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A Model of Export Marketing Performance for SMEs: The Role of Fourth-Generation Technology in the Medical Equipment Industry

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ABSTRACT

Objective: This study aims to develop a comprehensive model to identify the key Industry 4.0–driven drivers influencing export marketing performance in Iranian medical equipment small and medium-sized enterprises (SMEs).

Methodology: This research is quantitative and application-oriented, employing a two-phase methodological approach. First, 30 potential drivers were identified through a systematic literature review and expert consultations with ten specialists in export marketing and Industry 4.0 technologies. These drivers were screened using the Fuzzy Delphi method, yielding 11 drivers with defuzzified values above the 0.7 threshold. In the second phase, a cross-impact analysis was conducted using the MicMac software to examine the structural relationships, influences, and dependencies among the selected drivers.

Results: The results indicate that four drivers—AI-based export data analytics, ML-based optimization of export marketing decisions, AI-enabled customer behavior analysis, and IoT-enabled export quality and standards control—are the most influential determinants of export marketing performance. AI-based analytics and ML-driven decision optimization are bidirectional and risk-prone, forming the strategic nucleus of the system. AI-enabled customer behavior analysis and IoT-based quality control are key influential variables, underscoring the importance of market intelligence, quality assurance, and traceability.

Conclusion: The study demonstrates that the synergistic adoption of Industry 4.0 technologies can address structural weaknesses in export marketing, including limited market intelligence, weak forecasting, and low supply chain transparency. The proposed model offers a practical framework for policymakers and firms to prioritize digital investments and achieve sustainable export growth in emerging markets.

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Introduction

In today's linked and highly competitive world, organizations are expanding their operations across borders to access new marketplaces (Kumar, 2024). In response to globalization, the availability of large markets, and other factors, a sizable proportion of firms have adopted exports as a global growth strategy in recent decades, and trade liberalization initiatives in many countries have brought major shifts in the global economy (Hassen et al., 2024).

Exporting is a key driver of economic progress and business performance, and a feasible strategic option for enterprises aiming to access worldwide markets, as it remains the primary method of entering international markets. According to statistics, the successful execution of a goods and services export strategy will yield benefits that not only help firms and countries expand and develop (Cugno et al., 2025) but also create jobs and increase productivity (Taghavi, 2023).

Companies have a strong ambition to improve export performance in order to achieve growth, profitability, survival, market opportunities, and tax benefits. Competitive challenges, proximity to foreign customers, and surplus capacity contribute to their need to export. In today's world, export development entails more than simply generating foreign cash. It also plays an important role as a growth strategy, including the export of goods and services and the development of national and global networks. In addition, rivalry in global markets is growing quickly (RezaiDolatAbadi & AliKhasi, 2019). Small and medium-sized enterprises (SMEs) are the principal drivers of this effort, with their export engagement exceeding that of larger firms in the majority of cases. Metrics include volume, dollar worth, and intensity (OECD, 2019). As a result, the internationalization of small and medium-sized businesses is a crucial strategic move due to the benefits it offers (Berku Obeng Damoah, 2018).

Exporting is entirely dependent on advertising. According to research in export marketing, initiatives increase performance. Today's volatile world necessitates that we adapt to new opportunities and challenges in complicated global markets. Exporters require marketing expertise to adapt to rapid change, an intangible resource that enables them to respond to shifting demands, resulting in successful market segmentation and targeting (Obadia & Vida, 2024).

Marketing aids exporting firms in acquiring and developing new resources to gain a competitive edge in both domestic and foreign markets. An export marketing strategy is designed to provide a framework for a firm to generate substantial earnings and essential foreign exchange profits. It adjusts to the interplay between internal and external factors to achieve its export-related objectives. Marketing is an important aspect of exporting; success is defined as the ability to engage

consumers, build relationships with them, and fulfill their needs most effectively. However, a current assessment of the research on the impact of a foreign marketing strategy on export performance produced varied and inconclusive results (Isichei et al., 2023).

Export performance is critical for firm sustainability and survival (RezaeiDoltaAbadi & Alikhasi, 2019). It reflects the relative success (or failure) of a country or business firm in exporting to international marketplaces (Handoyo et al., 2024). While boosting export performance is vital in today's global economy, international trade contributes significantly to many businesses' revenue (Purwaningsih et al., 2024). Despite almost 60 years of scientific research demonstrating that improving export performance is one of the most successful ways to increase exports, the truth remains that academic research has not yet yielded definitive answers on the measures that businesses can use to ensure their export performance (Obadia & Vida, 2024).

The export performance of Iranian enterprises is not encouraging, even though exporting is one of the primary strategies many nations use to support their economies and enhance the productivity of their manufacturing sectors. The high rate at which Iranian export commodities are returned from nearby nations, the transfer of target markets to foreign rivals, and the persistent decrease in the market share of Iranian export firms all point to the fact that the management of these businesses has not been effective in terms of marketing skills (Derakhshandeh et al., 2023).

One of the primary issues is that the Iranian economy relies on oil and oil products, which creates volatility in export revenues. Several policies and solutions have been implemented in the nation's development strategies to address this issue. A surge in non-oil exports has been identified as the primary strategy of Iran's export development policy.

As a result, the export policy should be shifted toward non-oil exports, such as medical equipment. To do so, the potential of the medical device industry should be recognized and an operating component granted. The medical device industry has grown into one of the most important and rapidly expanding sectors worldwide. Because of its direct influence on people's lives and the increasing demand for its products and services from various sectors, this business is regarded as one of the most vital in the world (Chen & Liu, 2025).

The leading players in the medical equipment market in 2022 were Germany, the United States, Belgium, Switzerland, and Ireland, which together accounted for more than half of the market share of pharmaceuticals and medical equipment. Also, in 2022, about 226 countries exported pharmaceuticals and medical equipment, of which Iran ranked 83rd with a share of 0.01 percent, and the total value of Iran's exports of these products was $106.4 million (Iran's Deputy Minister

of Foreign Affairs for Economic Diplomacy, 2024). There are 2,214 active manufacturers in Iran's medical equipment and supplies sector, and the market value of production in this field exceeds 30 trillion.

Given the sophistication of export technology as a critical measure of a country's export quality to encourage trade expansion, and in light of today's competitive dynamics, firms must stay up to date and strategically monitor global market trends. Consequently, academics have closely studied the role of digital skills in commerce and their capacity to improve industrial firm performance (Liang & Tan, 2024).

The world is on the verge of a scientific and technological revolution. With the development and successful innovation of blockchain, cloud computing, and big data, the digital economy is emerging as a significant force for global factor redistribution, economic structural change, and the evolution of competitive patterns. (Liang & Tan, 2024; Kolářová and Kolářová, 2020).

The process of global economic integration, amid rapid scientific and technological advancement, presents both opportunities and challenges for all countries, particularly developing countries (Tien & Ngoc, 2019). The incorporation of fourth-generation technological capabilities into marketing activities has consistently affected businesses' competitive advantage and performance. The fundamental concept of Industry 4.0, the movement toward digitalization, automation, and greater usage of information and communication technologies, is known as digital transformation. While the digital transition is significantly changing people's lives and livelihoods, it is also creating new economic opportunities, particularly in emerging countries. The general public is optimistic about Industry 4.0 jobs (Monteiro et al., 2019).

Despite the growing production capacity of Iranian small and medium-sized enterprises (SMEs) in the medical equipment industry, their export marketing performance remains weak and unsustainable. Industry reports and official statistics indicate a significant mismatch between domestic manufacturing capabilities and international market presence. In 2022, although Iran ranked among countries with an active medical equipment manufacturing base, its share of global exports in this sector was only 0.01 percent, placing the country 83rd worldwide. This low export share, combined with frequent returns of exported products from neighboring markets and the gradual loss of target export destinations to foreign competitors, provides clear empirical evidence of deficiencies in export marketing performance rather than in production capacity.

From an industrial perspective, these challenges are primarily manifested in limited access to reliable export market intelligence, weak demand forecasting, insufficient compliance with

international quality and regulatory standards, low transparency in export logistics and supply chains, and inadequate utilization of advanced digital tools in marketing decision-making. Field observations and prior studies on Iranian exporting firms suggest that traditional export marketing practices are no longer capable of addressing the complexity, speed, and uncertainty of global medical equipment markets.

At the same time, international evidence demonstrates that firms operating in highly competitive and technology-intensive industries increasingly rely on fourth-generation (Industry 4.0) technologies—such as artificial intelligence, the Internet of Things, big data analytics, and blockchain—to enhance export marketing efficiency, reduce transaction risks, and strengthen their international competitiveness. However, in the Iranian medical equipment industry, the adoption of these technologies in export marketing activities remains fragmented, unsystematic, and largely experience-based, lacking a coherent analytical framework for prioritization and implementation.

Therefore, the core research problem addressed in this study arises from a clear industrial gap. While Industry 4.0 technologies offer substantial potential to improve export marketing performance, Iranian medical equipment SMEs lack an integrated and evidence-based model to identify the most influential technological drivers and understand their structural interrelationships. This gap limits managers' ability to allocate resources effectively, adopt appropriate technologies, and design data-driven export marketing strategies. Addressing this problem is essential for improving export marketing performance, reducing export failures, and enhancing the international competitiveness of the medical equipment industry.

Given the growing need to boost non-cash exports and Iran's loss of market share and ceding of export markets to competing countries in this cycle, this study seeks to develop a model of the factors influencing the export marketing performance of Iranian enterprises. Given the country's considerable medical equipment production capacity, the medical equipment industry, a profitable export market, has been specifically chosen for research. Our goal in this research is to find the answers to the following two questions:

1- What are the factors affecting export marketing performance with a focus on 4.0 capabilities?

2. What is the relationship between these factors?

Literature Background

Export marketing

Export marketing is the process of identifying, predicting, and estimating the needs of foreign customers, and its final stage is export sales. Its components include market identification and research, product characteristics (profit and quantity), advertising, pricing, import regulations, and related factors. Research into export markets improves the marketing performance of products and services. Export marketing focuses on increasing export volume, diversifying export products, and maintaining competitiveness in foreign markets, and its effects directly affect export performance (Songur, 2023).

Export marketing performance

Marketing performance is a continuous cycle of measurement, analysis, and improvement that involves constantly monitoring trends, identifying opportunities, and proactively adjusting approaches to stay ahead of the competitive landscape. Marketing performance refers to a company's ability to meet and retain customer needs by providing quality products and services (Khalayleh & Al-Hawary, 2022).

Fourth Generation Technologies

The Fourth Industrial Revolution is built on the technological advances and capabilities opened up by the three previous revolutions, fundamentally reshaping industrial processes and economic systems. Now, the Fourth Industrial Revolution is built on the third revolution and with a set of new technologies that blur the lines between the physical and digital worlds (Shaji George, 2024). Industry 4.0 involves the use of new technologies that bridge the physical and virtual worlds (World Economic Forum, 2015). These enabling technologies, known as 4.0 technologies, include various ICT tools used in industrial production processes that enable simultaneous device connectivity and real-time information exchange, creating the Industry 4.0 paradigm. The long list of Industry 4.0 technologies includes the Internet of Things, big data, artificial intelligence, industrial robots, simulation, virtual and augmented reality, cyber-physical systems, cybersecurity, cloud computing, and additive manufacturing (Kourkoles et al., 2025).

Said & Soi (2025) examined how digital innovation can help Indonesian micro, small, and medium-sized enterprises (MSMEs) grow their export markets. MSMEs are vital to Indonesia's economy, but they face many challenges, including limited access to finance, marketing challenges, weak infrastructure, and a shortage of skills. The research focused on how digital technology could

help address these problems and enhance MSMEs' competitiveness. It involved in-depth interviews with 46 online entrepreneurs and used secondary data for analysis. Findings showed that adopting e-commerce and cloud technologies can boost efficiency and cut costs. The study recommends improving digital literacy, updating infrastructure, simplifying access, and fostering partnerships with e-commerce platforms. It suggests further research on AI and machine learning on MSMEs.

Duo and Huang (2025) highlight the lack of research on the relationship between digital capability and export performance among Chinese SMEs. Using transaction cost theory and a digital governance perspective, they conducted an empirical analysis through structural equation modeling, based on survey data from 332 export-oriented SMEs on Alibaba. The study examines how digital capability enhances export performance by reducing perceived uncertainty and transaction costs while expanding export markets. The findings show that digital capability significantly reduces uncertainty and transaction costs, thereby promoting market expansion and improving export performance. Mediation analysis reveals that transaction costs (both transaction expenses and perceived uncertainty) form a significant mediating chain between digital capability and export market expansion. However, perceived uncertainty alone does not act as an independent mediator. Additionally, export market expansion itself mediates the relationship between digital capability and SMEs' export performance.

Cugno et al. (2025) discussed how Industry 4.0 can help Small and Medium Enterprises (SMEs) improve their global market strategies. A study examined 2,972 Italian manufacturing SMEs in 2022 to examine how technology affects various export aspects. Key findings show that adopting Industry 4.0 technologies positively impacts export performance, including export intensity, which measures international sales compared to total sales. The research suggests that SMEs need to invest significant resources in these technologies. It emphasizes the importance of aligning technical spending with export objectives and encourages further investigation into this topic.

Rehman et al. (2025) stated that a company's success is closely linked to Industry 4.0 standards. This study examines how Industry 4.0 technologies affect the international performance of small and medium-sized businesses (SMEs), drawing on theories of institutions and dynamic capabilities. It finds that factors like environmental change and competition influence how dynamic capabilities affect SMEs' success abroad. Data were collected from 301 exporting SMEs in Malaysia, and analyses included multiple regression and structural equation modeling. The research recommends that managers promote networking and focus on Industry 4.0 technologies and dynamic capabilities to improve international performance.

Purwaningsih et al. (2024) found that SMEs' international performance is strongly influenced by Industry 4.0 technologies, particularly through the mediating role of ambidextrous dynamic capabilities. Using data from 301 Malaysian exporting SMEs and applying regression and PLS-SEM analyses, the study shows that technologies such as machine learning enhance firms' dynamic capabilities, which, in turn, improve export performance. Environmental dynamism and competition further strengthen this relationship. The study recommends that managers prioritize Industry 4.0 adoption, build dynamic capabilities, and enhance responsiveness to competitive and environmental changes to improve international success.

Bai et al. (2020) explain that Industry 4.0, driven by advanced intelligent and information technologies, enhances production efficiency and has significant implications for social and environmental sustainability. Noting a gap in comprehensive guidance, the study proposes a sustainability assessment framework aligned with the UN SDGs and integrates economic, environmental, and social indicators. It also develops a hybrid decision-making method combining hesitant fuzzy sets, cumulative prospect theory, and the VIKOR approach to evaluate Industry 4.0 technologies. Using World Economic Forum data, the findings show that mobile technology has the most substantial overall sustainability impact, while nanotechnology, simulation, and drones are most impactful in specific sectors. The study recommends adopting Industry 4.0 technologies strategically, prioritizing those with the highest sustainability benefits and ensuring strong leadership for effective implementation.

The reviewed literature demonstrates that export marketing performance has become increasingly complex and dynamic in response to intensified global competition and rapid technological change. Traditional export marketing activities—such as market research, pricing, promotion, and regulatory adaptation—remain essential; however, recent studies consistently emphasize that these activities alone are no longer sufficient to ensure sustainable export success. Instead, firms’ ability to integrate advanced digital and Industry 4.0 technologies has emerged as a critical determinant of export performance.

Empirical evidence indicates that Industry 4.0 technologies and digital capabilities enhance export marketing performance by improving operational efficiency, reducing uncertainty and transaction costs, expanding access to international markets, and strengthening firms’ dynamic and ambidextrous capabilities. Studies conducted across diverse national contexts confirm that these technologies play a mediating and enabling role in transforming internal capabilities into superior export outcomes. Moreover, the literature highlights that environmental dynamism and competitive intensity further shape the effectiveness of these technological capabilities in international markets.

Despite these valuable insights, the existing body of research reveals several gaps. Most prior studies focus on the direct or mediating effects of digital and Industry 4.0 technologies on export performance, while offering limited understanding of the structural relationships and interdependencies among technological, organizational, and export marketing factors. In addition, few studies provide a systematic framework for prioritizing key drivers or translating technological adoption into coherent export marketing strategies and practical managerial guidance.

Consequently, there is a clear need for integrative and analytical approaches to identify the most influential factors, examine their interactions, and support strategic decision-making in export marketing. Addressing these gaps not only contributes to the theoretical development of export marketing and international business literature but also provides practical insights for managers seeking to enhance export marketing performance in the context of Industry 4.0.

Materials and Methods

The present study aims to develop a model that identifies the factors influencing the export marketing performance of small and medium-sized enterprises (SMEs), with an emphasis on the capabilities of 4G technology in the medical device industry. To achieve this goal, this study uses the Fuzzy Delphi and Interaction Analysis (MicMac) techniques to identify the key factors influencing export marketing performance. Both methods are quantitative and rely on evaluative and analytical data for their findings. Specifically, the Fuzzy Delphi method was used to screen the factors, and the MicMac technique was used to identify the most impactful factors. Since this research provides practical insights for improving export marketing performance, its methodology is quantitative and applied. Data collection was conducted through a survey.

The drivers analyzed in this study were identified through an extensive review of the literature related to export marketing, export performance, export marketing performance, Industry 4.0, and the medical device sector. These identified factors were further investigated through structured questionnaires completed by experts. The evaluation of the expert questionnaires was conducted using the Fuzzy Delphi technique, while the interaction analysis questionnaires were evaluated using the MicMac technique. The validity of the research instruments was verified by referring to authoritative articles in the fields of export marketing performance and Industry 4.0. In addition, the Lavish Content Validity Index was used to verify the questionnaires' validity, with all stimuli scoring above 0.79, indicating strong validity.

The expert participants in this study included university faculty members and Chamber of Commerce members, selected through judgmental sampling based on their expertise in export marketing and Industry 4.0. The final sample size consisted of 10 eligible individuals.

To ensure transparency, rigor, and practical applicability, the present study followed a systematic and step-by-step research execution algorithm. The overall research process was designed to identify, screen, and structurally analyze the key drivers influencing export marketing performance with a focus on Industry 4.0 capabilities. The execution algorithm consisted of five main stages, as described below.

Stage 1: Identification of Initial Factors

In the first stage, a comprehensive review of international and domestic literature related to export marketing, export marketing performance, Industry 4.0 technologies, and the medical equipment industry was conducted. In parallel, exploratory consultations with industry experts were carried out. As a result, an initial list of 30 potential drivers affecting export marketing performance was identified.

Stage 2: Expert Selection and Questionnaire Design

In the second stage, a panel of experts was formed, including university scholars and professionals from the Chamber of Commerce with demonstrated expertise in export marketing and Industry 4.0 technologies. Based on the identified drivers, a structured questionnaire was designed using a five-point Likert scale and corresponding triangular fuzzy numbers to capture expert judgments.

Stage 3: Screening of Factors Using the Fuzzy Delphi Method

The third stage involved applying the Fuzzy Delphi method to screen and refine the initial list of drivers. Expert responses were aggregated and defuzzified to obtain crisp values for each factor. Drivers with defuzzified values equal to or greater than the threshold (0.7) were retained for further analysis. This step reduced the initial 30 drivers to 11 key factors, ensuring consensus and relevance from an industrial perspective.

Stage 4: Cross-Impact Analysis Using MICMAC

In the fourth stage, the selected drivers were analyzed using cross-impact analysis through MICMAC software. Experts evaluated the pairwise relationships among the 11 factors based on their direct influence and dependence, using a standardized scale (0–3). The resulting influence–

dependence matrix was processed to generate direct and indirect influence maps, enabling the identification of driving, dependent, autonomous, and linkage variables within the export marketing system.

Stage 5: Interpretation and Model Development

In the final stage, the MICMAC outputs were interpreted to classify the drivers into meaningful categories and to develop an integrated structural model of the factors influencing export marketing performance. The model highlights key leverage variables and strategic technological drivers that can guide managers and policymakers in improving export marketing performance in the medical equipment industry.

Table 1. Spectrum of the Fuzzy Delphi Method

Verbal variable	Fuzzy value	Triangular fuzzy number
Very low	$\tilde{1}$	(0, 0, 0/25)
Low	$\tilde{2}$	(0, 0/25, 0/5)
Medium	$\tilde{3}$	(0/25, 0/5 , 0/75)
High	$\tilde{4}$	(0/5 , 0/75 , 1)
Very high	$\tilde{5}$	(0/75 , 1, 1)

The Micmac program was developed by the Institute of Computer Innovation for Business, with help from its creators at the Research Laboratory for Future Strategy and Organization, LIPSOR (Godet, 1999). This pertains to structural analysis, which views a structure as a system studied, with its components interconnected (Mojica, 2005). Furthermore, this method enables consideration of qualitative elements and examination of different future scenarios (Jimenez, 2009).

The technique starts with defining the issue, then identifying a list of both internal and external variables. It then examines how these elements interact within the system, calculating relationships based on how each affects the others' presence. The impact of these parameters is assessed on a scale of no influence, low, medium, or high, which may be represented as 0, 1, 2, or 3, or 0, 1, 3, or 4. In general, the information input is qualitative, allowing for changes in relationship strength (0 = none, 1 = weak, 2 = moderate, 3 = strong, P = potential). The ratings help to identify important aspects by classifying them as either direct or indirect.

The way different elements interact and rely on one another is determined by where each item falls within a quadrant. This categorizes a factor as either a power, independent, conflict, or output factor, depending on the degree of influence and reliance (Benjumea-Arias et al., 2016).

Table2. Factors affecting export marketing performance by focusing on Industry 4.0

No.	Research drivers	Research resources	Content validity Index	Defuzzified number
A1	Increasing trust in international transactions through the immutable recording of information by blockchain	Purwaningsih et al. (2024)	0.88	0.23
A2	Reducing order processing time using blockchain	Purwaningsih et al. (2024)	0.82	0.78
A3	Optimizing inventory management using blockchain and the Internet of Things	Purwaningsih et al. (2024) Said & Soi (2025)	0.81	0.81
A4	Reducing operating costs by eliminating intermediaries and automating supply chain processes using blockchain	Cugno et al. (2025)	0.80	0.48
A5	Accurate tracking of products from purchase to consumption using blockchain and the Internet of Things	Purwaningsih et al. (2024)	0.82	0.80
A6	Reducing delivery time using artificial intelligence, blockchain, and the Internet of Things	Bai et al. (2020)	0.87	0.83
A7	Increasing production efficiency and reducing operating costs using artificial intelligence	Cugno et al. (2025)	0.82	0.25
A8	Optimizing export decisions using big data	Siddiqui & Singh (2020) Merín-Rodríguez et al. (2025) Zahoor & Lew (2023)	0.89	0.30
A9	Developing exports and the ability to enter new markets using 4th-generation technologies	Bai et al. (2020)	0.88	0.23
A10	Increasing international brand credibility using 4th generation technologies	Bai et al. (2020)	0.80	0.21
A11	Attracting international customers due to the popularity of using 4th-generation technologies	Racela & Thoumrungroje (2020)	0.81	0.36
A12	Economic and social sustainability using 4th generation technologies	Bai et al. (2020)	0.87	0.20
A13	Increasing exports by using robots in the production process	Alguacil et al. (2022)	0.81	0.21
A14	Increasing the productivity of production factors using robots	Naglič et al. (2020)	0.88	0.23
A15	Analyzing export data using Artificial Intelligence	Samadzadeh (2024)	0.87	0.79
A16	Optimizing export marketing decisions using machine learning	Naglič et al. (2020)	0.85	0.82
A17	Increasing brand awareness using digital marketing	Abdurashitova (2022)	0.80	0.34
A18	Better preparedness for international competition using 4.0 generation technologies	Naglič et al. (2020)	0.87	0.18
A19	Diversifying export markets using big data	Naglič et al. (2020)	0.88	0.20

A20	Ability to adapt quickly to changes in customer needs using 4.0 generation technology	Bai et al. (2024)	0.89	0.25
A21	Quality control and export standards using the Internet of Things	Samadzadeh (2024)	0.83	0.81
A22	Optimizing the customs process using the Internet of Things	Samadzadeh (2024)	0.86	0.81
A23	Analyzing customer behavior using artificial intelligence	Abdurashitova (2022)	0.82	0.82
A24	Increasing brand engagement using artificial intelligence	Taghavi et al. (2023)	0.87	0.18
A25	Personalizing advertising using artificial intelligence	Maina (2021)	0.88	0.23
A26	Reducing fraud risk using smart contracts	Obtaining opinions from experts	0.89	0.78
A27	Reducing infrastructure costs using cloud computing and spending more on marketing and advertising	Obtaining opinions from experts	0.86	0.20
A28	Creating interactive and engaging experiences to display products using virtual and augmented reality	Obtaining opinions from experts	0.87	0.28
A29	Demand forecasting using artificial intelligence algorithms	Maina (2021)	0.84	0.81
A30	Creating enjoyable value through digital platforms	Siddiqui & Singh (2020)	0.88	0.27

Of the 30 variables derived from the research history and expert perspectives, 11 drivers had defuzzification values above the 0.7 threshold, leading to their selection as the primary drivers for the last assessment, as shown in the fuzzy Delphi table. The remaining drivers after screening, according to the table above, are: lowering order processing time via blockchain (A2), optimizing inventory management via blockchain and IoT (A3), precisely tracking items from order to consumption via blockchain and IoT (A5), shortening delivery time via artificial intelligence, blockchain, and IoT (A6), analyzing export data using AI (A15), optimizing export marketing decisions using machine learning (A16), controlling export quality and standards using IoT (A21), optimizing the customs process using IoT (A22), analyzing customer behavior using AI (A23), minimizing fraud risk using smart contracts (A26), and predicting demand using AI algorithms (A29).

After identifying the important elements influencing export marketing performance, these characteristics are evaluated using cross-impact analysis. This step was accomplished by distributing the effect research survey to specialists. The replies were subsequently processed using the MicMac application.

In this section, the research variables were investigated using cross-impact analysis. The first step in evaluating the cross-impact effect after establishing the expert group is to develop an n.n

matrix and have the professionals fill it in. In this study, assuming the presence of the final 9 elements, a 99 matrix is constructed, with its cells populated with the numbers 3, 2, 1, and 0. The number 3 denotes a strong influence, 2 indicates a moderate effect, and 1 denotes a low effect. The number 0 represents the lack of effect and association. Then, the 99 completed questionnaires from the experts are collected, and the cells of the initial access matrix are filled in according to the mode. The characteristics of the cells in the initial access matrix are listed in the table below.

Table 3. Cross-impact analysis indicators

INDICATOR	VALUE
Matrix size	11
Number of iterations	2
Number of zeros	11
Number of ones	59
Number of twos	35
Number of threes	16
Number of P	0
Total	110
Fillrate	90.90909%

According to the questionnaires, MicMac software ranks components by impact and reliance, as shown in the tables below. The row total reflects influence, while the column total indicates dependence. The higher the row sum of a factor, the higher its influence, and the higher the column sum, the higher its dependence.

Table 4. Row and column sum of a matrix

N°	VARIABLE	TOTAL NUMBER OF ROWS	TOTAL NUMBER OF COLUMNS
1	A2	3028	4448
2	A3	2979	4520
3	A5	3700	4132
4	A6	2857	4702
5	A15	6024	4025
6	A16	5676	4042
7	A21	4750	3122
8	A22	4338	4154
9	A23	4845	3847
10	A26	3100	4258
11	A29	3245	3292
	Totals	177	177

Table 5. Ranking factors based on direct and indirect effects

Rank	Label	Direct influence	Label	Direct dependence	Label	Indirect influence	Label	Indirect dependence
1	A15	1412	A6	1073	A15	1352	A6	1055
2	A16	1242	A2	1016	A16	1274	A3	1014
3	A23	1129	A3	1016	A23	1087	A2	998
4	A21	1073	A22	960	A21	1066	A26	955
5	A22	960	A26	960	A22	973	A22	932
6	A5	847	A5	903	A5	830	A5	927
7	A29	734	A15	903	A29	728	A16	907
8	A2	677	A16	903	A26	695	A15	903
9	A26	677	A23	847	A2	679	A23	863
10	A3	621	A29	734	A3	668	A29	739
11	A6	621	A21	677	A6	641	A21	700

According to the table above, factors A15, A16, A23, and A21, in order, have the most influence, and A6, A3, A3, and A26, in order, have the most dependence.

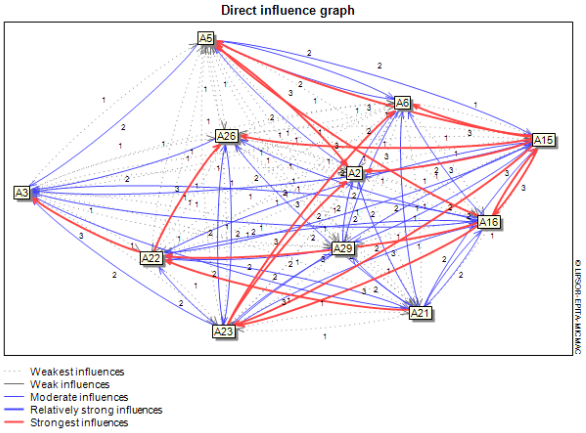

Figure 1. Direct influence graph

The direct influence graph shown in Figure 1 depicts the immediate, observable effects that one variable exerts on another, as determined by expert evaluations. This graph highlights short-term causal relationships and helps identify variables with a substantial, immediate impact on export marketing performance. In an industrial context, these relationships are particularly relevant for operational decision-making, as they reflect direct managerial interventions and their immediate consequences.

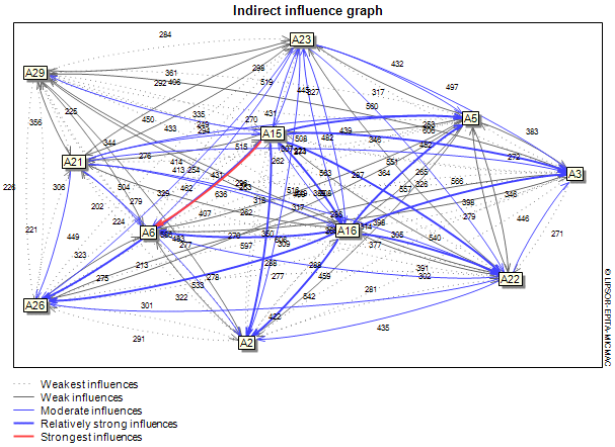

Figure 2. Indirect influence graph

The indirect influence graph represents the cumulative effects of variables through intermediary pathways within the system. These effects capture long-term, feedback-driven, and non-linear interactions that are not apparent in direct relationships alone. This graph is essential for understanding how changes in one technological capability may propagate through the export marketing system over time, ultimately affecting performance outcomes. From a strategic perspective, indirect influences reveal hidden leverage points that can drive sustained competitive advantage.

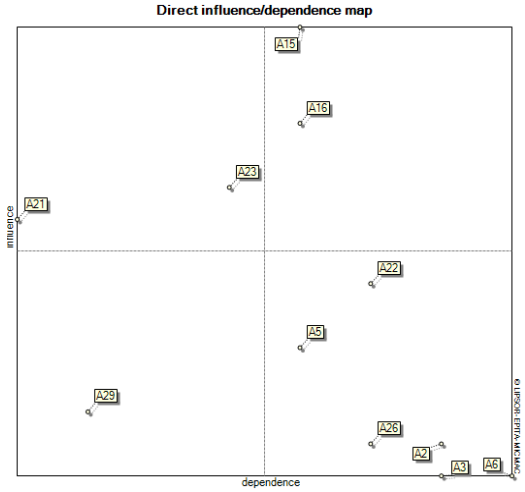

Figure 3. Direct influence/dependence map

The picture above depicts four distinct pieces that may be interpreted as a trigonometric circle with four regions (quarters). The first section on the northeastern side of the diagram represents the two-faced variables, which have a significant impact and dependence. These characteristics

contribute to instability. The parameters in this sector are divided into two groups: risk and target variables. Now, picture a diagonal line that runs through the first and third sections. A variable can be regarded as a risk variable if it lies along the diagonal line in the northeast region; such variables have a strong ability to become crucial players in the system. Target variables are those located below the diagonal line in the northeast area, which are more affected than influential. By manipulating these characteristics, evolutionary changes in the system can be induced (Maleki et al, 2025).

The second region is located in the northwestern section of the diagram. The variables in this region have a significant impact and are often beyond the system's capacity to manage. These variables are regarded as system inputs.

The third component concerns the independent factors, shown in the southwestern section of the diagram. These characteristics are unaffected by, and have no impact on, other variables in the system. They have very little interaction with the system and do not cause any key variables to stop or change. These elements are divided into three groups: discrete variables, secondary leverage variables, and regulatory variables. Discrete variables are found near the origin of the coordinate system, implying they are unrelated to the system's dynamics and current changes and can be removed from the system. Despite being independent, secondary leverage variables are more important than influential and are found above the diagonal line in the third area. Regulatory factors are placed near the diagram's center of gravity and function as secondary leverage, weak targets, and secondary risk variables.

The fourth area concerns the influential or dependent variables, which are positioned in the southeast region of the diagram. These factors have minimal influence and are highly interdependent. As a result, they are susceptible to changes in important and two-way factors. These characteristics are regarded as the system's output. By paying attention to this section of the diagram, technological and innovation-related parameters can be viewed as dependent or significant variables. The table below summarizes the characteristics of these variables.

Table 6. Typology of model variables in the influence-dependence diagram

Variable type	Desired variable
Two-faced variable	A15, A16
Risk variable	A15, A16
Target variable	-
Influential	A21, A23
Independent	A29
Dependence	A2, A3, A5, A6, A22, A26

Discussion and Conclusion

The purpose of this study was to develop an applied and industry-oriented model for identifying and structuring the key factors influencing export marketing performance in small and medium-sized enterprises (SMEs), with a specific focus on fourth-generation technological capabilities in the medical equipment industry. By integrating the Fuzzy Delphi method and MICMAC cross-impact analysis, the study moves beyond traditional linear assessments. It provides a systemic understanding of how Industry 4.0 technologies shape export marketing performance. In the first stage, 30 components were identified through a literature review. Of these 30 parameters, 11 had a desirable defuzzified score after providing an expert questionnaire and screening using the fuzzy Delphi approach. Finally, the aspects were assessed using the Impact Assessment questionnaire and the MicMac software.

The findings clearly demonstrate that export marketing performance in technology-intensive industries is no longer driven primarily by traditional marketing activities alone, such as promotion or pricing strategies. Instead, the results indicate that data-driven and intelligent technologies constitute the core foundation of effective export marketing systems. In particular, AI-based export data analytics and machine learning-based optimization of export marketing decisions emerged as the most critical drivers, occupying central and unstable positions within the MICMAC influence–dependence structure. Their classification as two-faced (linkage) variables suggests that these technologies simultaneously influence and depend on other system components, making them decisive leverage points for strategic intervention.

From a conceptual perspective, this finding reinforces the argument that export marketing performance should be understood as a dynamic capability rather than a static outcome. The ability of firms to collect, process, and analyze large volumes of export-related data enables more accurate market selection, demand forecasting, pricing decisions, and risk management. In the medical equipment industry—where regulatory compliance, product quality, and trust are central—such analytical capabilities are particularly critical. This explains why improvements in AI-driven analytics and machine learning-based decision systems can trigger cascading effects across the entire export marketing system.

The influential role of AI-enabled customer behavior analysis and IoT-based quality control and standards monitoring further highlights the strong interconnection between market intelligence and operational reliability. These findings suggest that understanding international customer needs and ensuring compliance with global quality standards are not peripheral activities but rather structural drivers of export marketing success. This result is especially relevant for Iranian medical equipment SMEs, which face high rates of export product rejection and limited brand credibility in international markets. By embedding Industry 4.0 technologies into quality assurance and

customer analysis processes, firms can significantly reduce export risk and enhance trust in foreign markets.

The dependent variables identified in the MICMAC model—such as reduced order processing time, optimized customs procedures, and lower fraud risk—represent tangible operational outcomes that materialize only when core technological drivers are effectively implemented. This structural insight explains why fragmented or isolated digital initiatives often fail to deliver sustainable improvements in export performance. Without strengthening high-impact technologies at the system's core, improvements in downstream processes remain limited and unstable.

Overall, this study's results confirm that improving export marketing performance in the medical equipment industry requires a strategic, integrated approach to digital transformation. The proposed model demonstrates that Industry 4.0 technologies influence export outcomes not only through direct efficiency gains but also by reshaping the structural relationships among marketing, logistics, quality control, and decision-making processes. This systemic perspective provides a more comprehensive explanation for export performance gaps observed in emerging economies and offers a practical roadmap for technology prioritization in resource-constrained SMEs.

In conclusion, this research contributes to both theory and practice by offering a structured, quantitative, and industry-oriented model that clarifies the role of fourth-generation technologies in export marketing performance. For policymakers, the findings highlight the importance of supporting data infrastructure, digital skill development, and technology adoption in export-oriented industries. For managers, the model provides clear guidance on where to invest to achieve the most significant impact on export marketing performance. Future research may extend this model to other industries or examine the dynamic evolution of these relationships over time.

Data Availability Statement

Data available on request from the authors.

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Ethical considerations

The authors avoided data fabrication, falsification, and plagiarism, as well as any form of misconduct.

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Conflict of interest

The authors declare no conflict of interest.

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