



Analysing supply chain coordination mechanisms dealing with repurposing challenges during Covid-19 pandemic in an emerging economy: a multi-layer decision making approach

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Abstract

Following the outbreak of the Covid-19 pandemic, there was a serious need for the pharmaceutical industry to combat the disease more quickly and effectively. In this regard, numerous companies set out to repurpose current drugs. The noticed decision has major challenges in various dimensions, including the creation and management of an efficient supply chain. The present study attempts to examine the significance and relationships of the repurposing challenges and analyze the effectiveness of supply chain coordination contracts confronting them. In this regard, a combination of Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Network Process (ANP) named DANP method is applied to investigate the relationships and extracting the weights of the mentioned challenges and the multi-criteria optimization and compromise solution technique called VIKOR is employed to prioritize the supply chain coordination contracts found on their impact facing with repurposing challenges. The mentioned techniques have been conducted under the condition of linguistic Z-numbers. The results demonstrated that financial support and digitalization are the most influential challenges. Moreover, collaboration and data availability have the most weight. In addition, four contracts including effort sharing, cost-sharing, credit option and buyback are the best contracts that companies in the merging economy of Iran should concentrate on them. This research proposes a novel framework of decision-making by integrating DANP and VIKOR with linguistic Z-numbers. Additionally, this study takes a new look at the use of coordination contracts from the viewpoint of repurposing challenges which is highlighted particularly during the Covid-19 pandemic.

Keywords Supply chain coordination contracts · Repurposing strategies · Covid-19 pandemic · Multi-layer decision making · Linguistic Z-numbers

1 Introduction

Throughout history, the human being has struggled with a variety of illnesses and disturbances. Per year, 7% of the population is affected by a rare illness (Hanisch and

Rake 2021; Roessler et al. 2021). Since its discovery in mid-2019, the COVID-19 pandemic has become the most heinous outbreak. Before February 2021, the disaster would have claimed over 2 million lives (Kim et al. 2021) and about 108 million people have been infected. Despite many

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anodyne findings by foreign firms, nations (i.e. emerging economies such as Iran) have been unable to introduce an effective vaccination process for their population due to the impossibility of establishing a supply chain network capable of meeting the vaccine's demand (Duong and Chong 2020). According to the literature, the primary causes of medical supply chain reliability are resource optimization, demand management, and output rate monitoring (Papalexi et al. 2020) which is more catastrophic in countries with underdeveloped infrastructures. In other words, supply chain inefficiency is caused by uncertainty and organizational dysfunctionality (Negi and Anand 2018). On the one hand, health discomfiture is a relatively recent source of supply chain disruption. Furthermore, the globalization of supply chains necessitates flexibility and coordination in supply chain technology (Pettit et al. 2013). In recent years, factors such as coordination, a greater understanding of the medical supply chain system, financial efficiency enhancement, supply and demand forecasts, and product growth duration have been identified as the most significant factors reducing the likelihood of supply chain interruption (Munusamy and Murugesan 2020; Porter and Reay 2016; Wagner and Thakur-Weigold 2018).

Members of the supply chain repurpose their output to reduce total inventory and increase value generation within organizations (Kurt et al. 2019). The repurposing paradigm has highly been examined as a beneficial procedure like information sharing, creativity, or recycling that benefited the supply chain efficiency effectiveness. However, when a rare illness is discovered, manufacturers must find a new use for or reposition their common goods to meet customer demands and resolve supply chain disruptions (Mohanty et al. 2020). This intervention cuts the time required for product production and reportedly lowers the expense and R&D practice in medical industries (De et al. 2021). In the last two years, scholars have conducted extensive research on the concept using artificial intelligence (Zhou et al. 2020), experimental, and data-driven methodologies (Lakizadeh and Hassan Mir-Ashrafi 2021). However, in an emerging economy such as Iran, due to infrastructural, economic, environmental, social and political barriers, implementing new and modern approaches in supply chain management such as supply chain 4.0 or 5.0 is not possible.

In these circumstances, managers develop strategic tactics such as collaboration to deal with disturbances (Mohammaddust et al. 2017). Coordination allows partners to collaborate, schedule, and prioritize their priorities while also saving money and resources (Cao et al. 2010). Managers ensure their organizations' resilience and visibility by doing so (Cao and Zhang 2011). According to a new report, contract coordination enables companies to outperform their competitors in cost savings and market responsiveness (Jamal et al. 2019). Contracts for supply chain coordination

assist businesses in making more coordinated decisions than decentralized activities (Mahdiraji et al. 2014). In the case of the COVID-19 pandemic, these contracts are incredibly advantageous in achieving the joint goal of sellers and buyers, namely overcoming delays in meeting vaccine demand. Supply chain coordination contracts (from now on, SCCCs) often facilitate information exchange and a greater likelihood of sharing experience (Wang et al. 2020a, b), which increases the possibility of repurposing production. Numerous SCCCs have been studied in the last few years using various experimental, computational, and mathematical modeling approaches (Hu et al. 2018b; Li et al. 2021a; Wang et al., 2020b; Xin et al. 2020). However, there are insufficient studies in the literature regarding joint supply chain contracts on commodity repurposing.

As previously mentioned, managers benefit from both repurposing and collaboration contracts as instruments with comparable characteristics for effectively exchanging information and reducing research and development costs. There are currently several distinct types of SCCCs documented in the literature, and administrators may take advantage of a variety of repurposing techniques (see Table 1). However, researchers have not yet evaluated how well these methods interact with one another and how they can deal with repurposing challenges. The following paper is a response to the call from scholars (e.g. Pushpakom et al. 2018; Sultana et al. 2020) that emphasized coordination importance and a meaningful link between stakeholders to design a functional strategic plan for successful repurposing. As a result of the necessity of repurposing before and after the pandemic, the present study provides a comprehensive decision-making framework built on the various repurposing challenges, taking into account the uncertainty condition of the pandemic. This study seeks to identify the significance of the challenges by examining the relationships between them and evaluating the impact of numerous SCCCs on them. In this regard, the first step of this study involves performing a systematic literature review to explain the various types of SCCCs. The segment concludes with an analysis of recent research on multiple repurposing challenges and problems. The components are then arranged in a hybrid multi-layer decision-making structure to aid in assessing the effect of each repurposing challenge on coordination mechanisms. Furthermore, to consider uncertainty in the studied research, Z-numbers as one of the most popular and recent approaches have been employed in the decision support system. Since emerging markets are given a higher priority of collaboration for reacting to demand during disruptions such as a pandemic (Reardon et al. 2020), the Iranian pharmaceutical industry was selected as the studied case. The experts of the aforementioned sector responses are then analyzed to provide a clear picture of each collaborative contract's functionality when faced with various repurposing challenges.

Table 1 Types of Supply Chain Coordination Contracts

Type of Contract	Description	Sample Authors
Wholesale Price	The supplier sells their goods at wholesale prices to the retailer. However, the retailer is not allowed to return unsold items	(Fang 2018; Heydari et al. 2020a, b) (Hosseini-Motlagh et al. 2019a, b) (Hu et al. 2018a, b; Li and Liu 2020) (Hosseini-Motlagh et al. 2019a, b)
Revenue Sharing	The supplier sells products at a discount to the manufacturer. In exchange, the manufacturer pays the supplier a portion of sales	(Vafa Arani et al. 2016) (Hu et al. 2016; Liu et al. 2017) (Liang et al. 2017; Hou et al. 2017)
Two-Part Tariff	Although the supplier charges the wholesaler with the production cost, the agreement obligates retailers to pay a fixed franchise fee to the supplier	(Liu et al. 2021) (Li and Liu 2015) (Bai et al. 2020, 2017)
Buyback	With the wholesale price, a certain quantity of units is sold. Unlike wholesalers, retailers, on the other hand, are allowed to return unsold products at a lower price than wholesale	(Qin et al. 2020) (Shi et al. 2020) (Zhao et al. 2018) (Xie et al. 2020)
Quantity Flexibility	A specified quantity of units is purchased, and at the end of the season, the supplier compensates the manufacturer for unsold goods at a negotiated rate	(Li et al. 2016; Nikkhoo et al. 2018) (Song and Gao 2018) (Heydari et al. 2020a, b)
Backup Supplier	The contract structure is comparable to that of a buyback agreement. The seller offers to purchase the unsold products at the end of the contract under this type of arrangement. Additionally, the customer is offered an opportunity to increase the order quantity	(Chen et al. 2019) (Giri and Bardhan 2014) (Namdar et al. 2018)
Rebate	In this type of coordination contract, the wholesaler is charged with a special rate per unit. By the end of the selling period, the retailer is awarded a rebate for extra units that exceed the threshold value	(Zhan et al. 2019) (Chiu et al. 2020) (Zhan 2021)
Quantity Discount	The supplier offers a dynamic price depending on the order quantity. The wholesaler's price decreases as the amount purchased increases	(Yoshida et al. 2020) (Nie and Du 2017) (Zhao et al. 2020)
Advanced Purchase Discounts	Under this type of contract, the supplier decides period by period to offer a discounted price to a retailer who advances its orders	(Pellegrino et al. 2020)
Bonus	Bonus contracts have a fixed base amount. Moreover, the additional reward is offered found on the supplier's performance, discourage waste and inefficiency, and avoid moral hazard problems	(Yin and Ma 2015)
Cost Sharing	This contract shares the costs of research and development, marketing, energy storage, social responsibility, etc., amongst the members	(He et al. 2020)
Credit Option	This type of contract considers the demand history of the backorders	(Hasani and Khoshalhan 2011)
Effort Sharing	To encourage the retailer, the wholesaler reflects the sale effort of the retailer under this type of contract	
MarkDown	This contract is a form of rebate in which a wholesaler subsidizes a retailer's clearance pricing after the regular season	
Option	Under this type of contract, a retailer has a right to modify his order after the submission	(Peng et al. 2020)
Profit-Sharing	This contract provides unequal profit sharing amongst the members, usually found in their bargaining power. This contract leads to higher coordination in SC and raises overall profit	(Ajmi et al. 2019)
Risk Sharing	Under this type of contract, both wholesalers and retailers face the risk of shortages, delays and financial losses	(Antonanzas et al. 2019)

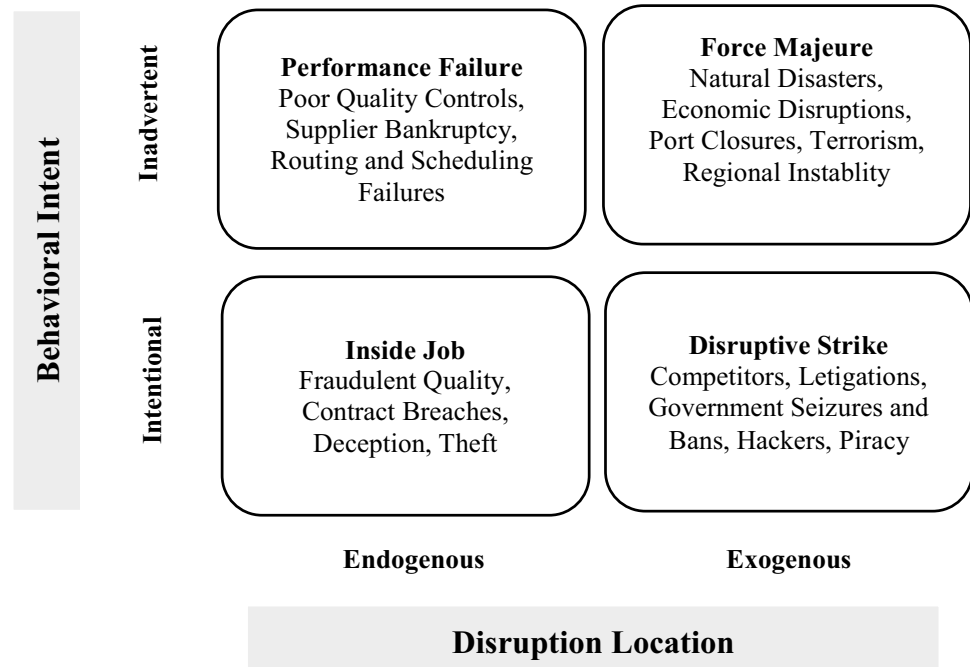
2 Literature review

2.1 Supply chain disruption

Over the past few decades, supply chains have been impacted

by various natural and human-made disturbances, including the 2011 Japan tsunami (Pavlov et al. 2019), the 2004 Indian Ocean earthquake, and the 2008–2009 financial crisis (Baldwin and di Mauro 2020). Figure 1 elaborates on the disruptive events.

Fig. 1 Classification of Disruptive Events (Resource: Res et al. 2017)



As depicted in Fig. 1, 4 types of disruptive events could be classified found on disruption location and behavioral intent. Force majeure events are a highlighted category of events. Two types of force majeure events are including direct and indirect events. Direct events disrupt the supply chain physically e.g. tsunami, earthquake, etc. In contrast, indirect events affect the supply chain e.g. financial crisis, pandemic, etc. Disruptions result in inefficiencies in supply and demand (Ocampo et al. 2016), disruptions in manufacturing (Ji and Wang 2017), and predicting volatility, requiring managers to build supply chains with a higher probability of stability throughout disruptions. In general, natural hazards and environmental conditions (Lawrence et al. 2020), labor shortages (Nagurney 2021), sanctions (Hamidieh et al. 2018), pricing (Bugert and Lasch 2018), knowledge exchange (Yoon et al. 2020; Dorcheh et al. 2021), and political problems (Asif et al. 2019) have been identified as the most important causes of supply chain instability in the last several years. When the virus spread, the destruction sources were fully redesigned. For instance, Hurricane Katrina impacted a relatively small geographical area (Skipper et al. 2007). As a result, other countries pressed for the provision of medical equipment and food to alleviate the disruption impact. Consequently, not only producers and suppliers of raw materials have been impacted by the pandemic (Habib et al. 2021), but it has also created difficulties for service providers. As a lesson, damage should be minimized both before and after the pandemic.

According to a new report (Ivanov et al. 2017), two forms of deterrence tactics may help administrators reduce the risk of supply chain interruption. The first choice is for company owners to avoid disruptions by developing proactive strategies. For instance, Samani et al. (2020) proposed a two-step process for managing instability in the platelet supply chain, consisting of a proactive and constructive phase to minimize the risk of disruption (Samani et al., 2020). Previously, Pal et al. (2014) investigated a three-tier supply chain to demonstrate the critical nature of stock control during disruptions (Pal et al. 2014). Also, Wang et al. (2020a, b) proposed a comprehensive supply chain network to promote stability through disruptions (Wang et al. 2020a). The second strategic solution is focused on taking steps in the face of disturbances. The reactive approach enables supply chain members to make quick decisions to adapt to shifts with the least amount of danger (Chowdhury et al. 2021). As an illustration, Zhao et al. (2019) created an agent-based simulation to determine whether a firm's reactive approach prevents disruption (Zhao et al. 2019). Furthermore, Lücker et al. (2019) emphasized the role of inventory and reserve power in stochastic demand as a defensive strategy that minimizes the disturbance (Lücker et al. 2019). Additionally, Jabbarzadeh et al. (2018) suggested a stochastic optimization model for modeling a closed-loop supply chain (CLSC) (Jabbarzadeh et al. 2018). Besides, transshipment was discovered to be a reactive approach that mitigates supply chain disruption (e.g. Elluru et al. 2019; Kaur and Singh 2020). Assuming that coordination contracts serve as a means of proactive

policy procurement and repurposing as a reactive strategy, the remainder of this section discusses various types of coordination contracts. Additionally, problems associated with repurposing are studied.

2.2 Coordination contracts

Multiple criteria such as price, size, and quality are described in a buyer–seller partnership by a contract that defines itself as an agreement that ensures all supply chain components function in an integrated rather than decentralized fashion (Tsay et al. 1999). These contracts provide significant benefits in terms of risk mitigation by cooperation (Ghadge et al. 2017), inventory cost savings (Sainathan and Groenevelt 2019), and overall value enhancement by supply chain management (Hu and Feng 2017). Contracts for coordination are mainly focused on game theory, under which each group has the option of cooperating or acting decentralized (Govindan et al. 2013). According to Cachon (2003), supply chain participants cannot profitably deviate arbitrarily from a set of supply chain optimum actions that should be considered coordinated (Cachon 2003). In other terms, they are built following the Nash equilibrium theorem (Biswas and Avittathur 2019). Each contract has several advantages and disadvantages. As a case in point, the wholesale contract approach is risk-free for the manufacturer, and there is no obligation to deliver goods in a certain quantity within a specified time (Adabi and Mashreghi 2019). However, the literature indicates that the primary disadvantage of this contract is the double marginalization effect (Fang 2018). Although the revenue-sharing contract eliminates this impact, it requires retailers to exercise more control over product shortages and sales practices since both the seller and manufacturer share revenue (Vafa Arani et al. 2016). In contrast to these contracts, the two-part tariff (TPT) arrangement provides the wholesaler with the output rate, which is cheaper than the previous methods. This contract has become increasingly popular in recent years as a cost-effective method of minimizing distribution costs within wholesalers (Lv et al. 2019; Mahdiraji et al. 2019). Although these contracts organize the production chain to determine the sale price, other types of contracts include quantity control strategies to manage unsold batches after each season. For instance, the buyback contract enables retailers to return unsold products at a typically lower price than wholesale (Tavana et al. 2019). The model has been commonly used in risk management (Adhikari et al. 2020), sustainable development (Lu and Chen 2014), and pharmaceutical case studies (Tat et al. 2020).

Similarly, the supplied backup and flexible quantity contract allow retailers and wholesalers to handle their inventories effectively. As a result, these contracts have been extensively used to address trade disruption (Asian et al. 2020;

Tavana et al. 2019) (Asian et al. 2020; Rahbari et al. 2021), supply chain sustainability (Chan et al. 2018; Hajiagha et al. 2021), and supply chain coordination issues (Lu and Liu 2021). While any of these contracts has been beneficial in resolving new supply chain problems, researchers have found that a mixed combination of collaboration contracts allows for a greater understanding of a supply chain model under various coordination contracts. For instance, the swap between rebate, buyback, and flexible quantity contract demonstrates the rebate agreement's extraordinary flexibility (Mahdiraji et al. 2019). Comparing these contracts in a single sense helps clarify their meaning, but determining the most appropriate contract form for each business type is beneficial. As a result of the literature analysis, we can identify the most often used contracts in recent years. These results are beneficial in determining the usefulness of each type in the pharmaceutical context and manage supply chain disturbances. Table 1 describes and addresses several cooperative games focused on contract structure and supply chain collaboration.

2.3 Supply chain repurposing

As the global COVID-19 pandemic emergency unfolds, one pressing issue is a lack of essential equipment such as gloves, ventilators, and diagnostic kits for the healthcare system and the general public (López-Gómez et al. 2020) especially for emerging and underdeveloped countries. Policymakers are urging manufacturers in all industries to repurpose their output to boost global production potential briefly. The concept of repurposing or repositioning is a fast reaction in response to shortages or individual needs during disruptions such as the COVID-19 (Sultana et al. 2020). According to the study of the literature, this technique has been generally used in medical case studies and, more specifically, in drug production (Sindhu and Murugan 2020). Since protection and formulation application checks have been passed, scholars have shown that repurposing helps expedite the conventional method of remedy discovery (Shah and Stonier 2019). Discussing an "off-the-table" prescribing case study (Rogosnitzky et al. 2020) emphasized the importance of rapid drug repurposing. Additionally, (Talevi and Bellera 2020; Rahbari et al. 2021) indicated that the risk of consumption is significantly lower in the case of drug repurposing once the early stages of preclinical use are complete. According to similar researches, the risk and financial assistance associated with repurposed materials were reduced by up to 60% (Fetro and Scherman 2020). Finally, the technique is advantageous for identifying potential prospects and optimizing product use (Gautam et al. 2020).

Regardless of the pharmacy's view on repurposing, administrators must overcome many obstacles during the repurposing process. The first impediment is legal and administrative

impediments that prevent producers from repurposing their routine manufacturing processes (Breckenridge and Jacob 2018). According to relevant researches, unfavorable legislation and laws discourage producers from repurposing, and government support helps manufacturers manage the repurposing process more effectively (Hernandez et al. 2017). A new case study using over 2000 clinical trials demonstrated that repurposing is a prevalent innovation method, and managers must understand the value of organizational collaboration and innovation strategies as an effective mechanism for repurposing. Additionally, Shamas-Din and Schimmer (2015) emphasized the importance of academic centers and their cooperation with industry as a powerful repurposing method (Shamas-Din and Schimmer 2015). To summarize, Table 2 demonstrates recent core repurposing challenges (henceforth CRCs).

Several types of research have studied the repurposing challenges. These papers have only introduced the challenges and provided a brief explanation of them. As an illustration Talevi and Bellera (2020) have presented repurposing challenges and opportunities (Talevi and Bellera 2020). Moreover, Polamreddy and Gattu (2019) have reviewed the drug repurposing landscape from 2012 to 2017 and discussed the opportunities, challenges and limitations (Polamreddy and Gattu 2019). Furthermore, Parvathaneni and Gupta (2020) have summarized drug repurposing approaches and examples, specific to respiratory viruses, limitations of utilization and related challenges e.g. localized delivery in the respiratory tract (Parvathaneni and Gupta 2020). None of the above studies have examined the challenges in more detail. Alongside a deeper exploration of the challenges, the present research investigates the relationships between them and extracts their significance.

On the other hand, the study of coordination contracts has not been comprehensive and various researches deal only with

one or more specific types of these contracts. For instance, Sadeghi and Hemmati (2021) have focused on rebate contracts (Sadeghi and Hemmati 2021), Jabarzare and Rasti-Barzoki (2020) has concentrated on revenue-sharing and profit-sharing contracts (Jabarzare and Rasti-Barzoki 2020), and Wang et al. aims attention at cost-sharing contracts (Wang et al. 2019b).

3 Methodology

3.1 Basics and definitions

Zadeh has introduced fuzzy sets in 1965 to deal with uncertainty by assigning a membership degree to each element (Zadeh 1965). Since then, numerous developments of fuzzy numbers are presented e.g. intuitionistic fuzzy, hesitant fuzzy, fuzzy type 2, etc. Intuitionistic fuzzy sets try to consider nonmembership of the elements in addition to membership (Atanassov 1986). Moreover, fuzzy type 2 sets assign a secondary membership to each element (Rickard et al. 2009). Furthermore, hesitant fuzzy sets consider the hesitation of the decisions (Rodríguez et al. 2011). Z-numbers were first proposed by Zadeh to deal with uncertainty (Zadeh 2011; Mokhtarzadeh et al. 2020, 2021). The concept of z-numbers is associated with the issue of the reliability of the information. Due to uncertain conditions alongside high unreliability which was emerged by the Covid-19 pandemic, Z-numbers are a good tool to bring the results closer to reality. Each z-number, $Z = (A, B)$, has two components in which A is a restriction on the value and B is a reliability of the A. As a huge amount of information is provided by semantic terms, linguistic Z- numbers have been nominated (Wang et al. 2017). Two basic definitions regarding these numbers are described as follows.

Table 2 Core repurposing challenges

Code	Acronym	Repurposing Challenges	Definition	Sample Reference
C ₁	FS	Financial Support	Inability to find the right commercial partners, and a lack of funds and resources	(Polamreddy and Gattu 2019)
C ₂	RF	Regulation Framework	Legal aspects that could impair patenting a new medical use and/or the enforcement of patent rights	(Breckenridge and Jacob 2018)
C ₃	IN	Innovation Network	Lack of organizational structure to implement business innovation faster and more efficient	(Hanisch and Rake 2021)
C ₄	PB	Political Backup	Lack of government focus and support for enterprises	(Talevi and Bellera 2020)
C ₅	MB	Manufacturing Base	Lack of appropriate infrastructure and capabilities of the production procedure	(Polamreddy and Gattu 2019)
C ₆	D	Digitalisation	Implementing and controlling technology among supply chains to improve data flow and efficiency	(Harrington et al. 2018)
C ₇	DA	Data Availability	Limitation of public access to certain types of data (e.g., clinical trials)	(Talevi and Bellera 2020)
C ₈	C	Collaboration	Lack of identification and access to partners such as academia	(Shamas-Din and Schimmer 2015)

Definition 1. Let X be a universe of discourse, $S_1 = \{s_0, s_1, s_2, \dots, s_{2l}\}$ and $S_2 = \{s'_0, s'_1, s'_2, \dots, s'_{2k}\}$, be two finite and ordered linguistic terms, l and k are nonnegative integer numbers, $A_{\phi(x)} \in S_1$ and $B_{\varphi(x)} \in S_2$, a linguistic Z-number set Z in X is defined as Eq. (1).

$$Z = \{(x, A_{\phi(x)}, B_{\varphi(x)}) | x \in X\} \tag{1}$$

Note that in Eq. (1), $A_{\phi(x)}$ is a restriction on the value and $B_{\varphi(x)}$ is a reliability of the $A_{\phi(x)}$.

Definition 2. Let $Z_\alpha = (A_{\phi(\alpha)}, B_{\varphi(\alpha)})$ be linguistic Z-number. The score of the Z_α is computed by Eq. (2).

$$S(Z_\alpha) = f^*(A_{\phi(\alpha)}) \times g^*(B_{\varphi(\alpha)}) \tag{2}$$

It is noticeable that in Eq. (2), f^* and g^* are in order the linguistic functions of $A_{\phi(\alpha)}$ and $B_{\varphi(\alpha)}$ which are obtained by Eqs. (3) and (4) (Jiang et al. 2020).

$$f^*(A_{\phi(\alpha)}) = \frac{\phi(\alpha)}{2l} \tag{3}$$

$$g^*(B_{\varphi(\alpha)}) = \frac{\varphi(\alpha)}{2k} \tag{4}$$

3.2 Methods and tools

DEMATEL-based ANP DEMATEL-based ANP (DANP) was first proposed by Chiu et al. in 2013 due to the problems of interdependence and feedback among certain criteria (Chiu et al. 2013). This method applies DEMATEL to construct an influential network relations map and, ANP to extract the weights of the criteria. DANP attempts to reduce the gap in each dimension and criterion. This method is described in the following (Hashemi et al. 2021).

Step 1. The influence of each criterion on other criteria is evaluated by experts, normally applying a scale of 0 (no influence) to 4 (highly influence). Matrix G of the Eq. (5) illustrates the result of these assessments.

$$G = [g_c^{ij}] = \begin{bmatrix} g_c^{11} & \dots & g_c^{1n} \\ \vdots & \ddots & \vdots \\ g_c^{n1} & \dots & g_c^{nn} \end{bmatrix} \tag{5}$$

It is notable that in Eq. (5), g_c^{ij} indicates the influence of i_{th} criterion on the j_{th} criterion.

Step 2. The normalized matrix X is computed by Eq. (6), where the value of v is obtained by Eq. (7).

$$X = vG = v[g_c^{ij}] \tag{6}$$

$$v = \min\left\{ \frac{1}{\max_{ij} \sum_{j=1}^n g_c^{ij}}, \frac{1}{\max_j \sum_{i=1}^n g_c^{ij}} \right\} \tag{7}$$

Step 3. The total-influential matrix T_c is obtained by Eq. (8) where (I) is the identity matrix.

$$T_c = [t_c^{ij}] = X + X^2 + \dots + X^l = X(I - X); \text{ when } \lim_{l \rightarrow \infty} X^l \tag{8}$$

Step 4. Subsequently, the row sum and the column sum of the matrix are calculated by Eqs. (9) and (10).

$$r_i = [\sum_{j=1}^n t_c^{ij}] \tag{9}$$

$$s_i = [\sum_{i=1}^n t_c^{ij}] \tag{10}$$

It should be noted that if $(r_i - s_i) > 0$, then criterion i is a member of the casual group which means it affects other criteria. On the other hand, if $(r_i - s_i) < 0$, then criterion i is a member of an influenced group. In addition, two different influence matrices are employed. T_c is devoted to n criteria and T_D pertains to m dimensions of the T_c as elaborated in Eq. (11).

$$T_c = \begin{bmatrix} T_c^{11} & \dots & T_c^{1m} \\ \vdots & \ddots & \vdots \\ T_c^{m1} & \dots & T_c^{mm} \end{bmatrix} \tag{11}$$

Step 5. The total influence matrix T_D is normalized by Eq. (12). Hence, normalized total influence matrix T_C is built as Eq. (13).

$$T_D^{nor} = \begin{bmatrix} t_D^{nor_{11}} & \dots & t_D^{nor_{1m}} \\ \vdots & \ddots & \vdots \\ t_D^{nor_{m1}} & \dots & t_D^{nor_{mm}} \end{bmatrix} = \begin{bmatrix} \frac{t_D^{11}}{t_D^1} & \dots & \frac{t_D^{1m}}{t_D^1} \\ \vdots & \ddots & \vdots \\ \frac{t_D^{m1}}{t_D^m} & \dots & \frac{t_D^{mm}}{t_D^m} \end{bmatrix} \tag{12}$$

$$T_C^{nor} = \begin{bmatrix} T_c^{nor_{11}} & \dots & T_c^{nor_{1m}} \\ \vdots & \ddots & \vdots \\ T_c^{nor_{m1}} & \dots & T_c^{nor_{mm}} \end{bmatrix} \tag{13}$$

Note that in Eq. (12), t_D^i is the sum row of the i_{th} dimension attained by Eq. (14).

$$t_D^i = [\sum_{j=1}^m t_D^{ij}] \tag{14}$$

Step 6. Unweighted supermatrix W_C is constructed by transposing the normalized total influence matrix T_C^{nor} as shown in Eq. (15).

$$W_C = [T_C^{nor}]' = \begin{bmatrix} w_c^{11} & \dots & w_c^{1m} \\ \vdots & \ddots & \vdots \\ w_c^{m1} & \dots & w_c^{mm} \end{bmatrix} \tag{15}$$

Step 7. The influential weights of the DANP are attained by Eq. (16).

$$W_C^* = T_C^{nor} \times W_C = \begin{bmatrix} T_c^{nor_{11}} \times w_c^{11} & \dots & T_c^{nor_{1m}} \times w_c^{1m} \\ \vdots & \ddots & \vdots \\ T_c^{nor_{m1}} \times w_c^{m1} & \dots & T_c^{nor_{mm}} \times w_c^{mm} \end{bmatrix} \tag{16}$$

Step 8. The DANP is obtained by limiting the weighted supermatrix W_C^* by raising it to a sufficiently large power φ as Eq. (17) until it is converged.

$$w = (w_1, w_2, \dots, w_m) = \lim_{\varphi \rightarrow \infty} (w_c^*)^\varphi \tag{17}$$

Comprise Ranking Method (VIKOR) The VIKOR method has been presented as a multi-criteria decision-making (MCDM) technique to prioritize alternatives found on conflicting criteria (Opricovic and Tzeng 2007). This method proposes its indices base on the closeness to the ideal solution (Sayadi et al. 2009). The Steps of the VIKOR are elaborated below (Fei et al. 2019).

Step 1. The decision matrix is constructed as in Eq. (18).

$$D = [x_{ij}] = \begin{bmatrix} x_{11} & \dots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \dots & x_{nm} \end{bmatrix} \tag{18}$$

Note that in Eq. (18), x_{ij} is the value of the i_{th} alternative based on the j_{th} criterion.

Step 2. The decision matrix is normalized by Eq. (19).

$$N = [n_{ij}] = \left[\frac{x_{ij}}{\sqrt{\sum_{j=1}^n x_{ij}^2}} \right] \tag{19}$$

Step 3. The ideal (f^*) and anti-ideal (f^-) solution is determined by Eq. (20).

$$\begin{cases} f_j^* = \max_i c_{ij} \\ f_j^- = \min_i c_{ij} \end{cases} \text{ if } c_{ij} \text{ is the benefit criterion} \tag{20}$$

$$\begin{cases} f_j^* = \min_i c_{ij} \\ f_j^- = \max_i c_{ij} \end{cases} \text{ if } c_{ij} \text{ is the cost criterion}$$

Step 4. S_i and R_i indices are computed by Eqs. (21) and (22).

$$S_i = \sum_{j=1}^m w_j \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \tag{21}$$

$$R_i = \max_j w_j \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \tag{22}$$

It is notable that in Eqs. (21) and (22), w_j is the weight of criteria j which is extracted by another technique.

Step 5. Eventually, the index Q is computed by Eq. (23).

$$Q_i = \nu \left(\frac{S_i - S^*}{S^- - S^*} \right) + (1 - \nu) \left(\frac{R_i - R^*}{R^- - R^*} \right) \tag{23}$$

Notice that in Eq. (23), S^* and R^* are in order the minimum of S_i and R_i . In addition, S^- and R^- are in order the maximum of S_i and R_i . Moreover, parameter ν indicates the degree of the agreement of the decision-makers. If the degree of the agreement is high, then $\nu > 0.5$. If the agreement is reached by the majority of the opinions, then $\nu = 0.5$. At last, if the degree of the agreement is low, then $\nu < 0.5$.

3.3 Research steps

As illustrated in the literature, numerous contradictory criteria (as repurposing challenges) should be considered while selecting the type of SCCCs. Hence, a hybrid DEMATEL-ANP-VIKOR approach is applied to deal with varied criteria and alternatives. In addition, Z-numbers are employed due to the condition with high uncertainty as a result of the COVID-19 pandemic. The research steps are discussed as follows.

Step 1. Identifying Supply chain coordination contracts. Numerous types of SCCCs are gathered by reviewing the literature. These SCCCs are demonstrated in Table 1.

Step 2. Extracting Repurposing Challenges. By studying the literature, different CRCs are detected which are illustrated in Table 2.

Step 3. Data Gathering. A group of experts is invited to discuss the questionnaires of the research. This group included fifteen experts with high experience and expertise in the field of study from the health, drug and pharmaceutical sectors of the emerging economy of Iran (see the expert profiles in Fig. 2). These experts were selected by snowball sampling found on researchers' judgment on their expertise and experience. This means that each expert introduced several other experts to complete the group. Two face-to-face sessions (considering social distancing) have been organized which lasted approximately 12 h in total. In the first session, researchers introduced the concept of collected core repurposing challenges in Table 2. In the following, the experts have discussed the impact of each challenge on others to reach a consensus. This group applied the linguistic Z-number scale of Table 3 to express their opinion.

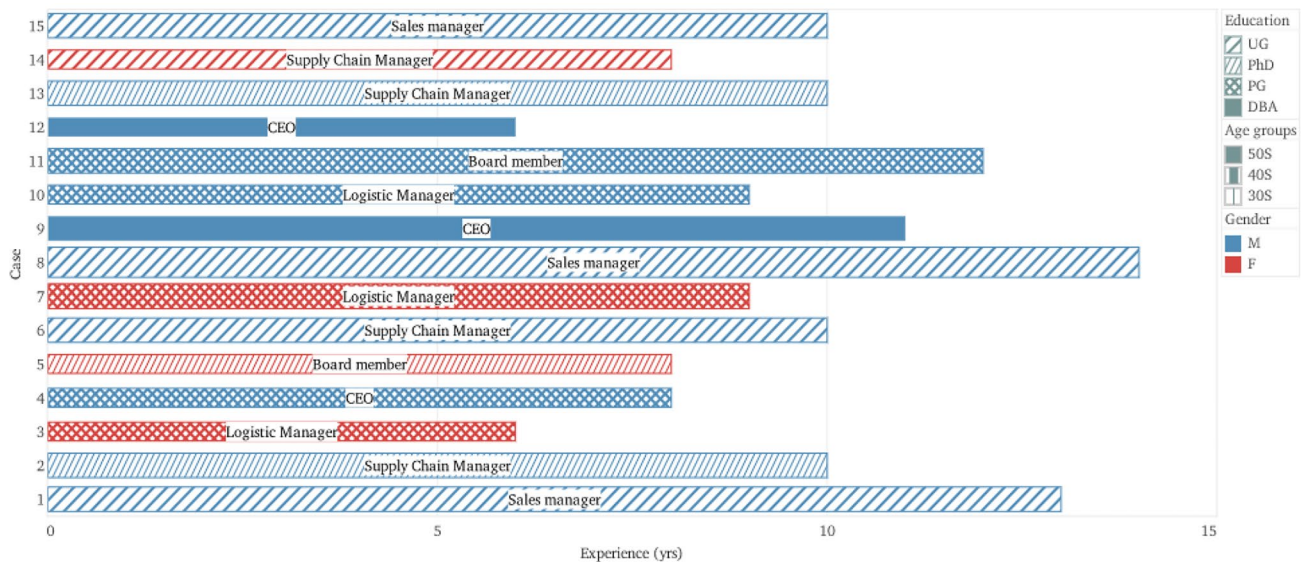


Fig. 2 Experts' Profile Infographic

In the second session, the SCCCs were elaborated by researchers for experts according to Table 1. Then the experts argued to assess the influence of each SCCC facing the challenges of repurposing. Likewise, they have applied the linguistic z-number scale of Table 4.

The demographic information of the experts is shown in Fig. 2.

Step 4. Extracting the weights of CRCs via linguistic Z-DANP. To consider the uncertainty and to obtain more reliable results, the DANP method is applied under the condition of linguistic Z-numbers. The steps of Z-DANP are described below.

1. The effect of each criterion on other criteria and the certainty of each evaluation are determined by pairwise applying the Z-number scale of Table 3. The evaluation matrix of Eq. (24) is constructed.

$$G_Z = [Z_{ij}] = [(s_k, s'_l)_{ij}] \tag{24}$$

Table 3 Linguistic Terms to Evaluate Criteria (core repurposing challenges)

Symbol	Linguistic Term	Symbol	Linguistic Term
S_0	No Influence	s'_0	Uncertain
S_1	Very Low Influence	s'_1	Slightly Uncertain
S_2	Medium Influence	s'_2	Medium
S_3	High Influence	s'_3	Slightly Sure
S_4	High Influence	s'_4	Sure
S_5	Very High Influence		
S_6	Extremely High Influence		

Note that in Eq. (24), s_k is the influence of criterion i on criterion j and s'_l is the reliability of the evaluation.

2. The score of each evaluation is computed by Eq. (2) to (4) and the crisp matrix of Eq. (25) is shaped.

$$G_c = [g^c_{ij}] = [(f^*(s_k) \times g^*(s'_l))_{ij}] \tag{25}$$

3. The weights of the criteria are extracted by the DANP method, applying Eq. (5) to (17).

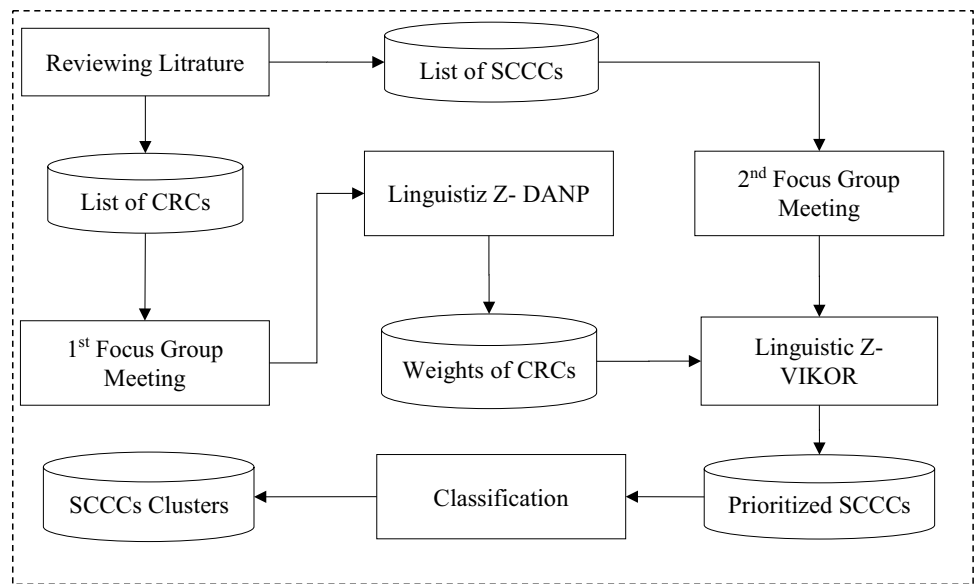
Step 5. Prioritizing the SCCCs via linguistic Z-VIKOR. Alongside DANP, to achieve more reliable prioritization of the contracts, linguistic z-numbered evaluations of the experts are analyzed by the VIKOR method. The steps of the linguistic Z-VIKOR are elaborated below.

1. The decision matrix of Eq. (26) is composed of applying linguistic terms in Table 4.

Table 4 Linguistic Terms to Evaluate Alternatives (SCCCs)

Symbol	Linguistic Term	Symbol	Linguistic Term
s''_0	Strongly Ineffective	s'_0	Uncertain
s''_1	Ineffective	s'_1	Slightly Uncertain
s''_2	Nearly Ineffective	s'_2	Medium
s''_3	neither Effective nor Ineffective	s'_3	Slightly Sure
s''_4	Nearly Effective	s'_4	Sure
s''_5	Effective		
s''_6	Strongly Effective		

Fig. 3 Research Framework



$$D_Z = [z'_{ij}] = [(s''_k, s'_l)_{ij}] \tag{26}$$

It is noticeable that in Eq. (26), s''_k is the influence of the alternative i on the criterion j and s'_l is the certainty of the assessment.

- The scores of the z-numbered evaluations are calculated by Eq. (2) to (4) and the crisp decision matrix is shaped as demonstrated in Eq. (27).

$$D_c = [x_{ij}] = [(f^*(s''_k) \times g^*(s'_l))_{ij}] \tag{27}$$

- The alternatives are prioritized by the VIKOR method employing Eq. (18) to (23).

Step 6. Classifying The SCCCs. The prioritized SCCCs are clustered into four groups (according to the score quartiles emanated from linguistic Z-VIKOR) including diamond,

gold, star and question mark. After that, each group is discussed. The research steps are presented in Fig. 3.

4 Findings and results

The current study considers 17 coordination contracts with an integrated approach and evaluates their effects on mitigating repurposing challenges. By using an uncertain multi-criteria decision-making multi-layer approach including DEMATEL, ANP and VIKOR with linguistic Z-numbers, an accurate ranking of contracts based on their effectiveness in the face of challenges is provided. Hence, companies can implement the most appropriate possible strategies based on them. At first, by reviewing the literature the various types of SCCCs and the CRCs are gathered which have been illustrated in Tables 1 and 2, respectively. Next, the evaluations of experts on the effect of each CRCs on others have been collected to extract the weights of CRCs. The results are illustrated in Table 5.

Table 5 The Z-numbered matrix of the influences of criteria on each other

i/j	Financial Support C ₁	Regulation Framework C ₂	Innovation Network C ₃	Political Backup C ₄	Manufacturing Base C ₅	Digitalization C ₆	Data Availability C ₇	Collaboration C ₈
C ₁	*	(s ₆ , s' ₄)	(s ₄ , s' ₂)	(s ₄ , s' ₂)	(s ₄ , s' ₃)	(s ₆ , s' ₄)	(s ₅ , s' ₂)	(s ₅ , s' ₂)
C ₂	(s ₂ , s' ₂)	*	(s ₄ , s' ₃)	(s ₃ , s' ₂)	(s ₃ , s' ₂)	(s ₂ , s' ₃)	(s ₅ , s' ₂)	(s ₅ , s' ₃)
C ₃	(s ₂ , s' ₁)	(s ₅ , s' ₃)	*	(s ₃ , s' ₁)	(s ₂ , s' ₂)	(s ₄ , s' ₂)	(s ₅ , s' ₃)	(s ₅ , s' ₂)
C ₄	(s ₁ , s' ₂)	(s ₃ , s' ₂)	(s ₃ , s' ₂)	*	(s ₂ , s' ₂)	(s ₄ , s' ₂)	(s ₅ , s' ₃)	(s ₃ , s' ₂)
C ₅	(s ₄ , s' ₂)	(s ₆ , s' ₃)	(s ₄ , s' ₂)	(s ₄ , s' ₂)	*	(s ₅ , s' ₂)	(s ₆ , s' ₃)	(s ₅ , s' ₃)
C ₆	(s ₁ , s' ₃)	(s ₃ , s' ₂)	(s ₃ , s' ₂)	(s ₂ , s' ₂)	(s ₂ , s' ₃)	*	(s ₅ , s' ₂)	(s ₅ , s' ₂)
C ₇	(s ₃ , s' ₁)	(s ₂ , s' ₂)	(s ₃ , s' ₁)	(s ₃ , s' ₂)	(s ₂ , s' ₃)	(s ₃ , s' ₂)	*	(s ₅ , s' ₃)
C ₈	(s ₂ , s' ₃)	(s ₄ , s' ₂)	(s ₄ , s' ₂)	(s ₄ , s' ₂)	(s ₂ , s' ₂)	(s ₃ , s' ₁)	(s ₄ , s' ₂)	*

Table 6 Total influence matrix of DEMATEL

i/j	Financial Support C ₁	Regulation Framework C ₂	Innovation Network C ₃	Political Backup C ₄	Manufacturing Base C ₅	Digitalization C ₆	Data Availability C ₇	Collaboration C ₈
C ₁	0.0939	0.4402	0.2454	0.2148	0.2449	0.3978	0.3487	0.3559
C ₂	0.0979	0.1382	0.2138	0.1448	0.1368	0.1648	0.2524	0.2973
C ₃	0.0757	0.2625	0.0964	0.1125	0.1154	0.1737	0.2848	0.2508
C ₄	0.0649	0.1594	0.1341	0.0666	0.1022	0.1591	0.2622	0.1858
C ₅	0.1596	0.3586	0.2220	0.2008	0.1150	0.2493	0.3858	0.3688
C ₆	0.0764	0.1648	0.1366	0.1080	0.1205	0.0828	0.2171	0.2202
C ₇	0.0756	0.1417	0.1063	0.1250	0.1169	0.1370	0.1163	0.2559
C ₈	0.1036	0.1894	0.1581	0.1459	0.1048	0.1220	0.2043	0.1270

After evaluating the effects, the score of each linguistic z-assessment is computed and the crisp matrix is constructed (Eqs. (2) to (4)). Next, the matrix is normalized (Eqs. (6) and (7)). Afterwards, the total influence matrix is computed (Eq. (8)) which is shown in Table 6.

The CRSs are analyzed by obtaining the row sum and the column sum (Eqs. (9) and (10)) of the total influence matrix (Table 6). The results are presented as follows (Table 7). The green cells in the last column present the causes and the red ones the effects.

As illustrated in Figure, C₁ is the most influential criterion on others. Moreover, C₇ and C₈ are the most influenced criteria. In addition, C₂ is the most related within the system.

Table 7 z-DEMATEL results

CRC	Codes	r	s	r+s	r-s
Financial Support	C ₁	2.3417	0.7477	3.0894	1.5940
Regulation Framework	C ₂	1.4461	1.8548	3.3009	-0.4087
Innovation Network	C ₃	1.3719	1.3128	2.6847	0.0591
Political Backup	C ₄	1.1343	1.1184	2.2527	0.0159
Manufacturing Base	C ₅	2.0599	1.0565	3.1163	1.0034
Digitalisation	C ₆	1.1263	1.4865	2.6128	-0.3602
Data Availability	C ₇	1.0747	2.0715	3.1463	-0.9968
Collaboration	C ₈	1.1550	2.0617	3.2167	-0.9066

Succeeding, the total influence matrix is normalized (Eq. 11) as shown in Table 8 and the cause and effect diagram of CRCs is shaped in Fig. 4.

By transposing the normalized total influence matrix (Eqs. (12) and (13)), an unweighted supermatrix is constructed. Consequently, the weighted supermatrix is constructed by the multiplication of the total influence matrix and unweighted supermatrix via Eqs. (14) to (16). Finally, the weights of the criteria are extracted employing limiting the weighted supermatrix by raising it to a sufficiently large value by Eq. (17). The weights of the core repurposing challenges are mentioned in Table 9.

As elaborated in Table 9, collaboration is the most significant CRC. Besides, data availability is also crucial. In the following, the experts evaluated the effect of each SCCC facing with each of CRCs. The evaluations have been conducted applying the Z-numbered scale and the Z-numbered decision matrix of Table 10 has been constructed.

The score of the evaluations of the decision matrix is computed (Eqs. (2) to (4)) and the crisp decision matrix is shaped (Eq. (18)). After attaining the crisp matrix, the decision matrix is normalized to apply the VIKOR method by Eq. (19). The results are illustrated in Table 11. As all the criteria are benefit criteria, the ideal value is the maximum

Table 8 Normalized total influence matrix for DANP

i/j	Financial Support C ₁	Regulation Framework C ₂	Innovation Network C ₃	Political Backup C ₄	Manufacturing Base C ₅	Digitalization C ₆	Data Availability C ₇	Collaboration C ₈
C ₁	0.0401	0.1880	0.1048	0.0917	0.1046	0.1699	0.1489	0.1520
C ₂	0.0677	0.0956	0.1479	0.1001	0.0946	0.1140	0.1745	0.2056
C ₃	0.0552	0.1914	0.0703	0.0820	0.0841	0.1266	0.2076	0.1828
C ₄	0.0573	0.1405	0.1182	0.0587	0.0901	0.1403	0.2311	0.1638
C ₅	0.0775	0.1741	0.1078	0.0975	0.0558	0.1210	0.1873	0.1790
C ₆	0.0678	0.1464	0.1213	0.0959	0.1069	0.0735	0.1927	0.1955
C ₇	0.0704	0.1318	0.0989	0.1163	0.1088	0.1275	0.1082	0.2381
C ₈	0.0897	0.1640	0.1369	0.1263	0.0907	0.1056	0.1769	0.1099

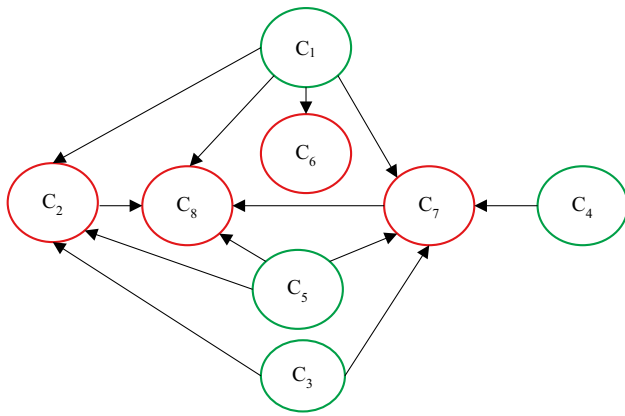


Fig. 4 Cause and Effect Diagram of CRCs

value and the anti-ideal value is the minimum value of each column as shown in the last two rows (Eq. (20)).

Consequently, S_i , R_i , and Q_i are computed via Eqs. (21) to (23). Accordingly, the final score and rank of SCCCs are obtained and presented in Table 12. It is notable that due to the major agreement of the experts, (v) was considered 0.5.

As illustrated in Table 12, effort-sharing contracts can reduce the challenges of repurposing more effectively than other types of contracts. In contrast, risk-sharing contracts cannot face the challenges, efficiently. Following, the contracts are divided into four groups according to the score quartiles emanated from linguistic z-*VIKOR* including diamond, gold, star and question mark as illustrated in Table 13.

Table 13 demonstrates the four groups of contracts. As shown in the mentioned table, effort sharing, cost-sharing, credit option and buyback contracts are the best contracts that companies can select to reduce CRCs. These findings are discussed further in Sect. 5.

5 Discussion and implications

With the spread of Covid-19, the future of numerous industrial infrastructures and planning in all countries was seriously questioned. This ignorance and inability to

predict the future had serious effects on various industries. Under these circumstances, the activities of the pharmaceutical industry not only did not stop like many other industries but also increased rapidly (Fox et al. 2020). In this situation, pharmaceutical companies were forced to try to achieve drug treatment and vaccines for this disease, as well as develop the production volume of their current effective drugs. In addition to investing in scientific studies and manufacturing infrastructure, focusing on distribution systems also became crucial for these companies (Lucero-Prisno et al. 2020). There were two main reasons for this. First, that corporate distribution systems could not cope with the high volume of production. Second, quarantine in countries has severely disrupted transportation and imposed significant costs on companies. This situation was even more intensive for underdeveloped countries and emerging economies such as Iran as the studied case. Hence, the way pharmaceutical companies collaborate with other companies inside and outside the industry (Vedel 2021), governments and international institutions, including the World Health Organization (WHO), faced serious changes (Chakraborty et al. 2020). In this regard, according to the weights extracted in Table 9, collaboration got the most critical challenge for these companies. Moreover, escalating the speed of companies' comprehensive activities increased their need for data (Bolislis et al. 2020). This need took on a more serious form as data collection and analysis faced meaningful difficulties in the new context. On the other hand, in addition to the ignorance of the new situation, the competition for the highest benefit also became another major reason for companies not having access to data (Meyer 2020). Therefore, as shown in Table 9, data availability is a significant challenge for companies. Furthermore, The Covid-19 pandemic disrupted all the rules, regulations, and orders governing corporate interactions that had been created and developed over the years (Ueda et al. 2021). As a result, according to Table 9, the regulation framework plays a highlighted role as a CRC. In contrast, the new conditions predicted that pharmaceutical companies would become the most profitable enterprises. As a consequence, the willingness to invest in these companies increased and

Table 9 Weights of CRCs (core repurposing challenges) emanated from z-DANP

Symbol	CRC	Weight
C ₁	Financial Support	0.0687
C ₂	Regulation Framework	0.1495
C ₃	Innovation Network	0.1156
C ₄	Political Backup	0.1001
C ₅	Manufacturing Base	0.0933
C ₆	Digitalization	0.1186
C ₇	Data Availability	0.1745
C ₈	Collaboration	0.1799

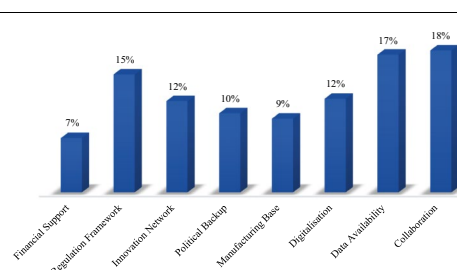


Table 10 The linguistic Z-numbered decision matrix for VIKOR

i/j	Financial Support	Regulation Framework	Innovation Network	Political Backup	Manufacturing Base	Digitalization	Data Availability	Collaboration
Wholesale Price	(s_6'', s_8')	(s_5'', s_2')	(s_2'', s_2')	(s_6'', s_3')	(s_2'', s_3')	(s_1'', s_3')	(s_1'', s_3')	(s_2'', s_2')
Revenue Sharing	(s_4'', s_2')	(s_6'', s_3')	(s_3'', s_2')	(s_5'', s_3')	(s_6'', s_3')	(s_5'', s_3')	(s_5'', s_2')	(s_1'', s_0')
Two-Part Tariff	(s_4'', s_2')	(s_6'', s_2')	(s_4'', s_2')	(s_6'', s_3')	(s_6'', s_4')	(s_4'', s_2')	(s_2'', s_2')	(s_6'', s_3')
Buyback	(s_6'', s_3')	(s_5'', s_2')	(s_4'', s_3')	(s_3'', s_2')	(s_5'', s_3')	(s_3'', s_3')	(s_4'', s_3')	(s_3'', s_2')
Quantity Flexibility	(s_6'', s_3')	(s_4'', s_3')	(s_3'', s_2')	(s_2'', s_3')	(s_6'', s_3')	(s_2'', s_2')	(s_5'', s_2')	(s_4'', s_2')
Backup Supplier	(s_6'', s_4')	(s_5'', s_3')	(s_4'', s_2')	(s_2'', s_2')	(s_1'', s_2')	(s_1'', s_2')	(s_2'', s_2')	(s_4'', s_2')
Rebate	(s_6'', s_2')	(s_3'', s_2')	(s_3'', s_1')	(s_3'', s_1')	(s_2'', s_2')	(s_2'', s_2')	(s_2'', s_2')	(s_4'', s_2')
Quantity Discount	(s_6'', s_4')	(s_4'', s_2')	(s_5'', s_3')	(s_3'', s_2')	(s_5'', s_3')	(s_2'', s_2')	(s_4'', s_2')	(s_4'', s_2')
Advanced Purchase Discounts	(s_6'', s_3')	(s_5'', s_3')	(s_4'', s_2')	(s_5'', s_3')	(s_4'', s_2')	(s_3'', s_1')	(s_1'', s_2')	(s_3'', s_1')
Bonus	(s_6'', s_2')	(s_3'', s_1')	(s_6'', s_3')	(s_2'', s_2')	(s_4'', s_1')	(s_4'', s_2')	(s_5'', s_3')	(s_6'', s_4')
Cost Sharing	(s_4'', s_1')	(s_3'', s_3')	(s_2'', s_3')	(s_4'', s_2')	(s_6'', s_3')	(s_3'', s_2')	(s_5'', s_3')	(s_4'', s_3')
Credit Option	(s_4'', s_2')	(s_3'', s_2')	(s_5'', s_3')	(s_4'', s_1')	(s_5'', s_3')	(s_4'', s_1')	(s_5'', s_3')	(s_6'', s_4')
Effort Sharing	(s_5'', s_3')	(s_5'', s_3')	(s_4'', s_2')	(s_5'', s_3')	(s_5'', s_3')	(s_3'', s_1')	(s_4'', s_2')	(s_5'', s_3')
Mark Down Contract	(s_5'', s_4')	(s_4'', s_2')	(s_4'', s_1')	(s_4'', s_2')	(s_5'', s_3')	(s_4'', s_2')	(s_4'', s_2')	(s_4'', s_2')
Option	(s_3'', s_1')	(s_4'', s_3')	(s_5'', s_3')	(s_4'', s_2')	(s_5'', s_3')	(s_3'', s_3')	(s_4'', s_1')	(s_3'', s_2')
Profit-Sharing	(s_5'', s_3')	(s_4'', s_1')	(s_4'', s_2)	(s_3'', s_2)	(s_4'', s_2)	(s_1'', s_3)	(s_3'', s_2)	(s_4'', s_3)
Risk Sharing	(s_5'', s_3)	(s_2'', s_1)	(s_1'', s_2)	(s_4'', s_2)	(s_1'', s_4)	(s_3'', s_3)	(s_4'', s_2)	(s_1'', s_2)

the shares of these companies jumped significantly. In addition, governments and international organizations have invested heavily in the development of pharmaceutical companies. For this reason, financial support for

companies according to Table 9 is not a significant challenge in the merging economy of Iran as the majority of the economy and enterprises in the drug and pharmaceutical sectors are managed by the officials.

Table 11 Normalized decision matrix





i/j	Financial Support	Regulation Framework	Innovation Network	Political Backup	Manufacturing Base	Digitalisation	Data Availability	Collaboration
Wholesale Price	0.2967	0.2291	0.1084	0.4473	0.1088	0.1085	0.0960	0.0821
Revenue Sharing	0.1319	0.4124	0.1626	0.3727	0.3263	0.5425	0.3199	0.0000
Two-Part Tariff	0.1319	0.2749	0.2168	0.4473	0.4351	0.2893	0.1279	0.3694
Buyback	0.2967	0.2291	0.3251	0.1491	0.2719	0.3255	0.3838	0.1231
Quantity Flexibility	0.2967	0.2749	0.1626	0.1491	0.3263	0.1447	0.3199	0.1642
Backup Supplier	0.3956	0.3436	0.2168	0.0994	0.0363	0.0723	0.1279	0.1642
Rebate	0.1978	0.1375	0.0813	0.0745	0.0725	0.1447	0.1279	0.1642
Quantity Discount	0.3956	0.1833	0.4064	0.1491	0.2719	0.1447	0.2559	0.1642
Advanced Purchase Discounts	0.2967	0.3436	0.2168	0.2485	0.1450	0.1085	0.0640	0.0616
Bonus	0.1978	0.0687	0.4877	0.0994	0.0725	0.2893	0.3199	0.4925
Cost Sharing	0.0659	0.2062	0.1626	0.1988	0.3263	0.2170	0.3199	0.2463
Credit Option	0.1319	0.1375	0.2710	0.0994	0.2719	0.1447	0.3199	0.4925
Effort Sharing	0.2472	0.3436	0.2168	0.3727	0.3263	0.1085	0.2559	0.3078
Mark Down Contract	0.2198	0.1222	0.0723	0.1325	0.1813	0.1929	0.1706	0.1095
Option	0.0494	0.2749	0.2710	0.1988	0.1813	0.3255	0.1279	0.1231
Profit-Sharing	0.1648	0.0916	0.2168	0.1491	0.2175	0.1085	0.1919	0.2463
Risk Sharing	0.2472	0.0458	0.0813	0.1988	0.0725	0.3255	0.2559	0.0410
Ideal	0.3956	0.4124	0.4877	0.4473	0.4351	0.5425	0.3838	0.4925
Anti-Ideal	0.0494	0.0458	0.0723	0.0745	0.0363	0.0723	0.0640	0.0000

Table 12 Prioritization of SCCCs

SCCC	S_i	R_i	Q_i	Rank
Wholesale Price	0.6926	0.1570	0.7286	14
Revenue Sharing	0.4030	0.1799	0.5000	9
Two-Part Tariff	0.4321	0.1396	0.3105	5
Buyback	0.4475	0.1349	0.3033	4
Quantity Flexibility	0.5268	0.1199	0.3172	7
Backup Supplier	0.6682	0.1396	0.6011	12
Rebate	0.8091	0.1396	0.7746	15
Quantity Discount	0.5243	0.1199	0.3142	6
Advanced Purchase Discounts	0.6856	0.1745	0.8175	16
Bonus	0.4563	0.1401	0.3433	8
Cost Sharing	0.5390	0.0904	0.1675	2
Credit Option	0.4915	0.1121	0.2300	3
Effort Sharing	0.4250	0.1095	0.1335	1
Mark Down Contract	0.7571	0.1399	0.7124	13
Option	0.6403	0.1396	0.5668	10
Profit-Sharing	0.6870	0.1308	0.5751	11
Risk Sharing	0.7329	0.1649	0.8223	17

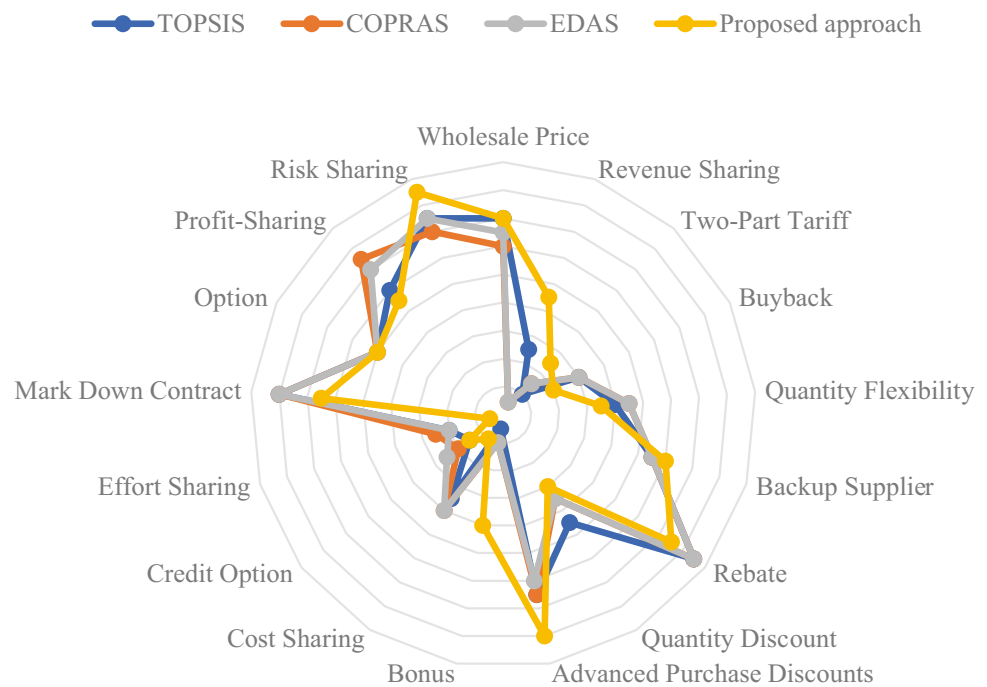
On the other hand, according to Table 13, four types of diamond contracts (the highest-ranked cluster of coordination contracts) are effort sharing, cost-sharing, credit option and buyback. This means that the four contracts are more effective in reducing the severity of the repurposing challenges. As in the new context, achieving the desired result and goals is not very reliable, contracts that focus on the efforts of companies instead of focusing on the results can help them solve the challenges (Mahdiraji et al. 2020). For this reason, the effort-sharing contract was ranked first in the diamond category. In addition, as explained earlier, with a sudden mutation incorporate costs, sharing these costs can go a long way toward solving their challenges, and as a result, cost-sharing contracts have a high priority. Moreover, due to the high increase in demand and limitations in

Table 13 SCCCs Clusters

SCCC	Ranking	Cluster	Icon
Effort Sharing	1	Diamond	
Cost Sharing	2		
Credit Option	3		
Buyback	4		
Two-Part Tariff	5	Gold	
Quantity Discount	6		
Quantity Flexibility	7		
Bonus	8		
Revenue Sharing	9	Star	
Option	10		
Profit-Sharing	11		
Backup Supplier	12		
Mark Down Contract	13	Question mark	
Wholesale Price	14		
Rebate	15		
Advanced Purchase Discounts	16		
Risk Sharing	17		

responding to the needs of all applicants, it is especially important to pay attention to their past performance and historical orders to prioritize them and pricing appropriately. That's why credit option contracts are in the diamond category. Finally, since the required capital and production, distribution, and sales costs, as well as the existing demand, are not predictable, the buyback contract can provide sufficient confidence for the members of the supply chain. This prioritization seems to be reasonably valid for the developing country of Iran as well. However, given the financial sanctions, financial support seems to be more important, and in addition, contracts that pay more attention to this issue, such as cost-sharing contracts, received a higher rank. As collaboration and data availability are the most significant challenges, the contracts that can reduce the effects of the mentioned challenges are also efficient. Hence, four contracts including two-part tariff, a quantity discount, quantity flexibility and bonus contracts are classified as the gold cluster. A two-part tariff contract obligates retailers to pay a fixed franchise fee to suppliers. Hence, it makes a relation between retailer and supplier directly and strengthens supply chain relationships and, on the other hand, provides suppliers with more information from retailers, which can be very helpful. Moreover, the quantity flexibility and quantity discount contracts, which are found on the number of orders, are very effective against the challenge of lack of demand information. Flexibility reduces potential losses in erroneous demand forecasting, and discount-based contracts generally reduce the cost of large quantity orders. Additionally, these contracts can increase the level of collaboration by encouraging buyers, which in turn ensures the supplier's profit. Furthermore, bonus contracts can consolidate the relationships in the supply chain by increasing collaboration through more supplier involvement in all aspects of the supply chain. Contrarily, star clusters containing revenue sharing, option, profit sharing, and backup supplier contracts can sometimes be brilliant in reducing challenges; however, they can not have a favorable effect on other challenges for all members of the supply chain. Revenue and profit-sharing contracts can lead to more supplier collaboration with lower levels of the supply chain. Nonetheless, due to the lack of information about the certainty of sufficient income and profit, the collaboration would not be stable. The other two contracts in this cluster can also affect the challenge of data availability by empowering and supporting lower levels of the supply chain; nevertheless, it does not necessarily mean that they will satisfy the supplier and thus building up the collaboration. Eventually, the effect of the last cluster contracts on resolving or reducing the challenges is not clear and these contracts are not recommended for repurposing strategies.

To check the validity of the results, the ranking of the proposed approach with other popular methods including

Fig. 5 Comparison of rankings and robustness of results

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), COMplex PROportional ASsessment (COPRAS), and Evaluation Based on Distance from Average Solution (EDAS) has been considered (Mahdiraji et al. 2021). The results are presented as a radar chart illustrated in Fig. 5. As the figure presents, there is no marked difference amongst the methods, indicating the robustness of the proposed multi-layer approach.

In the present study, an attempt has been made to present a new framework to view coordination contracts with a unique perspective. These efforts have been made in the past, but the condition of the Covid 19 pandemic needs to be reconsidered. Combining DEMATEL-ANP and VIKOR methods with linguistic Z-number was one of the new achievements of this research. Shen and Wang (2018) and Das et al. (2020) have integrated the Z-numbers with VIKOR but linguistic Z-numbers have not been employed before (Shen and Wang 2018; Das et al. 2020). Moreover, Kumar and Anbanandam (2020) and Li et al. (2021a, b) have in order applied to grey and interval-valued intuitionistic fuzzy DANP, but also no research has combined linguistic Z-number with the DANP method (Kumar and Anbanandam 2020; Li et al. 2021b). It is important to pay attention to this combination to ensure sufficient validity of the calculations and the results obtained because the degree of uncertainty in these conditions is very high.

As explained above, Covid 19 disease created new conditions for companies, and supply chain managers were forced to look at partnership contracts from a different perspective.

Until now, looking at contracts has generally been aimed at increasing capabilities and gaining more advantage from them. However, in the new context, paying attention to the challenges and reducing the effect of their potential harms on the performance of companies became especially important, and as a result of the present study, it tried to look at the issue of coordination contracts from this perspective and their impact in mitigating repurposing challenges. Iran as an emerging economy has faced serious obstacles in the development of its pharmaceutical industry due to mismanagement, corruption, and financial sanctions. Even after the outbreak of this disease, Iran needs to establish communication and cooperative interactions more than developed countries. However, even many underdeveloped or emerging countries have managed the vaccination procedure more efficient than Iran (e.g. Cuba, Turkey, UAE, etc.). This happened at a time when, first, international financial transfers were not as easy as in other countries, and second, Iran's financial and economic structure was more vulnerable than in developed countries. In this regard, Iran tried to meet its needs by relying on its domestic capabilities. To achieve this, it became important to establish a broader horizontal and vertical relationship in the supply chain of pharmaceutical companies, which are also the governmental public sector. As a result, this country has entered the fifth peak of the COVID-19 death rate in July 2021. Although the Iranian pharmaceutical industry faced this pandemic differently from the rest of the world, diamond-type contracts, and in particular cost-sharing contracts, can help address key repurposing challenges, including financial support.

6 Conclusion and future recommendations

With the spread of the covid-19 pandemic, serious global developments took place in various industries. The pharmaceutical industry is one of the main industries that had to adapt quickly to the new conditions. In this regard, the industry needs to review various aspects of its operations, including supply chain management. Choosing the right coordination contract, which until now was mainly aimed at increasing the advantage, now needs to be done to reduce the impact of the repurposing challenges. In this research, a DEMATEL-ANP-VIKOR framework under the condition of linguistic Z-numbers has been proposed to evaluate the effect of each supply chain coordination contract on the decrease of the core repurposing challenges. The results demonstrated that collaboration, data availability, and regulatory framework are the most significant repurposing challenges and effort sharing, cost-sharing, credit option and buyback contracts can affect them more influentially.

This research also faces some limitations. First of all, only the experts of the Iranian pharmaceutical sector have participated in this research. Furthermore, a questionnaire was attained by the focus group. The results would be changed if each expert complete the questionnaire independently. Moreover, this research was implemented in the emerging economy of Iran. It is recommended to run similar research for developed countries for benchmarking the results. Additionally, this study is achieved during Covid-19. Complementary research is suggested to perform for post-Covid-19. Sooner or later, other scholars can conduct the scheduled approach in their sector, industry, supply chain, or territory and benchmark the results with this research. From the perspective of theory, although, this article has benefited from linguistic Z-numbers in the multi-layer decision-making approach; however, it is recommended to apply novel techniques such as the Markov chain to consider the dynamism of the data during the time in future studies. Moreover, besides linguistic Z-numbers, other conditions of uncertainty e.g., hesitant fuzzy, interval-valued intuitionistic fuzzy, and Neutrosophic numbers can also be integrated with MCDM techniques to check whether the results are robust or not. Furthermore, the results emanated in this research are based on selective methods including DEMATEL, ANP, and VIKOR. The authors recommend that in the future, other scholars benefit from the combination of interpretive structural modeling (ISM) (Jafari-Sadeghi et al. 2021) and principal component analysis (PCA) with the DEMATEL method for more reliability of the results and a clear conceptual model demonstrating the relationship amongst the repurposing challenges.

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