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| RESEARCH ARTICLE

Determine and Clarify the Primary Elements for Measuring Agility in Mining Industries

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| ABSTRACT
With the increasing competitiveness of markets and a greater focus on increasing productivity and reducing costs among businesses, quick access to accurate information has become an Aggressive advantage for companies. This study seeks to determine and clarify the primary elements for measuring agility in mining industries. The qualitative section was recognized using a meta-synthesis method of 124 sources and 16 agility measurement criteria containing IT communications, customer orientation, coordinated planning, etc. A survey with 20 mining industry experts using the Fuzzy Delphi method identified and prioritized key factors for supply chain agility: quality level, market adaptability, dispatch speed, pliability, expense reduction, novelty, customer-centricity, and IT communications, utilizing the DANP method and interpretive structural modeling. Findings revealed that customer orientation is a fundamental driver of agility, influencing each cost reduction and innovation. These factors impact product quality and communication, ultimately affecting responsiveness and delivery speed about market opportunities.

| KEYWORDS
Mining Industries, Agile Supply Chain, Cost Reduction, Fuzzy Delphi Method, DENP Method

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1. Introduction

Agility in a supply network refers to its capacity to quickly adapt to market fluctuations (Abdelilah et al., 2023) and buyer demands, serving as a key competitive advantage in today's business environment (Fidel, 2018). The concept of supply network responsiveness emerged in the late 1990s alongside developments in agile systems, manufacturing, and supply network management (Banifazel et al., 2021). The supply network's awareness of internal plus external changes in the logistics network's ability to use resources flexibly and promptly is essential (Jindal et al., 2021). With Growing competition in markets and the increasing focus on increasing productivity and reducing costs among businesses, quick access to accurate information has become a competitive advantage for companies, which can be employed to reduce costs by reducing inventory, increasing the speed of material turnover, and faster implementation of customer feedback in the final product, etc. (Chen et al., 2018). Innovation is currently advancing rapidly. In a changing market with new products and unpredictable competitors, delivering the right product at the right price and time is essential for competitive success and business survival (Jindal et al., 2021). According to the studies conducted and the study of the relationships and evolution of production systems and the transformation of organizations, it seems that the category of agility is one of the solutions to respond to this need. Agility is a strategy for change and, due to its irreversibility, leads to organizational superiority. Agility is being introduced in the manufacturing sector and is also undergoing an extension to the logistics chain (Queiroz et al., 2022).

Supply chain optimization is now a key issue in marketing and retail management discussions (Nie & Wang, 2019). To achieve growth and innovation in a business delivery structure (Drake et al., 2023), one must be agile enough to cope with disruptions (Goldberg, 2023). This issue became even more evident during the coronavirus pandemic, as agile supply chains have allowed companies to maintain their market share in adverse and pervasive conditions by accelerating new business possibilities in a responsive plus scalable method (Dubey et al., 2021).

The inflexible supply chain does the opposite, reducing the ability to leverage a strong customer experience or even leading to the complete demise of the business (Nguyen et al., 2021). Improving overall operational performance and responding to changing market needs create value-creation power for companies and thus enhance their competitive ability (Shafiee et al., 2021). Nimbleness allows the supply network to adapt to changes in consumer desires plus competitive pressures quickly, making it essential for organizations to succeed in the fluctuating and uncertain market of the 21st century (Shukor et al., 2021). With the entry into the information and technology era, new products enter the market quickly, and consumer tastes also change rapidly (Slocum et al., 2014). In such an environment, a lack of knowledge about the market growth trend, customer needs, and tastes can produce detrimental outcomes for companies and organizations and destroy their position (Teagarden et al., 2008). Therefore, paying attention to the agile supply chain as a new paradigm to deal with threats and gain profits is essential (Campion & Campion, 2024).

Extensive research on supply chain nimbleness in the mining industry focused on each design and validation. However, a notable research gap exists in (developing an agility model driver that can provide beneficial insights and knowledge to managers of all companies active in the supply chain so that they can effectively plan for making the supply chain agile). This gap is significant because many successful international companies develop and implement practical plans for implementing the supply chain. However, supply chain agility is not implemented in most Iranian companies and is an abstract concept (Manikas et al., 2023). Part of this neglect is due to the lack of awareness of company managers about the theory of agility and its constituent factors (Zahed et al., 2020). Although there is complete consensus among marketing researchers regarding supply chain agility, there is a lack of a comprehensive model concerning supply chain flexibility that presents the various prerequisites of this phenomenon in a structured manner. A significant research gap, especially in domestic studies, is related to this and has implications for supply chain dynamism. The investigation on the supply chain dynamism model has not been conducted with sufficient comprehensiveness to cover many of the components involved in supply chain nimbleness. Dealing with this research gap is crucial as it aims to enhance supply chain management literature by offering a complex model that incorporates numerous prerequisites culminating in supply chain nimbleness. This investigation develops a model specifically for supply chain agility in the mining industry. There is a significant gap in understanding the factors affecting agility in the mining industry. It has led to a new theory of the role of digital technologies and data mining in increasing supply chain agility and enabling companies to respond quickly to market changes. This study aims to design and validate a supply chain agility model tailored to the country's mining sectors. This study identifies and analyzes the key factors affecting supply chain agility and examines the causal relationships between these elements. Given the gaps in the research literature and the lack of awareness among mining industry managers about agility and its influencing factors, this study attempts to help managers and decision-makers respond effectively to market needs and customer changes.

2. Literature review

Zhang (1999) defines organizational nimbleness as the capacity to address unforeseen difficulties and leverage changes as opportunities (Sharifi & Zhang, 1999). Li et al. (2008) nimbleness is a complex plus Multifaceted concept that includes the capacity to move quickly and easily, nimbleness in adapting, and efficiency in addressing challenges. Agility encompasses physical and mental flexibility, enabling individuals or organizations to navigate using uncertainties and seize opportunities in a dynamic environment (Li et al., 2008). Yang and Liu (2012) The arrangement explained agility as a management concept that responds to turbulent and dynamic market and customer demands. It is not merely a solution for organizational survival but also an opportunity to achieve a sustainable advantage (Yang & Liu, 2012). Sangari et al. (2015) note that substantial efforts focus on improving agile supply chains in the mining industry. They stress the critical role of customer orientation in meeting the diverse needs of different customer groups (Sangari et al., 2015).

The link between supply network nimbleness, pliability, risk mitigation, reactivity, and competitiveness is well-recognized. Singh (2025) discovered that advanced DACs enhance agility and pliability, improving (SCRP)[1]. Cooperation and consistency in the supply network are vital for this flexibility. Digital twin technology significantly enhances the relationship between supply chain

[1] Supply Network Resilience Performance

collaboration (SCC), supply chain flexibility (SCF), and supply chain responsiveness performance (SCRP). It improves flexibility and agility through real-time sensing, predictive analytics, and process alignment. Stakeholder collaboration plays a mediating role in enabling organizations to reap the full benefits of DTT (Singh, 2025). Abdelwahed & Soomro (2025) revealed that (SCI)[2] negatively affects (SCP)[3] among managers in Egyptian manufacturing companies. They noted that adopting efficient blockchain technology can boost performance in manufacturing and SMEs by enhancing supply chain practices and increasing productivity and profits (Abdelwahed & Soomro, 2025). Kang & Bhawna (2025), Current machine learning applications in supplier selection mainly target binary classification, indicating a significant gap in the literature for more complex approaches (Kang & Bhawna., 2025). Kandan et al. (2025) This report shows how crucial nebula technology represents the change in contemporary businesses (Kandan et al., 2025). Shukor et al. (2021) investigation found a strong link between environmental uncertainty plus supply network integration, encompassing buyer, purveyor, plus domestic aspects. It highlighted that organizational ambivalence significantly impacts this integration. Furthermore, supply chain integration enhances agility and organizational flexibility within the company (Shukor et al., 2021). Fayezi et al. (2017) investigation found that supply network stakeholders need to focus on relationship integration when engaging in agility and pliability advancement programs to optimize supply network functionality (Fayezi et al., 2017).

Research Gap and Novelty

A literature analysis indicated that some experts believe a pliability supply network emphasizes quick responsiveness to market fluctuations. The compulsion to innovate and use intelligent systems may conflict with traditional approaches. The compulsion to innovate and use intelligent systems may conflict with conventional methods. Also, while effective collaboration can help improve agility, there are challenges in creating these collaborations. In addition, changing customer needs may not match supply chain capacities, and the complexities of interacting with multiple actors can negatively affect supply chain dexterity and adjustability. These discussions highlight the challenges in attaining nimbleness and collaboration in the supply network. While this concept is considered a key strategy to respond to changing customer needs and market changes, there are also several challenges. Cultural changes and organizational resistance can hinder the realization of agility, and the complexities of interacting with suppliers and customers may lead to inconsistencies and increased costs. In addition, the conflict between customer expectations and supply chain capabilities and the challenges of innovation and implementation of new technologies requires effective management and a comprehensive approach. The gap between changing consumer preferences and unpredictable competitor behavior poses a significant challenge for companies. Rapid modifications to consumer tastes and needs, especially with technological advancements, force companies to change their marketing and production strategies. The behavior of competitors, who may suddenly enter the market with new and innovative initiatives, makes it difficult to predict. This uncertainty can lead to a decrease in customer satisfaction and market share. The initial research model shows that customer orientation influences cost reduction and innovation, thus altering pliability, product excellence, plus communication. These factors impact reactivity and delivery speed, ultimately leading to supply chain nimbleness.

[2] Supple Network Unification

[3] Supply Network Performance

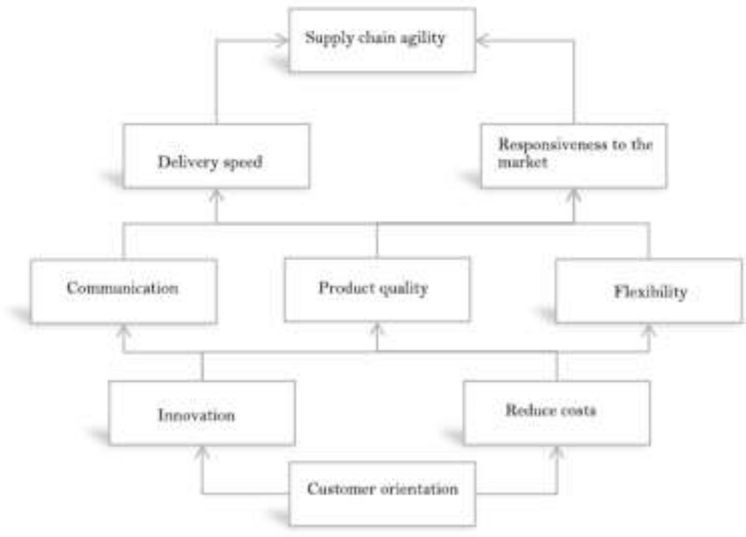

Fig (1). Research conceptual model

3. Methods

The present study considered applied developmental research from the perspective of its objective, and it is also a descriptive investigation in data gathering conducted using a cross-sectional survey method. The Sampling frame includes managers and experts from manufacturing and supplying companies in the mining industry. The size of the statistical population is approximately 2,000 individuals. Therefore, to ascertain the sample amount, the Cochran formula was employed as follows:

$$n = \frac{N \times (Z_{\frac{\alpha}{2}})^2 \times pq}{\varepsilon^2 (N-1) + (Z_{\frac{\alpha}{2}})^2 \times pq}$$

$$\frac{2000 \times (1.96)^2 \times (0.5 \times 0.5)}{(0.05)^2 \times (2000) + (1.96)^2 \times (0.5 \times 0.5)} = 322 \cong 325$$

The research steps are in diagram (1).

Table (1). Sample and research community in different stages of research

Research stages	Analysis method		Research Community	Research sample
Identification of research variables, indicators	1	Structured literature review	Articles on supply chain nimbleness	125 reviewed articles
	2	Fuzzy Delphi method and DNP	Supply chain experts	20 experts available
Conceptual model design	3	Interpretive structural modeling	Supply chain experts	20 experts available
	4	Fuzzy cognitive map	Supply chain experts	20 experts available
Statistical analysis of the conceptual model and other proposed relationships	5	Structural equation modeling	Managers of producing and supplying companies in the mining industry	325 questionnaires received

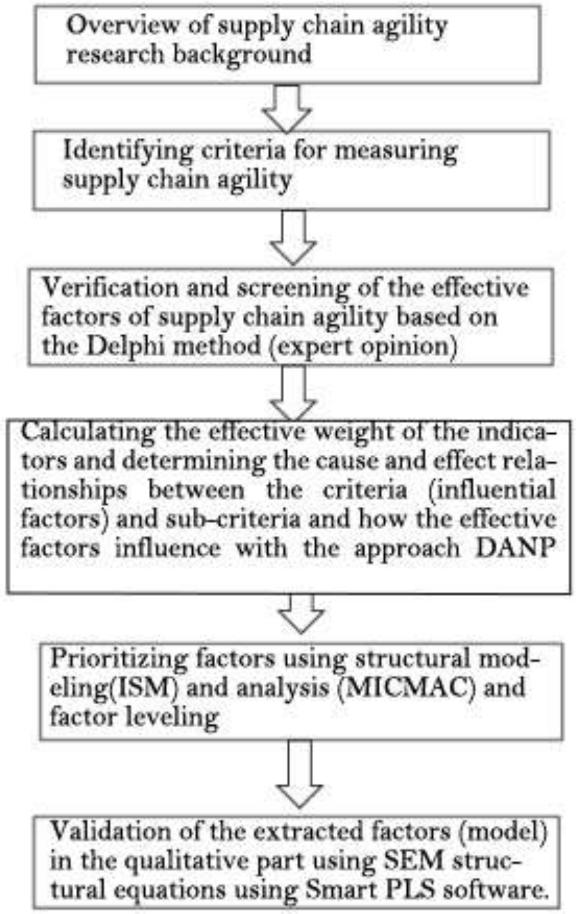

Diagram (1). Research steps

The products derived from mining are categorized based on the classification provided by the Ministry of Industry, Mine, and Trade into ten groups, which serve as the foundation for this research (Ayoub & Abdallah, 2019).
These groups are as follows:
Cement Group: Cement, concrete components, and related products.
Glass Group: Flat glass, safety glass, mirrors, optical glass, and glass containers.
Ceramics Group: Ceramic tiles, sanitary porcelain, ceramic insulators, industrial ceramics, and porcelain dishes.
This group includes gypsum, lime, bricks, sand and gravel, construction stones, waterproofing, and thermal insulation resources.
Ferrous Metals Group:
This group comprises iron and steel.
Non-Ferrous Metals Group:
This group comprises lead, zinc, copper, aluminum, and gold.
Industrial Minerals Group:
This group features sodium sulfate, calcium carbonate, silica, dolomite, and kaolin.
Abrasives Group:
This group encompasses grinding stones and fiber stones.
Ferroalloys Group:
This group contains ferrochrome, ferrosilicon, ferromanganese, and ferromolybdenum.
Refractory Products Group:
It includes refractory bricks, saggers, and refractory parts, such as masses and mortars.
Considering the extensive nature of the research topic within the supply chain of industrial mineral industries, this study is conducted comprehensively and relies on the latest available knowledge. The study's thematic scope encompasses all small and large mineral industries, as the flexibility of each directly affects the overall agility of the sector. Therefore, considering the whole supply chain is essential. Since the relevance of this research pertains to mineral industries, the thematic scope will encompass the supply chain of mineral industries in Iran. The borders of Iran define the geographical scope of the research.

A literature review was conducted alongside a screening of variables based on expert opinions, using the fuzzy Delphi method to identify the variables. This approach facilitated the selection of qualified variables for developing the conceptual model.

In the second stage, the identified variables were systematically reviewed and screened based on expert opinions and classified at various levels using interpretive structural modeling (ISM). The research identified the relationships among these variables, which led to the creation of research hypotheses. This process aided in developing the conceptual model and recognizing the association between the structural model and supply chain nimbleness.

In the conclusion stage, researchers employed the structural equation Template to assess the conceptual template, which aligned with the quantitative model supported by experts. They calculated the final factor weights using the fuzzy Delphi method and relevant software.

In this stage, after calculating and identifying the main elements influencing supply chain agility, their weights will be determined in the mineral industries. Subsequently, using the DANP Decision-Aware Network Process method, the criteria (factors) and sub-criteria will be analyzed, and their importance, weights, and causal relationships will established. The research utilized a questionnaire as the primary data collection tool, featuring main constructs, specialized five-point Likert scale questions, and general questions. Experts validated the questionnaire had a Cronbach's alpha of 0.875 in a preliminary investigation. Researchers then evaluated it for construct validity, external model validity, convergent validity (AVE[4]), and Convergent validity (Shafiee et al., 2021). The (AVE) for all factors should surpass 0.5. For reliability assessment, the pair (CR[5]) plus Cronbach's alpha for each factor must be greater than 0.7 (Nozari et al., 2021). The HTMT single-dual validity criterion was used for validity evaluation, replacing the Fornell-Larcker method. The acceptable range for HTMT is (0.85 to 0.9) provided that values are below 0.9, the divergent validity is considered satisfactory (Chen et al., 2018). Divergent validity is a criterion for evaluating measurement model fit in the PLS method, which was employed to validate the designed model. This approach includes pair external (measurement) and internal (structural) models. After confirming the reliability of the measurement model, Convergent and divergent validity consisted of two assessments, and the results were analyzed using Smart (PLS)[6] software.

4. Results

Descriptive Findings

The expert interview section utilized the perspectives of 20 experts, including specialists from the ministry and universities. Regarding gender, 16 individuals (%80) were male, and four individuals (%20) were female. Among them, 15 individuals (%75) held master's degrees, and five individuals (%25) held doctoral degrees. In terms of experience, ten individuals (%50) had 10 to 20 years of experience, seven individuals (%35) had 21 to 30 years of experience, and three individuals (%15) had over 30 years of experience.

The questionnaire section presents the perspectives of 325 managers and experts from mineral industries used to show the initial model. Regarding gender, 292 individuals (%90) were male, and 33 (%10) were female. Of this group, 222 individuals (%68) were producers, 84 individuals (%26) were suppliers, and 19 individuals (%6) were distributors. Based on organizational position, 37 individuals (%11) were managers, 39 individuals (%12) were consultants, and 249 individuals (%77) were experts. In terms of education, 50 individuals (%15) had associate degrees, 173 individuals (%53) had bachelor's degrees, and 102 individuals ((%31) had postgraduate degrees—the demographic Features presented in Tables (2) and (3).

Table (2). Demographic Features of Experts

Demographic characteristics		Frequency	Percentage (%)
Gender Identity	Woman	4	20.0
	Man	16	80.0
Education Level	Master's Degree	15	75.0
	Doctorate	5	25.0
Work Experience	10 to 20 Years	10	50.0
	21 to 30 Years	7	35.0
	Over 30 Years	3	15.0

Table (3). Demographic Features of Respondents

[4] Average Variance Extracted
[5] Composite reliability
[6] Partial Least Squares

Demographic Features		Rate	(%)
Gender	Man	292	90.0
	Woman	33	10.0
Role	Producer	222	68.0
	Supplier	84	26.0
	Distributor	19	6.0
Position	Manager	37	11.0
	Consultant	39	12.0
	Expert	249	77.0
Education Level	Associate Degree	50	15.0
	Bachelor's Degree	173	53.0
	Postgraduate Degree	102	31.0
Work Experience	Less than 10 years	25	8.0
	10 to 15 years	129	40.0
	Ages 15 to 20	107	33.0
	Over 20 years	64	20.0
Overall		325	100.0

Results of the Fuzzy Delphi Method

In this stage, the expert group members provided a questionnaire including 16 factors influencing supply chain agility in the mineral industries, extracted from interviews and a literature review using the Fuzzy Delphi method. Experts expressed their opinions on each criterion using verbal variables included in the questionnaire. The initial results from the experts' views appear in Table 4.

First Round Survey:

Table (4): Results of the First Round Survey, Along with the Average Expert Opinions

Agents	Linguistic value	Very much	Researchers sent the selected indicators to the group members acquired from a systematic literature analysis. They recorded the level of agreement with each indicator and categorized the comments and suggestions for revisions. The final average indicates the	Average	low	Very little	Min	Mod	Max	Unfuzzified average of expert opinion

			degree of agreement among the experts regarding each research factor. The researchers presented the computation results in tables. High							
	Numerical value	9	7	5	3	1				
	Fuzzy value	(7,9,10) (0.75, 0.75, 1)	(5,7,9) (0.5, 0.75, 1)	(3,5,7) (0.25, 0.5, 0.75)	(1,3,5) (0.0, 0.25, 0.5)	(0,1,3) (0,0,0.25)				
Communication and information technology	C1	14	6	0	0	0	6.4	8.4	9.7	8.28
Customer-oriented	C2	17	1	1	0	1	6.35	8.3	9.45	8.17
Coordinated planning	C3	14	1	2	2	1	5.55	7.5	8.8	7.39
Staff skill development	C4	12	3	1	2	0	5.3	7.3	8.7	7.20
Integration of processes	C5	14	3	3	0	0	6.1	8.1	9.4	7.98
Customer satisfaction	C6	14	4	1	0	1	6.05	8	9.3	7.89
Flexibility	C7	16	0	4	0	0	6.2	8.2	9.4	8.07
Product Quality	C8	17	2	1	0	0	6.6	8.6	9.75	8.46
Reduce costs	C9	15	3	1	1	0	6.2	8.2	9.45	8.08
Sensitivity and responsiveness to the market	C10	14	5	1	0	0	6.3	8.3	9.6	8.18
Innovation	C11	15	5	0	0	0	6.5	8.5	9.75	8.38
Introducing new products	C12	13	6	1	0	0	6.2	8.2	9.55	8.09
Delivery speed	C13	13	6	1	0	0	6.2	8.2	9.55	8.09

Technological changes	C14	13	3	2	1	1	5.65	7.6	8.95	7.50
Education and learning	C15	10	6	2	2	0	5.4	7.4	8.9	7.32
Delivery speed	C16	10	4	3	3	0	5.1	7.1	8.6	7.02

Second Round Survey:

In this phase, a second questionnaire was prepared and sent to the other group members, along with each individual's previous comments and the degree of their differences from the opinions of different experts. In the second round, the members of the second expert group responded based on the views of other group members and the changes made to the questions. The researchers presented the results in the Table below.

Table (5): Results of the Second Round Survey, Along with the Average Expert Opinions

Agents	Linguistic value	Very much	High	Average	low	Very little	Min	Mod	Max	Unfuzzified average of expert opinion	The difference between the average of the first and second questionnaires	Result
	Numerical value	9	7	5	3	1						
	Fuzzy value	(7,9,10) (0.75, 0.75, 1)	(5,7,9) (0.5, 0.75, 1)	(3,5,7) (0.25, 0.5, 0.75)	(1,3,5) (0.0, 0.25, 0.5)	(0,1,3) (0,0,0.25)						
Communication and information technology	C1	15	3	2	0	0	6.3	8.3	9.55	8.18	1.01	Accept
Customer-oriented	C2	17	1	0	2	0	6.3	8.3	9.45	8.16	1.01	Accept
Coordinated planning	C3	14	4	0	1	1	5.95	7.9	9.2	7.79	0.4	Rejection
Staff skill development	C4	14	3	3	0	0	6.1	8.1	9.4	7.98	0.78	Rejection
Integration of processes	C5	13	4	2	1	0	5.9	7.9	.259	7.79	0.19	Rejection
Customer satisfaction	C6	14	4	1	0	1	.056	8	9.3	7.89	0.81	Rejection
Flexibility	C7	14	0	4	0	0	6.2	8.2	9.4	8.07	0.21	Next
Product Quality	C8	17	2	1	0	0	6.6	8.6	.759	8.46	0.28	Next
Reduce costs	C9	15	3	1	1	0	6.2	8.2	.459	8.08	0.01	Accept
Sensitivity and responsiveness to the market	C10	14	5	1	0	0	6.3	8.3	9.6	8.18	0	Accept

Innovation	C11	15	3	1	1	0	6.2	8.2	.459	8.08	0.31	Next
Introducing new products	C12	13	6	2	1	0	6.4	8.6	.151 0	8.49	0.19	Rejection
Delivery speed	C13	13	6	1	0	0	6.2	8.2	.559	8.09	0.1	Accept
Technological changes	C14	13	4	2	2	0	.955	8.05	9.5	7.94	0.29	Rejection
Education and learning	C15	10	6	2	2	0	5.4	7.4	8.9	7.32	0.86	Rejection
Delivery speed	C16	10	4	3	3	0	5.1	7.1	8.6	7.02	0.38	Rejection

Based on the opinions presented in the first round and their comparison with the results of this phase, the survey process halted if the difference between the two rounds was less than the threshold of 0.2. Some factors achieved consensus among the expert group, with differences below the 0.2 threshold in the first and second rounds, resulting in the survey's termination. Additionally, among the mentioned factors, those with a non-fuzzy average of opinions less than eight are excluded from the model, and the study regarding the remaining factors will proceed as outlined in the next phase (Phase Three).
In this phase, after making the necessary adjustments to the model factors, a third survey was developed and forwarded to the specialists once again, along with each individual's previous comments and the degree of their differences from the average opinions of other experts—the results presented in Table 6.

Summary of the Fuzzy Delphi Method
In this study, the researchers conducted the Fuzzy. In the third round, the difference in the non-fuzzy average compared to the second round was less than 0.2, indicating the conclusion of the Fuzzy Delphi stages. Therefore, the survey halted at this stage.
8 of the 16 identified factors (from the systematic literature review) were ultimately confirmed throughout the three survey phases, as presented in Table (7) in a coded format. The sub-indicators, which are the questions from the questionnaire, are also included.

Table (6): Results of the Third Round Survey Along with the Average Expert Opinions

Agents	Linguistic value	Very much	High	Average	low	Very little	Min	Mod	Max	Unfuzzified average of expert opinion	The difference between the average of the second and third questionnaires	Result
	Numerical value	9	7	5	3	1						
	Fuzzy value	(7,9,10) (1,0.75, 0.75)	(5,7,9) (1,0.75,0.5)	(3,5,7) (0.75,0.5,0.25)	(1,3,5) (0.5,0.25,0.0)	(0,1,3) (0.25,0, 0)						
Flexibility	C7	16	2	1	1	0	6.3	8.3	9.5	8.17	0.10	Accept
Product Quality	C8	15	4	1	0	0	6.4	8.4	9.65	8.28	0.18	Accept
Innovation	C11	14	4	2	0	0	6.2	8.2	9.5	8.08	0.00	Accept

Table (7): Influential Indicators on Supply Chain nimbleness in the Mineral Industries

The main criterion	The main standard code	Sub-criterion (questionnaire questions)	Sub-criterion code
Communication (information technology)	A	Access to information and advanced technologies facilitates the implementation of tasks across the entire mining industry process, overcoming geographical barriers.	A1
		To what extent is the endowment and development of information technology facilities[8]in the organization[7]	A2
		Availability of resources and quick and appropriate information in all production processes	A3
Customer-oriented	B	Quick response to changes in customer demand	B1
		How many employees can produce and quickly deliver the required goods to customers?	B2
		Paying attention to the price to compete with other industries	B1
Flexibility	C	How much flexibility does the company consider when formulating its strategy?	C1
		Determining suitable production at different times of the year	C2
		How much can the company respond to the diverse demands of the products?	C3
Product Quality	D	What is the increase in durability according to the national and international standards of the product in different conditions?	D1
		Not in production and increasing quality according to market needs	D2
		Ensuring the product's quality level in comparison with other similar products	D3
Reduce costs	E	Responding to customers' orders promptly and providing raw materials and required parts at the right time	E1
		Increasing productivity and reducing production overhead costs	E2
		Assessing and controlling the amount of capital and the amount of production and determining the annual performance	E3
		Elimination or reduction of normal and abnormal waste from production	E4
Sensitivity and responsiveness to the market	F	Market orientation involves generating insights inside industrial units regarding current and future customer needs.	F1

[7] Hardware
[8] Updatedness of the industrial automation system

		Providing services with warranty after selling products to customers	F2
		Searching for new markets in different regions and marketing them appropriately	F3
Innovation	G	Continuous measurement of production capacity along with new and innovative plans in mining industry units	G1
		Achieving self-sufficiency in the production of mineral industries by using innovations	G2
		Senior management's commitment and support for innovative strategies and risk-taking in all fields	G3
Delivery speed	H	To what extent is the speed of adapting to changes in mining industry processes in the organization	H1
		Reducing the maximum production time of the product according to the customer's request	H2
		Proper packaging and properly sending the goods and paying attention to reducing the time interval	H3

DANP Method

The study first assessed the impact of research factors using the DANP method (Table 8). It includes specific steps to determine importance, weight, priorities, causal relationships, and primary and secondary criteria.

Researchers developed and normalized the complete relationships matrix (Tc) and evaluated the influence and dependence of sub-criteria.

Finally, they normalized the complete relationships matrix (Tc) and formed the unweighted supermatrix.

Formation of the weighted supermatrix.

It was constraining the weighted supermatrix.

Based on Table 8, the researchers categorized the criteria for relationships—namely, Information Technology (A), Customer Orientation (B), Cost Reduction (E), and Innovation (G)—as causes. The researchers classified the remaining criteria as effects.

Table (8): Impact and Dependence of Main Criteria

	R	D	D+R	D-R	Criterion type
A	3.785	3.804	0.019	7.590	Cause
B	3.575	3.793	0.217	7.368	Cause
C	3.818	3.723	0.096	7.541	Caused
D	3.792	3.763	0.028	7.555	Caused
E	3.698	3.871	0.174	7.569	Cause
F	3.791	3.631	0.160	7.421	Caused
G	3.795	3.864	0.139	7.589	Cause
H	3.758	3.493	0.265	7.252	Caused

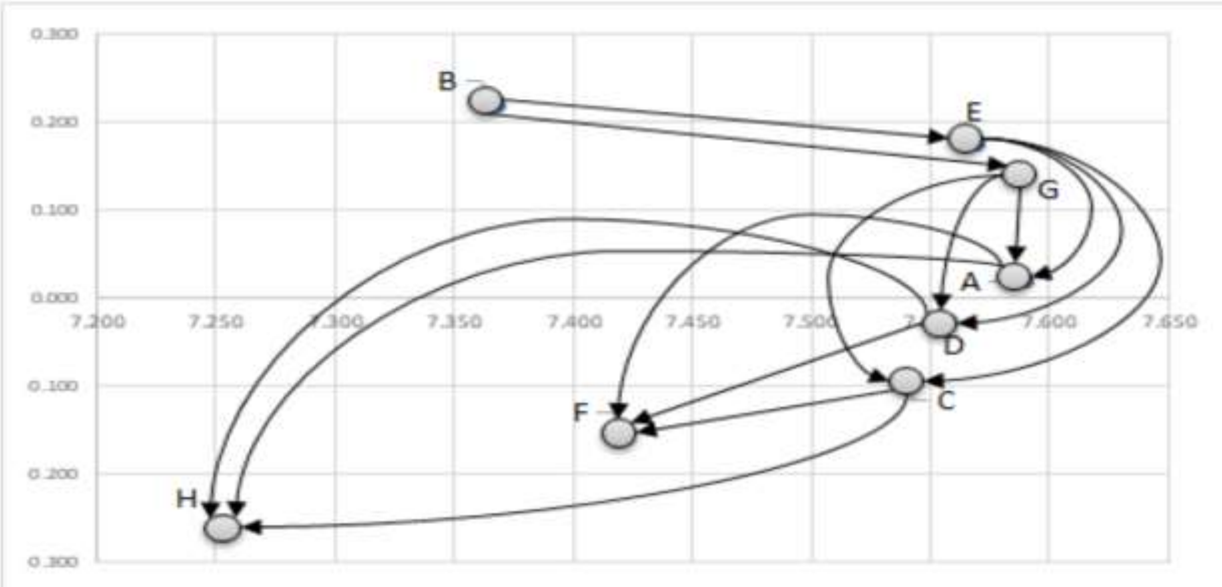

Diagram (2). Causal diagram of the main criteria

Definitive weights of criteria and sub-criteria were derived from the constrained supermatrix and shown in Table (9). According to Table (9), the flexibility criterion has secured the first rank with a weight of 0.12740. Market sensitivity and responsiveness rank second with a weight of 0.1267, while product quality holds the third rank with a weight of 0.1265.

Additionally, among the sub-criteria, senior management's commitment and support for innovative strategies and risk-taking in all areas have secured the first rank with a weight of 0.4388. Changes in production, an increase in quality in line with market needs, and the speed of adaptation to changes in mineral industry processes have secured the second and third ranks, respectively.

Table (9): Definitive weights of criteria and sub-criteria

Criterion title	Ness mass	Ultimate weight	Rating
Communication (information technology)(A)	0.12626		4
Fast access to information and use of new technologies	0.3413	0.04309	1
Equipping and developing information technology facilities	0.3203	0.04044	3
Availability of resources and quick and appropriate information in all production processes	0.33840	0.04273	2
Customer-oriented(B)	0.11954		8
Quick response to changes in customer demand	0.3486	0.04167	1
Employees' capacity to swiftly manufacture and provide the necessary goods to customers.	0.3178	0.03799	3
Paying attention to the price to compete with	0.3337	0.03989	2

other industries			
Flexibility(C)	0.12740		1
The company's attention to flexibility in formulating strategy	0.3423	0.04361	1
Determining suitable production at different times of the year	0.3189	0.04063	3
The company's ability to respond to diverse product demands	0.3388	0.4316	2
Product quality(D)	0.12654		3
Increasing durability by national and international product standards	0.3271	0.04140	2
Change in production and increase quality according to market needs	0.3458	0.04376	1
Ensuring the product's quality level in comparison with other similar products	0.3271	0.04139	3
Reduce costs(E)	0.12345		7
Responding to customers' orders on time and providing raw materials and required parts at the right time	0.2536	0.03131	2
Increasing productivity and reducing production overhead costs	0.2607	0.03218	1
Assessing and controlling the amount of capital and the amount of production and determining the annual performance	0.2411	0.02976	4
Elimination or reduction of normal and abnormal waste from production	0.2446	0.03020	3
Sensitivity and responsiveness to the market (F)	0.12674		2
market orientation, creating intelligence throughout the industrial units about the present and future requirements of the customer	0.3283	0.04162	3
Providing services with warranty after selling products to customers	0.3327	0.04217	2
Searching for new markets in different regions and marketing them appropriately	0.3389	0.04296	1

Innovation(G)	0.12438		6
Continuous measurement of production capacity along with new and innovative plans in mining industry units	0.3175	0.03949	3
Achieving self-sufficiency in the production of mineral industries by using innovations	0.3298	0.04102	2
Senior management's commitment and support for innovative strategies and risk-taking in all fields	0.3528	0.04388	1
Delivery speed(H)	0.12568		5
Speed in adapting to changes in mining industry processes	0.3478	0.04371	1
Reducing the maximum production time of the product according to the customer's request	0.3274	0.04115	2
Proper packaging and properly sending the goods and paying attention to reducing the time interval	0.3248	0.04082	3

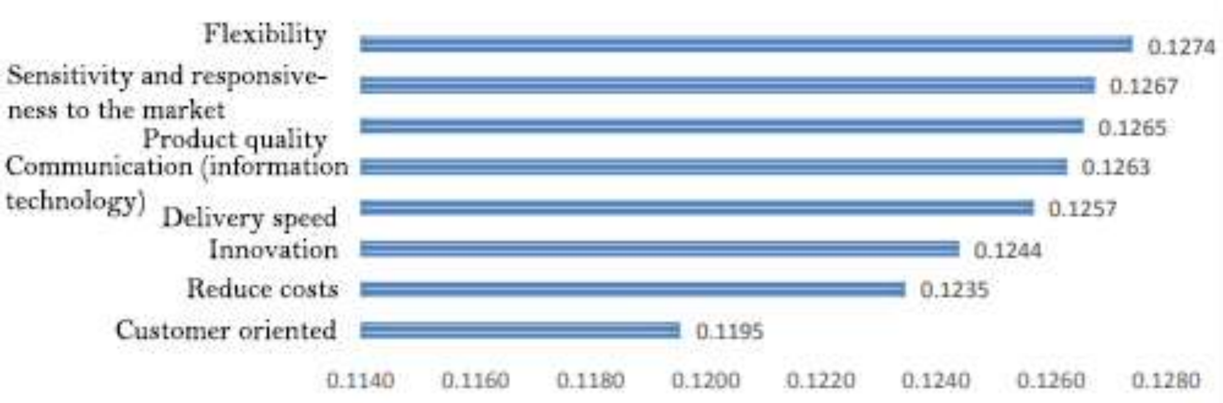

Chart (1): Weight and final ranking of the main criteria

Results of Interpretive Structural Modeling (ISM)

This section uses the ISM method to examine the factors' influence and dependence levels. Utilizing the output of the DEMATEL method as input for ISM is an effective tool for analyzing influence levels through DEMATEL relationships (Huo et al., 2018). Since the nature of both the DEMATEL and ISM methods is quite similar, instances arise where the analysis utilizes two questionnaires, which can lead to differing results if the inputs for the two methods differ. Therefore, researchers can combine DEMATEL and ISM approaches to yield more accurate results. The researchers outlined the steps of this method below.

Formation of the Initial Reachability Matrix

In this step, the researchers obtained the threshold value (arithmetic mean) from the complete relationships matrix of DEMATEL, which equaled 0.468. Then, they assigned a value of 1 to the elements that exceeded the threshold value, while they assigned a value of 0 to those that did not. This process occurred in Table (10), which represents the reachability matrix.

Table (10): Initial Reachability Matrix

1) Standard	2) A	3) B	4)	5) C	6) D	7) E	8) F	9) G	10) H
11) A	12) 0	13) 0	14	15) 0	16) 0	17) 0	18) 1	19) 0	20) 1
21) B	22) 0	23) 0	24	25) 0	26) 0	27) 1	28) 0	29) 1	30) 0
31) C	32) 0	33) 0	34	35) 0	36) 0	37) 0	38) 1	39) 0	40) 1
41) D	42) 0	43) 0	44	45) 0	46) 0	47) 0	48) 1	49) 0	50) 1
51) E	52) 1	53) 0	54	55) 1	56) 1	57) 0	58) 0	59) 0	60) 0
61) F	62) 0	63) 0	64	65) 0	66) 0	67) 0	68) 0	69) 0	70) 0
71) G	72) 1	73) 0	74	75) 1	76) 1	77) 0	78) 0	79) 0	80) 0
81) H	82) 0	83) 0	84	85) 0	86) 0	87) 0	88) 0	89) 0	90) 0

Formation of the Consistent Initial Reachability Matrix

Once the researchers obtained the initial reachability matrix, they established its internal consistency. For example, if variable one led to variable two, and variable two led to variable three, then variable one also led to variable three. If it met in the reachability matrix, they modified it to include and correct such relationships. It achieved adding secondary relationships that did not exist previously in the initial reachability matrix. Table (11) shows that the cells marked with 1 indicated the relationships established in the consistent matrix.

Table (11): Consistent Initial Reachability Matrix

91) Standard	92) A	93) B	94) C	95) D	96) E	97) F	98) G	99) H	100) Penetration power
101) A	102) 1	103)	104) 0	105) 0	106)	107) 1	108)	109) 1	110) 3
111) B	112) 1 *	113)	114) 1 *	115) 1 *	116)	117) 0	118)	119) 0	120) 6
121) C	122) 0	123)	124) 1	125) 0	126)	127) 1	128)	129) 1	130) 3
131) D	132) 0	133)	134) 0	135) 1	136)	137) 1	138)	139) 1	140) 3
141) E	142) 1	143)	144) 1	145) 1	146)	147) 1 *	148)	149) 1 *	150) 6
151) F	152) 0	153)	154) 0	155) 0	156)	157) 1	158)	159) 0	160) 1
161) G	162) 1	163)	164) 1	165) 1	166)	167) 1 *	168)	169) 1 *	170) 6
171) H	172) 0	173)	174) 0	175) 0	176)	177) 0	178)	179) 1	180) 1
181) The degree of dependence	182) 4	183)	184) 4	185) 4	186)	187) 6	188)	189) 2	190)

In this step, we calculate each factor's input (predecessor) and output (reachability) criteria and then identify the common factors. A criterion has the highest level when its set of outputs (reachability) equals the set of common characteristics. After determining this variable or variables, we eliminate their corresponding rows and columns in the Table and repeat the operations for the remaining benchmarks. Researchers extracted the outputs and inputs from the consistent initial reachability matrix (Table 11). For this purpose, the count of 1s in each row indicates the outputs, while the count of 1s in the corresponding column indicates the inputs.

Table (12): Level 1 Criteria

191) Criterion name	192) Output	193) Input	194) Subscription	195) Level
196) A	197) A-F-H	198) A-B-E-G	199) A	200)
201) B	202) A-B-C-D-E-G	203) B	204) B	205)
206) C	207) C-F-H	208) B-C-E-G	209) C	210)
211) D	212) D-F-H	213) B-D-E-G	214) D	215)
216) E	217) A-C-D-E-F-H	218) B-E	219) E	220)
221) F	222) F	223) A-C-D-E-F-G	224) F	225) 1
226) G	227) A-C-D-F-G-H	228) B-G	229) G	230)
231) H	232) H	233) A-C-D-E-G-H	234) H	235) 1

236) The Level (1) criteria, which include criteria (F & G), are extracted in Table 12. It is sufficient to remove the rows and columns of these two criteria from the consistent reachability matrix and then perform the calculations to determine the outputs and inputs again.

237)

238) Table (13). Level 2 criteria

239) Criterion name	240) Output	241) Input	242) Subscription	243) level
244) A	245) A	246) A-B-E-G	247) A	248) 2
249) B	250) A-B-C-D-E-G	251) B	252) B	253)
254) C	255) C	256) B-C-E-G	257) C	258) 2
259) D	260) D	261) B-D-E-G	262) D	263) 2
264) E	265) A-C-D-E	266) B-E	267) E	268)
269) G	270) A-C-D-G	271) B-G	272) G	273)

274) Table 13 extracts the Level (2) criteria, which include criteria (A, C, and D). For the Level (3) criteria, it is sufficient to remove the rows and columns of these three criteria from the consistent reachability matrix (Table 13) and then perform the calculations to determine the outputs and inputs again. The researchers showed the Level 3 and 4 criteria in Table 14.

275)

276) Table (14). Level 3 and 4 criteria

277) Criterion name	278) Output	279) Input	280) Subscription	281) level
282) B	283) B-E-G	284) B	285) B	286) 4
287) E	288) E	289) B-E	290) E	291) 3
292) G	293) G	294) B-G	295) G	296) 3

ISM Interaction Network

In the fifth step, the ISM interaction network uses the levels obtained from the criteria. Suppose a relationship exists between two variables, iii and J., as indicated by a directed arrow. The final diagram that eliminates the redundant states and utilizes the partitioning of the derived stages is in Fig (2). Therefore, it was assessed and viewed at four levels. The fourth level includes the Customer Orientation (B) indicator, which is the most influential. In contrast, the first level, which has two indicators, is identified as the most dependent level.

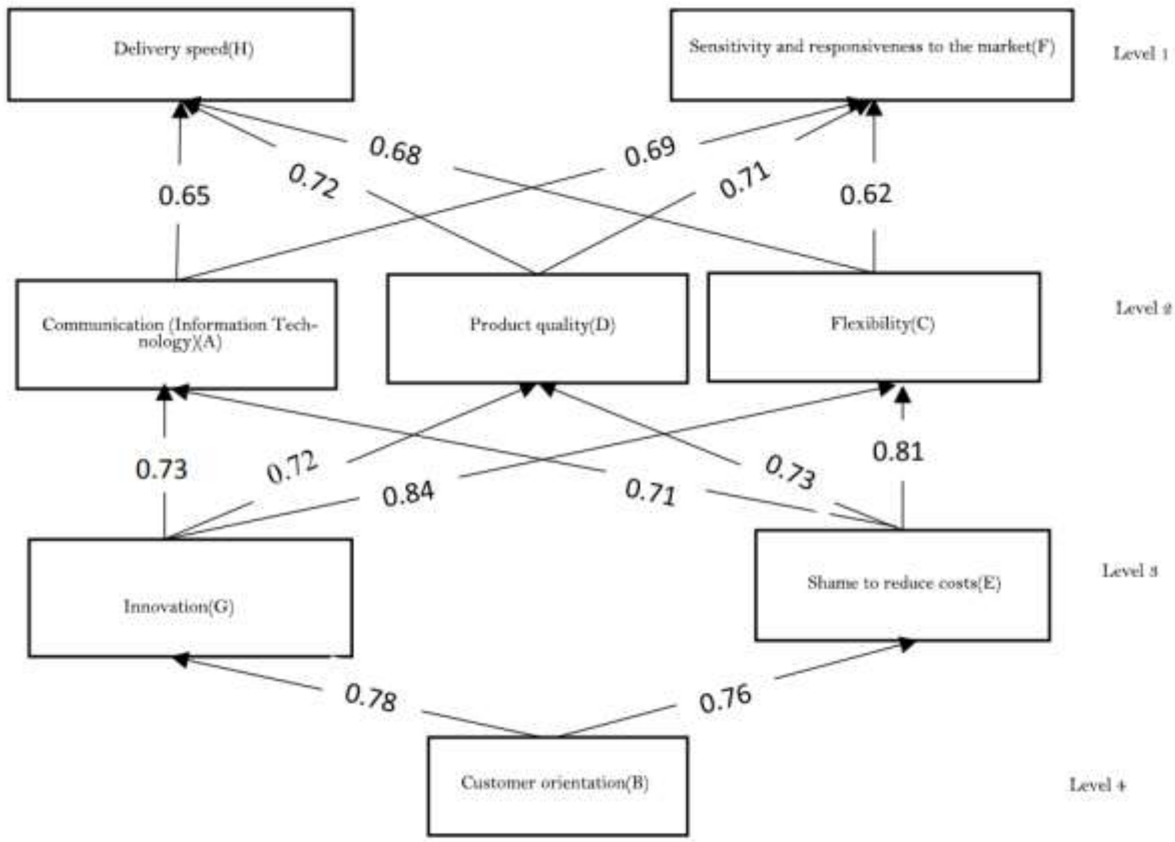

Fig (2). Research ISM model

Mic Mac Analysis

The research model (depicted in Figure 2) and detailed in Table (8) categorizes Customer Orientation (B), Cost Reduction (E), and Innovation (G) as independent variables due to their high impact and low dependence. Conversely, the remaining criteria are classified as dependent variables, characterized by strong dependence and weak influence, indicating they possess high reliance but low impact on the system.

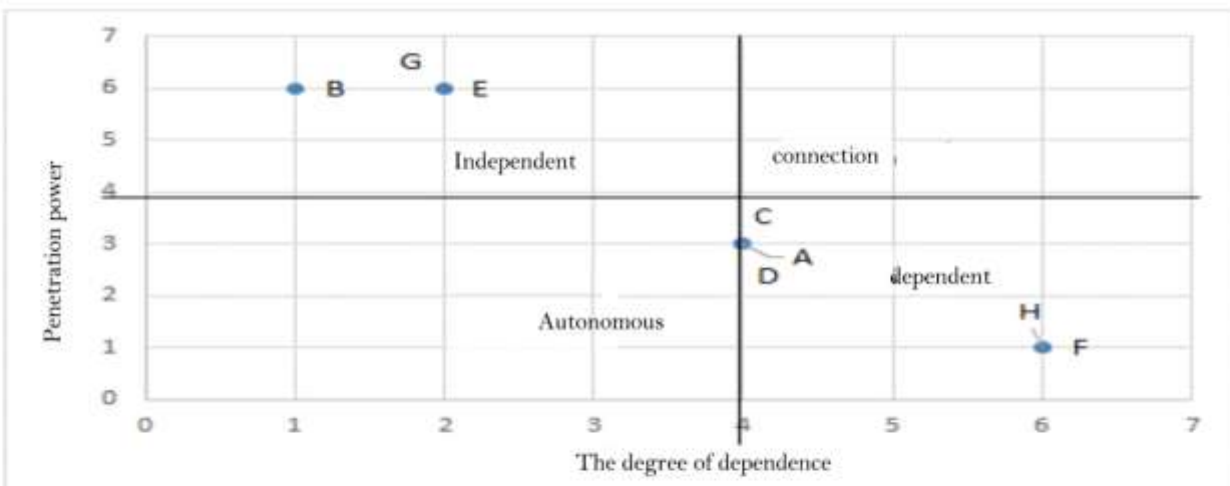

Diagram (3). Influence-dependence matrix

Researchers collected data from 325 individuals to investigate the relationships between variables and test hypotheses. They used SPSS version 24 and Smart PLS version 3, applying the (PLS) process to authenticate the supply chain agility template in the mineral industries. The validation results used the standard estimation mode, with the t-statistic assessing the significance of the relationship. In Figures 3 and 4, the path coefficients are.

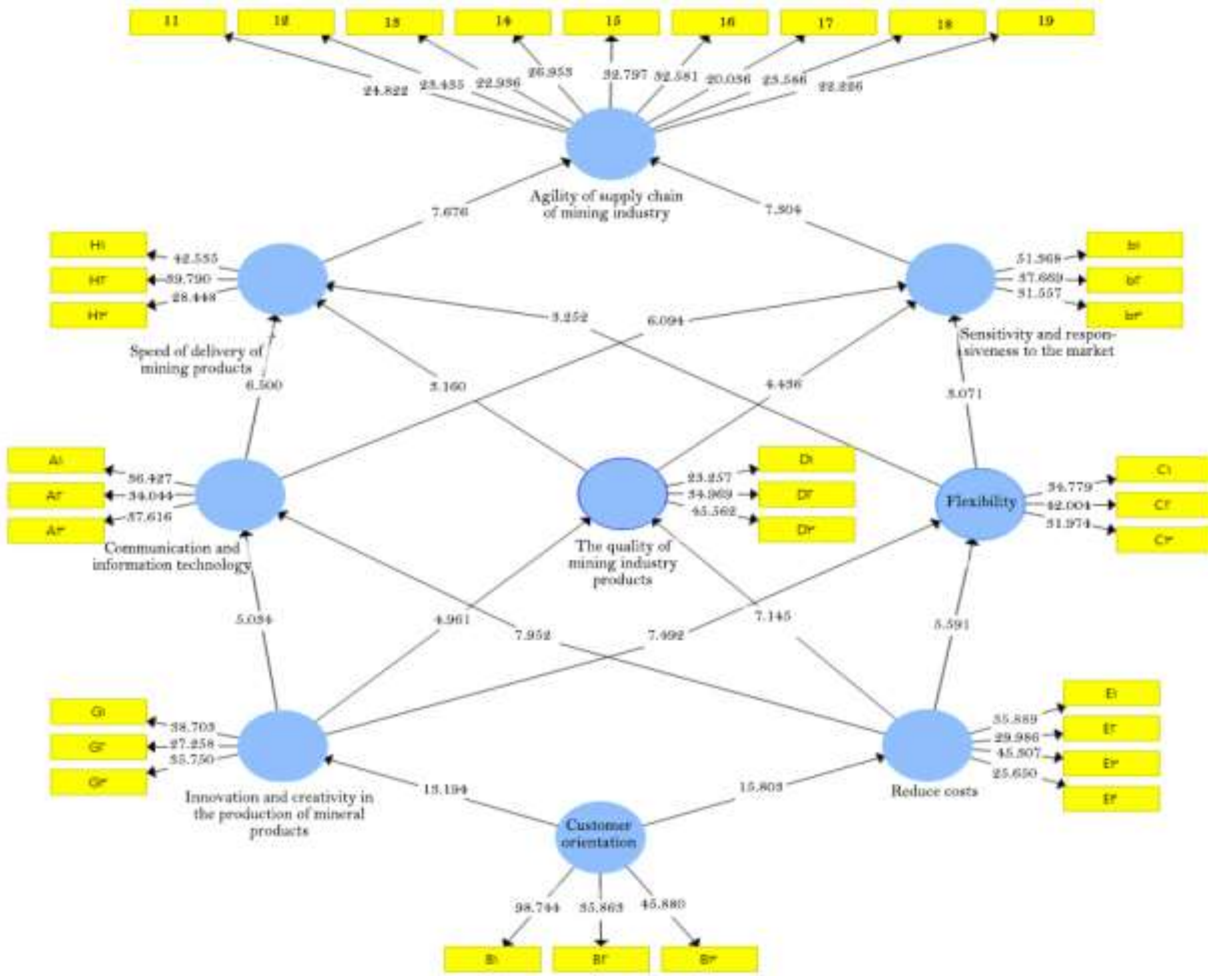

Fig (3). T-value values of the research model

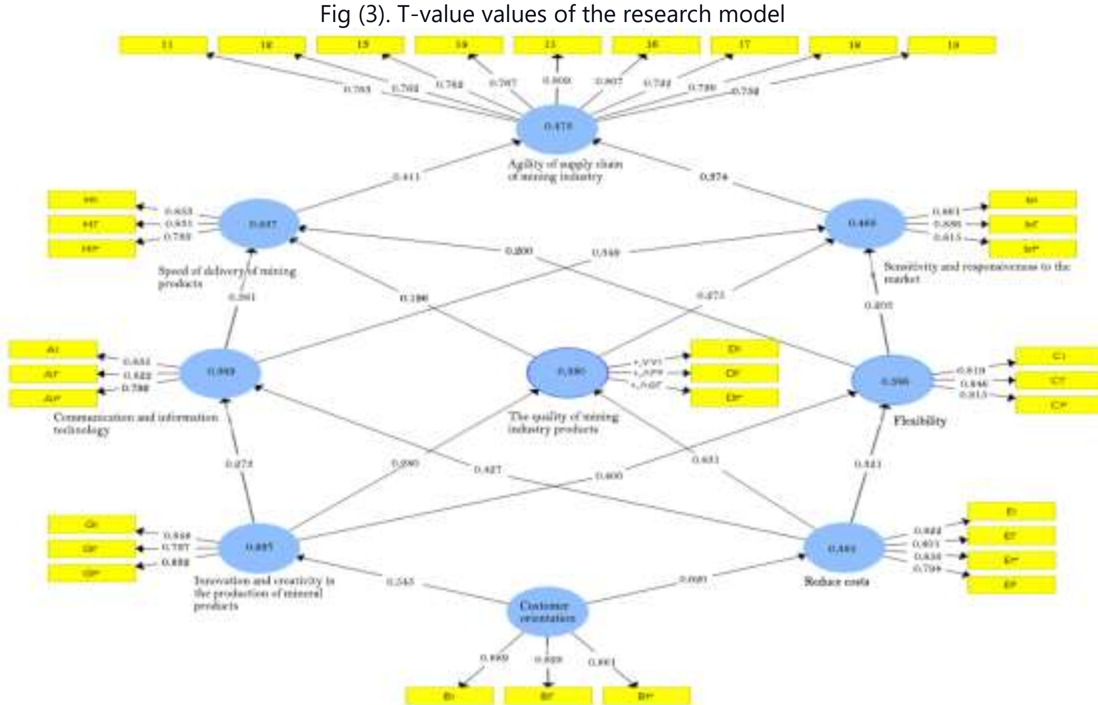

Fig (4): Path Coefficients of the Variables in the Partial Least Squares Model (Standard Estimation)

The research summary appeared in the results of hypothesis testing presented in Table 15.

Table (15): Overview of the Hypothesis Testing Findings

297) Variables	298) Coefficient	299) Average	300) Standard deviation	301) Test scores 302) T-value	303) Significant level	304) Result
305) Communication -> Delivery speed	306) 0.381	307) 0.378	308) 0.059	309) 6.500	310) 0.000	311) Confirmation
312) Communication -> Responsiveness to the market	313) 0.349	314) 0.350	315) 0.060	316) 6.094	317) 0.000	318) Confirmation
319) Flexibility -> Speed of delivery	320) 0.200	321) 0.206	322) 0.066	323) 3.252	324) 0.002	325) Confirmation
326) Flexibility -> Responsiveness to the market	327) 0.203	328) 0.198	329) 0.062	330) 3.071	331) 0.001	332) Confirmation
333) Delivery speed -> Supply chain nimbleness	334) 0.411	335) 0.408	336) 0.052	337) 7.676	338) 0.000	339) Confirmation
340) Customer-oriented -> Innovation	341) 0.545	342) 0.546	343) 0.045	344) 13.194	345) 0.000	346) Confirmation
347) Customer-oriented -> Reducing costs	348) 0.620	349) 0.603	350) 0.041	351) 15.803	352) 0.000	353) Confirmation
354) Innovation -> Communication	355) 0.273	356) 0.277	357) 0.0593	358) 5.034	359) 0.000	360) Confirmation
361) Innovation -> Flexibility	362) 0.600	363) 0.419	364) 0.0592	365) 7.492	366) 0.000	367) Confirmation
368) Innovation -> Product Quality	369) 0.280	370) 0.292	371) 0.060	372) 4.961	373) 0.000	374) Confirmation
375) Responsiveness to the market -> supply chain nimbleness	376) 0.374	377) 0.377	378) 0.055	379) 7.304	380) 0.000	381) Confirmation
382) Cost reduction -> Communication	383) 0.427	384) 0.423	385) 0.050	386) 7.952	387) 0.000	388) Confirmation
389) Cost reduction -> Flexibility	390) 0.321	391) 0.332	392) 0.051	393) 5.591	394) 0.000	395) Confirmation
396) Cost reduction -> Product Quality	397) 0.431	398) 0.413	399) 0.058	400) 7.145	401) 0.000	402) Confirmation
403) Product quality -> Delivery speed	404) 0.196	405) 0.193	406) 0.064	407) 3.160	408) 0.000	409) Confirmation
410) Product quality -> Responsiveness to the market	411) 0.275	412) 0.272	413) 0.064	414) 4.436	415) 0.002	416) Confirmation

The researchers used the t-statistic in Smart PLS to assess the significance of coefficients, with a critical value of 1.96 for a 5% error level. If the statistic (t) is greater than 1.96, it detects a significant relationship and confirms its validity. The researchers also evaluated the strength of these relationships to investigate connections between variables, as illustrated in the accompanying figure showing the significance coefficients.

The outer model is analyzed using Converging validity, Construct reliability, plus Cronbach's alpha. Convergent validity is satisfactory if the AVE exceeds 0.5. Composite reliability is preferred over Cronbach's alpha because it prioritizes indicators with higher factor loadings, providing a more accurate measure of constructs.

Table (16) summarizes the model fit evaluation results for the measurement model.

(AVE[9]) is over 0.5, confirming convergent validity, plus Cronbach's alpha exceeds 0.7, indicating reliability. These results validate the outer model, allowing for trustworthy hypothesis testing.

Table (16): Summary of the Model Fit Evaluation Results for the Measurement Model

417) Branch	***418) (Alpha>0.7)***	***419) (Cr>0.7)***	***420) (AVE>0.5)***
421) Communication	***422) 0.750***	***423) 0.857***	***424) 0.667***
425) Flexibility	***426) 0.787***	***427) 0.875***	***428) 0.701***
429) Delivery speed	***430) 0.765***	***431) 0.865***	***432) 0.681***
433) Customer-oriented	***434) 0.824***	***435) 0.895***	***436) 0.739***
437) Innovation	***438) 0.768***	***439) 0.866***	***440) 0.682***
441) Responsiveness to the market	***442) 0.788***	***443) 0.788***	***444) 0.702***
445) Supply chain nimbleness	***446) 0.911***	***447) 0.926***	***448) 0.584***
449) Reduce costs	***450) 0.782***	***451) 0.873***	***452) 0.697***
453) Product Quality	***454) 0.757***	***455) 0.850***	***456) 0.673***

Table (17). Divergent validity of research constructs (HTMT index)

[9] Average Variance Extracted

457) Main structures	***458) 1***	***459) 2***	***460) 3***	***461) 4***	***462) 5***	***463) 6***	***464) 7***	***465) 8***	***466) 9***
467) Communication (1)	***468) 0.816***	***469)***	***470)***	***471)***	***472)***	***473)***	***474)***	***475)***	***476)***
477) Flexibility (2)	***478) 0.581***	***479) 0.837***	***480)***	***481)***	***482)***	***483)***	***484)***	***485)***	***486)***
487) Delivery speed (3)	***488) 0.618***	***489) 0.560***	***490) 0.838***	***491)***	***492)***	***493)***	***494)***	***495)***	***496)***
497) Customer-oriented (4)	***498) 0.604***	***499) 0.539***	***500) 0.532***	***501) 0.825***	***502)***	***503)***	***504)***	***505)***	***506)***
507) Innovation (5)	***508) 0.512***	***509) 0.579***	***510) 0.624***	***511) 0.585***	***512) 0.620***	***513)***	***514)***	***515)***	***516)***
517) Responsiveness to the market (6)	***518) 0.478***	***519) 0.575***	***520) 0.532***	***521) 0.528***	***522) 0.545***	***523) 0.826***	***524)***	***525)***	***526)***
527) Supply chain nimbleness (7)	***528) 0.617***	***529) 0.585***	***530) 0.593***	***531) 0.610***	***532) 0.71***	***533) 0.582***	***534) 0.764***	***535)***	***536)***
537) Reduce costs (8)	***538) 0.550***	***539) 0.527***	***540) 0.569***	***541) 0.569***	***542) 0.602***	***543) 0.474***	***544) 0.586***	***545) 0.835***	***546)***
547) Product quality (9)	***548) 0.563***	***549) 0.580***	***550) 0.584***	***551) 0.522***	***552) 0.587***	***553) 0.487***	***554) 0.604***	***555) 0.546***	***556) 0.820***

The inner (structural) model fit is analyzed using three criteria: the (R^2)[10], the (Q^2)[11], and the (GOF[12]) index. The Conclusions of this evaluation are in the table below.

Table (18). Overview of structural model fit assessment findings

557) Main structures	***558) Detection coefficient***	***559) Q2***	***560) F2***	***561) GOF***
562) Communication	***563) 0.435***	***564) 0.330***	***565) 0.218***	***566) 0.535***
567) Flexibility	***568) 0.449***	***569) 0.392***	***570) 0.236***	
571) Delivery speed	***572) 0.475***	***573) 0.354***	***574) 0.240***	
575) Customer-oriented	***576) -***	***577) 0.462***	***578) 0.248***	
579) Innovation	***580) 0.388***	***581) 0.361***	***582) 0.322***	
583) Responsiveness to the market	***584) 0.529***	***585) 0.394***	***586) 0.246***	
587) Supply chain agility	***588) 0.497***	***589) 0.475***	***590) -***	
591) Reduce costs	***592) 0.406***	***593) 0.385***	***594) 0.260***	
595) Product Quality	***596) 0.457***	***597) 0.345***	***598) 0.233***	

[10] Coefficient of determination
[11] Stone–Geisser indicator
[12] Goodness-of-fit

The coefficient of determination (R^2) indicates how well independent variables explain changes in dependent variables. Chin (Chin, 1998) set thresholds of (0.19, 0.33), plus (0.67)for a Feeble, moderate, and powerful fit. The (R^2) for supply chain agility in the mineral industries was 0.497, deemed acceptable.

The Stone-Geisser criterion (Q^2) assesses a model's predictive power via the blindfolding resampling technique. Henseler defined thresholds of 0.02, 0.15, and 0.35 for Feeble, moderate, and robust forecasting power (Gligor et al., 2021). All constructs in this study had positive Q^2 values over 0.35, indicating strong predictive capability. The (GOF)[13] index is the most significant fit measure in the (PLS)[14] method.

Tenenhaus et al. (Banifazel et al., 2021) developed the (GOF) benchmark. Wetzels et al. established limits of (0.01, 0.25), and (0.36) for feeble, moderate, plus robust (GOF) indicators (Gligor et al., 2021). The (GOF) index was determined using the geometric mean of (R^2) values and commonalities, resulting in a worth of (0.554), which reflects a good model fit.

This article enhances operations management theory and practice by improving supply network processes in the mining industry. It aligns with the Journal of Operations Management Research's focus on original, high-quality research. The results of this research considerably influence the new theory of supply chain agility in the mining industry. The findings show that key factors such as customer orientation, innovation, and product quality directly affect supply chain agility, helping companies to respond quickly to market changes and customer needs, contributing to the development of a new theory that considers supply chain agility as a dynamic and multifaceted process that is constantly affected by the interactions of various factors. In particular, emphasizing the role of new technologies and stakeholder collaboration can enrich this theory and show how the effective utilization of information and communication can help improve supply chain performance and flexibility in the mining industry. In this way, this research sheds light on the factors affecting supply chain agility and provides space for the growth of new and applied theories in this field.

5. Discussion

A-Interpretation of results

This research focused on designing and validating a supply chain agility model for the mining industry. Findings indicate that previous approaches are inadequate for addressing modern organizational challenges, emphasizing the necessity of an agile supply network to respond swiftly plus efficiently to market fluctuations. The following is an interpretation of the results.

Expert Interviews:

Twenty experts participated, comprising 80% male and 20% female. Seventy-five percent held a graduate degree, and 50% had 10-20 years of work experience.

Questionnaire Respondents: 325 managers and experts; 90% were male and 10% were female. The roles included 68% manufacturers, 26% suppliers, and 6% distributors. Education levels varied, and 53% had an undergraduate degree.

Fuzzy Delphi Method Results

Indicators: 16 indicators affecting supply chain agility were recognized. The first round gathered expert opinions, which led to adjustments based on feedback.

Consensus:

The review steps confirmed (8) factors influencing supply chain agility, including flexibility, product quality, and innovation.

Insights from the DANP Method

Causal Relationships:

Information technology, customer focus, cost reduction, and innovation were identified as causes and determined as effects.

Weighting and Ranking:

[13] Goodness-of-fit
[14] Partial Least Squares

Flexibility ranked highest (0.12740), followed by Market Sensitivity and Responsiveness (0.12674) and Product Quality (0.12654).

Interpretive Structural Modeling (ISM) Findings.

Levels of Influence:

ISM identified a hierarchy in which customer focus had the highest influence. The model consists of four levels that show the relationships between the criteria.

Analysis of Mic Mac

Classification:

The variables evaluated were:

Independent variables: Customer focus, cost reduction, and innovation

Dependent variables: Other elements.

Structural Model Evaluation

Validity:

The model demonstrated strong reliability and validity through various measures, including (AVE > 0.5)[15] and Cronbach's alpha (> 0.7).

Predictive Power:

The model demonstrated strong predictive power with Q2 values above 0.35 and a good fit with the GOF index of 0.554.

Hypothesis Test Results

Significant Relationships: Key relationships were confirmed, including:

Communications positively affect the speed of delivery and market responsiveness.

Flexibility affects the speed of delivery and market responsiveness.

Customer orientation significantly leads to innovation and cost reduction.

B- Significance and Implications

The study finds that supply network nimbleness in the mining sector is markedly affected by innovation, product quality, and responsiveness to customer needs. According to expert opinions and data collected from 325 managers and specialists, organizations can increase their skills to compete in the marketplace and achieve improved operational efficiency by focusing on these factors. Emphasizing a culture of innovation (Sharma et al., 2023) and flexibility enables institutions to respond rapidly to alterations in their surroundings, improving consumer satisfaction (Lee, 2023). Additionally, this investigation provides an applicable guide for administrators to optimize the supply chain and improve overall organizational performance.

C- Limitations and Future Research

Limitations and suggestions for future research This study contributes to the development of a new theory of supply chain agility. One of the main limitations is the low diversity of the sample, which may have influenced the results. It indicates the need to include the views and experiences of different groups in future research to explore more dimensions of supply chain agility in the mining industry. The data comes from a specific geographic area, limiting the results to other regions. Future research should include comparative studies across locales to help identify similarities and differences in supply chain agility. This research enhances decision-making in supply chain agility through advanced models and long-term analyses. It emphasizes the importance of new technologies and stakeholder collaboration in improving supply chain performance and resilience. The

[15] Convergent validity

findings can serve as a foundation for developing new theories in supply chain agility, aiding managers and decision-makers in enhancing organizational performance.

D- Comparison with previous findings

The customer orientation component is considered the most significant aspect of the original research model. Adams et al. (2019) affect cost reduction and innovation. The effects of features on cost reduction and innovation are enhanced, and customer-centric relationships and other factors affecting supply chain agility are analyzed. In this research, we identified and analyzed the key factors affecting supply chain agility and showed that customer orientation not only affects cost reduction and innovation but also impacts flexibility, product quality, and speed of response to market changes. These aspects are explicitly included in our new model and help managers apply the necessary optimizations in their supply chain. Therefore, while Adams et al. have pointed out the importance of customer orientation, our research contributes to a deeper understanding of supply chain agility in the mining industry by providing a more comprehensive model.

The research of Baran & Woznyj (2020) has pointed out the impact of innovation on cost reduction and its relationship with flexibility and product quality. In this research, we have examined the relationships between factors more comprehensively and shown how these factors affect supply chain agility individually and as part of an integrated model. In more detail, we have identified and analyzed the interrelationships between cost reduction, innovation, flexibility, and product quality. Therefore, while previous research has pointed out these relationships, our research has contributed to a deeper understanding of supply chain agility by providing a comprehensive model and emphasizing the interactions between these factors. This new approach can help managers and decision-makers develop more effective strategies to improve their organization’s performance.

The findings of Farhadi et al.’s (2019) study are consistent and point to the impact of the aforementioned factors on responsiveness and speed in the supply chain. This study emphasizes that speed, delivery, and market responsiveness increase supply chain agility. Our study analyzes these relationships more comprehensively and presents a new model. We discuss in more detail how these factors affect each other and supply chain agility. We have examined the interactions between delivery speed, market responsiveness, and supply chain agility and have shown how these factors act synergistically. While Farhadi et al.’s study points to the impact of these factors, our study helps managers design better strategies to improve their supply chain performance by providing an integrated model and a deeper understanding of the relationships between these factors.

Li et al.’s (2008) research defines agility as a complex and multifaceted concept that includes the capacity to move quickly, adapt, and be productive at the forefront of challenges. This definition emphasizes the importance of physical and mental flexibility. However, our research examines the factors influencing supply chain agility in the mining industry and identifies 16 key factors. Through the Fuzzy Delphi and DANP methods, these factors are ordered and demonstrate that customer orientation is the main factor that affects the other factors. While Li et al.’s research examines agility in general, our study uses data collected from 325 managers and experts in the mining industry to provide a practical and applied perspective that can help managers make effective decisions. In this way, our research contributes to a deeper understanding of supply chain agility in the mining industry.

E- Policy Implications

This research focuses on developing a comprehensive framework for supply chain agility in the mining industry, identifying and analyzing the driving factors of agility and their causal relationships. The results indicate that identifying and validating key elements of supply chain agility, such as customer orientation, innovation, and product quality, can enhance organizational performance and improve the competitive capabilities of companies in turbulent markets.

These findings serve as practical guidance for optimizing processes and reducing costs in the mining industry, enabling organizations to respond quickly to market changes and customer needs. This research introduces a new theory that perceives supply chain agility as a dynamic, multifaceted process shaped by various interactions.

It enriches the existing literature, strengthens efficient supply chains in the mining sector, and acts as a reference for managers to optimize logistics networks and improve overall organizational effectiveness. However, some limitations highlight the need for future research to explore more diverse samples and additional factors. It also emphasizes the role of digital technologies and stakeholder collaboration in enhancing agility, providing valuable insights for practitioners and researchers alike. By addressing the identified research gaps, this study contributes to the theoretical understanding of supply chain agility and supplies practical guidance for improving organizational performance in the mining sector.

Conclusion

This research focuses on developing a comprehensive framework for supply chain agility in the mining industry, identifying and analyzing the driving factors of agility and their causal relationships. The results indicate that identifying and validating key elements of supply chain agility, such as customer orientation, innovation, and product quality, facilitates enhanced organizational performance and improves the competitive capabilities of companies in turbulent markets. These findings serve as practical guidance for optimizing processes and reducing costs in the mining industry, enabling organizations to respond quickly to market changes and customer needs. This research introduces a new theory that perceives supply chain agility as a dynamic, multifaceted process shaped by various interactions. It enhances existing literature, strengthens efficient supply chains in the mining sector, and acts as a reference for managers to optimize logistics networks and improve overall organizational effectiveness.

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