Providing a Causal Model of Industrial Resilience Using Thematic Analysis and Interpretive Structural Modeling in the Automotive Parts Manufacturing Industry

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Abstract

The aim of this study is to provide a causal model of industrial resilience using thematic analysis and interpretive structural modeling in the automotive parts manufacturing industry. The research approach is applied, and in terms of nature and method, it is descriptive-analytical and survey-based, falling under the category of mixed methods research (initially qualitative, followed by quantitative). Data and information were collected through a review of library and documentary sources and field observations (interviews and questionnaires). Quantitative models and software were employed for data analysis. Additionally, through thematic analysis and expert interviews, key drivers influencing industrial resilience were identified and selected. Based on the research findings, the overall pattern of industrial resilience drivers in the automotive parts manufacturing industry reflects an unstable environmental system, demonstrating an intermediate state of influence and susceptibility. To identify the relationships between variables and network resilience, the combined DEMATEL-ISM technique was utilized. The study's findings indicate 32 dimensions for designing the industrial resilience model. The results of interpretive structural modeling reveal that the factors of multiple suppliers and contractors, employee training, and knowledge transfer are the most influential components of the resilience model. Conversely, components such as facilitating inter-company collaboration, activities related to sales promotion, networking and cooperation with competitors, institutions, and research and knowledge-based organizations, product marketing and promotion, customer communication, and feedback reception are the most impacted components of the resilience model in the automotive parts manufacturing industry.

Keywords: *Industrial Resilience, Thematic Analysis, Interpretive Structural Modeling, Automotive Parts Manufacturing Industry*

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1. Introduction

Uncertainty about the future, changes, transformations, and environmental risks have jeopardized the survival of today's industries. However, the question that arises is: why do some industries continue to thrive and grow despite these changes, while others fail to withstand similar environmental conditions and face failure? What is the secret to the success and distinctiveness of these industries? In management, three concepts are relevant: stability, sustainability, and resilience. Stability is considered as the absence of or minimal changes. Sustainability is defined as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs [1-5]. The necessity of achieving sustainable survival and success has led many industries to reevaluate their business priorities and focus on adapting to business changes and responding appropriately to environmental imperatives.

To achieve this, resilience has emerged as a concept in policy theory and risk management, reflecting a multidisciplinary approach to its measurement [6]. Resilience refers to the capacity of a business to survive, adapt, and sustain itself when faced with turbulent and chaotic changes. A fundamental requirement for resilience is accepting change. Sustainability in a constantly changing environment necessitates resilience at various levels. Among all, industry, which is connected to human societies and the economy, plays a crucial role. As Fiksel notes, in the face of increasing complexity and volatility affecting the world, sustainability needs to be dynamic to address uncertainties [7, 8].

Resilience and sustainability are directly related. Gunderson and Prichard even argue that resilience, or the ability to recover from disturbances, is the essence of sustainability [9]. Resilience can be defined as the power to survive after facing shocks. In general, resilience is described as a dynamic adaptive process [10] through which a system returns to or moves toward one or more equilibria [11]. Holling was the first to introduce the term "resilience," which is often categorized into three forms: "ecological resilience," "engineering resilience," and "adaptive resilience" [11]. According to Holling, both ecological and engineering resilience refer to the ability to maintain, recover, or shift the state of a system from disturbances to a single equilibrium [11]. Adaptive resilience, however, is seen as the capacity to adapt or how a system reconstructs itself in response to shocks, not limited to a single equilibrium [12].

Some articles on resilience management divide it into four types: technical, organizational, economic, and social, each with components like robustness, redundancy, resourcefulness, and rapidity [13]. Overall, resilience in all contexts refers to an element's capability to return to a stable state after encountering a disturbance [14].

Industries are the backbone of the economy in many countries, with significance in exports, economic growth, employment, and more. Industrial systems are considered complex adaptive systems capable of self-organization [15]. Features of industrial systems include ecological efficiency, broader environmental goal attainment, and the emergence of increasingly complex structures.

Industrial resilience involves studying a network of factories, logistics, supply chains, and external institutions such as governments, universities, regulators, and financial agents. It examines events surrounding industrial systems to understand how they correlate with system vulnerabilities and create risks, addressing which requires investing in specific capabilities. Since resilience directly affects sustainability, enhancing or hindering resilience becomes a key focus to maintain or improve sustainability. A study by Royal Dutch Shell identified four distinguishing factors contributing to corporate longevity: "sensitivity and adaptability to the business environment," "cohesion and a sense of identity," "tolerance for diversity," and "conservative use of capital" [16].

Actions to improve resilience and sustainability are often qualitative and difficult to measure but can serve as guidelines for the industry. Fiksel outlines key features aiding industrial resilience: "diversity," "efficiency," "adaptability," and "cohesion." From a top-down approach, sound national or regional policies can bolster resilience and promote sustainability [7, 8]. Some literature highlights technology as a solution to combat factors that disrupt resilience, ensuring product quality and preventing losses leading to instability. Technologies like blockchain can enhance product traceability at different stages of the industrial supply chain [17].

Examining factors affecting resilience in the industry, especially in automotive parts manufacturing, requires awareness and understanding of their characteristics. These industries share common features, such as resource scarcity. Three main barriers hinder industry owners from improving resilience: 1) limited awareness of their operational environment, 2) inability to identify and manage key vulnerabilities, and 3) lack of capacity to foster adaptability [18]. Research on system resilience and vulnerability falls into two spectrums: studies aimed at national or regional economic use and studies on industrial systems. The industrial sector sits at the intermediate level of the economy, between micro-level (individual businesses or households) and macro-level (aggregated economic units forming the economy's foundation) [18]. To produce outputs in the industrial sector, inputs like human resource costs, material expenses, and energy costs are essential.

Resilience in industrial systems, akin to smaller-scale supply chains, hinges on supply-demand relationships for products and services. Literature on supply chains, especially concerning sudden changes and vulnerabilities, can elucidate industrial system resilience concepts. Aspects such as the trade-off between risk and profit reduction, sourcing flexibility [19], strategic reserves [20], network structure transparency [21], timely notifications [22], information sharing, inter-organizational capacity integration [23], trust, and collaboration [24] are relevant. For industries to be resilient, sustainable measures to enhance supply chain resilience are necessary [25].

Focusing solely on a single firm in supply chain research has been challenged, leading to new definitions and practical examples. For instance, Lee et al. illustrated how small, sudden changes amplify throughout supply chains [26]. Empirical studies confirm the negative effects of these sudden changes on firms' operational efficiency [27]. Craighead et al. argue that the intensity of sudden changes in supply chains depends on inherent adaptability—resilience—and deliberate mitigation capabilities [22].

Bass and Boons suggest that regional or sectoral industrial systems can develop within policies supporting initiatives like the UK's National Industrial Symbiosis Programme [28]. In a study by Zhu et al., the authors examined the trade-off between optimizing material and energy flow for efficiency versus system resilience, concluding that high interdependence among firms reduces resilience [29]. Another study using data envelopment analysis offered a framework to measure industrial resilience, noting that exchange rate shocks reduce efficiency, and proposed a performance measurement method based on resilience [30].

Cao et al. developed an agent-based model for industrial system evolution using emergy accounting and sustainability indices, defining the environment, factory, and consumer as three agents [31]. Bichraoui et al. simulated the development of industrial symbiosis, where factories act as agents linked by material exchange, to study collaboration levels and learning conditions' role [32]. Lozano and Arenas analyzed how organizational diversity enhances resilience in regional innovation systems facing social and economic uncertainty [33].

William Demmer and colleagues highlighted the role of knowledge-based human resources and innovation in product development as key factors for small companies' resilience. Their study identified factors like challenging the status quo, top management support for innovation, strengthening internal and external knowledge networks, adopting an organic structure, opportunity discovery, externalizing innovation, implementing entrepreneurship-focused strategic planning, concurrent modernization and optimization, positioning in the customer value chain, investing in innovative human resources, and supporting strategic initiatives in the automotive industry [34].

Gunasekaran et al. identified internal, external, and enabling factors for resilience in the automotive parts industry, including quality, managerial attributes, and organizational behavior [35]. Pal et al. determined that learning and culture, dynamic competitiveness, and assets influence industrial resilience in automotive manufacturing [36]. Khwastar and Beatty examined the impact of change processes on industrial resilience [37].

The literature indicates that understanding industrial resilience involves examining internal and external components, such as human resources, management, suppliers, independence from the status quo, top management support for innovation, strengthening internal and external knowledge networks, adopting an organic structure, discovering new opportunities, externalizing innovation, implementing strategic planning focused on entrepreneurship, concurrent modernization and optimization, positioning in the customer value chain, investing in innovative human resources, and more. These components form the basis for structuring research questionnaires and interviews. Despite past studies on various industrial issues, causal modeling for resilience, particularly in industry, remains underexplored, emphasizing the need for further scientific research.

The current study uniquely focuses on extracting, presenting, and measuring harmonized indicators of industrial resilience through expert analysis, with special emphasis on causal modeling. Given industries' economic importance, such as job creation and national income growth, findings suggest that sectors like automotive parts manufacturing remain highly vulnerable to environmental threats, suffering considerable damage due to resource shortages. Therefore, industrial resilience is crucial for long-term survival, especially in Iran's current economic climate, ensuring industries' sustained performance. The main research questions are: 1) What factors influence industrial resilience in automotive parts manufacturing? 2) How are these resilience factors related? 3) Which factors have the greatest impact? 4) Which factors are most susceptible to impact? This study aims to present a causal model of industrial resilience using thematic analysis and interpretive structural modeling, identifying dimensions and causal relationships to guide policy-making and managerial decision-making.

2. Methodology

The present study is "applied" in terms of purpose and "descriptive-survey" in terms of nature and method, categorized as a mixed methods research (initially qualitative, followed by quantitative). Data and information collection tools in this research included a review of library and documentary sources, field observations, and consultations with relevant organizations and institutions.

To present the causal model, key factors affecting the subject must first be identified, followed by defining different states for each key factor. To identify the driving forces influencing industrial resilience, the first step involved recognizing factors affecting industrial resilience through a review of documents and sources. In this phase, the researcher systematically searched for articles published in various journals. A total of 91 articles and sources were found, of which 24 were analyzed.

The inclusion and exclusion criteria for the research included:

1. Master's theses, doctoral dissertations, and review or scientific-research articles focused on industrial resilience, published in both domestic and international databases.
2. The research topic was related to resilience, industrial resilience factors, or factors affecting resilience.
3. The research employed qualitative, field, or survey methods.
4. At least one component of resilience was examined in these studies. Before any analysis, the researcher reviewed the articles, theses, and dissertations based on the above criteria.

Once the articles were assessed for compatibility with study parameters, the next step involved evaluating the methodological quality of the studies. The "Critical Appraisal Skills Programme" was used for this purpose.

After identifying the relevant research, the entire text of these articles was considered data to address the research question. Therefore, the data were qualitative. Due to the qualitative nature of the data, the open coding method, one of the most well-known qualitative data analysis techniques, was used. This coding method is similar to the initial coding phase in grounded theory research.

At this stage, 86 codes were identified. The next step involved analyzing, synthesizing, and integrating the codes into components. The identified codes were grouped and combined based on conceptual similarity. This process categorized the extracted codes into 16 components, which were further classified into four dimensions at a higher level.

In the second step, a list of the driving forces affecting industrial resilience was compiled based on existing studies and presented to experts. At this stage, experts and managers were asked, through interviews and questionnaires, to identify the key drivers of industrial resilience. The experts consulted had at least one of the following characteristics:

1. Senior managers in the industry and related organizations with over 20 years of experience.
2. University professors in industrial management or engineering disciplines with the rank of assistant professor or higher and relevant teaching experience.
3. Specialists and researchers with authored or translated books and articles on industrial resilience.

The snowball sampling method was used to select research participants for the interviews. In qualitative studies, it is not possible to predetermine the number of participants needed to fully understand the phenomenon of interest. Ideally, data collection continues until reaching the saturation point, where new data no longer differ from the previously collected data. Khwastar, quoting Lincoln and Guba, states that in a well-conducted study with an evolving and sequential sampling method, data saturation can be reached with around 12 participants and probably no more than 20. In this research, 12 experts were consulted. It is worth mentioning that theoretical saturation was achieved by the ninth participant, but interviews continued until the twelfth participant for additional assurance.

In this context, thematic analysis was used to identify the main and sub-themes influencing the enhancement of industrial resilience. These factors were then prioritized and the most critical ones identified based on their importance and uncertainty using the "MICMAC" software. In the second stage, the causal model of industrial resilience was designed using the combined DEMATEL-ISM approach. This section utilized interpretive structural modeling to determine causal relationships among the main resilience themes in the industry.

3. Findings

Factors influencing industrial resilience are categorized into two main groups: internal and external factors. Through interview analysis using thematic techniques, the internal factors were identified as five main themes: managerial factors, human resources, production and operations, marketing and sales, and internal redundancy. The external factors comprised four main themes: government support, associations and trade unions, inter-organizational cooperation and communication, and external redundancy. A summary of the identified factors related to industrial resilience derived from the interviews is presented in the Table 1. It also consolidates results from the interviews and document reviews regarding factors affecting industrial resilience:

Table 1. Factors, Categories, and Themes Related to Industrial Resilience

Factors	Category	Theme
Internal Factors	Human-Managerial	Attitude toward change and strategic thinking
		Support for employees' innovative ideas
		Employee training and knowledge transfer
		Leadership style and leadership traits
		Collective learning and teamwork
		Employee commitment and sense of belonging to the organization
		Adaptive capacity and flexible culture
		Market discovery, development, and organizational knowledge and communication
	Research & Development	Production line flexibility
		Machinery modernization and efficiency
		Quality
		Flexible structure and process improvement
		Capability in innovation and new product development
		Product introduction and advertising
		Customer communication and feedback collection
		Market discovery and development
		Timely delivery and after-sales service
	Internal Redundancy	Precautionary reserves in raw materials, semi-finished parts, and final products
		Reserves related to infrastructure, equipment, and critical spare parts
		Human resource reserves for key positions
		Financial reserves
		Cost control
		Management of material resources
External Factors	Government Support	Tax exemptions and reductions
		Provision of facilities with favorable interest rates
		Export incentives
		Establishment of industry support institutions
	Associations & Trade Unions	Organizing seminars and training sessions, providing consulting services
		Efforts to amend and regulate laws
		Facilitating inter-company collaboration and promotional activities
	Inter-Organizational Cooperation	Networking and collaboration with competitors, institutions, and research and knowledge-based organizations
	External Redundancy	Multiple suppliers and contractors

In the third step, the research variables were analyzed using the cross-impact analysis method in the MICMAC software environment. A 32x32 matrix, including four dimensions—research and development, external factors, human-managerial factors, and internal redundancy—with 32 variables, was utilized to determine the status of each within the system (industrial resilience). Respondents were asked to conduct pairwise comparisons of the research variables. The initial analysis of the matrix data and cross-impacts indicated that, given the matrix dimensions, there were 1,024 options, of which 732 relationships were assessable. The matrix's filling degree was 71.48%, indicating that 71.48% of the selected factors influenced one another. Additionally, the matrix was optimized and validated through two rounds of data rotation, achieving 100% desirability and optimization, reflecting high validity of the questionnaire and responses.

Table 2. Direct Impact of Dimensions and Variables on Each Other

Dimension	Number	Variable	Impact Score	Rank	Results	Impact Score	Rank	Results
External Factors	1	Tax exemptions and reductions	43	9	331 points (2.29%) Second Place	46	10	430 points (9.37%) First Place
	2	Provision of facilities with favorable interest rates	42	10		37	16	
	3	Export incentives	21	29		26	25	
	4	Multiple suppliers and contractors	63	1		32	18	
	5	Establishment of industry support institutions	44	8		57	4	
	6	Efforts to amend and regulate laws, compensate for damages, restore to suitable job conditions	35	15		60	3	
	7	Facilitating inter-company collaboration and sales promotion activities	23	27		65	1	
	8	Networking and collaboration with competitors, research institutions, and knowledge-based organizations	22	28		57	4	
	9	Organizing seminars and training sessions, providing consulting services	38	14		50	6	
Human-Managerial	10	Attitude toward change and strategic thinking	47	6	271 points (9.23%) Third Place	24	27	201 points (7.17%) Third Place
	11	Support for employees' innovative ideas	28	25		30	19	
	12	Employee training and knowledge transfer	61	2		30	19	
	13	Leadership style and traits	44	8		40	13	
	14	Collective learning and teamwork	29	24		8	13	
	15	Employee commitment and sense of belonging	11	31		25	30	
	16	Adaptive capacity and flexible culture	10	32		30	26	
	17	Market discovery, development, and organizational communication	41	11		14	19	
Internal Redundancy	18	Financial reserves	59	2	233 points (5.20%) Fourth Place	29	22	212 points (7.18%) Fourth Place
	19	Human resource reserves for key positions	47	5		49	8	
	20	Cost control	30	21		28	24	
	21	Management of material resources	38	13		40	13	
	22	Reserves related to infrastructure, equipment, and critical spare parts	27	26		16	29	
	23	Precautionary reserves in raw materials, semi-finished parts, and final products	32	19		50	6	
Research & Development	24	Production line flexibility	29	23	298 points (3.26%) First Place	6	31	290 points (25.6%) Second Place
	25	Machinery modernization and efficiency	30	21		6	31	
	26	Quality	39	12		48	9	
	27	Flexible structure and process improvement	20	29		29	23	
	28	Capability in innovation and new product development	56	4		42	12	
	29	Product introduction and advertising	33	18		45	11	

	30	Customer communication and feedback collection	27	15		61	2	
	31	Market discovery and development	21	20		33	17	
	32	Timely delivery and after-sales service	43	7		20	28	
Total	-	-	1133	-	100%	1133	-	100%

Table 3. Indirect Impact of Dimensions and Variables on Each Other

Dimension	Variable Number	Variable	Impact Score	Overall Rank	Dimension Result	Impact Score	Overall Rank	Dimension Result
External Factors	1	Tax exemptions and reductions	54967	10	420,764 points (2.29%) Second Place	53740	9	542,527 points (7.37%) First Place
	2	Provision of facilities with favorable interest rates	51726	7		49208	16	
	3	Export incentives	26590	30		34073	24	
	4	Multiple suppliers and contractors	78768	3		39120	17	
	5	Establishment of industry support institutions	56406	6		70220	5	
	6	Efforts to amend and regulate laws	44958	19		78076	3	
	7	Facilitating inter-company collaboration and sales promotion activities	28962	28		81178	1	
	8	Networking and collaboration with competitors, research institutions, and knowledge-based organizations	29154	27		72110	4	
	9	Organizing seminars and training sessions, providing consulting services	49233	14		64802	6	
Human-Managerial	10	Attitude toward change and strategic thinking	59147	8	342,369 points (8.23%) Fourth Place	30166	27	257,173 points (9.17%) Third Place
	11	Support for employees' innovative ideas	34025	26		35319	20	
	12	Employee training and knowledge transfer	77483	2		39842	21	
	13	Leadership style and traits	54510	16		49509	14	
	14	Collective learning and teamwork	36040	25		10979	12	
	15	Employee commitment and sense of belonging	14580	31		32729	32	
	16	Adaptive capacity and flexible culture	13510	32		39522	26	
	17	Market discovery, development, and organizational communication						

The distribution of variables on the impact-influence axis indicates the stability or instability of the system. If the variables are arranged in an L-shape, the system is stable, reflecting consistency in the influencing variables and the continuation of their effects on others. If the variables are dispersed from the axis towards the edges of the chart, the system is unstable, with a lack of influential variables threatening the system. This scenario makes the assessment and identification of key factors very challenging.

The extent of a driver's influence and susceptibility determines its nature. After evaluating the effects of variables on one another, experts plot them on a chart (coordinate network) called the Influence-Susceptibility Plan, based on mathematical relationships. The variables' positions on the chart indicate their status in the system and their role in future system dynamics and transformations. The observed distribution of drivers impacting industrial resilience suggests system instability.

Table 4. Key Variables Determining Industrial Resilience (Based on Direct Influence)

Region/Category	Variables	Impact Score	Susceptibility Score	Net Influence (Determination Power)	Net Influence Ranking
Region 1, Influencing Variables	Timely delivery and after-sales service	43	20	23	5

	Employee training and knowledge transfer	61	30	31	1
	Financial reserves	59	29	30	3
	Multiple suppliers and contractors	63	32	31	1
	Attitude toward change and strategic thinking	47	24	23	5
	Market discovery and development, organizational knowledge and communication	41	14	27	4
Region 2, Dual-Role Variables	Capability in innovation and new product development	56	42	14	5
	Human resource reserves for key positions	47	49	-2	10
	Tax exemptions and reductions	43	46	-3	13
	Quality	39	48	-9	14
	Organizing seminars and training sessions, providing consulting services	38	50	-12	15
	Establishment of industry support institutions	44	57	-13	17
Region 5, Indeterminate Variables	Market discovery and development	21	33	-12	15
	Management of material resources	38	40	-2	10
	Provision of facilities with favorable interest rates	42	37	5	7
	Leadership style and traits	44	40	4	8
	Cost control	30	28	2	9
	Support for employees' innovative ideas	28	30	-2	10

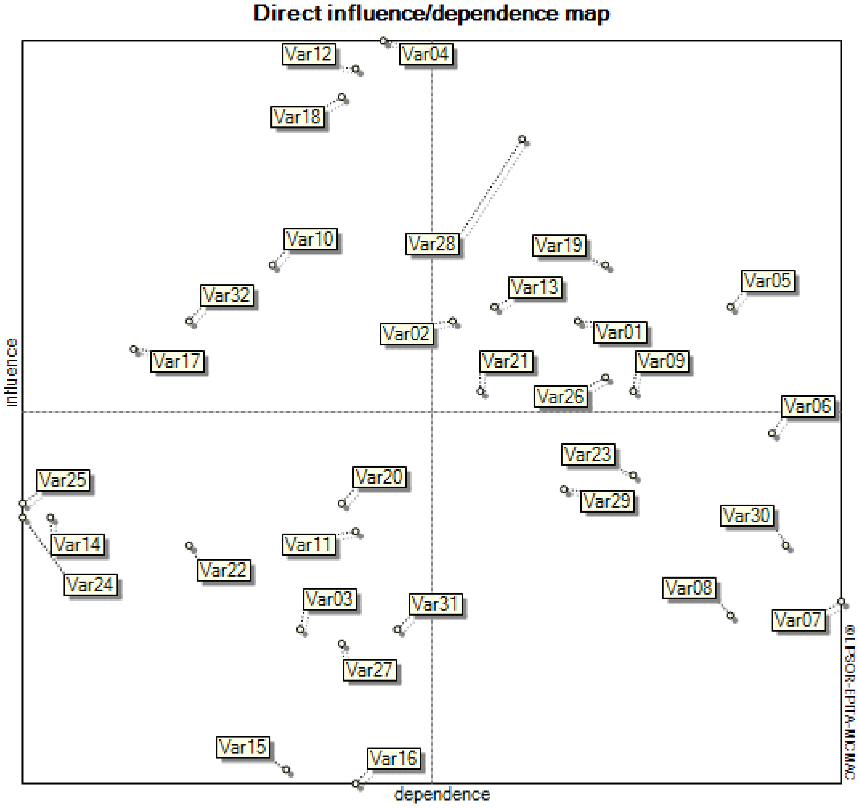

Figure 1. Distribution Map of Variables Based on Direct Impacts and Variable Numbers

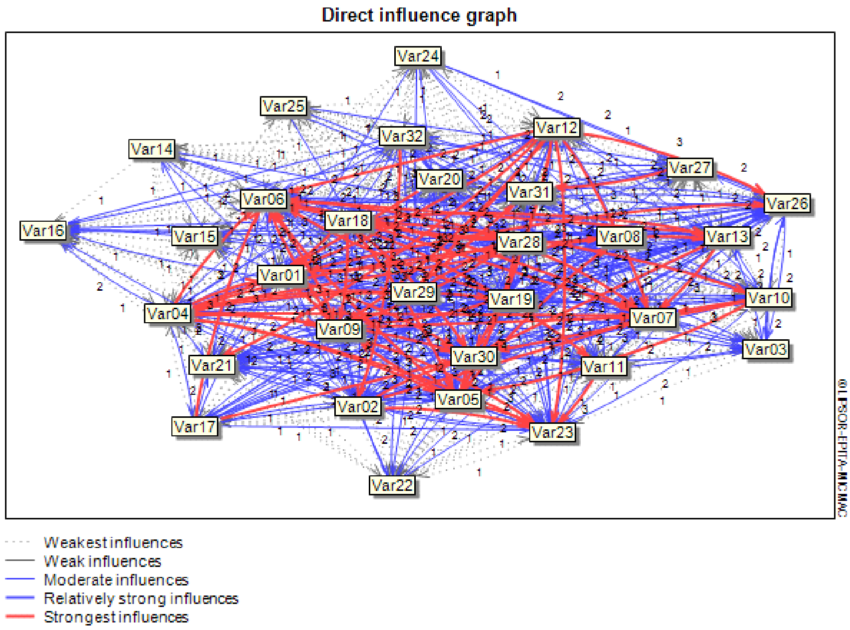

Figure 2. Graph of Direct Relationships Between Variables (from very weak to very strong impacts)

Table 5. Key Variables Determining Industrial Resilience (Based on Indirect Influence)

Region/Category	Variables	Impact Score	Susceptibility Score	Net Influence (Determination Power)	Influence Ranking
Region 1, Influencing Variables	Timely delivery and after-sales service	56372	21094	35278	4
	Employee training and knowledge transfer	77483	39842	37641	2
	Financial reserves	73489	38010	35479	3
	Multiple suppliers and contractors	78768	39120	39648	1
	Attitude toward change and strategic thinking	59147	30166	28981	6
	Market discovery and development, organizational knowledge and communication	53074	19107	33967	5
Region 2, Dual-Role Variables	Capability in innovation and new product development	71953	53817	18136	7
	Human resource reserves for key positions	60004	60840	-836	12
	Quality	48933	58621	-9688	15
	Tax exemptions and reductions	54967	53740	1227	10
	Organizing seminars and training sessions, providing consulting services	49233	64802	-15569	17
Region 5, Indeterminate Variables	Market discovery and development	27902	41212	-13310	16
	Management of material resources	47936	51181	-3245	14
	Provision of facilities with favorable interest rates	51726	49208	2518	9
	Leadership style and traits	54510	49509	5001	8
	Support for employees' innovative ideas	34025	35319	-1294	13
	Cost control	38774	38413	361	11

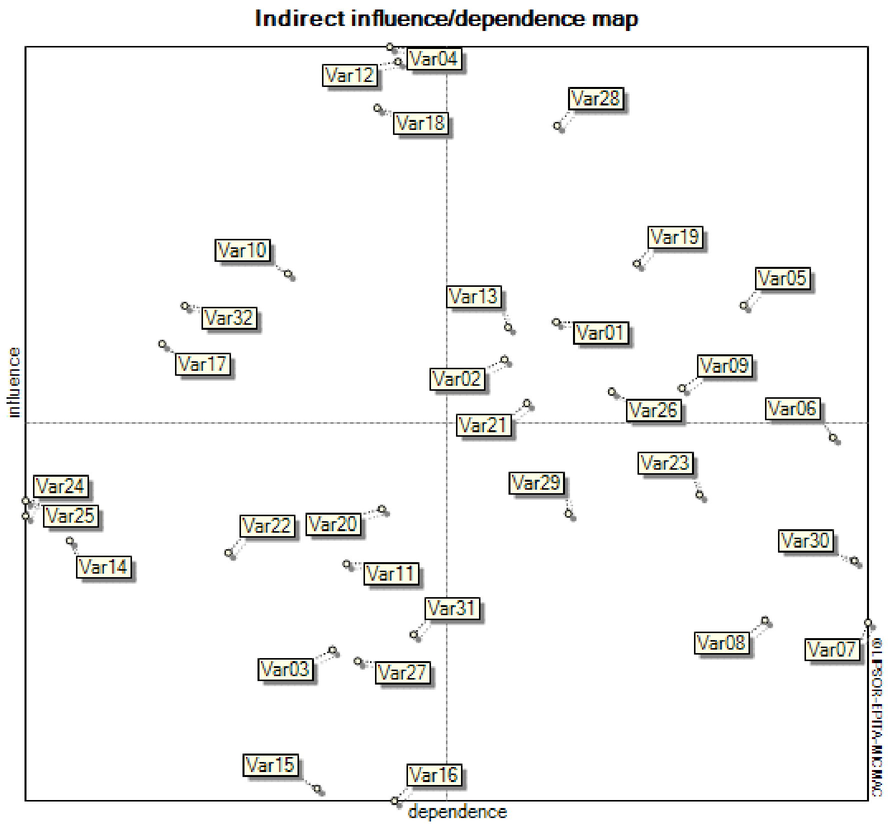

Figure 3. Distribution Map of Variables Based on Indirect Impacts and Variable Numbers

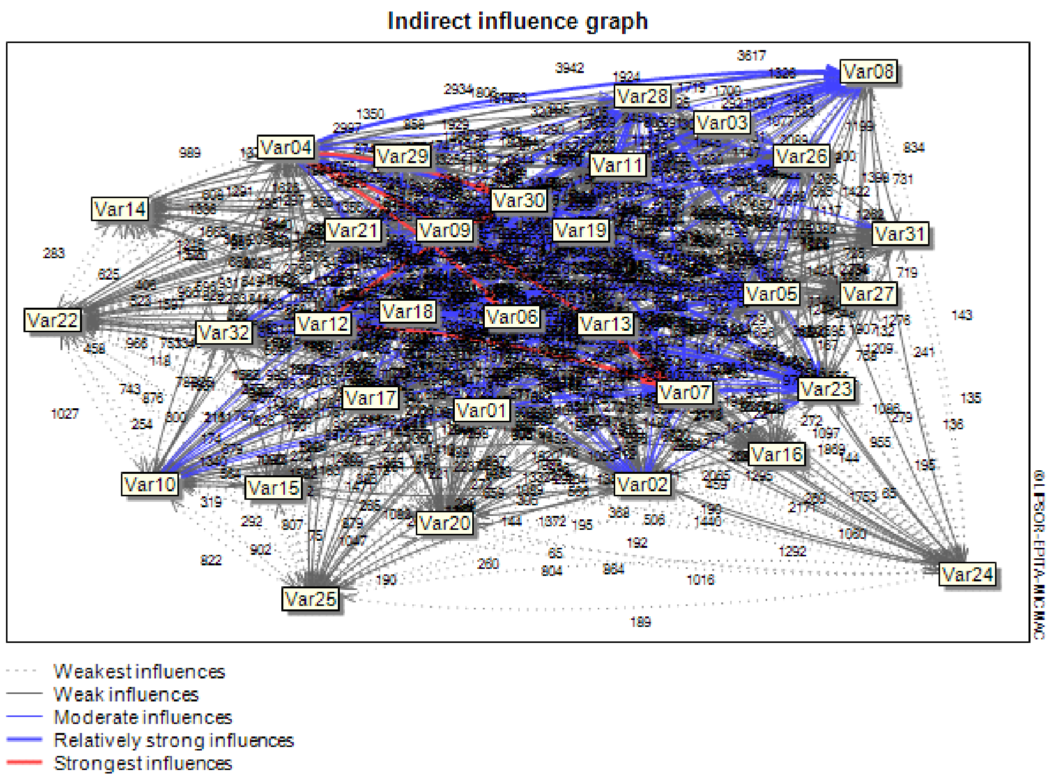

Figure 4. Graph of Indirect Relationships Between Variables (from very weak to very strong impacts)

In the next stage of analysis, following the confirmation of the main components, the causal model of industrial resilience was designed using the combined DEMATEL-ISM method. The combined DEMATEL-ISM technique is a widely used method for multi-criteria decision-making. This hybrid approach starts with DEMATEL and then uses the DEMATEL output as the input for ISM. DEMATEL quantifies the cause-and-effect relationships between factors, measuring the intensity of interactions and the strength of relationships.

1. **Constructing the Direct Relationship Matrix**: The initial step involves forming the direct relationship matrix from the DEMATEL survey results.
2. **Normalizing the Direct Relationship Matrix**: The direct relationship matrix from step 1 is normalized by dividing each element by the largest sum of rows or columns.
3. **Calculating the Total Relationship Matrix (Tc)**: The normalized matrix is subtracted from the identity matrix I, then inverted and multiplied by the normalized matrix to produce the total relationship matrix.
4. **Visualizing the Network Map**: In the final step of DEMATEL, connections below a certain threshold are removed to create a network of significant relationships.
5. **Forming the Structural Self-Interaction Matrix (SSIM)**: This begins the ISM method, using the DEMATEL output to create the ISM SSIM.
6. **Defining Relationships and Leveling Indicators**: Levels are determined by comparing output and input relationships. If output indicators match shared indicators at any step, they form that level. The process continues until no additional factors remain.

After calculating the final reachability matrix, the leveling of the components has been carried out. For each component, an output column (indicating the component's influence on other model components) and a prerequisite column (indicating the component's susceptibility to other model components) are created. The next step involves calculating the intersection of these two columns, with the final output being the component that has the same elements in both the intersection and output columns. The leveling performed in various stages is shown below.

Table 6. Stage 1: Determining the Level of Industrial Resilience Components

Component	Symbol	Prerequisites	Intersection	Output
Tax exemptions and reductions	C1	C1, C4, C12, C18, C28	C1	C1, C5, C6, C7, C8, C9, C30
Provision of facilities with favorable interest rates	C2	C2, C4, C12, C32	C2	C2, C6, C7, C8, C23, C30
Export incentives	C3	C3	C3	C3
Multiple suppliers and contractors	C4	C4	C4	C1, C2, C4, C5, C6, C7, C8, C9, C13, C19, C21, C23, C26, C28, C29, C30
Establishment of industry support institutions	C5	C1, C4, C5, C10, C12, C13, C18, C19, C28, C32	C5	C5, C6, C7, C8, C9, C23, C30
Efforts to amend and regulate laws, compensate for damages	C6	C1, C2, C4, C5, C6, C9, C10, C12, C13, C17, C18, C19, C21, C26, C28, C32	C6, C9, C28	C6, C7, C9, C28
Facilitating inter-company collaboration and sales promotion activities	C7	C1, C2, C4, C5, C6, C7, C9, C10, C12, C13, C17, C18, C19, C21, C26, C28, C32	C7	C7
Networking and collaboration with competitors, research institutions, and knowledge-based organizations	C8	C1, C2, C4, C5, C8, C10, C12, C13, C17, C18, C19, C28	C8	C8
Organizing seminars and training sessions, providing consulting services	C9	C1, C4, C5, C6, C9, C10, C12, C18, C19, C28	C6, C9	C6, C7, C9, C23, C30
Attitude toward change and strategic thinking	C10	C10	C10	C5, C6, C7, C8, C9, C10, C23, C30
Support for employees' innovative ideas	C11	C11, C18	C11	C11
Employee training and knowledge transfer	C12	C12	C12	C1, C2, C5, C6, C7, C8, C9, C12, C13, C19, C21, C23, C26, C28, C29, C30
Leadership style and traits	C13	C4, C12, C13, C18	C13	C5, C6, C7, C8, C13
Collective learning and teamwork	C14	C14	C14	C14
Employee commitment and sense of belonging	C15	C15	C15	C15
Adaptive capacity and flexible culture	C16	C16	C16	C16

Market discovery, development, and organizational communication	C17	C17	C17	C6, C7, C8, C17, C30
Financial reserves	C18	C18, C28	C18, C28	C1, C5, C6, C7, C8, C9, C11, C13, C18, C19, C23, C26, C28, C29, C30
Human resource reserves for key positions	C19	C4, C12, C18, C19, C28	C19	C5, C6, C7, C8, C9, C19, C23, C30
Cost control	C20	C20	C20	C20
Management of material resources	C21	C4, C12, C21	C21	C6, C7, C21, C30
Reserves related to infrastructure, equipment, and critical spare parts	C22	C22	C22	C22
Precautionary reserves in raw materials, semi-finished parts, and final products	C23	C2, C4, C5, C9, C10, C12, C18, C19, C23, C28	C23	C23
Production line flexibility	C24	C24	C24	C24
Machinery modernization and efficiency	C25	C25	C25	C25
Quality	C26	C4, C12, C18, C26	C26	C6, C7, C26, C30
Flexible structure and process improvement	C27	C27	C27	C27
Capability in innovation and new product development	C28	C4, C6, C12, C18, C28	C6, C18, C28	C1, C5, C6, C7, C8, C9, C18, C19, C23, C28, C29, C30
Product introduction and advertising	C29	C4, C12, C18, C28, C29	C29	C29
Customer communication and feedback collection	C30	C1, C2, C4, C5, C9, C10, C12, C13, C17, C18, C19, C21, C26, C28, C30	C30	C30
Market discovery and development	C31	C31	C31	C31
Timely delivery and after-sales service	C32	C32	C32	C2, C5, C6, C7, C8, C32

The results in Table 6 show that the first-level outputs include export incentives, facilitating inter-company collaboration and sales promotion activities, networking and collaboration with competitors, support for employees' innovative ideas, collective learning and teamwork, employee commitment and sense of belonging, adaptive capacity and flexible culture, cost control, reserves related to infrastructure, precautionary reserves, production line flexibility, machinery modernization, flexible structure and process improvement, product introduction and advertising, customer communication and feedback collection, and market discovery. These components form the highest section of the industrial resilience model. Removing these components, the second level is calculated in Table 7.

Table 7. Stage 2: Determining the Level of Industrial Resilience Components

Component	Symbol	Prerequisites	Intersection	Output
Tax exemptions and reductions	C1	C1, C4, C12, C18, C28	C1	C1, C5, C6, C9
Provision of facilities with favorable interest rates	C2	C2, C4, C12, C32	C2	C2, C6
Multiple suppliers and contractors	C4	C4	C4	C1, C2, C4, C5, C6, C9, C13, C19, C21, C26, C28
Establishment of industry support institutions	C5	C1, C4, C5, C10, C12, C13, C18, C19, C28, C32	C5	C5, C6, C9
Efforts to amend and regulate laws, compensate for damages	C6	C1, C2, C4, C5, C6, C9, C10, C12, C13, C17, C18, C19, C21, C26, C28, C32	C6, C9, C28	C6, C9, C28
Organizing seminars and training sessions, providing consulting services	C9	C1, C4, C5, C6, C9, C10, C12, C18, C19, C28	C6, C9	C6, C9
Attitude toward change and strategic thinking	C10	C10	C10	C5, C6, C9, C10
Employee training and knowledge transfer	C12	C12	C12	C1, C2, C5, C6, C9, C12, C13, C19, C21, C26, C28
Leadership style and traits	C13	C4, C12, C13, C18	C13	C5, C6, C13
Market discovery and development, organizational knowledge and communication	C17	C17	C17	C6, C17
Financial reserves	C18	C18, C28	C18, C28	C1, C5, C6, C9, C13, C18, C19, C26, C28
Human resource reserves for key positions	C19	C4, C12, C18, C19, C28	C19	C5, C6, C9, C19
Management of material resources	C21	C4, C12, C21	C21	C6, C21
Quality	C26	C4, C12, C18, C26	C26	C6, C26
Capability in innovation and new product development	C28	C4, C6, C12, C18, C28	C6, C18, C28	C1, C5, C6, C9, C18, C19, C28
Timely delivery and after-sales service	C32	C32	C32	C2, C5, C6, C32

The results in Table 7 show that the second-level outputs include efforts to amend and regulate laws, compensation, and organizing seminars and providing consulting services, which are placed at the highest section of the industrial resilience model. Removing these components, the third level is calculated in Table 8.

Table 8. Stage 3: Determining the Level of Industrial Resilience Components

Component	Symbol	Prerequisites	Intersection	Output
Tax exemptions and reductions	C1	C1, C4, C12, C18, C28	C1	C1, C5
Provision of facilities with favorable interest rates	C2	C2, C4, C12, C32	C2	C2
Multiple suppliers and contractors	C4	C4	C4	C1, C2, C4, C5, C13, C19, C21, C26, C28
Establishment of industry support institutions	C5	C1, C4, C5, C10, C12, C13, C18, C19, C28, C32	C5	C5
Attitude toward change and strategic thinking	C10	C10	C10	C5, C10
Employee training and knowledge transfer	C12	C12	C12	C1, C2, C5, C12, C13, C19, C21, C26, C28
Leadership style and traits	C13	C4, C12, C13, C18	C13	C5, C13
Market discovery and development, organizational knowledge and communication	C17	C17	C17	C17
Financial reserves	C18	C18, C28	C18, C28	C1, C5, C13, C18, C19, C26, C28
Human resource reserves for key positions	C19	C4, C12, C18, C19, C28	C19	C5, C19
Management of material resources	C21	C4, C12, C21	C21	C21
Quality	C26	C4, C12, C18, C26	C26	C26
Capability in innovation and new product development	C28	C4, C12, C18, C28	C18, C28	C1, C5, C18, C19, C28
Timely delivery and after-sales service	C32	C32	C32	C2, C5, C32

The results in Table 8 show that the third-level outputs are provision of facilities with favorable interest rates, establishment of industry support institutions, market discovery and development, management of material resources, and quality. Removing these components, the fourth level is calculated as shown in Table 9.

Table 9. Stage 4: Determining the Level of Industrial Resilience Components

Component	Symbol	Prerequisites	Intersection	Output
Tax exemptions and reductions	C1	C1, C4, C12, C18, C28	C1	C1
Multiple suppliers and contractors	C4	C4	C4	C1, C4, C13, C19, C28
Attitude toward change and strategic thinking	C10	C10	C10	C10
Employee training and knowledge transfer	C12	C12	C12	C1, C12, C13, C19, C28
Leadership style and traits	C13	C4, C12, C13, C18	C13	C13
Financial reserves	C18	C18, C28	C18, C28	C1, C13, C18, C19, C28
Human resource reserves for key positions	C19	C4, C12, C18, C19, C28	C19	C19
Capability in innovation and new product development	C28	C4, C12, C18, C28	C18, C28	C1, C18, C19, C28
Timely delivery and after-sales service	C32	C32	C32	C32

The results in Table 9 show that the fourth-level outputs are tax exemptions and reductions, attitude toward change and strategic thinking, leadership style and traits, human resource reserves for key positions, and timely delivery and after-sales service. Removing these components, the fifth level is calculated as shown in Table 10.

Table 10. Stage 5: Determining the Level of Industrial Resilience Components

Component	Symbol	Prerequisites	Intersection	Output
Multiple suppliers and contractors	C4	C4	C4	C4, C28
Employee training and knowledge transfer	C12	C12	C12	C12, C28
Financial reserves	C18	C18, C28	C18, C28	C18, C28
Capability in innovation and new product development	C28	C4, C12, C18, C28	C18, C28	C18, C28

The results in Table 10 show that the fifth-level outputs are financial reserves and capability in innovation and new product development. Removing these components, the sixth level is calculated as shown in Table 11.

Table 11. Stage 6: Determining the Level of Industrial Resilience Components

Component	Symbol	Prerequisites	Intersection	Output
Multiple suppliers and contractors	C4	C4	C4	C4
Employee training and knowledge transfer	C12	C12	C12	C12

The results in Table 11 show that the sixth-level outputs are multiple suppliers and contractors, and employee training and knowledge transfer. These components are the most influential factors in the industrial resilience model. According to the results, the components of export incentives, support for employees' innovative ideas, collective learning and teamwork, employee commitment and sense of belonging, adaptive capacity and flexible culture, cost control, reserves related to infrastructure, production line flexibility, machinery modernization, population density, and market discovery are independent variables with minimal impact or influence, and thus are excluded. Finally, removing indirect relationships and based on the aggregate matrix from experts, the causal diagram of components for enhancing industrial resilience, representing the conceptual model, is drawn as shown in Figure 5.

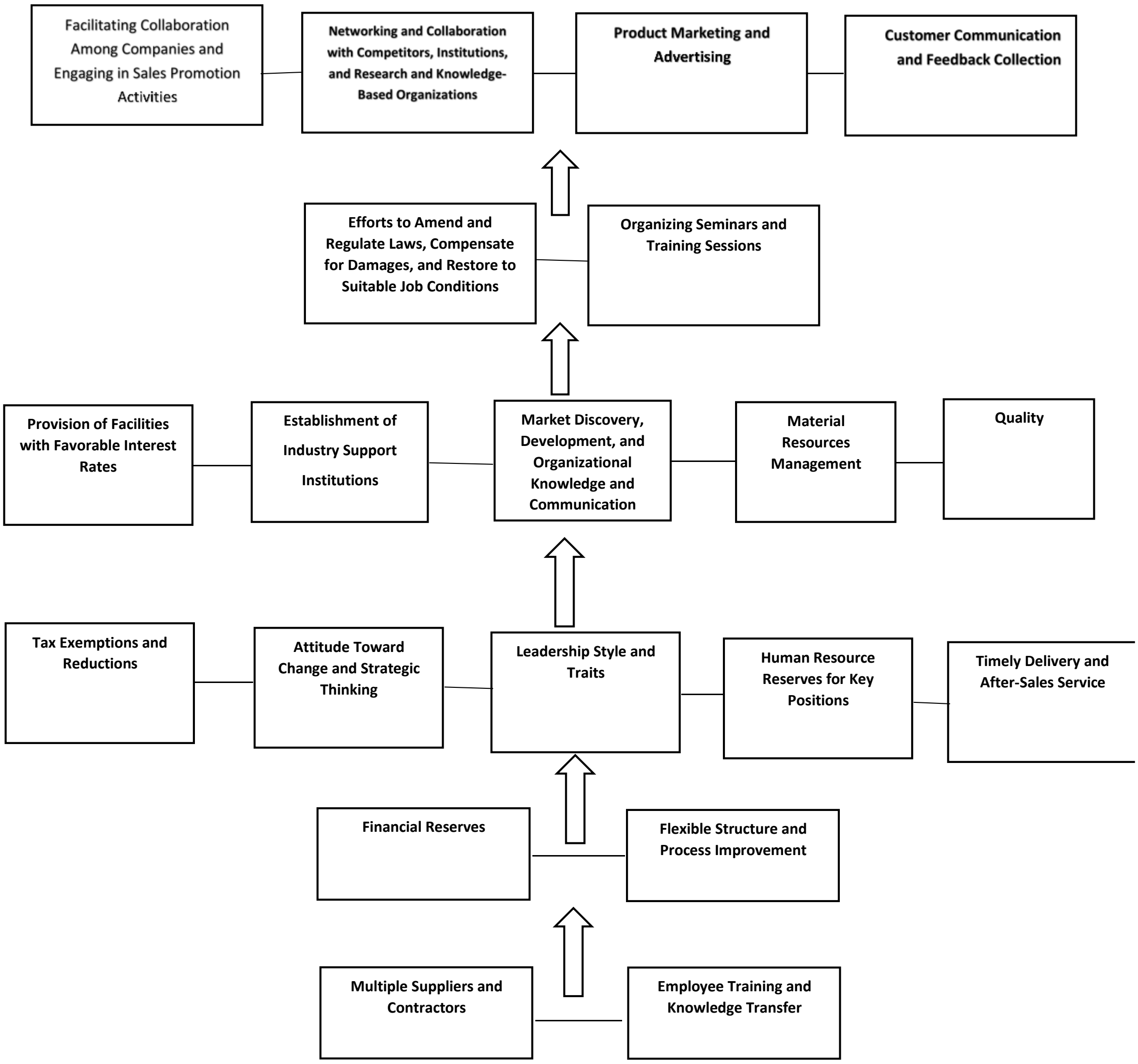

Figure 5. ISM Model for Enhancing Industrial Resilience

The results in Figure 6 indicate that in the causal model of industrial resilience, the components of multiple suppliers and contractors, and employee training and knowledge transfer are the most impactful. These components are at the lowest level of the model and exert a stronger influence compared to other components. They can directly and indirectly affect the other components of the model, forming the foundation of resilience in the industry. Strengthening these components can enhance the overall resilience of the industry, as they influence financial reserves and flexible structures and improve processes at level five.

4. Discussion and Conclusion

The purpose of this article was to present a causal model of industrial resilience using thematic analysis and interpretive structural modeling in the industry. The research findings indicated that to achieve industrial resilience, the components of the resilience model and its main elements must be considered as a systemic issue. The results showed that the most critical factors in industrial resilience are multiple suppliers and contractors, as well as employee training and knowledge transfer.

Additionally, the findings revealed that in the proposed causal resilience model, financial reserves and a flexible structure with improved processes are two primary components of resilience, which are directly influenced by multiple suppliers and contractors, and employee training and knowledge transfer. The study by Demmer et al. (2020) concluded that eliminating dependency on the status quo, top management support for innovation, strengthening internal and external knowledge networks, adopting an organic structure, discovering new opportunities, externalizing innovation, implementing strategic planning focused on entrepreneurship, simultaneous modernization and optimization, positioning in the customer value chain, investing in innovative human resources, and supporting strategic initiatives are influential factors for resilience in the automotive industry. Similarly, Gunasekaran et al. (2019) found that the factors affecting the resilience of the automotive parts industry include internal factors (organizational behavior, managerial characteristics, quality), external factors (globalization), and enablers (supply chain integration, use of technology, marketing, capital production) [35].

The research by Demmer et al. (2011) also highlighted the role of knowledge-based and entrepreneurial human resources, as well as product innovation and development, as significant influences on the resilience of small companies [34]. Therefore, it can be stated that the results of this study align with and corroborate previous research findings.

Ultimately, the resilience model derived in this article demonstrated that factors such as facilitating collaboration among companies and engaging in sales promotion activities, networking and cooperation with competitors, institutions, and research and knowledge-based organizations, product marketing and advertising, customer communication, and feedback collection are first-level components in the industrial resilience model. These components are influenced by other elements in the model and have a minimal impact on other components. In the resulting model from this project, inter-organizational cooperation and communication emerged solely as an influenced component.

Despite prior researchers' emphasis on the main components of the resilience model in previous studies, this article first adopted a localized perspective on the issue of resilience in the automotive industry and aimed to pay particular attention to the capacities of the automotive sector, especially in the sub-themes of the proposed model. Additionally, the research highlighted that previous studies had not addressed the internal and causal relationships among these components. It should be noted that most resilience studies have focused on merely identifying and measuring the components of resilience models. However, given the multidimensional nature of the industry and the interdependence of various variables, these components have intrinsic relationships that must be understood to make informed decisions for enhancing industrial resilience. The findings of this article can assist policymakers and decision-makers in the industry in making appropriate decisions.

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Authors equally contributed to this article.

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Declaration of Interest

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Ethical Considerations

All procedures performed in this study were under the ethical standards.

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