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Providing a framework for adopting a circular supply chain with the approach of stakeholder analysis and interpretive structural modelling (Case Study: Steel Industry)

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Abstract: The circular supply chain has many advantages, however, its implementation is associated with obstacles in many countries, including developing countries. This study aimed to provide a model for the circular supply chain acceptance, using the qualitative approach of stakeholder analysis and the quantitative approach of interpretive structural modelling. A mixed exploratory approach has been used in this research. Qualitatively, the community included the key stakeholders of the supply chain of the steel industry and the sample consisted of 10 specific representatives who were selected purposefully. Barriers were extracted through semi-structured interviews with key stakeholders and analysed by thematic analysis method. In the quantitative part, the statistical population included supply chain experts and the sample included 10 experts who are proficient in the subject and modelling management concepts, who were selected as the target sample. The research tool in the quantitative part was the interpretive structural equation questionnaire. 17 barriers to the circular supply chain acceptance from the perspective of the key stakeholders were extracted. Using MICMAC analysis, the type of variables was determined. The variables were divided into independent and linked groups and were plotted at three levels in an interactive network. This study has presented a model for circular supply chain acceptance. Determining the type of variables and the relationships between them and presenting a model can lead to a better understanding of the issue and making appropriate decisions about the circular supply chain acceptance.

Keywords: *Circular supply chain, Interpretive structural modelling, Steel industry, Circular economy, Stakeholder analysis.*

Introduction

Considering the noticeable consumption of natural resources, the resulting public unrest, and environmental destruction, the governments, including the Chinese government, have turned their attention to environmental modernization and green production due to their circular economy strategy (Geng et al., 2013). Supply chains tend to operate without regard to their wider environment (Wieland, 2021). For many industries, moving towards a circular economy is relatively challenging because the companies need to cooperate with drivers inside and outside the

industry boundaries (Schultz et al., 2021). On the other hand, with the increase of population and consumption, circular economy approach for sectors like stakeholders, production, manufacturing, etc. (Williams, 2001), rather, the entire supply chain needs to change from a linear to a circular model.

Circular supply chain merges the concept of circular economy in the supply chain and offers new facilities to increase the sustainability of supply chain process (Lahane and Kant., 2021). The circular supply chain has a comprehensive purpose beyond the green and traditional supply chain and eliminates the shortcomings of the linear supply chain (Genovese et al., 2017). In general, a circular supply chain can be a valuable method to solve problems like pollution, unattainable production and consumption patterns, climate changes, and resource scarcity; because it is able to force organizations to reduce waste and negative environmental effects (Nasir et al., 2017; Genovese et al., 2017).

Therefore, adopting a circular economy approach in the supply chain is a providential sustainability approach and its implementation results in economic, social, and environmental benefits (Lahane et al., 2020). Managers play an important role in the effective transition to the circular supply chain due to their ability to influence environmental sustainability in their supply chain (Asante et al., 2022). China, Japan, and South Korea are among the developed countries that have national strategies for the implementation of the circular economy approach. For the past 20 years, these countries have made benefit of industrial parks that use the principles of circular economy to link corporate supply chains (together) and reuse or recycle common materials (Geng et al., 2019).

However, despite the many advantages of application and implementation of this approach in other countries such as Iran, it has not been operational due to some barriers. In other words, there is a lack of a framework for the development of economic, social, and environmental indexes in the circular supply chain (Zeng et al., 2017; Nasir et al., 2017; Batista et al., 2018; Howard et al., 2018; Mangla et al., 2018). In addition, due to the significant risks associated with it, the percentage of acceptance and implementation of the circular supply chain management is low (Lahane and Kant., 2021). Therefore, the present study aims to provide a model for barriers to the circular supply chain acceptance by considering economic, social, and environmental scales through a stakeholder analysis approach and interpretive structural modelling. The identification of barriers to the circular supply chain acceptance is very important because these criteria determine why the organizations should implement the circular economy approach in the supply chains (Govindan and Hasanagic., 2018; Farooque et al., 2019). Considering that the first step for the sustainability of the supply chain is to interview the stakeholders, it is very important to identify the obstacles to the adoption of the circular supply chain from the point of view of the key stakeholders. Despite numerous studies in the field of identifying circular supply chain drivers, the circular supply chain acceptance model has received less attention (Mangla et al., 2018). On the other hand, Today, steel and its derivatives are present in almost all areas of people's lives and are widely used metals. Since the demand for this valuable material is very high, by recycling this highly consumed metal, part of the needs of the society and the country can be met. It also saves energy, money and natural resources. Due to its high capacity for recycling and reuse, in addition to the ability to repair and increase its useful life, steel is considered a symbolic example of the circular economy (Lopez et al., 2020). In other words, the steel industry is considered as an integral part of the circular economy model (Beker and Tillman, 2016). In the steel industry, there are wastes such as melting slag. Smelting slags are sold to various companies, such as slag cement companies, road and flooring companies, and construction companies, and smelting slags are sent after granulation as

production resources for the construction industry. Also, waste such as types of oils that are not used in the steel industry are collected in special barrels after their use and duration of use and are sent to oil refining factories. In the closed-loop supply chain of the steel industry, many scraps are recycled, but there are still scraps that are not reused. For example: the steelmaking process can remove most of the impurities that may be present in the steel scrap. However, some elements, especially copper in steel can lead to the loss of ductility and as a result surface defects. In the future, due to the expansion of the electricity industry in society, we will face an increase in the percentage of copper in recycled scrap.

Therefore, taking into account the aforementioned research gap, the present research tries to use a combined approach (qualitative and quantitative), first to identify the obstacles to the acceptance of circular supply chain in the steel industry by using the qualitative approach of stakeholder analysis, and in the next step, Using the structural and interpretive modelling approach, provide a framework for accepting the circular supply chain in the steel industry.

Literature Review

Given that this study aims to investigate the barriers to the circular supply chain acceptance in developing countries, the theoretical basis of research related to the circular economy, circular supply chain, and barriers to its implementation has been evaluated in both developing and developed countries.

Circular economy

The demand for resources is increasing rapidly as the world population is steadily growing (Lieder and Rashid, 2016). The relationship between industry and environment is critical to business performance. Environmental impacts are steadily increasing the pressure on the industrial companies. Today, because of the growth of the community and the considerable growth of the industrial actions, emissions into the environment, solid waste manufacturing, and landfilling have been increasingly raised. On the other hand, the global economy is growing by about 3% annually, indicating a grow in the market request and the production volume to keep up this request. In addition, due to the limited global resources, it will be difficult to meet the demands of the global population. The significance of this matter is revealed by considering the point that the experts predict the world population to reach 9 billion in 2050 and 10.1 billion in 2100 (Bastein, 2013).

In a circular economy, the use of non-renewable resources and the generation of waste are minimized, while reuse and recycling dominate the life cycle of materials (Rosenboom et al., 2022). The concept of circular economy can be considered as a solution to a set of challenges such as waste generation, resource scarcity, and conservation of economic benefits. In order to better understand this issue, the European Commission has calculated the annual economic income equivalent to a billion euros for the production sector using the circular economy approach. (Korhonen et al., 2018). The circular economy is now a public concept hold up by the European Union, several national governments, and many corporations around the world. Also, this approach, as an approach to combat environmental challenges and promote sustainable development, has recently received more attention in the industrial development discussions (Korhonen et al., 2018). In the context of business models in the circular economy and its role in the supply chain, the results indicate that circular business and circular supply chain lead to increased sustainability (Geissdoerfer et al., 2018; Batista et al., 2018; Pieroni et al., 2021). In general, the concept of the circular economy has been promoted as a response to the increasing scarcity of resources and as a driver of the transition towards a more sustainable economic system (Mies and Gold, 2021).

To better understand the concept of circular economy, some concepts of sustainability are required to be examined. Green supply chain management: it involves examining the environmental impact of all processes involved in a supply chain to minimize its negative consequences (Kaur et al., 2018). Industrial parks: Industrial parks are a group of companies located in an area that communicate and cooperate with each other in a network with the aim of improving sustainability (Bellantuono, et al., 2017). Sustainable supply chain management: management of materials, information, and capital flow, as well as, cooperation among the companies throughout the supply chain so that all three dimensions of sustainable economic, social, and environmental development are considered and the customer and stakeholder requirements are met in it (Seuring and Müller, 2008).

Closed-loop supply chains: Closed-loop supply chains are separated into two groups: straight and reverse supply chains. Supply chains are made up of in a row level that meet customer needs by attaching worth to the raw materials and turning them into the end product. Reverse networks also assist to gather and reuse end products to get raw materials, parts, and products for the straight network and to reduce the environmental impact of waste. The closed-loop issue mainly focuses on the flow of primary goods and deals with the synergistic disadvantages of by-products and the flow of useful waste.

The concept of circular economy is used in the study of real-world and nonlinear systems to facilitate the efficient flow of materials, energy, labour, and information. Murray et al. added that the circular economy approach for reducing environmental impacts increases circular flows, while maintaining maximum resource efficiency (Murray et al., 2017). In recent years, the linear economy has been introduced under the circular economy. Circular economy can be used as a suitable solution for environmental, economic and social issues (Millar et al., 2019).

Circular supply chain

Today, supply chain management has become a vital factor in the global markets. Supply chain management includes the planning and management of all activities involved in resource supply, conversion, and all logistics activities. More important is coordination and cooperation with chain partners who can be suppliers, intermediaries, third party service providers, and customers. In fact, supply chain management involves the integration of supply and demand management within and between the companies (Ardito et al., 2018).

Using circular economy in the supply chain results in various benefits, including resource availability improvement (Goyal et al., 2018), improvement of the end-of-life strategies (De Jesus and Mendonça., 2018), value-added propositions (Mishra et al, 2018), Zero- waste production (Kurniawan et al., 2021), sustainability improvement (Sehnem et al., 2019), and social benefits improvement (Despeisse et al., 2017) (Lahane et al., 2020). Circular supply chains require integrated supply chain models in which products from the end consumers are returned to the chain through retrieval operations such as reuse, repair, reconstruction, and recycling (Batista et al., 2018).

Two unique aspects of circular supply chain management are: 1- Designing the restoration cycle and rebuilding it based on circular thinking 2- The perspective of a waste-free economy. However, none of the sustainability concepts has systematically linked the concept of the philosophy of circular economy to supply chain management (Batista et al., 2018; Govindan and Hasanagic., 2018). In general, the circular supply chain has a comprehensive purpose that goes beyond the traditional and green supply chain and eliminates the shortcomings of the linear supply chain (Genovese et al., 2017). It is noteworthy that the concepts of green and sustainable supply chain management have been developed in parallel with the circular economic discourse that is being

expanded in the industrial environment and ecosystem literature (Nasir et al., 2017). Thus, the circular supply chain includes the concepts of circular economy, sustainable supply chain, green supply chain, industrial parks, and closed-loop supply chain (Masi et al., 2017).

Barriers to circular supply chain acceptance

There are many barriers to supply chain processes for implementing sustainable operations that may vary from industry to industry (Kazancoglu et al., 2020). Moving from a linear supply chain to a circular supply chain is a challenging process for the organizations (Levering and Vos., 2019). The circular supply chain can address the challenges of pollution, unattainable production and consumption patterns, resource scarcity, and climate change (Nasir et al., 2017; Genovese et al., 2017; Sehnem et al., 2019). The circular supply chain has many advantages, however, its implementation in some countries is associated with problems (Zeng et al., 2017; Nasir et al., 2017; Batista et al., 2018; Howard et al., 2018; Mangla et al., 2018; Levering and Vos, 2019; Khandelwal and Barua, 2020; Lutra et al., 2022; Yan et al., 2022; Kazancoglu et al., 2022; Ayati et al., 2022). Managers' focus on one or more important obstacles affects the success rate and efficiency of circular supply chain management. However, given the interactive relationships, one barrier can significantly affect other barriers in the approval of circular supply chain management (Mangla et al., 2018). Therefore, the recognition and analysis of the barriers to the adoption and approval of circular supply chain concepts should be comprehensively examined (Levering and Vos., 2019). In general, lack of awareness of the concept of circularity, economic constraints, and managerial approaches are among the obstacles to application of the circular supply chain approach.

Therefore, the society and consumers' awareness of the circular economy should be given more attention. These key barriers prevent the implementation of the circular economy, and awareness of these factors can provide an important source of information for the managers and decision makers (Govindan and Hasanagic., 2018). The two main barriers to implementing a circular supply chain are: Lack of appropriate environmental laws and their implementation. In this regard, the most important obstacle of the circular supply chain is the lack of cooperation and support of the actors of the chain (Farooque et al., 2019).

In addition, the organizations have difficulty in dealing with technological challenges and technical knowledge because the products must be designed with environmentally friendly technologies. Kazancoglu et al. categorized circular supply chain barriers into cause-and-effect groups and identified lack of collection, sorting, and recycling and problems with uniformity and standardization as the most important barriers, respectively. Kazancoglu et al. also provided a comprehensive conceptual framework for the circular supply chain barriers in the textile industry. In the focus group study, supply chain barriers that hinder the implementation of the circular economy were classified into 9 main categories: management and decision- making, work, design challenges, materials, rules and regulations, lack of knowledge and awareness, lack of integration and cooperation, cost, and technical infrastructure (Kazancoglu et al., 2020).

In addition, the lack of tax facilitation policies and poor enforcement of laws and regulations to protect the environment are the most important barriers. (Khandelwal and Barua., 2020). In this regard, the lack of government support and incentives and the lack of the related policies and protocols are important barriers to the implementation of the circular economy model. In another study, lack of support of the senior management and lack of commitment to adopt circular practices was identified as the most important barrier and low acceptance of the refurbished, recycled, and repaired products was identified as the least important barrier (Lahane et al., 2021).

Methodology

This section presents a combined approach of stakeholder analysis and interpretive structural modelling to extract the barriers and determine the relationships among them. In this approach, first, the qualitative data is collected and, in the next step, the researcher can examine the relationships between qualitative data by collecting the quantitative data. In this study, according to the purpose and questions, the stakeholder analysis approach has been used to extract the barriers to the circular supply chain acceptance from the perspective of stakeholders. At this stage, the report provided by the steel industry was used in connection with the analysis of stakeholders. In the next step, barriers were extracted through semi-structured interviews with key stakeholders of the steel industry supply chain. Then the quantitative approach of interpretive structural modelling was used to analyse the relationships between barriers, and finally, using MICMAC analysis, the influence and dependence power of variables were determined.

Qualitative approach: Stakeholder analysis

In the qualitative approach of stakeholder analysis, each subject has a stakeholder or stakeholders who influence or are influenced by it (Greger et al., 2014). Stakeholders' analysis begins with the identification of stakeholders and provides information about their activities, perceptions, behaviours, and their thoughts about the phenomenon in question (Project Management Institute., 2013). Stakeholder qualitative analysis approach has been used in various research studies in the field of circular economy (Camilleri., 2020; Gupta et al., 2019; Kunz et al., 2018; Schaubroeck et al., 2019) as well as the circular supply chain (Kazenkoglu et al., 2020). This approach provides an excellent basis for developing a decision support tool (Grimble and Wellard, 1997; Reed et al., 2009; Bryson, 2004). Since a set of misleading data may be obtained through the stakeholder approach, the resulting bias should be reduced (Aly et al., 2019). There are several ways to reduce the bias, one of which is to have a structured framework with a coherent process and to provide precise definition of terms. In addition, to engage all stakeholders of the group, emphasis should be placed on selecting diverse participants, which has the potential to build trust and reveal the potential biases (Reed et al., 2009; Guðlaugsson et al., 2020). Bias may arise as the result of the efforts made by powerful stakeholders to influence the research process and data or it may be the result of the researcher bias (Reed et al., 2009; Newig and Koontz., 2014).

In general, in the stakeholder qualitative approach, the main goal is to identify the key stakeholders who have more influence and interest in the project (Table 1) and to ultimately benefit from their point of view (Aaltonen and Sivonen., 2009). In addition, various stakeholders with different perspectives are involved in the project implementation. It is practically impossible to consider all points of view. Therefore, identifying, evaluating, and prioritizing the stakeholders is of great importance. According to the purpose of the study, the interest and power matrix was used in the stakeholder analysis approach. The statistical population of this research includes all stakeholders in the steel industry. First, we will refer to the steps of performing a stakeholder qualitative analysis, which actually determines what steps the researcher must take to carry out this approach.

According to Figure 1, the first step in the stakeholder analysis approach is the identification of stakeholders by the researchers.

Figure 1: Stakeholder analysis steps

Identification of the key stakeholders

There are many stakeholders in the supply chain of the steel industry. In this the data extraction was done by informed stakeholders and the researcher gave an opinion on the selection of the sample, the sampling method was purposeful. Purposive sampling means that the researcher himself gives an opinion on what items to choose for the selected sample. In this study, the informed stakeholders are: the production manager of the pelletizing unit, the production manager of the coloured sheet unit, the repair manager, the environment manager, the education, research and technology expert of Imidro Organization, the sales expert of Servo Rang Company, the sales expert of Adran Dej Company, the sales manager Zob furnaces, director of financial affairs and environmental organization of the country (air pollution monitoring group).In this research, codes and classes were formed from the initial interview, and then data reduction continued in all analysis units (codes) until themes emerged. The interviews continued until the theoretical data saturation stage. At this stage, the report provided by the steel industry was used in connection with the analysis of the stakeholders (Steel Industry Supply Chain Report, 2019).

Stakeholders in the steel industry include: shareholders, customers, suppliers, business partners, employees, the society and legal entities, securities and stock exchange organization, the environmental protection organization, retired people, contractors, the ministry of health and medical education, the ministry of welfare, labour and social affairs, regulatory institutions and organizations, bachelor jobs staff, technicians, operators and repairman, members of parliament, research and educational organizations and institutions, Iranian commodity exchange joint stock Company, tax affairs organization, social security organization, non-profit organizations and institutions and non-governmental organizations, spouses and children of employees, suppliers of consumables, machinery and spare parts, government and public agencies, employees of managerial and supervisory jobs, suppliers of financial resources, suppliers of raw materials and energy.

Stakeholder prioritization

After identifying the stakeholders of the circular supply chain of the steel industry, the position of each stakeholder in the interest and power matrix was determined (Supply chain report of the steel industry, 2019). Since it is practically not possible to extract obstacles from the point of view of all stakeholders, it is necessary to prioritize the stakeholders. Considering that the reported list of the steel industry was used in the previous stage to identify and classify the stakeholders, the key stakeholders are the stakeholders who have higher power and interest.

Stakeholder groups are classified into four predefined clusters (Figure 2).

Role-Players: They have both great interest and considerable power, including role-players in the group of managers, owners or shareholders, partner or competitor organizations, and some employees of the organization.

Institutions: They have high interest, but little power, including important groups of social and civic institutions such as non-government organizations, universities and research centres, city or local councils, and even some other employees of the organization.

Founders: This group has power but its direct interest is low, which can include the government, the founders of government organizations such as the tax administration, the municipality, and the banks.

Common people: This group has both low power and interest and includes most of the common and ordinary people in the society (Bryson., 2004).

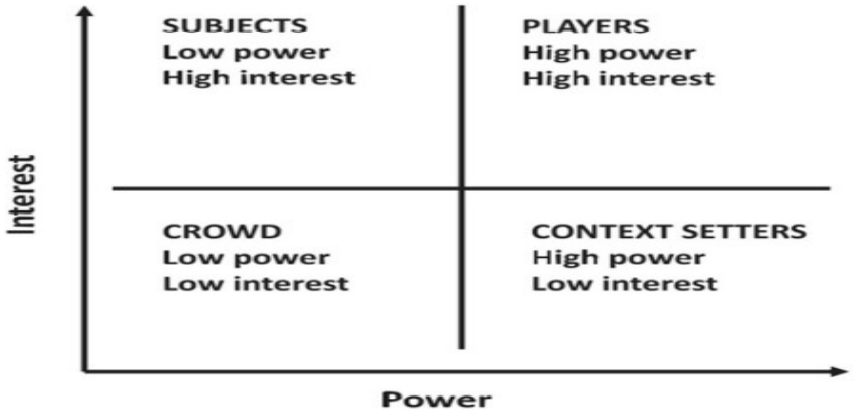

Figure 2: Interest-Power Matrix (Ackerman and Eden, 2001)

Extracting the barriers to the circular supply chain acceptance from the perspective of stakeholders

The most difficult and important step in stakeholder analysis is to identify and extract barriers to the circular supply chain acceptance from the perspective of stakeholders. At this stage, the barriers are identified through interviews with them. Setting barriers by the stakeholders themselves facilitates the achievement of more realistic results. After designing the interview questions, the interviewees are specified and the code is defined for the interviewees.

Table 1: List of interviewees

Interviewees	Interviewee code	Key stakeholders
Pelletizing unit production manager	Code 1	Employees of managerial and supervisory jobs
Color sheet unit production manager	Code 2	
Repair manager	Code 3	
Environmental manager	Code 4	
Education, research and technology expert of IMIDRO organization	Code 5	Imidro Organization, Justice Shares, Shasta and Mehr
Sales expert of Saro Rang Company	Code 6	Raw materials and energy suppliers
Sales expert of Adran Dej company	Code 7	
Sales manager of melting furnaces	Code 8	Customers of fluid transfer pipes, automobile manufacturing, packaging industries
Financial Affairs Manager	Code 9	Funding suppliers

National Environmental Organization (air pollution monitoring group)	Code 10	State and public institutions

Quantitative approach: Interpretive structural modelling

The interpretive structural modelling approach is used in sustainable supply chain research studies (Hussain et al., 2016; Shibin et al., 2017; Yang et al., 2017; Chen et al., 2018; Biswal et al., 2018; Mohanty., 2018; Sandeepa and chand., 2018; Darbari et al., 2018; Mohseni et al., 2019; Chand et al., 2020; Zayed and Yaseen., 2020) and in circular supply chain research studies (Ruben and Varthanan., 2019). After identifying the key stakeholders of the steel industry and extracting the barriers to the circular supply chain acceptance, the relationships between the barriers are evaluated, using an interpretive structural modelling approach.

Interpretive structural modelling is a technique that makes it possible to study the complexity of a system. This is an interpretive method because the judgment of a group of people determines whether there are relationships between these elements or not. This method is structural because the basis of relationships is an overall structure derived from a complex set of variables. This method is a modelling technique that shows specific relationships and general structure in a diagram model (Rezaee et al., 2019).

After identifying the key stakeholders of the steel industry and extracting the barriers to acceptance of the circular supply chain, the relationships between the barriers are examined using an interpretive structural modelling approach.

The various stages of interpretive structural modelling are as follows:

Step 1: The criteria or elements considered (in this research, effective barriers to the circular supply chain acceptance) are listed.

Step 2: Using the criteria or variables identified in the first step, according to each pair of criteria, a content relationship is defined between them.

Step 3: A self-interaction structural matrix is developed for the influential factors, showing the pairwise relationships between the factors influencing the circular supply chain acceptance in the steel industry.

Step 4: The access matrix is developed using the self-interaction structural matrix, and this matrix is examined for expansiveness.

Step 5: In the fourth step, the access matrix is divided into different levels.

Step 6: Based on the relationships defined in the access matrix, a directed Figure 3 is drawn and the expansion relationships are eliminated.

Step 7: The final diagram is turned to interpretive structural modelling by substituting the names of variables or criteria instead of nodes.

Step 8: Interpretive structural modelling developed in step 7 was reviewed to make sure that there is no inconsistency in terms of content. If there is inconsistency, the required corrections will be made (Rezaei Noor et al., 2016).

MICMAC analysis

The MICMAC methodology was developed by Michel Godet and François Borse (2011). This method of analysis includes a structural evaluation based on the conductivity index of each factor. The goal is to understand how the identified factor can be influenced by other factors (Ravi and Shankar, 2005). The purpose of this analysis is to identify and analyze the influence power and dependence of variables. Fuzzy MICMAC analysis method has been used to depict textual relationships and identify interrelationships between circular economy drivers (Mahal et al., 2021). In MICMAC analysis, the variables were classified into four different areas. These areas include

the autonomous region: the variables in this region have less influence and dependence than other variables. In other words, they have less connection with the system. Dependent area: Variables in this area have weak influence and high dependency. Link area: Variables have the highest degree of influence and dependence compared to other variables and any change in them affects the system. Independent region: In this region, variables have high influence power and weak dependence (Sahoo et al., 2011).

Results and Discussion

According to the combined approach, at first, with the help of the stakeholder analysis method, barriers to the circular supply chain acceptance, based on economic, social, and environmental criteria in the steel industry, were identified. Then, using quantitative structural interpretive modelling, the relationships among the dimensions and indices were determined and analysed in an integrated manner. Finally, using MICMAC analysis, the type of variables was determined based on the effect they have on or receive from other variables.

Stakeholders' qualitative analysis approach

Using stakeholders' qualitative analysis approach for the extraction of the barriers to circular supply chain acceptance, the following results were obtained:

At this stage, the report provided by the steel industry was used in connection with the analysis of the stakeholders (Steel Industry Supply Chain Report, 2019) (Table 2).

Table 2: Classification of the Circular Supply Chain Stakeholders of the Steel Industry

Satisfaction	**Effective management**
Customers of the steel industry, pipes and profiles, foreign customers Employees of bachelor, technician, operator and repair jobs Environmental Protection Organization securities and Stock Exchange organization	Imidro Organization, Justice Shares, Shasta and Mehr Customers of fluid transfer pipes, automobile manufacturing, packaging industries Raw materials and energy suppliers Funding suppliers Employees of managerial and supervisory jobs State and public institutions
Taking care	**Informing**
Subsidiary shareholders Customers of tanks, containers, pressure vessels, steel structures, heavy and industrial transport machines Contracting forces Retired people Ministry of Health and Medical Education Ministry of Welfare, Labor and Social Affairs Regulatory organizations and institutions Educational and research organizations and institutions	Customers of service centers, light metal industries, home and sanitary appliances, electrical industries Suppliers of consumables, machinery and spare parts, contractors (operation, development, and services), and foreign suppliers Spouses and children of employees Social security organization Tax affairs organization Organizations, Non-profit institutions, and non-governmental organizations Iran commodity exchange joint-stock company Local people

Parliament deputies	

There are many stakeholders in the supply chain of the steel industry. After identifying the stakeholders of the circular supply chain of the steel industry, the position of each stakeholder in the interest and power matrix was determined (Supply chain report of the steel industry, 2019).
Since it is practically not possible to extract obstacles from the point of view of all stakeholders, it is necessary to prioritize the stakeholders. Considering that the reported list of the steel industry was used in the previous stage to identify and classify the stakeholders, the key stakeholders are the stakeholders who have higher power and interest. After identifying the stakeholders of the circular supply chain of the steel industry, the position of each stakeholder in the interest and power matrix was determined (Supply chain report of the steel industry, 2019). (Table 3).

Table 3: Prioritization of the Stakeholders of the Circular Supply Chain in the steel Industry (Supply Chain Report of the Steel Industry, 2019)

Effective management
Imidro Organization, Justice Shares, Shasta and Mehr Customers of fluid transfer pipes, automobile manufacturing, packaging industries Raw materials and energy suppliers Funding suppliers Employees of managerial and supervisory jobs State and public institutions

In the third stage, the results of the Semi-structured interview related to the barriers to acceptance of the circular supply chain from the perspective of key stakeholders were identified in the table 4.

Table 4: Barriers to the Circular Supply Chain Acceptance from the Perspective of Stakeholders

Barriers to the circular supply chain acceptance	**Key Stakeholder Name**
Lack of collaboration and coordination between the chain members	Imidro Organization, Justice Shares, Shasta and Mehr
Lack of equipment, technology, and appropriate transportation system	
Return flow uncertainty	
Lack of proper motivation system	

Lack of teaching training of circular supply chain concepts	
Lack of stakeholder participation	
Lack of effective management style in connection with the projects' implementation	
Lack of a model for the circular supply chain acceptance	
Lack of knowledge and awareness of the employees	
Failure to implement circular plans	Raw materials and energy suppliers
Lack of funds and budget	
Sanctions	
Mere attention to quantity and not paying attention to quality	
High investment cost	Funding suppliers
Lack of information sharing system	Employees of managerial and supervisory jobs
Lack of organizational policies and rules	
Traditional culture and mentality of employees	
Lack of appropriate environmental policies	State and public institutions

Barriers were extracted through interviews with steel industry stakeholders and at this stage the qualitative approach of stakeholder analysis was completed. In the next stage, the relationships between the identified barriers are determined based on interpretive structural modelling.

Quantitative stage of interpretive structural modelling

Initially, the identified barriers to the circular supply chain acceptance were listed. Then, using the criteria or variables identified in the first step, a content relationship was defined between them according to each criteria pair. In the next stage, a self-interaction structural matrix was developed for the effective factors, showing the pairwise relationships between the factors influencing the circular supply chain acceptance in the steel industry. Then, the access matrix was developed using the self-interaction structural matrix and this matrix was examined for spread.

In the next step, the access matrix in the previous step was segmented into different levels and based on the relationships defined in the access matrix, a directed graph was drawn and the spread relationships were eliminated. The final diagram was then transformed into interpretive structural modelling by substituting the names of variables or criteria instead of nodes.

In the last stage, the interpretive structural modelling developed in the previous stage was reviewed to make sure that there is no inconsistency in terms of content. In the case of inconsistency, the required corrections were made (Rezaee et al., 2019).

Step 1: Determination of the variables

The list of variables was determined in the qualitative stage, which are:

Table 5: List of Variables Was Determined in the Qualitative Stage

A_1	Lack of appropriate organizational policies and regulations
A_2	Lack of appropriate environmental policies
A_3	More attention to quantity and lack of attention to quality
A_4	Return flow uncertainty
A_5	Lack of effective management style associated with the implementation of circular plans
A_6	Lack of implementation and execution of circular plans

A_7	Deficiency of cooperation between members and stakeholders
A_8	Deficiency of participation of stakeholders
A_9	Lack of proper motivational system
A_{10}	Lack of awareness and knowledge related to the circular chain concept
A_{11}	Lack of training of concepts and implementation of circular supply chain
A_{12}	Lack of equipment, technology, and proper transportation systems
A_{13}	Lack of information sharing system
A_{14}	Lack of a model for circular supply chain acceptance
A_{15}	High investment costs
A_{16}	Lack of budget
A_{17}	Sanctions

Step 2: Obtaining structural self-interaction matrix

The brainstorming technique was used to determine the type of relationships according to the point of view of experts and elites.

The following symbols were used to determine the type of relationship:

V: If criterion i only affects criterion j.

X: If both criterion i affects j and criterion j affects criterion i.

A: If the criterion j affects the criterion i.

O: If there is no effective relationship between the two criteria i and j.

The relationships between the variables were determined based on the opinions of experts (Table 6). In the next step, these relationships must be converted to the numbers zero and one.

Table 6: Determining the Relationships Between Variables Based on Experts' Opinions

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}	A_{17}
A_1		V	X	V	X	X	X	X	X	X	X	X	X	O	V	X	A
A_2			X	X	A	X	X	X	O	X	A	X	O	A	X	A	A
A_3				A	A	X	X	X	O	X`	A	X	X	A	X	X	A
A_4					A	V	V	V	O	A	A	X	A	O	O	O	O
A_5						V	V	V	V	V	V	V	O	V	V	O	O
A_6							X	X	X	X	X	X	A	A	V	V	A
A_7								X	X	X	A	O	A	A	X	X	O
A_8									X	X	A	O	A	A	X	X	O
A_9										X	X	O	X	O	A	V	O
A_{10}											A	V	X	A	X	X	O
A_{11}												V	O	A	V	X	O
A_{12}													A	A	A	A	A
A_{13}														A	X	A	A
A_{14}															V	V	O
A_{15}																V	A

A_{16}																	A
A_{17}																	

Step 3: Initial Access Matrix

At this stage, the structural self-interaction matrix was converted to the zero and one matrix (Table 6). There are only numbers zero and one in this matrix. The rule for inserting the numbers zero and one is as follows:

If the intersection of the criteria (i, j) in SSIM is V, in the access matrix, cell (i, j) is 1, and cell (i, j) is zero.

If the intersection of the criteria (i, j) in SSIM is X, in the access matrix, cell (i, j) is 1 and cell (i, j) is one.

If the intersection of the criteria (i, j) in SSIM is O, in the access matrix, cell (i, j) is 0 and cell (i, j) is zero.

If the intersection of the criteria (i, j) in SSIM is A, in the access matrix, cell (i, j) is 0 and cell (i, j) is one.

The structural self-interaction matrix was converted to the zero and one matrix. Based on these numbers, the internal consistency of the variables is determined in the next step.

Table 7: Initial Access Matrix

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}	A_{17}
A_1		1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0
A_2	0		1	1	0	1	1	1	0	1	0	1	0	0	1	0	0
A_3	0	1		0	0	1	1	1	0	1	0	1	1	0	1	1	0
A_4	0	1	1		0	1	1	1	0	0	0	1	0	0	0	0	0
A_5	1	1	1	1		1	1	1	1	1	1	1	0	1	1	0	0
A_6	0	1	1	0	0		1	1	1	1	1	1	0	0	1	1	0
A_7	0	1	1	0	0	1		1	1	1	0	0	0	0	1	1	0
A_8	0	1	1	0	0	1	1		1	1	0	0	0	0	1	1	0
A_9	0	0	0	0	0	1	1	1		1	1	0	1	0	0	1	0
A_{10}	1	1	1	1	0	1	1	1	1		0	1	1	0	1	1	0
A_{11}	1	1	1	1	0	1	1	1	1	1		1	0	0	1	1	0
A_{12}	1	1	1	1	0	1	0	0	0	0	0		0	0	0	0	0
A_{13}	1	0	1	1	0	1	1	1	1	1	0	1		0	1	0	0
A_{14}	0	1	1	0	0	1	1	1	0	1	1	1	1		1	1	0
A_{15}	0	1	1	0	0	0	1	1	1	1	0	1	1	0		1	0
A_{16}	1	1	1	0	0	0	1	1	0	1	1	1	1	0	0		0
A_{17}	1	1	1	0	0	1	0	0	0	0	0	1	1	0	1	1	

Step 4: The final (goal) achievement matrix

At this stage, the internal consistency between the variables is determined according to the spread relationship and also the influence power and the degree of dependence of the indicators are determined. The spread relation means that if i and j are related to each other and also j and k are related to each other, then, i and k would be also related to each other (Azar et al., 2013).

Spread relationships between the variables were determined based on the final received matrix and the degree of influence and dependence of each variable was determined based on the number of ones in each row and column, respectively (Table 8).

Table 8: Final Achievement Matrix

Degree of influence	A_{17}	A_{16}	A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8	A_7	A_6	A_5	A_4	A_3	A_2	A_1	**Final achievement matrix**
15	0	*1	*1	0	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	1	A_1
15	0	*1	*1	0	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	1	*1	A_2
15	0	*1	*1	0	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	1	*1	*1	A_3
13	0	*1	*1	0	0	*1	*1	*1	*1	*1	*1	*1	0	1	*1	1	*1	A_4
16	0	*1	*1	1	*1	*1	*1	*1	*1	*1	*1	*1	1	*1	*1	*1	*1	A_5
15	0	*1	*1	0	*1	*1	*1	*1	*1	*1	*1	1	*1	*1	*1	*1	*1	A_6
15	0	*1	*1	0	*1	*1	*1	*1	*1	*1	1	*1	*1	*1	*1	*1	*1	A_7
15	0	*1	*1	0	*1	*1	*1	*1	*1	1	*1	*1	*1	*1	*1	*1	*1	A_8
15	0	*1	*1	0	*1	*1	*1	*1	1	*1	*1	*1	*1	*1	*1	*1	*1	A_9
15	0	*1	*1	0	*1	*1	*1	1	*1	*1	*1	*1	1	*1	*1	*1	*1	A_{10}
15	0	*1	*1	0	*1	*1	1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	A_{11}
15	0	*1	*1	0	*1	1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	A_{12}
15	0	*1	*1	0	1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	A_{13}
16	0	*1	*1	1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	A_{14}
15	0	*1	1	0	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	A_{15}
15	0	1	*1	0	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	A_{16}
16	1	*1	*1	0	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1	A_{17}
	1	17	17	2	16	17	17	17	17	17	17	17	16	17	17	17	17	**degree of dependence**

Step 5: Determining the levels of the components

For this step, we needed to identify three sets:

Received set: The received set for a particular variable involves the name of that variable itself, as well as other variables that played role in and contributed to its creation.

Preliminary set: A preliminary set for each variable includes the name of that variable itself, as well as other variables that contributed to their creation.
Subscription set (shared): As its name implies, it is obtained from the common variables in the two above sets.
In the Table 9, after determining the received and preliminary set, the shared set was specified. Variables with similar received and shared sets are located at the top of the model. In the next step, the variables located at the highest level were removed from the received and preliminary sets of other variables and the received and shared sets were reviewed again. This process continued until all variables were levelled. Finally, the variables were classified into four levels.

Table 9: Determining the Levels of Components

Level	**Shared set**	**Preliminary set**	**Received set**	**Components**
1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	**1**
1	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	**2**
1	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	**3**
1	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	**4**
1	1,5, 10, 12,13,14,16,17	1,5, 10, 12,13,14,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	**5**
1	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	**6**
1	1,2,3,4,6,7,8,9,10,11,12,13,14,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	**7**
1	1,2,3,4,6,7,8,9,10,11,12,13,14,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	**8**
1	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	**9**
1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	**10**
1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	**11**
1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	**12**
2	1,2,3,4,5,6,7,8,9,10,11,12,13,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,12,13,15,16,17	**13**
3	1,2,3,6,7,8,9,10,11,12,14,15,16,17	1,2,3,5,6,7,8,9,10,11,12,14,15,16,17	1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17	**14**

1	1,2,3,4,6,7,8,9,10,11,12, 13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,1 2,13,14,15,16,17	1,2,3,4,6,7,8,9,10,11,12, 13,14,15,16,17	**15**
1	1,2,3,4,5,6,7,8,9,10,11,1 2,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,1 2,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,1 2,13,14,15,16,17	**16**
3	1,2,3,4,5,6,7,8,9,10,11,1 2,13,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,1 2,14,15,16,17	1,2,3,4,5,6,7,8,9,10,11,1 2,13,14,15,16,17	**17**

Step 6: Drawing a directed graph

After determining the levels, at this stage, the relationships between the factors were drawn based on the final matrix and elimination of spread relationships. The final model consists of three different levels (Figure 3). Factors at the first level are less effective, and barriers at the lower levels are more effective.

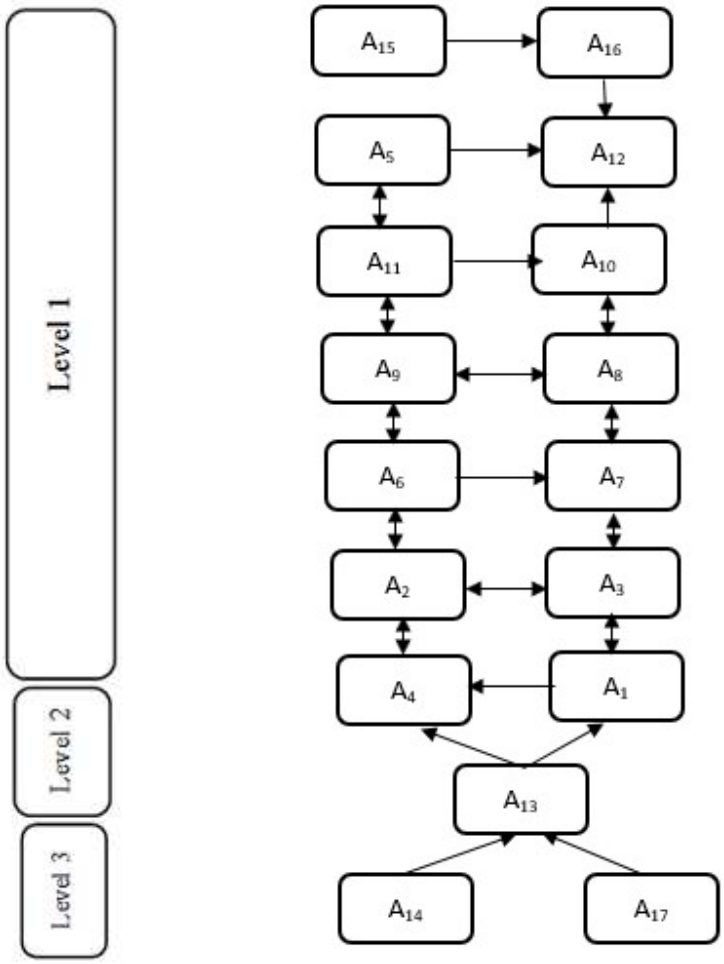

Figure 3: Interpretive Structural Model of Circular Supply Chain Acceptance Barriers

MICMAC analysis

To perform MICMAC analysis, it is necessary to calculate the influence power and dependence of each variable. The influence power was calculated by summing the numbers in each row and the dependence power was calculated by summing the numbers in the final achievement matrix column (Table 9).
According to figure 4, none of the barriers were located in the autonomous area (area with high influence power and low dependence) and also no barriers were placed in the dependent area (area with high dependence and low influence power). Most of the identified barriers are related to the linked area (area with a high degree of dependence and high influence power).

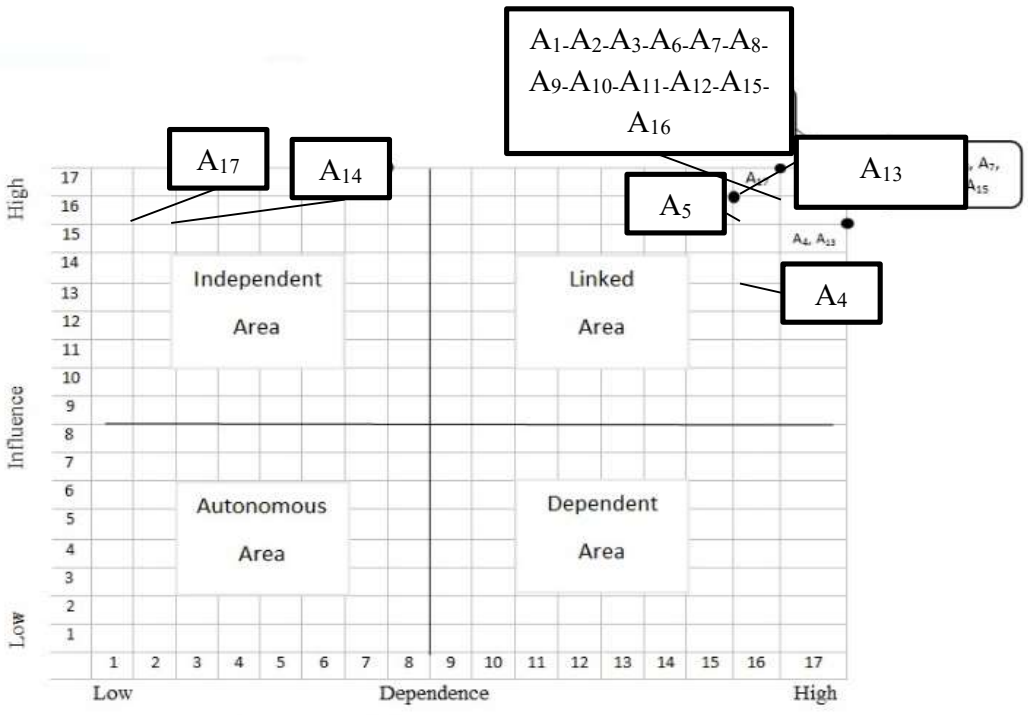

Figure 4: Figure of Influence and Dependence

After extracting the obstacles, the relationships between them were identified by using the interpretive structural modelling approach and MIM analysis. The questionnaire related to the interpretive structural modelling approach was distributed among steel supply chain experts. After determining the final achievement matrix, the 17 barriers identified by key stakeholders were grouped into three levels. The criteria of the third level or the last level (the lowest part of the

graph) have the most relevance and influence on the system, and with their change, the system changes. Here, the barriers of sanctions and the lack of a model for the barriers to adopting a circular supply chain are placed and have no direct relationship with each other. At the next level, the lack of information sharing system between chain members was hindered. The first level obstacles that are located in the highest part of the graph are: lack of appropriate organizational policies and rules, lack of appropriate environmental policies, lack of effective management style in connection with the implementation of circular plans, only attention to quantity and lack of attention to product quality. Uncertainty of return on investment, lack of implementation of circular projects, lack of cooperation between members and stakeholders, lack of stakeholder participation, lack of a suitable incentive system for managers, lack of awareness and knowledge of managers in relation to the concept of circular chain, lack of training Concepts and implementation of circular supply chain to managers, high investment costs, lack of equipment and technology and suitable transportation systems. These barriers have high penetration power and high dependence, and any change in these barriers affects other barriers as well. In other words, these obstacles depend on other obstacles and have mutual relations with each other. Most of the identified barriers were located in the linking area (high penetrating power and high dependence). In addition to influencing other variables, these variables are also influenced by them. In other words, the variables that are placed in the linked area are called trust variables. These variables are actually an indicator of instability in a system because they quickly absorb the effects due to their dependence on other variables. Due to their influence, they quickly transmit the effects. In other words, the speed of influence and effectiveness of these variables makes them have a high ability to disturb the instability of the system. Here, the obstacles that were placed in the link area are: lack of appropriate organizational policies and laws, lack of appropriate environmental policies, lack of information sharing system among chain members, only attention to quantity and not attention to product quality, uncertainty The flow of return on investment, the lack of implementation of circular projects, the lack of cooperation between members and stakeholders, the lack of stakeholder participation, the lack of a suitable incentive system for managers, the lack of awareness and knowledge of managers in relation to the concept of the circular chain, the lack of training in concepts and implementation Building a circular supply chain to managers, high investment costs, lack of equipment and technology and appropriate transportation systems. Any small change in these variables causes major changes in the system. Therefore, in order to accept the circular supply chain, it is very important to consider these obstacles and remove them. The obstacles of sanctions and the lack of a model for adopting a circular supply chain were also placed in the autonomous region. This means that these variables have the greatest impact on other variables and accept the least impact from them.

Conclusion

The purpose of this study was to provide a model for the circular supply chain acceptance, using the qualitative approach of stakeholder analysis and the quantitative approach of interpretive structural modelling. The report provided by the steel industry was used in connection with the analysis of the stakeholders (Steel Industry Supply Chain Report, 2019).

After identifying the stakeholders of the circular supply chain of the steel industry, the position of each stakeholder in the interest and power matrix was determined (Supply chain report of the steel industry, 2019). Then, through interviews, 17 barriers to the circular supply chain acceptance were extracted based on the perspective of key stakeholders. In the quantitative step, using simple random sampling, several experts, specialists, and managers of the steel industry were selected for the research and a structured matrix questionnaire was distributed to determine the relationships between them. Then, using interpretive structural modelling and MICMAC approaches, the data were analysed and plotted at three levels in an interactive network. barriers were divided into two independent and linked area. Obstacles that were placed in the linked area (have the greatest impact on other variables and get the most impact on other variables) are: Lack of appropriate organizational policies and regulations, lack of appropriate environmental policies, mere attention to quantity and lack of attention to quality, return flow uncertainty, lack of effective management style associated with the implementation of circular plans, Lack of implementation and execution of circular plans, Deficiency of cooperation between members and stakeholders, Deficiency of participation of stakeholders, Lack of proper motivational system, Lack of awareness and knowledge related to the circular chain concept, Lack of training of concepts and implementation of circular supply chain, Lack of equipment, technology and proper transportation systems, Lack of information sharing system,, High investment costs, Lack of budget. In general, considering all identified barriers and removing them is important for the successful implementation of a circular supply chain. Although some of the identified barriers are the same in the developed and developing countries, there are, however, some different barriers. Therefore, the separate identification of the barriers is necessary for the successful implementation of a circular supply chain in each industry. Moreover, the provision of a conceptual model for circular supply chain acceptance facilitates the implementation of this approach.

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