to analyze the variables better. The high value of the output degree for a variable indicates that the other variables are highly affected by this variable. Therefore, this variable is regarded as a critical variable affecting the sustainability performance level, and high priority consideration should be given to this variable to promote sustainability. On the other hand, if a variable's input degree value is high, that variable is highly affected by the other variable.

Therefore, it can be assumed that increasing the level of sustainability by concentrating on these variables is difficult. Figure 5 is drawn based on the maximum value of output degree, equal to 7, and input degree, equal to 5.51 for each variable. This figure classifies 18 variables into four categories C1 to C4.

- ***The first category (C1):*** this category includes variables with high output and input degrees. Variables that fall into this category need to be carefully managed. These variables have a high degree of centrality and need special attention in analysis related to improving sustainability performance levels. However, it should be noted that the high degree of input degree of these variables indicates that these factors are difficult to manage because other factors influence them. The variables Price of services provided by platforms compared to traditional competitors (EC3), Higher service quality of platforms than traditional competitors in the passenger transport industry (EC4), Change of traffic rate in cities and thus the effect on pollution (EC5) and The use of private cars by passengers (EN5) are in this category.
- ***Second category (C2):*** this category includes variables with high output and low input degrees. The importance of these categories' variables is their high potential to create an overall improvement in sustainability**.** Therefore, particular attention is required in managing the variables in this category. The high output degree of variables means that the management of these variables can significantly promote sustainability. Also, it should be noted that their low input degree indicates that they can be more easily controlled because they are not affected by other factors. Variable Motivation to make more use of the platform (EN1) is the only variable in this category.
- ***-The third category (C3):*** the variables in this category have low output and high input degrees. Due to the high degree of input, the variables that fall into this category are difficult to manage and control. Also, these variables in this category will have a low effect on sustainability because of their low output. Accordingly, it can be stated that the least amount of attention should be paid to these variables among all the map variables. Variables Creating monopoly power by platforms (EC1), Competitiveness of traditional competitors against platforms (EC2) and change of traffic rate in cities and thus the effect on pollution (EN4) are in this category.
- ***The fourth category (C4):*** this category contains low output and low input variables. Variables in this category will not have many outcomes for sustainability because of their low output degree. Their low influence from other variables means that they can be more easily managed because other variables do not influence them. The variables Ease of entering into the labor market for drivers (EC6), The flexibility of work for drivers (EC7), More efficient use of existing assets (car in this research) (EC8), The inefficiency of current laws in the transportation sector (EC9), lack of drivers' legal rights and classification of workers under labor law coverage (SO1), Excessive working and burnout of drivers (SO2), No job promotion for drivers (SO3), Social interactions at the community level (SO4), Public transport use (EN2) and More usage of transport industry because of improving security for the passenger (EN3)are in this category.

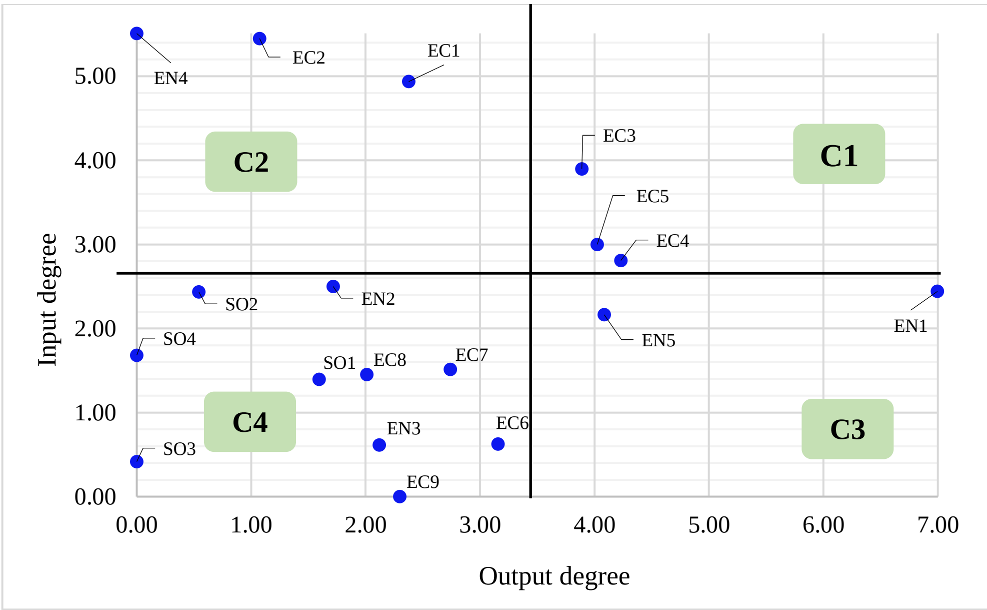

Figure 5. Classification of variables based on the input and output degree

5- Discussion and managerial applications

In the wake of population growth, global resource scarcity has raised sustainability concerns for decades, especially in the environmental sector (Jouzdani & Govindan, 2021). The sharing economy seems to offer new alternatives to existing consumption patterns (Curtis &Mont, 2020). In the first step of this study, the most important variables of the sharing economy business model that influence sustainability and localization in the Iranian transportation industry were identified using FDM. In the second step, which the causal relationships of the main variables were identified by FCM based on a survey of experts' opinions in two of the largest platforms in Iran.

To identify the most important sustainability variables based on the results of FCM, the degree of centrality index (summation degree of input and output degree) was used. Figure 4 shows the highest and lowest values based on the centrality index degree. The analysis of causal relationships between variables can provide great insights for industry managers and implications for future research. In this way, managers can focus their efforts on more efficient management and control of t variables that may positively or negatively affect other variables. Business managers must take steps to maximize their business's positive effects on economic, social, and environmental aspects of sustainability and minimize negative effects in order to improve sustainability. The following is a causal analysis with its managerial applications.

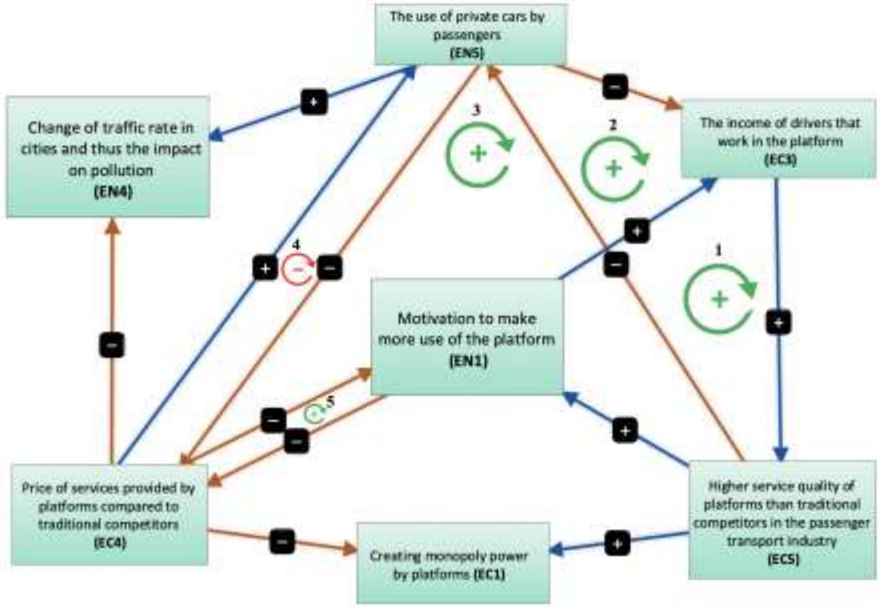

Figure 6. Cause-effect diagram of the most important problem variables with positive and negative loops

Table 8

Interactive matrix of the most important problem variables

Variables	EC1	EC3	EC4	EC5	EN1	EN4	EN5
EC1			0.42	0.62			
EC3	0.43		-0.63	0.71			
EC4	-0.77				-0.73	-0.74	0.67
EC5	0.70				0.73		-0.64
EN1	0.58	0.70	-0.70	0.56		0.57	-0.53
EN4							
EN5		-0.74	-0.65		-0.40	0.78	

Due to the high number of variables in the map shown in Figure 3, it is a rather complex and difficult task to analyze all variables' causal relationships. In order to provide more detailed results, we have given Table 8 in which seven variables, including EN1, EC3, EC1, EC4, EC5, EN5, and EN4, are selected according to the value of their centrality index. According to Table 7, all of these variables have a high output degree in addition to the degree of centrality. Hence, they will have a high impact on other variables. Based on table 8, the numbers' absolute mean value was first calculated, equal to 0.64. Then all the values were compared with this number, and those that were higher than this number were considered, and other values were excluded. The result is a simplified map to examine causal relationships that focus only on variables with a high positive or negative average influence. According to this, Figure 6 was drawn. One of the essential purposes of this research is to identify the causal relationships between variables. To cause-effect analyses between variables, positive and negative loops among these seven variables have been used, based on which, in addition to direct relationships, indirect relationships among variables can be achieved. In Figure 6, four positive loops and one negative loop can be identified.

- ***First loop:*** This loop, which contains the EC5 ➔ EN1 ➔ EC3 ➔ EC5 is a positive loop because all variables' relationships are positive. Based on this loop, it can be said that the higher the quality of services provided by the platforms, the higher the motivation of passengers to use these platforms. On the other hand, passengers' high usage of platforms will increase the platform's frequency of use, which will increase the number of passengers on the platform and generate more revenue for drivers. Increasing the income of drivers will also increase the quality of services provided. Due to this loop, the business managers present in the research by focusing on each of these variables can finally achieve positive results to improve sustainability.

- ***The second loop:*** This loop, which is considered EC5 ➔ EN5 ➔ EC3 ➔ EC5, is a positive loop because the multiplication of positive and negative direction of the relations in this loop is positive. Based on the relationships in this loop, it can be claimed that the higher the quality of services provided by the platforms, the less motivated passengers will be to use their private cars for transportation (inverse relationship). On the other hand, reducing passengers' motivation to use private cars increases the use of the platform and creates more income for drivers. As previously explained, the relationship between drivers' income levels and the quality of services is positive. In general, it can be asserted that increasing the quality of services will eventually lead to increasing itself. According to the analysis presented, the firms' managers present in this research are suggested to develop the quality of their services as much as possible. More service quality improvement will eventually lead to an increase in itself and create a higher sustainability level.
- ***The third loop:*** The third loop is one of the complex loops in the map, which includes EC4 ➔EN5 ➔ EC3 ➔ EC5 ➔ EN1 ➔ EC4. Given the multiplication direction of the relationships between the variables, this is a positive loop. We start analyzing this loop with the price level variable on the platform compared to traditional competitors. In the firms studied in this study in Iran, the price level is lower than traditional competitors. Low prices of services compared to traditional competitors will reduce the use of private cars due to more use of the platform by passengers (inverse relationship), which will increase the income of drivers who are members of the platform. Increasing drivers' income will increase the quality of services provided on the platform and thus increase passengers' motivation to enter the platform. Demand for using the platform as much as possible will lead to lower prices of services. Since this loop is a positive loop, improving the level of each of its variables can lead to better performance for sustainability.
- ***Fourth loop:*** This loop includes two variables EC4 and EN5. The fourth loop is one of the simple loops in the map, which shows a negative two-way causal relationship between the two variables of low prices on the platform and private cars' use by passengers instead of using the platform. A negative loop means that changes to a variable will work in the opposite direction to that variable. For example, in this loop, a decrease in the price level will lead to a decrease in the use of private cars by passengers, but on the other hand, a decrease in the use of private cars by passengers will lead to an increase in the price level. The goal of managers should be to eliminate negative loops as much as possible to improve the final performance of system sustainability.
- ***Fifth loop:*** The fifth loop, like the fourth loop, is one of the simple loops with a positive causal relationship. According to this loop, the lower the price level on the platform, the more motivation to use it, and on the other hand, the more motivation to use the platform will reduce

the price level. Therefore, managers should attempt to keep prices low because it will cause more passengers' use of the platform.

Most of the studies in the literature have been limited to identifying the variables affecting sustainability in the sharing economy context. Some identified only the positive effects of the growth of the sharing economy on sustainability, while others pointed to the negative effects in addition to these positive effects. These studies include Miller (2016), Schor (2016), Verboven and Vanherck (2016), Sabitzer et al. (2018), Martin et al. (2019), Govindan et al. (2020), Liu and Chen (2020), and Paundra et al. (2020) noted. From this point of view, this research can be placed in line with the above-mentioned studies. According to the obtained results, this research identifies the causal relationships between the variables of sustainability. Our study contributes to the literature by providing a better understanding of the effects of the sharing economy on sustainability. As mentioned earlier, to the best of our knowledge, no prior studies identified the causal relationships of sustainability variables in the sharing economy context. Due to this issue, it will not be possible to accurately compare the results of our research with any previous research.

Analysis of causal relationships can provide valuable results for future research. As a suggestion for future research, we offer the researchers to analyze variables' causal relationships with a dynamic approach over time by providing real data for each problem variable and scenario analysis using the systems dynamic method. The industry studied in this research has been the transportation sector. In future research, FCM can be used in other industries such as the accommodation industry. The comparison of the results in different industries can be valuable and interesting as well.

One of the most important limitations of this research has been the difficulty of accessing the experts, which took a significant amount of time for the authors to hold face-to-face meetings and receive the questionnaires. Also, to generalize the results in future research, cultural differences, people's economic level, welfare level, and attention to the general state of Iran with other countries should be considered.

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