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Exploring the factors for open innovation in post-COVID-19 conditions by fuzzy Delphi-ISM-MICMAC approach

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Abstract

Purpose – Open innovation has attracted the attention of experts and business entities for the sustainable survivability of firms, especially in the post-COVID-19 era. The food and beverage industry has been facing sustainable survivability problems. It is important to identify and evaluate the factors of open innovation from the perspectives of the food and beverage industry. This study serves that purpose by identifying and evaluating the factors of open innovation in the post-COVID-19 era with a special reference to Pakistan's economy.

Design/methodology/approach – The present study integrates the Fuzzy Delphi Method (FDM), Interpretive Structural Modelling (ISM) and Matrice d' Impacts Croises Multiplication Applique a Classement (MICMAC) methods to analyze the factors involved in the adoption of open innovation in the food and beverage industry in Pakistan. Firstly, based on an extensive literature review of the most relevant studies, the factors affecting open innovation have been identified and finalized using FDM and experts' opinions. Secondly, the hierarchical framework has also been prepared by implementing the ISM approach. Thirdly, the MICMAC approach was employed to evaluate the factors to examine the driving and dependence powers of the factors of open innovation adoption.

Findings – The study identified 17 factors of open innovation adoption in Pakistan's food and beverage industry and 16 factors were finalized using FDM. The ISM-MICMAC matrix unveiled that awareness seminars and training, along with a lack of executive commitments, were strong factors with high driving power, but these factors proved to be weakly dependent powers regarding the other factors. Moreover, a lack of innovation strategy, R&D and non-supportive organizational culture exhibited low driving power but strong dependent power.

Practical implications – The findings of the study could help firms and business entities understand the driving and dependent factors involved in open innovation for the sustainable survivability of the food and beverage industry. The study provides strong reasons to believe that an open innovation strategy, along with stakeholder collaboration, the adoption of rules and regulations and managerial commitment, could stimulate open innovation. Moreover, governments should promote the business sector, especially the food and beverage industry, to facilitate the sector while also providing awareness seminars and training, creating environments conducive to reducing innovation costs.

Originality/value – Some previous studies have analyzed the factors involved in green innovation from the perspective of the manufacturing industry and environmental protection. The present study is a pioneer study to examine the factors involved in the adoption of open innovation in the food and beverage industry in

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Pakistan from the perspective of the post-COVID-19 era. For this purpose, the present study uses an integrated Fuzzy Delphi-ISM-MICMAC approach for the analysis.

Keywords Open innovation, Factors, Sustainability, Food and beverage industry, ISM-MICMAC approach
Paper type Research paper

Introduction

The COVID-19 pandemic outbreak has caused millions of infections and deaths across the globe. Moreover, it has disrupted businesses and the business strategies of enterprises across the globe. The food and beverage industry is not an exception to the consequences of the pandemic; even in the post-pandemic era, industries are facing labor-related problems (Galanakis *et al.*, 2021). Due to COVID-19-related lockdowns and quarantine restrictions, similar to other industries, food factories have also faced shutdowns (Chesbrough, 2020). International trade restrictions issued by national governments also exacerbated problems and reduced trade by 12–33% (Hayat *et al.*, 2021a, b, c). More than 11% of companies declared bankruptcy during this time of crisis (Markovic *et al.*, 2021b). Similarly, the food and beverage industry is also among the affected sectors (Díaz and Duque, 2021). Many companies lost business temporarily and some lost their businesses permanently. The long-term impact of COVID-19 on the food sector has had a negative impact on firms' inbound and outbound sustainable survivability (Chesbrough, 2020; Aránega *et al.*, 2022; Markovic *et al.*, 2021a) stated that most economies are on the verge of recession due to the long-term consequences of the pandemic. Furthermore, the food and beverage companies have borne a huge loss in terms of lost consumers and brand value during and post the COVID-19 pandemic.

In the post-COVID-19 era, governments and businesses have been facing problems concerning economic recovery. Firms and business entities have been facing challenges in sustainable survivability. However, the latter could be possible through the adoption of open innovation. Open innovation could focus consumer attention toward food items. Open innovation refers to diversification, it is an innovative structural process consisting of the inbound and outbound knowledge taken from user interactions with consumers (Markovic *et al.*, 2021a; Ferraris *et al.*, 2021). Open innovation can be very helpful, especially in times of crisis, as it makes an organization capable of obtaining a good amount of diversity in their external resources (insight, ideas and information) that they otherwise may not have access to Jafari-Sadeghi *et al.* (2022) and Markovic *et al.* (2021a). The use of new technologies could play a productive role in creating new trends and predictions about consumer behavior. According to this approach, products and services beyond COVID-19 would be highly beneficial for businesses (Resciniti *et al.*, 2020). Currently, Iqbal *et al.* (2022) state that Pakistan is still facing the consequence of six COVID-19 waves. The current era of the post-COVID-19 consequences in Pakistan has opened new avenues for the food industry toward the adoption of open innovation related to inward and outward sustainability. There is an immense need to train and familiarize manufacturing and human resource managers with the driving, linkage and dependent barriers to open innovation implementation in manufacturing firms (Jun *et al.*, 2019; Hayat *et al.*, 2021a, b, c).

In the wake of the COVID-19 pandemic, Pakistani food and beverage companies are facing different problems, such as financial loss, issues related to consumer trust and a lack of strategies due to the uncertain pandemic situation, jeopardizing their sustainable survivability in the market. These emerging problems appeal to the introduction of a comprehensive study on influencing open innovation to ensure a firm's market sustainability. Furthermore, earlier studies have investigated open innovation factors, challenges and drivers in different countries and regions. However, there is an absence of analysis on the influencing factors involved in open innovation in the context of Pakistan's food and beverage industry for promoting a firm's sustainable survivability post-COVID-19. Based on the evident research gap, the following empirical research questions require answers. In this way, it becomes imperative to explore the driving factors that play a key role in the recovery of a firm's sustainable market survivability related to COVID-19. Moreover, the authors also find it necessary to investigate how firms responded to the market conditions that appeared due to the pandemic. In addition, it also calls for an analysis of the driving factors that encourage open innovation adoption in the food and beverage industry in Pakistan. Moreover, there is a dire need for a comprehensive model to explain and compile the open innovation factors. Earlier studies have emphasized the adoption of green innovation drivers in the context of the manufacturing industry (Ullah *et al.*, 2022). However, there is a need to explore the factors to the adoption of open innovation in the food and beverage industry in Pakistan, as no study has primarily focused on this issue, especially during the post-COVID-19 pandemic period. There is a dire need to reveal the inter-relationship between these factors (that is the main objective of the study) to provide a clear roadmap to industry policymakers, managers and the government. Therefore, this study aims to examine the open innovation factors involved in integration in Pakistan's food industry.

To examine these questions, this study adopts a novel methodological framework using the Fuzzy Delphi-ISM-MICMAC approach to fill the theoretical gap and evaluate the open innovation factors that play important roles in rebuilding sustainable market survivability in the context of Pakistani food and beverage companies. Firstly, the study identifies the factor of open innovation through an extensive literature search of the most relevant studies. Moreover, the identified factors have been finalized using the Fuzzy Delphi methods based on expert opinions. Secondly, the finalized open innovation factors were ranked from the perspective of the food and beverage industry and market sustainability concerns. For this purpose, the Interpretative Structural Model (ISM) was used to identify the interrelationship between the open innovation factors and develop a hierarchical structural framework of these open innovation factors. Moving forward, the MICMAC approach has been applied to build a link between these open innovation factors from the perspective of the food and beverage industry. This analysis revealed the dependence and driving power of the open innovation factors. The findings of the analysis provide guidelines for decision-makers in the food industry and the government to promote and adopt open innovation practices in the food sector. The adoption of such open innovation practices would be productive in promoting a firm's sustainable market survivability and consumer attachment to promote sales in the food and beverage industry of Pakistan.

Literature review

Several studies are available that concern open innovation, focusing on different industrial sectors and regions (see Table 1). For instance (de Oliveira *et al.*, 2018), conducted a systematic review to identify the most critical success factor involved in open innovation. While reviewing the previous studies in the context of research strategy approaches, objectives, theoretical backgrounds and methodological procedures, the authors revealed leadership, internal innovation capability, network and relationships, strategy, technology management and culture as pivotal success factors involved in open innovation. In another study (Xia *et al.*, 2019; Mokhtarzadeh *et al.*, 2020), attempted to establish a comprehensive barrier-identification system for green technology adoption at operational levels in business entities in China.

Some studies have focused on green innovation barriers in the industrial sector. For instance (Ullah *et al.*, 2021), examined the mapping interactions between the barriers to green innovation in the manufacturing industry in developing economies. The study revealed that the lack of enforceable laws related to goods and recycled goods, a lack of rules and

Study/reference	Objective	Method	Findings
Usmani *et al.* (2022a)	Empirical evaluation of CSR initiatives in the food sector in Pakistan	ISM–MICMAC	Training and workshops for employees and employee welfare and empowerment are pivotal CSR initiatives to be incorporated into the food sector in Pakistan
Saguy (2022)	Analysis of opportunities and challenges of open innovation in food SMEs	Review study	The food SMEs need a new paradigm shift to adopt open innovation, innovative strategies, new business models, management roles and collaboration between the stakeholders
Singh and Dhir (2022)	To expose the mutual relationship among influencing antecedents towards innovation adoption	ISM-MICMAC	Two antecedents as Leader competency and employee competency were founding the driving antecedents of innovation adoption
Bertello *et al.* (2022)	Analysis of challenges to open innovation in traditional SMEs	Longitudinal data analysis	SME level challenges, project level challenges
Ullah *et al.* (2022)	Analysis of factors to promote sustainability through green innovation adoption in the manufacturing industry of Pakistan	Fuzzy Delphi, ISM-MICMAC	Cost reduction and government support are critical factors in green innovation adoption
Novillo-Villegas *et al.* (2022)	Examination of the development of innovation capacity in developing economies	ISM-MICMAC Analysis	Promotion and protection of innovation and intellectual property are relevant to develop the ground for innovation capacity
Uttama (2021)	Analysis of open innovation and business model of the health food industry in Asian economies	Panel Quantile Regression	The concentration of distribution channels showed a negative and significant impact on health and food consumption
Gupta and Barua (2021)	Evaluation of the ability of the manufacturing organizations to overcome internal barriers to green innovations	ISM, BWM and VIKOR	Lack of resources and unavailability of financial and human capital are barriers to greening the operations of organizations
Ullah *et al.* (2021)	Mapping Interactions among Green Innovations Barriers in Manufacturing Industry	ISM-MICMAC	The lack of enforceable laws related to goods and recycled goods, lack of rules and regulations related to green practices and lack of collaboration with governments and environmental agencies are the pivotal factors of green innovation
Xia *et al.* (2019)	Identification of barriers to Green technology adoption for enterprises in China	Fuzzy AHP	Identified the framework and analyzed the system of barriers in the way to adopting green technology
de Oliveira *et al.* (2018)	A systematic review of factors of open innovation	A systematic review	The study identified leadership, internal innovation capability, network and relationships, strategy, technology management and culture as pivotal factors of open innovation

Table 1.
Review of relevant studies

regulations related to green practices and a lack of collaboration with governments and environmental agencies are the pivotal factors involved in green innovation in the manufacturing industries of developing countries. In another study (Ullah *et al.*, 2022), examined what factors promote sustainability through the adoption of green innovation in the manufacturing industry. The study used a hybrid analytical approach by integrating the Fuzzy Delphi, ISM and MICMAC approaches. The study revealed cost reduction and government support to be the important drivers that stimulate green innovation adoption in the manufacturing industry in Pakistan.

In another study (Bertello *et al.*, 2022; Satyanarayana *et al.*, 2022) examined the challenges facing open innovation in traditional SMEs and provided a multilevel analysis of SME-level challenges and project-level challenges. The SME-level challenges included a lack of innovation and strategy, a lack of partner mapping, inadequate information systems, time pressures, a lack of resources and a lack of commitment post-project, as well as inadequate management control systems, whereas project-level challenges included goal incongruence, unknown patterns, goal redefinition, understanding of partners' efforts, excessive numerosity and heterogeneity, delays in goal achievement, ineffective policies for higher technological readiness levels and bureaucratization.

In the same way (Gupta and Barua, 2021), highlighted the internal barriers to innovation in manufacturing firms, such as human constraints and a lack of resources. In addition, Fuzzy TOPSIS and BWM were applied to rank the barriers to innovation in the context of India; after a careful review of previous studies and taking the expert's opinion, 36 barriers were finalized. In another study (Singh and Dhir, 2022), identified eight antecedents to innovation implementation and demonstrated that competency antecedents, including leader competency and employee competency, have high driving power and weak dependence power. Moreover, the study further revealed that innovation implementation showed high dependence but low driving power, whereas strategic resources acted as a linkage factor. Using the ISM-MICMAC approach (Novillo-Villegas *et al.*, 2022; Hajiagha *et al.*, 2022), showed that the promotion and protection of innovation and intellectual property are relevant in paving the way for the development of innovation capacity.

Some recent studies have focused on innovation adoption in the food and beverages sector. For instance (Samborska *et al.*, 2022; Singh *et al.*, 2022), examined extensive historical literature on spray-drying methods for drying dates. However, the authors stressed the need for the adoption of innovative methods for processing and drying dates (Jafari-Sadeghi *et al.*, 2023; Saguy, 2022) argue that SMEs are the major contributor to job creation in global economies. However, it is important to exploit the competitive advantage of SMEs along with innovations in the era of the digital economy. The author asserts the adoption and implementation of open innovation in the post-pandemic period. The adoption of open innovation, especially in food SMEs, could contribute to productivity and efficiency, not only in developing sustainable food security and safety but also ensuring job creation (Uttama, 2021; Mahdiraji *et al.*, 2021). evaluated whether health trends, technology and market concentration affect the consumption of healthy foods in 14 Asian economies. The model estimations show that health trends and digital technology have a positive and significant impact, negatively affecting the consumption of healthy foods. The study asserted the need for a consumer-driven open innovation strategy for the development of health and wellness food businesses (Hayat *et al.*, 2020).

The food processing industry is considered the second largest industry and has contributed to the nation's economy by USD 223.5 in the last five years and it is 27% of the country's total production value (Usmani *et al.*, 2022a). In addition, it employs 16% of the country's population (Usmani *et al.*, 2022a). The food industry can be divided into the following sectors: (1) edible oil production units, (2) processed and frozen foods, (3) beverage production plants and (4) bakery and confectionery-based plants. In all of these sectors, a total of 15% of the food processing companies are present on the stock exchange market out of a total of 540 firms, accounting for 2.8% of the total listed firms in the country (Usmani *et al.*, 2022a). Furthermore, Pakistan is placed among the top 15 food-producing countries and has a consumer base of more than 200 million people, ranking it as the eighth largest market. In addition, consumers spent more than 42% of their total income on food. To meet these needs, firms must recruit more than the existing 16% of employees in the manufacturing sector (Agyemang *et al.*, 2020). Issues related to sustainability in food are naturally embedded due to the consumption of natural resources and the human need for nutrition. The overview of the existing literature on the factors of open innovation revealed that the majority of studies focused on the factors of open innovation in the manufacturing sector, including SMEs. However, a limited number of studies have focused on analyzing the factors affecting open innovation related to the food and beverage industry. Moreover, it is also notable that there is no such study that has focused on the analysis of the open innovation factors related to the food and beverage industry with a special reference to Pakistan's economy. Nevertheless, it is imperative to identify and evaluate the factors affecting open innovation adoption in the food and beverage industry in Pakistan to strategize food security and safety in the post-COVID-19 era. On the basis of previous studies, the proposed factors of open innovation are presented in Table 2.

Research methodology

This study aims to fulfill the research gap by adopting both quantitative and qualitative techniques. The barriers to open innovation were identified with the help of experts' opinions and a careful review of the earlier literature. Then, the Fuzzy Delphi method was used to filter these identified barriers. After the filtration and finalization of the barriers, the ISM-MICMAC technique is applied for empirical analysis. The ISM approach can gather expert opinions and hold panel debates to reveal the contextual relationship between the barriers. In some earlier studies, academic researchers have applied the ISM-MICMAC approach to promoting open innovation practices. For instance (Ullah *et al.*, 2022; Hayat *et al.*, 2021a, b, c), investigated the role of green innovation in sustainability for the promotion of manufacturing firms with the use of the ISM-MICMAC approach. (Ullah *et al.*, 2021) applied the ISM-MICMAC approach to evaluate barriers to green innovation in the manufacturing industry of a developing country. Applied the ISM-MICMAC approach to boost sustainable manufacturing in the context of India. Furthermore, MICMAC analysis is used to assess the dependency and driving

No	Factors	References
1	Lack of innovation strategy	Ullah *et al.* (2021, 2022)
2	Uncertainty in consumer demand	Ullah *et al.* (2022)
3	Lack of innovation experience	Ullah *et al.* (2021)
4	Lack of partner collaboration	Saguy (2022) and Ullah *et al.* (2021)
5	Lack of innovation motivation	Malek and Desai (2019)
6	High market saturation	Novillo-Villegas *et al.* (2022)
7	Lack of technical competence	Ullah *et al.* (2021)
8	Lack of regulations and standards	Bux *et al.* (2020)
9	High innovation cost	Bux *et al.* (2020) and Ullah *et al.* (2022)
10	Lack of technological advancement	Bux *et al.* (2020) and Ullah *et al.* (2021)
11	Fear of failure	Bux *et al.* (2020)
12	Lack of research and development	Novillo-Villegas *et al.* (2022)
13	Lack of time	Ullah *et al.* (2021)
14	Lack of seminars and training about open innovation	Gupta and Barua, (2021) and Ullah *et al.* (2022)
15	Lack of executive commitment	Malek and Desai (2019)
16	Un-supportive organizational culture	Malek and Desai (2019)
17	Lack of strategic fit*	Ullah *et al.* (2021)

Table 2.
Summary of Key factors of open innovation

influence of the barriers. The reason behind the adaptation of the ISM-MICMAC approach is that it can expose the contextual relationship between the different factors or barriers according to their driving and dependence power (Usmani *et al.*, 2022b; Mathiyazhagan *et al.*, 2013). It recommends a hierarchical model of proposed factors. Analytic Network Process (ANP) only recommends the hierarchy of proposed factors and does not expose the mutual relationship between the factors. Decision-Making Trial and Evaluation Laboratory (DEMATEL) techniques only reveal the mutual relationship between the factors. MICMAC analysis involves development and classifies the factors based on driving power and dependence power. MICMAC analysis is used to classify the factors and validate the interpretive structural model factors in the study to obtain results and conclusions. Several studies have proposed methods for modeling and examining the outcomes of change propagation. However, for reasons of practicality and design, these need to be supported by simple tools that enable them to model and analyze the dependencies between the key factors and barriers in the early design phase. In the initial stage, interpretive structural modeling (ISM) is utilized to arrange factors/barriers into a simple hierarchical form. In the following stage, cross-impact matrix multiplication (MICMAC) analysis is implemented to classify the factors/barriers in terms of their criticality.

The results from the modeling and analysis show that the proposed approach could be useful to the managers opting to use innovation methods as well as to those who rely only on their experience and knowledge to assess the consequences of changes. The reason behind the adaptation of the ISM-MICMAC approach is to identify which barriers to open innovation are relevant to the problem. After the identification of the key factors, the strategy introduces coping strategies related to the issue of establishing an open innovation culture in Pakistan's food and beverage industry, as well as strategies for retaining market sustainability. The second reason behind the selection of the ISM-MICMAC approach was that there was no study found that prioritizes the barriers to open innovation in the food and beverage industry of Pakistan in the post-COVID-19 period. In this vein, a novel ISM-MIMAC methodology was adopted to prioritize the driving factors to open innovation in the food industry of Pakistan. The steps of the ISM methodology are presented in Figure 1.

Step 1: Identification and selection of factors

The purpose of this study is to indicate and analyze the significant factors involved in the food and beverage industry of Pakistan. This aim was primarily achieved by collecting the relevant research concerning the open innovation factors in different concepts published throughout different journals related to innovation, sustainability, business, organizational studies and sustainable practices. The data used for this research were taken from reliable resources, including Scopus, Science Direct and Emerald insight Wiley online. Taylor, Springer and Google Scholar were searched by using the following keywords: open innovation, open innovation factors, open innovation drivers, innovation in the food industry and open innovation implementation in Pakistan.

Step 2: Screening of open innovation factors through FDM

FDM is largely used as a structured interpretive and communication method, which is highly dependent on the views of experts; thus, the use of multiple-round answers to these questions is suggested. At the end of each round, a facilitator or a moderator presents these questions in front of the expert. This is finalized and their responses are provided according to the answers given by their fellow panel members. This method encourages experts to finalize the number of factors and identify the best-suited factors.

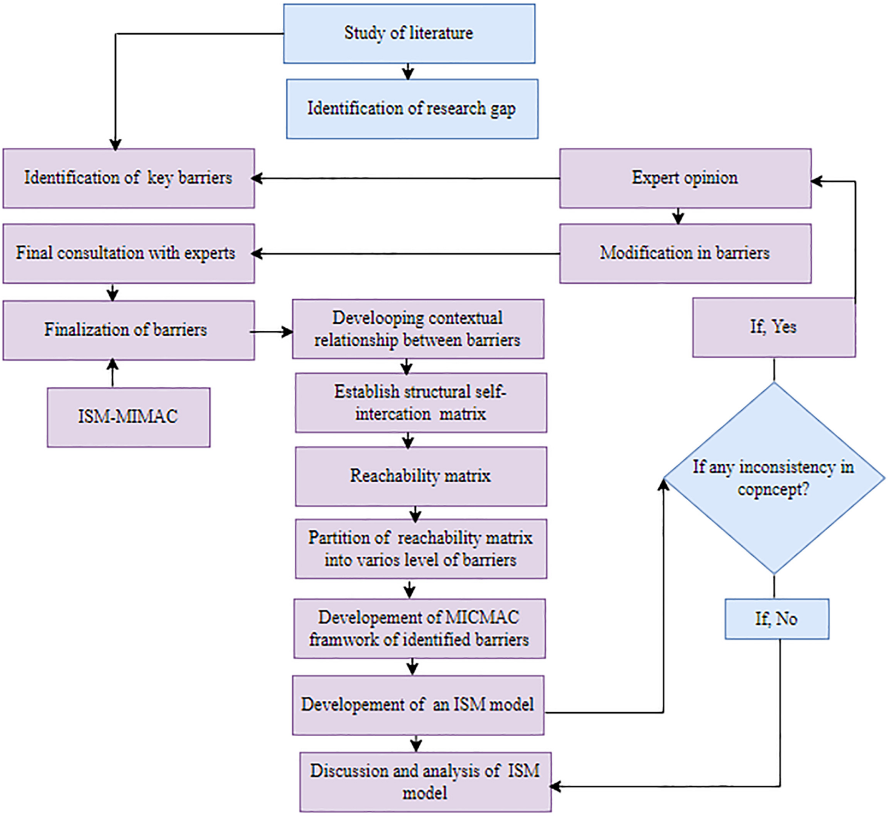

Figure 1.
Proposed research framework

To obtain expert consensus, the center of gravity rule is implemented. The method that is followed during FDM screening can be seen below.

$$V_k = (Minimum\,value,\ GM,\ maximum\,value)/3 \tag{1}$$

V_k shows the starting value chosen for the screening in the most suitable open innovation factors for further investigation. Following two variations of the Fuzzy Delphi method, a list of 17 open innovation factors was selected and the expert opinions concluded that 16 barriers exist in relation to open innovation. The experts suggested that strategic fit (B17) as a dominant orientation is not important for the case study. The open innovation barriers are shown in Table 1.

Step 3: ISM-MICMC

In this method, we checked the causes and effect element as a comprehensive method by finding many barriers or factors from complex processes (Mangla *et al.*, 2014). Different types of literature were applied to the ISM technique to analyze the impact of one barrier compared to others that are interrelated (Lim *et al.*, 2017). Warfield (1974) stated that there is always an essential need for experts and their valuable opinions regarding the establishment of the ISM model. In this regard, a panel of nine experts was selected. For instance, based on previous studies (Malek and Desai, 2019), adopted the ISM-MICMAC approach to calculate the driving and dependence powers related to sustainable manufacturing enablers in the context of India by only using the opinions of seven experts. In the same way, Ullah *et al.* (2021) incorporated the ISM-MICMAC approach and conducted research based on the opinion of six experts. Similarly, Ullah *et al.* (2022) used a mixed methodology ISM-MICMAC technique that was implemented to reveal the driving power behind drivers of green innovation adoption in the manufacturing industry by using the responses of seven experts. Furthermore, the studies of (Hussain *et al.*, 2019). Currently, Iqbal *et al.* (2021) stated in their study that expert-opinion-based methodologies, such as the ISM-MICMAC approach, require a low sample size for analysis. The threshold level of the sample size is a minimum of eight experts (Ahmad *et al.*, 2019). Based on earlier studies' sample sizes, our study sample size is adequate and meets the threshold requirements for sample size. All of the experts have 15 years of experience with case studies. All of these experts are well-trained and have sound knowledge related to the topic. In addition, all members of the panel were involved in open innovation practices and the use of this process. The profiles of the experts are given in Table 2. The research data were collected from the food and beverage industry of Pakistan. At the initial stage, twenty experts were approached through multiple emails and phone calls and the contact information was taken from the company's websites and some other sources. All of the experts were briefed about the research problems and the barriers facing open innovation. Finally, 9 out of the 20 experts agreed to share their personal opinion in the study. All of the experts have 15 years of experience with case studies. The ISM-MICMAC approach is based on expert judgments and opinions and for this purpose, the experts were selected based on their experience (Iqbal *et al.* 2022). All of these experts are well-trained and have sound knowledge related to the topic. In addition, all members of the panel were involved in open innovation practices and the use of this process. The profile of the experts is given in Table 3.

This study uses the ISM approach to identify and establish a contextual harmony among the factors with the help of an expert's opinion. The steps of the ISM process are as follows.

(1) The identification of the factors is conducted through the careful study of the previous literature. The barriers that are affecting the implementation process are identified by the panel of experts and they finalize them.

(2) To create a relationship, pairs of factors are made that are explained to create the structure self-interaction matrix for the development of a relationship among the factor and expert opinions are taken.

(3) The construction of the primary reachability matrix using SSIM is achieved by changing the suggestion of the experts into binary numbers. To establish the final reachability matrix, the transitivity rule is tested. The fundamental rule of transitivity states that if an element A is linked with B and B is linked to C, A must-have link with C.

(4) To generate the results of the MICMAC approach, the results of the MICMAC are obtained from the element of dependence and driving power. These barriers are divided into four clusters such as driving, dependent, linkage and autonomous.

(5) Format a suggested graph depending on connectivity between the factors presented in the last reachability matrix and then the transitivity linkage is eliminated.

(6) Use a directed paragraph to create an ISM structural factors model.

To check the authenticity of the results, the theoretical interpretive structural model is rechecked in cases of inconsistency. The steps used in ISM model modeling are shown in Figure 1.

The construction of the structural self-interaction matrix (SSIM)

To implement the ISM approach, the structural self-interaction matrix is the first step in the process of implementation. The structural self-interaction matrix (SSIM) proposes an optical demonstration of the expert opinions for further processing and to determine the contextual relationship between the identified factors. A research questionnaire was prepared and delivered to a group of experts with the basic aim of revealing the interrelation between the factors. The aim of the research problem and a brief introduction to the barriers are presented by the author to the experts. The provision of such details helped the experts to reveal the mutual relationship between each pair of factors. Questions were asked to the experts relating to the mutual relationship of each pair of barriers. The relationship direction between any two factors was based on (i and j). According to Luthra *et al.* (2014), the structural self-interaction matrix (SSIM) table was prepared with the use of the VAXO symbol as follows.

V: Factor (i) will help to reach factor (j)

A: Factor (j) will help to reach factor (i)

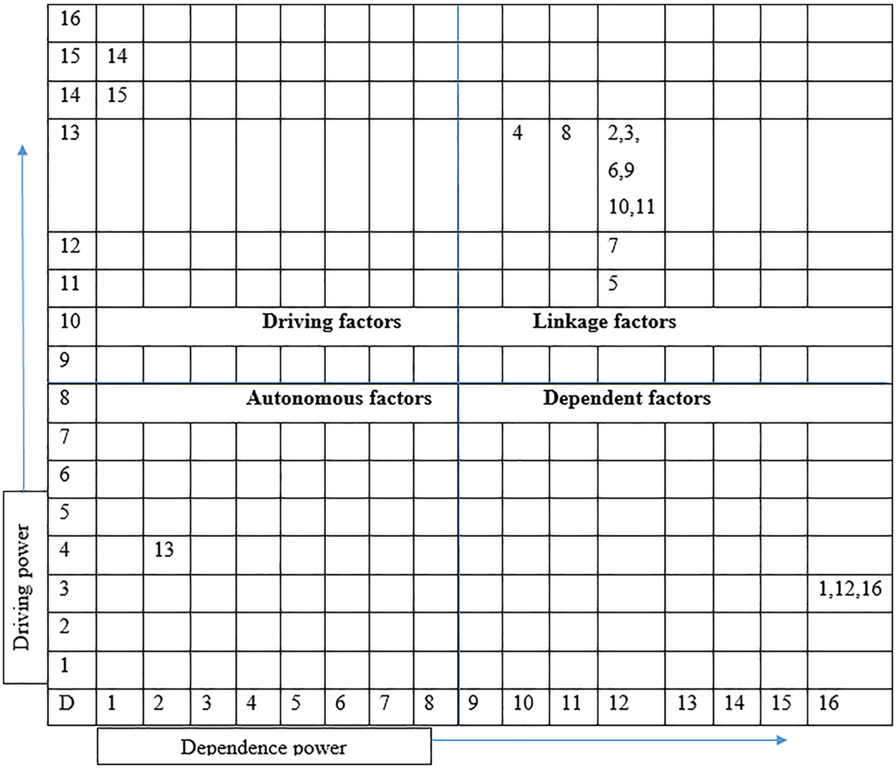

Figure 2.
MIMAC analysis matrix

X: Both factors (i) and (j) help to reach each other

O: Both factors (i) and (j) are not linked with each other

(1) According to Table 3, factor 2 helps to reach or influence factor 1. It means that “suddenly consumer demand” increases, then “lack of innovation strategy” increases. So, the relationship between factors 1 and 2 is denoted by “A” in Table 2 (see Table 4).

Table 3. Experts detail

Sr.no	Position	Experience	Education	Gender
1	Production manager	15	PhD	Male
2	Production manager	15	PhD	Male
3	Supply chain manger	12	Master	Female
4	Technological manager	15	PhD	Female
5	Technological manager	12	PhD	Male
6	Technological manager	11	Master	Male
7	Environmental protection manager	15	PhD	Male
8	Environmental protection manager	14	PhD	Female
9	Safety manager	12	Bachelor	Male

Table 4. Self structural Interaction Matrix (SSIM)

Sr.	Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
F1	Lack of innovation strategy		A	A	A	O	A	O	A	A	A	A	V	O	A	A	A
F2	Suddenly consumer demand			X	X	O	X	O	X	A	A	X	V	O	A	O	V
F3	Lack of innovation experience				X	O	O	O	A	X	A	X	V	O	A	O	V
F4	Lack of partner collaboration					O	V	O	V	A	A	A	V	O	A	O	V
F5	Lack of innovation motivation						O	O	A	X	A	A	V	O	A	O	V
F6	High market saturation							V	A	X	O	X	V	O	A	O	V
F7	Lack of technical competence								X	X	V	X	V	O	A	O	V
F8	Lack of time									V	V	V	V	O	A	O	V
F9	High innovation cost										X	X	V	O	A	O	V
F10	Lack of seminar and training on open innovation											A	V	O	A	O	V
F11	Lack of strategic fit												O	O	A	O	V
F12	Lack in research and development													A	O	O	V
F13	Lack in technology advancement														A	O	V
F14	Lack of regulation and standards															O	V
F15	Lack of executive commitments																O
F16	Un-supportive Organizational culture																

(2) Barrier 2 can be achieved by factor 3. Such as "suddenly consumer demand" assists in achieving factor 3, "Lack of innovation experience". Therefore, the relationship between factors 2 and 3 is denoted by "A" in Table 3.

(3) In addition, factors 2 and 3 support achieving each other. It means that "suddenly consumer demand" and "Lack of innovation experience" help to achieve each other. Therefore, the relationship between factor 2 and 3 is denoted by "X".

(4) At last, there is no relationship between factors 1 and 5. It means that "lack of innovation strategy" and "lack of innovation motivation" are unrelated to each other. Therefore, the relationship between factors 1 and 5 is denoted by "X" in Table 3.

The construction of the initial reachability matrix

The transformation of the SSIM matrix into a binary number (0, 1) is called the initial reachability matrix. The entry process of a binary number (0, 1) is as follows.

(1) Assume that, if a cell (i, j) is indicated with the symbol "V" in the SSIM table, then cell (i, j) is denoted with 0 and 1/we put the 1 and 0 for cell (i, j).

(2) Suppose that (i, j) is indicated with the symbol "A" in the SSIM table, then we put 0 and 1 for cell (j, i).

(3) Assume that if cells (i, j) and (j, i) are indicated with the symbol "X" in the SSIM table, then we put 1.

(4) Suppose that both cells (i, j) and (j, i) are denoted with the symbol "O" in the SSIM table, then we put 0.

Finally, we acquired an initial reachability matrix for the factors involved in open innovation by following the above principles.

Construction of final reachability matrix (FRM)

The next step is the development of a final reachability matrix. The transformations of the initial reachability matrix into the final reachability matrix are achieved with the help of the transitivity rule. According to the transitivity rule, it is mandatory to replace those cells comprising 0 to 1. Therefore, by following the transitivity rule, we put "*" into 1 in the final reachability matrix. The dependence and driving power of factors were determined with the help of the final reachability matrix by counting the entries of row and Column in the final reachability matrix, which is presented in Table 5.

Level partition

The next task is the level portioning of the factors. With the help of the final reachability matrix, the partition of factors was divided into different levels. The key concern of this partition is to recognize their value in the hierarchy. The principles of obtaining level are as follows: while the values of the interaction and reachability sets have the same factors, in this case, the factors will be given level one. The process was repeated until all of the factors were given a specific level. According to the results of our study, five levels were assigned to propose factors by following this procedure. "Lack of seminar and training about open innovation" and lack of executive commitments were found at level one. Similarly, a lack of partner collaboration and a lack of regulations and standards were assigned/appeared at level five. The results of all levels of this study are presented in Tables 6–10.

Sr.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
2	1	1	1	1	0	1	0	1	0	0	1	1	0	0	0	1
3	1	1	1	1	0	0	0	0	1	0	1	1	0	0	0	1
4	1	1	1	1	0	1	0	1	0	0	0	1	0	0	0	1
5	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1
6	0	1	0	0	0	1	1	0	1	0	1	1	0	0	0	1
7	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1
8	1	1	1	0	1	1	1	1	1	1	1	1	0	0	0	1
9	1	1	1	0	1	1	1	0	1	1	1	1	0	0	0	1
10	1	1	1	0	1	0	0	0	1	1	0	1	0	0	0	1
11	1	1	1	0	1	1	1	0	1	1	1	0	0	0	0	1
12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
13	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
14	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1
15	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 5.
Initial Reachability Matrix (IRM) designed for factors to open innovation

SR.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Driving Power
1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1*	3
2	1	1	1	1	1*	1	1*	1	1*	1*	1	1	0	0	0	1	13
3	1	1	1	1	1*	1*	1*	1*	1	1*	1	1	0	0	0	1	13
4	1	1	1	1	1*	1	1*	1	1*	1*	1*	1	0	0	0	1	13
5	1*	1*	1*	0	1	1*	1*	0	1	1*	1*	1	0	0	0	1	11
6	1*	1	1*	1*	1*	1	1	1*	1	1*	1	1	0	0	0	1	13
7	1*	1*	1*	0	1*	1*	1	1	1	1	1	1	0	0	0	1	12
8	1	1	1	1*	1	1	1	1	1	1	1	1	0	0	0	1	13
9	1	1	1	1*	1	1	1	1*	1	1	1	1	0	0	0	1	13
10	1	1	1	1*	1	1*	1*	1*	1	1	1*	1	0	0	0	1	13
11	1	1	1	1	1*	1	1	1*	1	1	1	1*	0	0	0	1	13
12	1*	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	3
13	1*	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	4
14	1	1	1	1	1	1	1	1	1	1	1	1*	1	1	0	1	15
15	1	1*	1	1*	1*	1*	1*	1*	1*	1*	1*	1*	0	0	1	1*	14
16	1	0	0	0	0	0	0	0	0	0	0	1*	0	0	0	1	3
Dependence Power	16	12	12	10	12	12	12	11	12	12	12	16	2	1	1	16	169

Table 6.
Final reachability matrix (FRM) designed for factors to open innovation implementation

Results of MICMAC analysis

First of all, the MICMAC analysis exposes the identification of the independent, dependent, autonomous and linkage factors. In addition, the MICMAC analysis presents a graphical picture of the power of the driving and dependence factors considered in this study. The MICMAC analysis ensures ISM model validation. In MICMAC analysis, the final reachability matrix (FRM) is used to calculate the driving and dependence power of each factor of the study. Furthermore, FRM is used in MICMAC analysis to interpret and calculate columns and

Sr.	Reachability set	Antecedent set	Intersection set	Level
1	1,12,16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,12,16	I
2	1,2,3,4,5,6,7,8,9,10,11,12,16	2,3,4,5,6,7,8,9,10,11,14,15,	2,3,4,5,6,7,8,9,	
3	1,2,3,4,5,6,7,8,9,10,11,12,16	2,3,4,5,6,7,8,9,10,11,14,15,	2,3,4,5,6,7,8,9,10,11,	
4	1,2,3,4,5,6,7,8,9,10,11,12,16	2,3,4,6,8,9,10,11,14,15,	2,3,4,6,8,9,10,11	
5	1,2,3,5,6,7,9,10,11,12,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,5,6,7,9,10,11	
6	1,2,3,4,5,6,7,8,9,10,11,12,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11	
7	1,2,3,5,6,7,8,9,10,11,12,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,5,6,7,8,9,10,11	
8	1,2,3,4,5,6,7,8,9,10,11,12,16	2,3,4,6,7,8,9,10,11,14,15	2,3,4,6,7,8,9,10,11	
9	1,2,3,4,5,6,7,8,9,10,11,12,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11	
10	1,2,3,4,5,6,7,8,9,10,11,12,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11	
11	1,2,3,4,5,6,7,8,9,10,11,12,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11	
12	1,12,16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	1,12,16	I
13	1,12,13,16	13,14		
14	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16	14	14	
15	1,2,3,4,5,6,7,8,9,10,11,12,15,16	15	15	
16	1,12,16	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16	16	

Table 7.
Level partition
(Iteration 1)

Sr.	Reachability set	Antecedent set	Intersection set	Level
2	2,3,4,5,6,7,8,9,10,11,16	2,3,4,5,6,7,8,9,10,11,14,15,	2,3,4,5,6,7,8,9,10,11	
3	2,3,4,5,6,7,8,9,10,11,16	2,3,4,5,6,7,8,9,10,11,14,15,	2,3,4,5,6,7,8,9,10,11	
4	2,3,4,5,6,7,8,9,10,11,16	2,3,4,6,8,9,10,11,14,15,	2,3,4,6,8,9,10,11	
5	2,3,5,6,7,9,10,11,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,5,6,7,9,10,11	
6	2,3,4,5,6,7,8,9,10,11,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11	
7	2,3,5,6,7,8,9,10,11,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,5,6,7,8,9,10,11	
8	2,3,4,5,6,7,8,9,10,11,16	2,3,4,6,7,8,9,10,11,14,15	2,3,4,6,7,8,9,10,11,	
9	2,3,4,5,6,7,8,9,10,11,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11	
10	2,3,4,5,6,7,8,9,10,11,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11	
11	2,3,4,5,6,7,8,9,10,11,16	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11	
13	13,16	13,14	13	
14	2,3,4,5,6,7,8,9,10,11,13,14,16	14	14	
15	2,3,4,5,6,7,8,9,10,11,15,16	15	15	
16	16	2,3,4,5,6,7,8,9,10,11,13,14,15,16	16	II

Table 8.
Level partition
(Iteration 2)

Sr.	Reachability set	Antecedent set	Intersection set	Level
2	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11,14,15,	2,3,4,5,6,7,8,9,10,11	III
3	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11,14,15,	2,3,4,5,6,7,8,9,10,11,	III
4	2,3,4,5,6,7,8,9,10,11	2,3,4,6,8,9,10,11,14,15,	2,3,4,6,8,9,10,11	
5	2,3,5,6,7,9,10,11	2,3,4,5,6,7,8,9,10,11,14,15	2,3,5,6,7,9,10,11	III
6	2,3,4,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11	III
7	2,3,5,6,7,8,9,10,11	2,3,4,5,6,7,8,9,10,11,14,15	2,3,5,6,7,8,9,10,11	III
8	2,3,4,5,6,7,8,9,10,11	2,3,4,6,7,8,9,10,11,14,15	2,3,4,6,7,8,9,10,11	
9	2,3,4,5,6,7,8,9,10,11,	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11,	III
10	2,3,4,5,6,7,8,9,10,11,	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11	III
11	2,3,4,5,6,7,8,9,10,11,	2,3,4,5,6,7,8,9,10,11,14,15	2,3,4,5,6,7,8,9,10,11	III
13	13	13,14	13	III
14	2,3,4,5,6,7,8,9,10,11,13,14,	14	14	
15	2,3,4,5,6,7,8,9,10,11,15,	15	15	

Table 9.
Level partition
(Iteration 3)

rows and determine the dependencies and driving powers. For each factor in the study, the interpretation of columns and rows reveals the dependence and driving power in Table 3.

Furthermore, the MICMAC analysis classifies the factors into four clusters, such as autonomous, dependent, linkage and independent clusters. The presentation of the clusters is given as I, II, III and IV, respectively.

Independent factors: This cluster of factors has weak dependent power and strong driving power and is positioned at the lowest level of the ISM model. It is evident from the MICMAC analysis that "lack of seminar and training about open innovation (F14)" and "lack of executive commitments (F15)" are key factors involved in open innovation implementation. The identification of the top factors involved in open innovation through MICMAC analysis motivates industrial managers to remove these barriers through employee training, rewards and the empowerment of top management. The analysis of MICMAC is presented in Figure 2.

Autonomous factors: In this cluster, a lack of time (F13) was found. This category of autonomous factors has weak dependence and driving power.

Dependent factors: This cluster of factors has identified only three barriers, which are "lack of innovation strategy (F1), a lack of research and development (F12) and unsupportive Organizational culture (B16). The cluster of dependent factors has a strong dependent force and weak driving force and it is positioned at the top of the ISM model.

Linkage factors: This cluster of barriers that have both strong powers, such as driving power and dependent power, are the ten factors found in the middle of the ISM model, which are sudden consumer demand (F2), lack of innovation experience (F3), lack of partner collaboration (F4), lack of innovation motivation (F5), lack of technical competence (F7), lack of regulations and standards (F8), high innovation cost (F9), lack of technology advancement (F10) and fear of failure (F11).

ISM analysis results

Open innovation has become the key business strategy to promote firm worth and sustainability during crisis periods. Tremendous efforts are underway in relation to open innovation, especially in developed countries. However, in developing countries, including Pakistan, the concept of open innovation has not matured enough in the food sector. For this purpose, the current study aims to analyze the factors that influenced open innovation adoption in the food industry of Pakistan during the pandemic outbreak. COVID-19 has wreaked chaos in our public health services system. This pandemic outbreak is also shrinking our economic systems. The recovery from the effects of the COVID-19 pandemic is increasingly dependent on innovation. In this domain, the author articulates that managing innovation is part of the recovery and provides some lessons that we can learn from how we have dealt with the virus thus far and what those lessons mean for managing innovation going forward (Galanakis *et al.*, 2021; Hayat *et al.*, 2021a, b, c).

The ISM-MIMAC approach was used to obtain the empirical results of the study. The five levels of the results were extracted with the help of the ISM-MICAC methodology provided in Table 11. The finding of level five indicated that "lack of seminars and training about open innovation" (F14) and "lack of executive commitment" (F15) are the key factors involved in

Sr.	Reachability set	Antecedent set	Intersection set	L
4	4,8,	4,8,14,15,	4,8	IV
8	4,8,	4,8,14,15	4,8	IV
14	4,8,14,	14	14	
15	4,8,15,	15	15	

Table 10.
Level partition (Iteration 4)

the adoption of open innovation. Human and financial resources are the initial need of firms to adopt any activity in their operations. "Lack of seminars and training about open innovation" (F14) and "lack of executive commitment" (F15) are human-related factors that hinder the adoption of open innovation in the food and beverage industry of Pakistan. Lack of workshops on open innovation and well-trained individuals are key impeding factors to implementing innovation in manufacturing firms (Sukumar *et al.* 2020). According to (Molina and Ortega, 2003; Hayat *et al.*, 2021a, b, c), previous studies have indicated that employee training and empowerment in developing countries are very poor, which leads to a critical factor involved in open innovation. According to (Usmani *et al.*, 2022a; Hayat *et al.*, 2020) employee training welfare and empowerment have also been given more importance. The empowerment of employees plays a key role in developing countries because of its close relationship to associated outcomes, such as job satisfaction and commitment to the firm's performance when implementing innovation. The results of the study revealed that a lack of executive commitment (F15) is the most significant factor involved in open innovation, which has higher driving power compared to others. As previous studies have indicated, due to internal organizational factors and poor knowledge about employee skills and abilities, executives are not committed to innovation (Bresciani, 2017; Hosseinzadeh *et al.*, 2022). Therefore, the implementation of open innovation is impossible without executive commitment as well as HR resources. The current study identifies that the leadership of firms in developing countries is not willing to adopt open innovation (see Table 12).

Level 4 comprises two factors involved in open innovation adoption, i.e. lack of partner collaboration (F4) and lack of regulation and standard (F8) (Luo *et al.*, 2019). stated that these two factors have crucial importance in the adoption of open innovation in the context of the Pakistani food industry. According to (Bux *et al.*, 2020), regulations and standards were not implemented efficiently in the case of developing countries, especially in Pakistan.

Table 11.
Level partition (Iteration 5)

Sr.	Reachability set	Antecedent set	Intersection set	L
14	14,	14	14	V
15	15,	15	15	V

Table 12.
Hierarchical levels at factors at each level

Sr. No	Factors	Level
F1	Lack of innovation strategy	I
F12	Lack in research and development	I
F16	Un-supportive organizational culture	II
F2	Suddenly consumer demand	III
F3	Lack of innovation experience	III
F5	Lack of innovation motivation	III
F6	High market saturation	III
F7	Lack of technical competence	III
F9	High innovation cost	III
F10	Lack in technology advancement	III
F11	Lack of strategic fit	III
F13	Lack of time	IV
F4	Lack partner collaboration	IV
F8	Lack of regulations and standards	IV
F14	Lack of seminar and training about open innovation	V
F15	Lack of executive commitments	V

Regulations and standards have a crucial value in achieving the organizational vision and consistent inward and outward sustainability survivability. In case of the absence of regulation and standards, firms cannot achieve their desired goals. Currently (Usmani *et al.*, 2022a), state that stakeholders of the firm are more focused on profit earning instead of promoting legislation. As (Ullah *et al.*, 2022) indicated in their study, the manufacturing industry of developing countries has neglected regulations and standards to open innovation implementation. For this reason, there is a dire need for regulations and standards in an appropriate way to implement open innovation, especially in the Pakistani food industry. A lack of partner collaboration (F4) is another hindering factor involved in open innovation, such as in times of crisis/during and post-COVID-19, due to lockdowns and poor digital networking and infrastructure in developing countries, which are the main causes of a lack of partner collaboration. In addition (Ullah *et al.*, 2022), expose that such collaboration in the context of the Pakistan food industry is not soundly rooted, while the implementation of open innovation and collaboration with the external and internal stakeholders in this combination firm can develop sustainability in their operations.

The discussion of the above-mentioned results reveals that government authorities can play an essential role in two ways. Firstly, the government should provide infrastructural facilities, physical processes and protocols for the working organization. Secondly, in addition to the previous point, introducing policies and incentives for well-entrenched regulations and standards.

Level 4 leads to the factors of level 3: high innovation cost (F9), a lack of innovation motivation (F5), a lack of technological advancement (F10), a fear of failure (F11), high market saturation, sudden consumer demand (F2), a lack of employee experience in open innovation (F3) and a lack of technical competence (F7).

High innovation cost (F9) is a critical factor involved in open innovation implementation in the context of developing countries, especially during the post-pandemic period. To ensure the generation of more sustainable business operations, firms need to implement human and financial resources. In their study (Bux *et al.*, 2020), proposed that manufacturing firms have an insufficient budget to implement open innovation; therefore, they emphasized investing in high-yield return projects to earn more outcomes. A lack of money or financial resources is the key factor involved in the adoption of open innovation (Ullah *et al.*, 2021). The adoption of open innovation practices in developing countries is considered expensive, as indicated in earlier studies.

Our results indicate a lack of technological advancement (F10) in developing countries, including Pakistani manufacturing companies, which are facing financial resources problems; therefore, companies cannot participate in open innovation activities because new plant machinery has not been incorporated due to insufficient financial resources. What factors hinder open innovation in the food sector during a pandemic crisis? The lack of technological advancement is the damaging barrier that interlinks and corresponds to the other barriers of a lack of time (F11), a lack of employee experience (F3) and a lack of technical competence (F7). Therefore, seminars and training relating to open innovation and executive commitment are crucial for formulating policies and strategies, in addition to hiring open innovation-related individuals. As (Ullah *et al.* 2021) proposed, insufficient seminar training, as well as time consumption and a lack of executive commitment, are hindering factors affecting the adoption of open innovation.

Accordingly, we find that a lack of innovation motivation (F5) has the highest driving and dependent power. Unfortunately, in times of crisis, the insufficiency of top management in motivating their employees in developing countries negatively impacts production. According to Malek and Desai (2019), management motivation in terms of the provision of innovative research labs and extra rewards have a significant impact on the adoption of innovation in manufacturing firms. Fear of failure (F11) is a damaging factor to open innovation adoption in food and beverage firms in developing countries. Because of the uncertain conditions of the post-COVID-19 period, stakeholders and top management are resistant to adopting innovation breakthroughs due to a fear of failure. Sudden consumer demand (F2), such as in an environment of panic, as seen during the COVID-19 pandemic, impacts consumer demand for eco-products on price rebates. Usually, this will force firms to engage in green practices instead of open innovation; sudden consumer demand is another hindrance to open innovation implementation. For high market saturation (F6), this study indicates that the managerial authorities of the manufacturing industry have limited knowledge about the market and their competitors. Therefore, firms hesitate to take the next step toward the open innovation process due to insufficient knowledge about the market(Novillo-Villegas *et al.*, 2022). The factors of level 3 lead to level 2.

An unsupportive organizational culture (B16) was found in level 2, having lower divining power and the highest dependent power. An unsupportive organizational culture is the biggest hindrance for the manufacturing industries of developing countries to undergo radical changes in production to ensure a firm's sustainable performance. Logically, a general hurdle to open innovation cannot properly be applied in the South Asia region country of Pakistan as there are many reasons to consider, such as fuel, the difference in economic growth, firm size, the implementation of rules and regulations and the pervading mindset at the corporate level (Ullah *et al.*, 2021). In this regard, thoughtful and focused efforts are necessary by executive management to motivate the organizational culture by raising awareness in the mind of employees about the true potential of open innovation by discussing the matter with employees about their contribution to open innovation in relation to the firm.

A lack of innovation strategy (F1) and a lack of research and development (F) were found in level 1. Both factors have weak driving power and strong dependent power. Therefore, these factors are the least important. Hence, (F5) and (F12) are placed at the top of the ISM-based model, as seen in Figure 3. Our results suggest that if the top executive is committed to promoting knowledge relating to open innovation, it will be fruitful for launching an innovation strategy and establishing a research and development environment in the

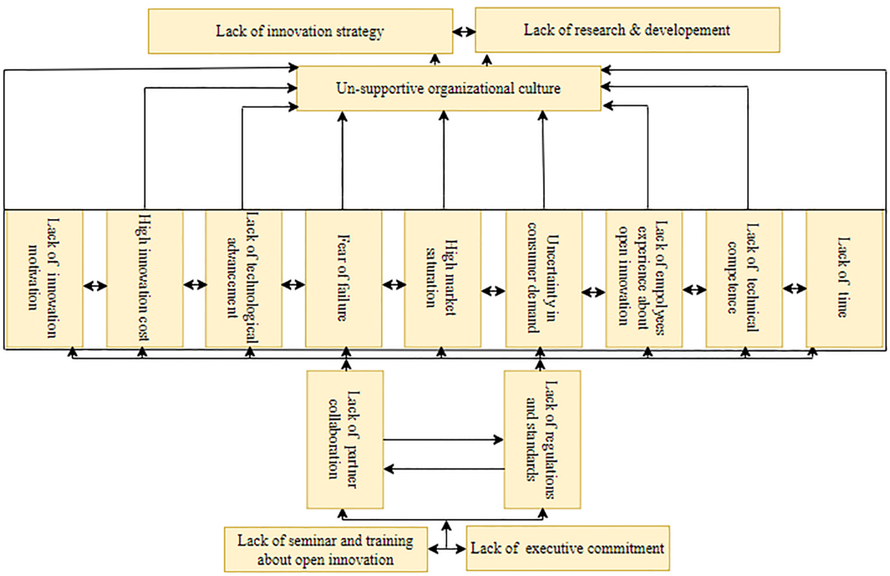

Figure 3.
ISM-based models of open innovation factors

organization. Another explanation of this study may be that if the human resources department fails to provide proper training concerning open innovation implementation, then firms cannot develop appropriate innovation strategies (see Figure 4).

Theoretical contribution

The present study is a novel attempt to find a wide range of factors involved in the establishment of a hierarchical structural framework. Most of the research is based on open

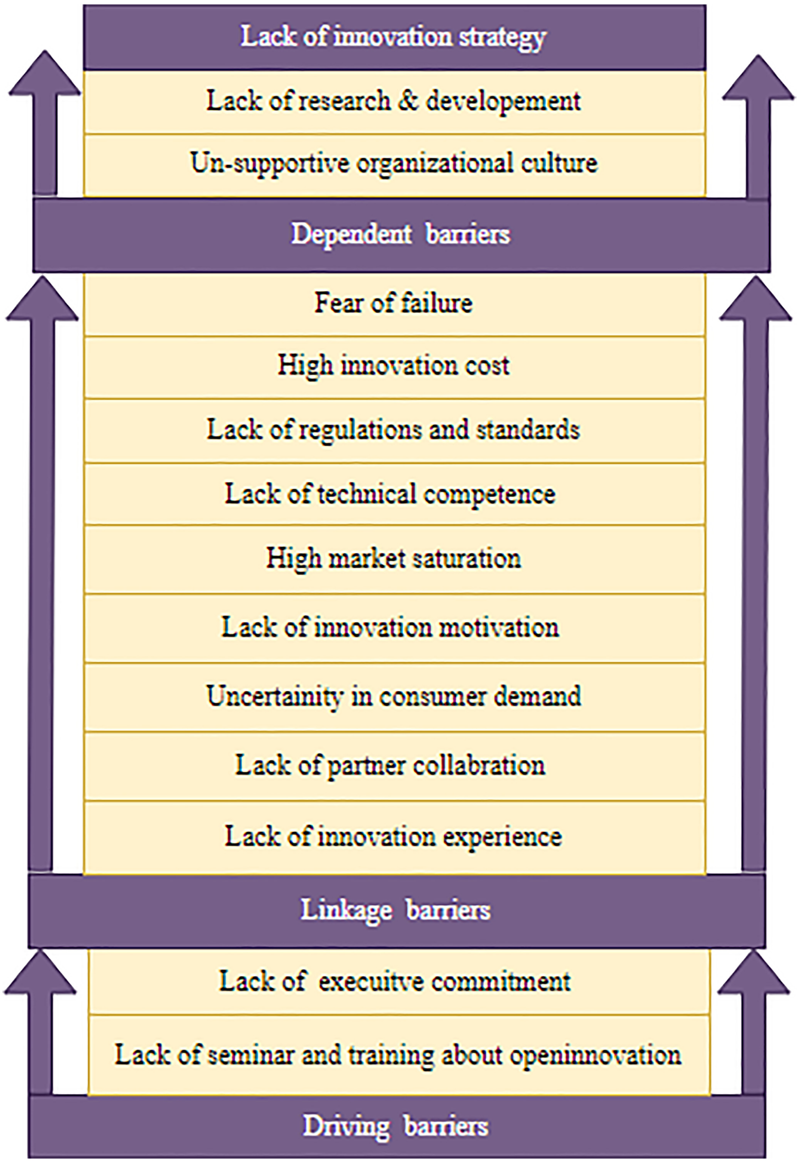

Figure 4.
MIMAC- based direction impact of open innovation factors

innovation and has established a short range of influencing barriers. Singh and Dhir (2022) adopted a framework by keeping in view only nine antecedents involved in open innovation implementation. Mergel (2018) determined that there were 12 factors involved in open innovation. Similarly, Travaglioni *et al.* (2020) carried out the research by considering 11 influencing factors involved in open innovation adoption related to digital manufacturing.

The former studies have explored the diverse factors, barriers and drivers involved in open innovation. Unfortunately, the previous researchers have failed to introduce a study concerning the significant barriers involved in open innovation for encouraging the sustainable survivability of the food and beverage industry in Pakistan in the post-COVID-19 period. For this reason, to complete the research gap and study the factors that provide a firm with a matchless vision of how to create market relationships and promote sustainable survivability in the post-COVID-19 period, the outcomes of this study are useful as they demonstrate the factors of open innovation involved in the sustainable survivability of the food and beverage industry in the post-COVID-19 period.

This research contains extensive knowledge relating to the food and beverage industry and weighs the sustainable survivability and long-standing relation with their inner and outer stakeholders. This study provides appropriate insight into the food and beverage industry and also promotes academic portions of the literature. Furthermore, the results highlight the special result of open innovation performance on both sustainable survivability and the market relationship of the food and beverage industry in the post-COVID-19 situation.

Practical implication

The study reveals the important factors that organizations could use to improve food and beverage companies' sustainable market survivability by measuring the set of influencing factors involved in open innovation. Open innovation is one of the vital characteristics from the perspective of a firm's sustainable survivability and market relationships. Open innovation, innovative strategy, partner collaboration, rules and regulations, management commitment and innovation cost are factors that must be considered when planning. The two aspects of the proposed research seem to be used to investigate the factors involved in open innovation that impact a firm's sustainable market survivability and relationships. The objective of this study was to explore the influencing factors involved in open innovation adoption and their impacts on the food and beverage industry to improve their sustainable market position. Global economies have been significantly impacted by the circumstances of the post-COVID-19 period. The proposed factors of this study can be implemented in strategy formulations as well as in future research projects. A mixed methodology ISM-MICMAC approach will assist strategists in selecting several factors according to their driving and dependence power when designing the appropriate strategies for food and beverage companies' sustainable survivability in the post-pandemic era. Due to the circumstances of the post-COVID-19 period, knowledge concerning different open innovation factors is critical and beneficial to the food and beverage industry. The results of this study suggest that a lack of executive commitments (F15) and a lack of seminars and training relating to open innovation (F14) are the key factors to the implementation of open innovation, having the highest driving powers.

The post-COVID-19 period has affected the food and beverage industry by causing several problems, such as the shutdown of food factories, labor problems, employee arrivals without gloves and masks, social distancing and lockdowns, worsening the impact on open innovation learning activities, seminars and training relating to open innovation as well as executive commitment towards open innovation. If these problems are not properly solved, certainly, the firm will experience losses, leading to business closures. As a result, viable supply chains can cope with such instabilities before and after the COVID-19 period.

In the food and beverage industry, open innovation must be used to manage and control the factors by using advanced technology. Likewise, digital classrooms or training centers enable employees to train in a safe environment. During the post-pandemic period, this strategy proved to be very useful. Keeping the above example in view, top executives not only determine the setting of innovative goals and long-term planning but also train and motivate employees toward the use of open innovation initiatives.

Furthermore, the results indicate that a lack of rules and regulations and a lack of partner collaboration are more critical factors relating to open innovation in the post-COVID-19 period. In this vein, we recommend some fruitful implications, which are that managers in the food and beverage industry must follow government instructions during times of crisis. Governments should impose pressure through regulations and standards and make appropriate policies to promote open innovation and create an environment that is highly sustainable for business survivability.

Another managerial implication for managers is the selection of and collaboration with partners. To obtain timely ideas, information and food materials, rapidly developing market relationships and innovation are required. The managerial authority can communicate with key business suppliers and customers through online media and the Internet, the cost of which is very low in Pakistan, providing a great opportunity for the food and beverage industry while launching digital communication strategies with business partners in the post-pandemic period.

Conclusion

The COVID-19 pandemic has led to historical changes in our society's norms and the way people interact. It also exhibited direct and significant impacts on the food sector, mainly affecting bioactive compounds, food safety, food security and sustainability. The lockdown of billions of people during the last winter and spring and the lockdown waves that are expected in the coming months/years led to different innovations in the food sector.

The concept of open innovation makes organizations and business enterprises capable of handling the issues related to inward and outward sustainability and their reputation. However, in addition to the successful adoption of open innovation in developing countries, the enforcement of open innovation is quite complicated in developing countries such as Pakistan due to different obstacles. Considering these problems, the study aims to highlight and analyze the key barriers facing open innovation from the perspective of Pakistan's food and beverage industry.

The results of the study are very attractive/pleasing and expose the real situation facing open innovation implementation in developing countries, especially in the Pakistani food industry. It is quite unexpected that, as an outcome of our study, a lack of training and seminars relating to open innovation, "lack of executive commitments (F15) and a lack of training and seminar relating to open innovation (F14) are generally categorized as independent barriers as they have low dependent power but high driving power. A lack of executive commitments (F15) and a lack of training and seminars relating to open innovation (F14) have a key role in the origin of the ISM hierarchical model, which reveals that competent human resources management is particularly important to the implementation of a system in the context of a developing country. In the context of the Pakistani food industry, human resources can only overcome the lack of training and seminars relating to open innovation and a lack of executive commitment by introducing innovative strategies, such as innovative training and a research lab for employees, employee motivation (salaries increment and bonus) and the empowerment of top management. Our study results will provide confidence to public institutions and the human resource personnel of firms to develop a sustainable working atmosphere for employees and to promote social, environmental and economic sustainability for the well-being of external stakeholders by emphasizing open innovation.

The results of the current study are accurate and unbiased. However, there are some limitations to the study. First, ISM is based on the subjective opinions of experts. In this case, if the experts are biased in the provision of the final opinion that has a direct impact on the final results of the study, maybe the model will fail during the initial stage. In addition, the current literature is based on the ISM model and reveals the mutual relationship between the proposed barriers. However, it does not strengthen the outcomes of the study because the proposed model was not statistically tested.

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