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Relational Approaches Related to Digital Supply Chain Management Consolidation

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Abstract: This study provides a specific theoretical–applicative approach, of economic content, containing information and reference data in a logical and relational structure centered on aspects deemed suitable for enhancing the digital performance of the current supply chain management. The objective of the study is to correlate as closely as possible the theoretical scientific content with the practical side, with an emphasis on modernity. This objective led to the scientific interpretation, from a methodological perspective, of a relevant approach that proposes the analysis of several mathematical relationships and a case study that justifies the significance of the essential characteristics in ensuring the viability and resilience of the digitally consolidated Supply Chain Management. The work is particularly of interest and utility to entrepreneurs and managers involved in the construction and effective administration of (already digital) supply chain management, which is undergoing continual digital transformation and consolidation. In addition, this research will enhance the number of specialized sources that may be used for future research in this topic's area of interest.

Keywords: digital transformation; digital supply chain management; smart digital technologies

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1. Introduction

Given the variety, volatility and problems of social, economic, geopolitical and current conflicts, the present and future relevance of digital supply chain management (SCM) becomes essential in the functional stages of "Society 5.0" and "Industry 5.0" [1–3].

As a result of the pandemic and the economic turmoil caused by the Ukrainian conflict, the topic of digital supply chain management is critical and should focus on smart technologies, which are required for continuous and resilient development via appropriate information systems that allow full integration; also the agile, efficient, and sustainable performance of all component organizations within the complex business system [3–5].

The digital transformation is being driven by the added value of new smart digital technologies, which are designed to ensure and determine flexibility, profitability and stability by implementing new business models, achieving and distributing competitive products, and achieving beneficial effects in complex and intelligent digital networks [6,7]. To achieve the proper digital transformation, supply chain organizations must create the essential innovative environment to enable effective action, performance and ongoing progress while maintaining the necessary enthusiasm and confidence. In this way, various other new goals for the future will be realized, including agility, sustainability and resilience [8–10].

If we take the literature as a reference, we notice that the concept of supply chain management has been extensively discussed in connection to digitization. Tsipoulanidis and Nanos [11], for example, examine the significance and influence of digital technology

on supply chain management transformation in their study. They provide a methodology built on the supply chain operations reference (SCOR) model and connected to lean thinking ideas. Using survey data from 272 Chinese manufacturing companies, Wang and Teng [12] examine the relationship between three significant categories of digital innovation (product, platform and service) and business environmental performance. The results show that improvements in digital platforms, products and services all enhance the capacity of supply chains.

The idea of a supply chain digital twin is studied by authors like Barykin [13] and Wang et al. [14] as a smart supply chain that needs connection, visibility and agility in addition to being integrated and intelligent. Wang et al. [14] suggest creating a DT-driven supply chain (DTSC) as a creative and all-inclusive approach to the smart supply chain in their article.

The evolved digitalization of supply–delivery chain management is generally dependent on the complex development of real-time manufacturing processes in accordance with customer requirements; on the necessary and timely realization of circuits and information flows between companies within and outside the business system in order to visualize, in due time, all supply, production and distribution processes; and on predictive analyses of risks that may occur in the supply chain [15,16].

The consolidation of the digital supply chain, on the other hand, is determined by several factors, the most important of which are: the need to develop efficient management skills for new digital technologies; overcoming functional visibility deficiencies encountered; the existence of inefficient working models in the digital system; and replacing many existing digital technologies with inadequate response times to new business requirements and so on [17].

Additionally, a substantial amount of research has been done to evaluate the effectiveness of the digitalized supply chain. The goal of Rasool et al.'s study [18] is to provide a comprehensive literature review on DSC performance measurement criteria in order to comprehend existing approaches, spot gaps, and support potential future research initiatives. According to the findings of Ukko et al. [19], the most important relational mechanisms of performance evaluation in the supply chain for digital services are trust between supply chain participants and knowledge creation through information sharing.

The main determinants of Digital Supply Chain Management performance growth are summarized in Figure 1. The recent socioeconomic transformations, as well as the difficulties and changes brought about by the pandemic and now the conflict in Ukraine, have rendered supply chains (regardless of complexity) increasingly vulnerable owing to inadequacies in sustainability, agility, resilience and overall robustness.

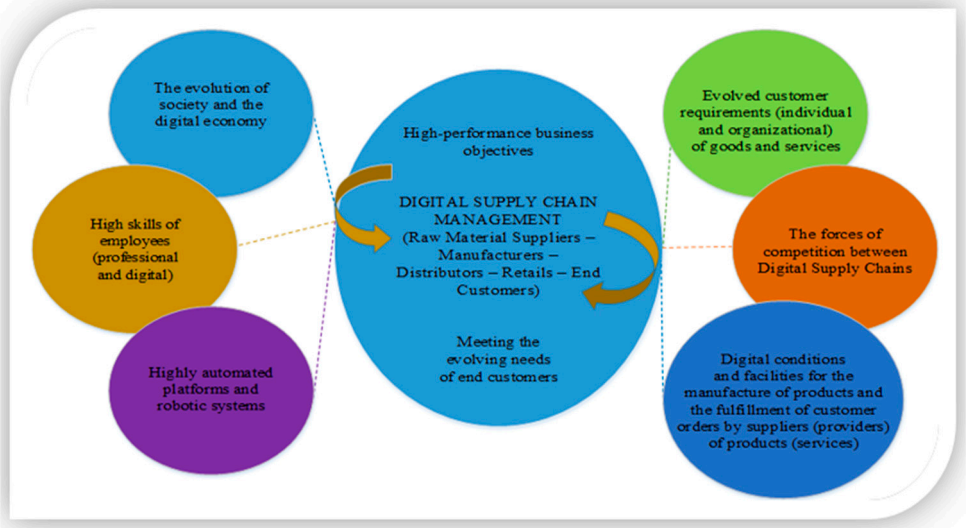

Figure 1. Determinants of Digital Supply Chain Management performance growth.

With all of the benefits of adopting a digital supply chain outlined, other authors have focused their studies on the challenges to its adoption. Agrawal et al. [20], for example, identify the primary barriers to digital supply chain adoption and analyze their interdependence. According to their study, the major impediments to digital supply chain transformation are "lack of industry specific guidelines", "lack of digital skills and talent", and "high implementation and running cost".

Other relevant study directions in the literature are concerned with supply chain resilience; in this sense, Irfan et al. [21] investigate supply chain resilience enhancers. The authors specifically investigate if and how dynamic capabilities and knowledge management might assist organizations in developing a resilient supply chain in times of high disruption and uncertainty. In his research [22], Ivanov proposes a related design and execution framework comprising various dimensions—management, organizational and technological—that might be instructional for supply chain managers looking to manage resilience during pandemic disruptions and employing digital technologies.

The development of strategies for integrating digitalization into manufacturing supply chains is another important study subject. Ho et al. [23] use a case study methodology to gather tacit knowledge from twelve multinational businesses within the theoretical confines of corporate strategy generation. The research's conclusions, and a theoretically developed framework, identify three different sorts of industrial supply networks' digital strategy building methodologies: top–down, bottom–up and mixed approaches.

The interconnection of the supply chain and other topics like human capital, intangible resources, knowledge management and sustainability are discussed in the literature. Environmental factors must increasingly be included in supply chain management study and practice. According to the theoretical framework, authors like Shan and Wang [24] analyze the research that has been done so far on green supply chain management, and their paper provides a thorough review of earlier work on the knowledge area using bibliometric analysis. For instance, Muafi and Sulistio [25] explore and analyze how Green Intellectual Capital (GIC), Supply Chain Integration (SCI), Digital Supply Chain (DSC), Supply Chain Agility (SCA) and Business Performance relate to one another. Their study's main contribution is the finding that supply chain integration, digital supply chains and supply chain agility are all positively impacted by green intellectual capital. The goal of Chen and Jang's study [26] was to investigate a novel kind of carbon-neutral sustainable supply chain network (SSCN). Another group of academics [27] established an evaluation methodology that a company might use to extend sustainability principles to the rest of the supply chain members. Additionally, it has been demonstrated that supply chain integration and digital supply chains affect business success. Schniederjans et al. [28] provide future research inquiries pertaining to how scholars can utilize the largely ignored areas of supply chain digitization, as well as the growing areas, in order to explain how the human dimension of supply chain management can be further explored for the purposes of optimizing supply chain digital performance. They do this by applying a knowledge management theoretical framework to supply chain management. To better understand how the human aspect of supply chain management can be further explored to improve supply chain digital performance, Schniederjans et al. [28] offer future research inquiries that make use of both the growing and largely untapped areas of supply chain digitization.

Another topic of interest in the field is spare parts supply chains (SC), because a well-designed SC may save costs and boost the competitiveness of spare parts retailers [29]. Cantini et al.'s [29] study, for example, assists managers and practitioners in developing their spare parts SCs by specifying the configuration of the spare parts SC and the manufacturing technology to be used through the creation of a decision support system (DSS). In a similar manner, Peron et al. [30] examine the impact of uncertain failure rate estimations on the optimum inventory level and the overall spare parts management costs. The findings showed that failure rate uncertainties had exponentially increasing effects on both the optimal inventory level and the overall costs of spare parts management, resulting in a divergence up to 250 percent for both.

The researchers' findings indicate that digitalization and sustainable supply chain management have complementary benefits. For instance, Zekhnini et al. [31] analyze the most recent research on the effectiveness of sustainable and digital supply chain management. The relationship between digital technologies, lean, green, sustainability and supply chain efficiency is examined by the writers. Mahroof et al.'s paper [32] provides a consolidated strategy for examining the potential role of digital technology in sustainable supply chain management for the sustainable performance of food supply chain firms via the lens of the circular economy principles. According to Tseng et al.'s results [7], four elements—effectiveness of digital platforms, digital communication from the standpoint of supply chain digitization, working circumstances and manufacturing procedures—are essential to sustainable supply chain management.

Even though there has been a body of research on digital supply chain management completed and published recently (in addition to the studies stated above, we can also name other recent studies [33–35]), it is important to focus this study on the crucial aspects of its consolidation. This study's scientific approach is one of the few that focuses on the specifics, connections, relationships, correlations, dependencies and interdependencies of concepts, systems, functions, physical and information flows, and so on, with the goal of revealing a truly efficient and consolidated functional synergy within an evolved digital supply chain. To that end, we assume that it is critical to implement a true digital transformation with sustainable benefits and resilient implications on supply chain management processes, activities and value flows by procuring and deploying smart digital technologies and integrating them with other technological and robotic systems within the complex business systems. All of this requires us to link theoretical aspects with elements appropriate to practical implementation.

The purpose of this research, is to develop a theoretical–applicative model that discloses innovative methods and techniques required for the functional, high-performance consolidation of the management of the digital supply–delivery chain.

This study used a mixed methodological approach to capture the entire picture of the challenges under discussion, integrating, analyzing and connecting broad theoretical knowledge on the strengthening of digital supply chain management using scientific research methods such as observation, analysis, comparison, induction, deduction, interpretation and case study.

To gather information relevant to the research, we performed broad analyses of the international literature utilizing the method of induction. We verified the concepts addressed using the deduction-specific method and phenomenon analysis to present our own opinions on the topic, and find solutions to the issue of strengthening supply chain management in response to economic development vulnerabilities caused by current challenges, disturbances and threats. In this regard, the article proposes a theoretical framework for defining relational considerations in the context of further evolution of digital supply chain management, given the role and importance of new digital technologies with a particular impact on increasing agility, resilience and robustness. Simultaneously, the data obtained through the deduction approach enabled us to develop mathematical relationships and the case study, as well as relevant conclusions and suggestions.

The contributions of this paper are based on the obtained results: first the theoretical considerations directly connected to the practical part of the study, supported by relevant figures and mathematical relationships that reflect elements of the digital supply chain management consolidation. Following that, we conducted a case study of a hypothetical situation that reflects the possibility of selecting an appropriate solution for the acquisition, installation, verification and full operation of a smart digital system to effectively consolidate the digital supply chain management mechanism.

This study will be useful for documentation analysis and assessment, including key highlights, in order to generate new predictions and scientific advances in the field of intelligent and efficient digital supply chain management operations.

In order to conduct research consistent with the topic of this article, it was necessary to answer the three essential questions listed below:

Why is it vital to continue digitizing supply chain management under the current circumstances and future challenges?

Does the fast growth of technological innovations and developments have a relationally transformative impact on the digital supply chain management components?

Does consolidation of digital supply chain management promote robustness, agility and resilience?

With regard to the above indicated questions, we began with the following questions in order to establish the methodological aspect of the research.

Can the resilience, agility and performance characteristics of digital consolidated supply chain management be highlighted and relationally aware?

Is it possible to find, select and implement a solution to improve digital supply chain management?

To answer the questions posed, we formulated the scientific research objectives aimed at: the importance of digital supply chain management; determining aspects of the evolution and functional consolidation of digital supply chain management; classifications developed by experts of some performing companies utilizing digital supply chain management; relational elements regarding the functional consolidation of digital supply chain management; information management within consolidated digital SCM; building appropriate mathematical relationships to strengthen the management of the digital supply chain; and developing a case study on the selection and implementation of the optimal and timely solution necessary to strengthen the management of the digital supply chain.

Due to the scarcity of documentary sources on the specific topic of strengthening the management of the digital supply–delivery chain, we intend this research to be particularly relevant and of interest to business people both theoretically and practically, because the results can add value to their economic activities by increasing institutional performance, particularly in the current conditions of a severe economic crisis on the global scale due to the ongoing conflict in Ukraine.

This article is organized as follows: Section 2 focuses on concepts and connections that are appropriately dimensioned to some of the research's major theoretical findings regarding the importance of digital supply chain management, the necessary actions for evolution and functional consolidation of digital SCM, and on the classification of high-performing organizations using digital SCM. Section 3 clarifies and defines the authors' theoretical-applied conception and presents the research methodology, based on theoretical and practical advancements. The graphic schemes and figures used by the authors support the scientific content of the two previously stated Chapters. The study's findings, limits of research and conclusions are detailed in the article's last parts.

2. The General Theoretical Framework of the Research

The following section of the research highlights relevant information and data on the importance and need to strengthen digital supply chain management, the necessary actions for the evolution and functional consolidation of digital SCM, and the classification of high-performing organizations using digital SCM.

2.1. The Importance of Digital Supply Chain Management

As a result of the large-scale implementation of digitalization in supply chain management, the inter-organizational linkages within the business system have been considerably enhanced, due to: the rapid collection of a large volume of information and data; efficient and continuous network connectivity both indoors and outdoors; the possibilities of continuous analysis of information and data that are necessary for making timely decisions specific to transactions, as well as for the creation of continuous inflows–outflows into/from the system; increasing the beneficial collaboration between the internal and external actors of the supply chain, in order to fully satisfy the clients' requirements, etc. [36].

These factors must enable and ensure, based on an evolved digital infrastructure, those dimensions that will strengthen the integration and efficient functioning of the components of digital supply chain management and increase its resilience to any challenges and disruptions. In light of the requirement for digital consolidation, Figure 2 illustrates the necessary dimensions to achieve this purpose.

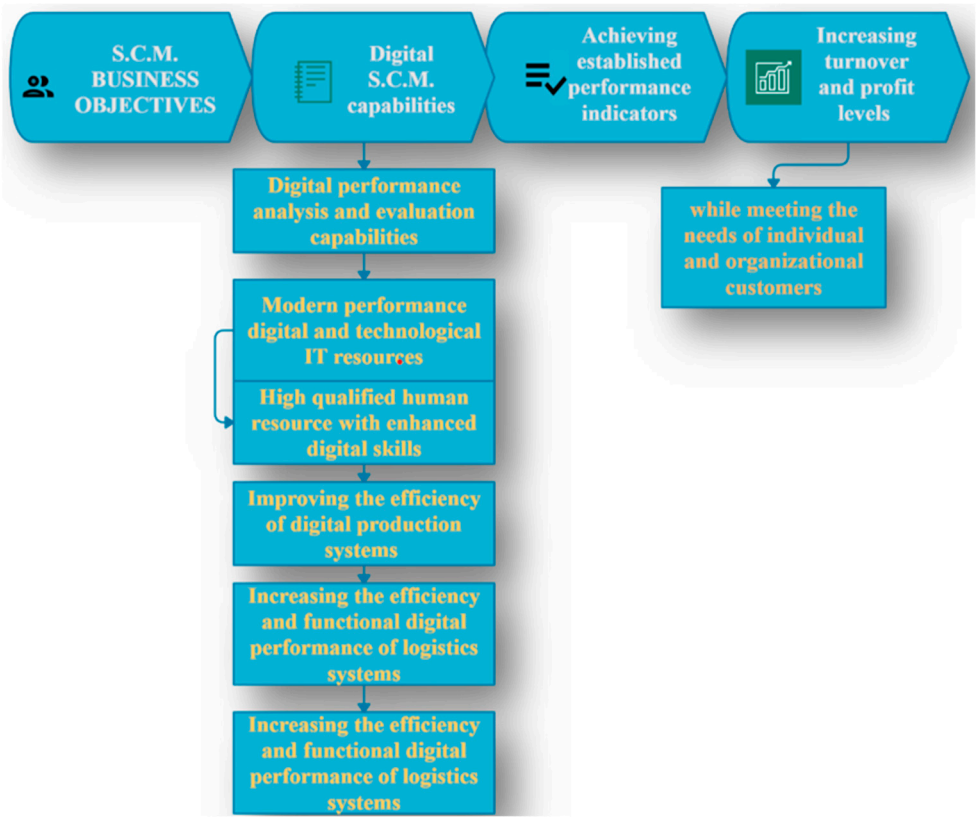

Figure 2. Supply chain management digitalization dimensions.

According to International Finance Corporation (IFC) specialists [37], the expansion of the digital functional mechanism of supply chain management involves various critical variables (derived from the research [37]) that impact the integration of its functions and components, which are as follows:

- "Visibility" reflects the established exchange of information, in a digitalized system, between the partners within the supply–delivery chain;
- "Trust" reveals strict exchanges of information and data to achieve levels of digital relationships and interaction that are necessary to achieve common goals within the business system;
- "Sustainability" highlights the viability and fairness of transactions in the digital system of the supply chain, for all partner companies;
- "Efficiency and standards" reveal the continuous observance of the principles imposed by standards, transparency and business ethics in the structure of the digital supply chain, to ensure the necessary collaboration, full functioning and performance [37].

As a result, modern supply chain management possesses and develops complex operations focused on several key elements, respectively: transparent information, circuits and complex information flows; continuous physical and financial flows in accordance with the transactional requirements designed and carried out with internal and external organizational actors; agility and skills to enable the development of strategies, policies, techniques and methods for sustainable, continuous, resilient and efficient operation at performance levels dictated by competitive market forces [38].

Based on what has been shown, it is apparent that supply chain management has evolved into a contemporary and efficient tool for resource management, integrated logistics management and process optimization. To completely fulfill customer requirements, all of this has been, and continues to be, feasible through the use of innovative digital technologies with favorable decision-making impact. As an important part of digital SCM, logistics benefits from important facilities through digitization for its efficient operation in support of immediate satisfaction of current and potential customer requirements, as can be essentially noted in Figure 3.

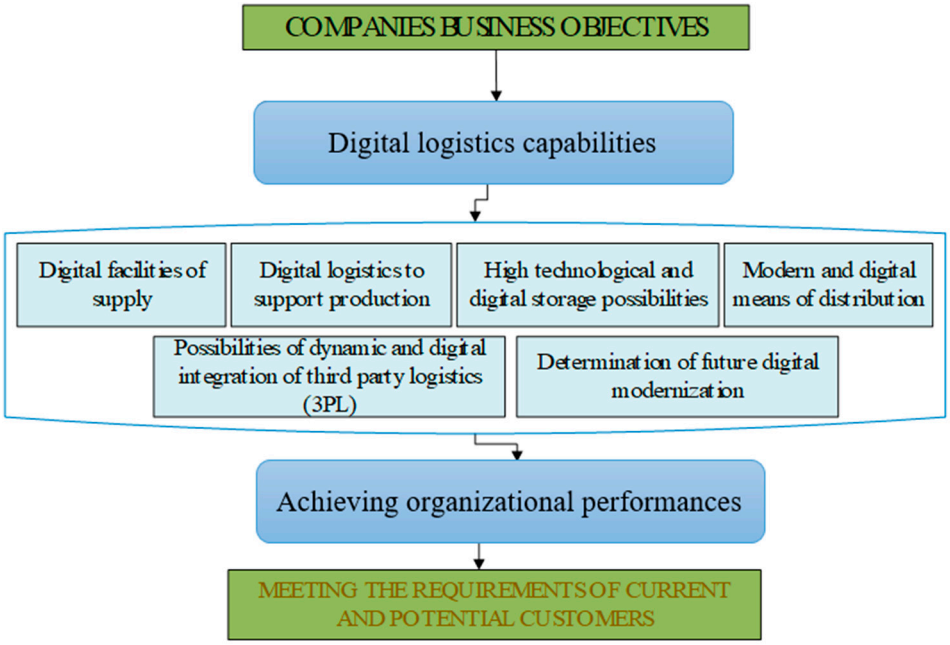

Figure 3. Digital logistics facilities within supply chain management.

In this framework geared toward competitiveness and performance, digital supply chain management seeks to evaluate efficiency by accomplishing those excellence goals that must be met simultaneously:

- Connection, i.e., adequate communications between the system components, as well as between them and the external environment, by ensuring all digital devices and interconnected processes;
- Information, through a complex informational system that facilitates inputs, processing, timely capitalization and outputs of information to the beneficiaries of the microenvironment and macroenvironment of supply chain management;
- Smart mechanism, which allows capabilities and rapid actions of advanced analysis for decision-making and real-time business process management;
- Automation using robots and other advanced technological systems to gain a competitive advantage over competitors by increasing productivity and reducing costs in the reference market or markets [39].

The local, zonal, national, or global positioning of a modern supply chain with advanced digital capabilities is dependent on its consolidated operation and on the successes achieved in its business. It explains, from our point of view, the sustainable digital capabilities of supply chain management to enable long-term value to be achieved, given both market conditions and the environments in which it operates (social, economic, political, natural, ecological, legislative), being in continuous competition with other comparable supply chains [40].

2.2. Actions That Are Required for the Evolution and Functional Consolidation of Digital Supply Chain Management

Because of the increasing demand for high-quality products and services, as well as the requirement to distribute/deliver them at the right places and times, the growth of the knowledge-based society has necessitated the modernization of supply chain management. The need to achieve the objectives of increasing the visibility and sustainability of processes within a supply chain has led to the transition to the advanced digitization phase of operations in its components. To boost efficiency and satisfy business performance objectives, this transition has entailed and involves the design and development of digital data development, communications integration and automation (extended or sequential).

According to the Association for Supply Chain Management, based on the opinions of professionals and practitioners in the field [15], efficient digital supply chain management requires advanced technologies for automation, integration and visibility of all processes, ensuring: the identification and collection (capture) of data of interest; the safe conduct of necessary communications; rapid analysis and relevant decision making; the design and execution of transactions in full accordance with customer requirements; improving all facilities dependent on speed, high quality and affordable costs; carrying out all operations specific to the SCM components based on real, up-to-date, relevant and sufficient information and data, which allow specialized personnel and robots multiple possibilities of analysis, evaluations and decisions appropriate to the business stages; fast, intelligent, adaptable and resilient action capabilities within and between partner firms [15].

Following the study of the digitalization phase over the past three years, experts in the area [15,41] have analyzed and evaluated the appropriate transformations of this mechanism in supply chain management, comprehending both the benefits and drawbacks of this aspect in the context of prolonged pandemic risks.

Over time, in the SCM, in addition to insufficient digitization and inadequate practices to provide management adapted to the requirements, based on the analyses and practical evaluations of McKinsey experts [41], it was determined that inside the SCM functional processes of firms, a number of syncopes with an influence on the efficient digital functioning may occur, mostly affecting scenarios such as:

- The existence of digital technical systems, supported by a small number of well-motivated professionals, is insufficient for the execution of complicated (digital) profile procedures in line with the constraints imposed by the business's complexity;
- The evolved digitalization only of some important functional segments from the staff of the partner companies of a supply–delivery chain, which did not determine an efficient holistic digital operation for the entire business system;
- The use of external (digitized) services for the creation of complicated SCM processes, which prohibited additional investments in digitization, training and skills development by field-based employees;
- Manifestation of deficiencies in business planning within SCM, due to the non-existence of a high-performance digital infrastructure;
- Despite the availability of modern digital infrastructure, some or all digitized business operations were carried out inefficiently, necessitating significant changes in the future;
- The absence of constant communication between the structures responsible for digital integration within the SCM components led to the non-optimal attainment of the efficiency metrics set by digitalization within the relevant business systems [41].

As a result, not all organizations now have the necessary technological resources to achieve evident visibility in supply chain management, and as a result, there are constraints in the effective use of resources and proper funding. In order to completely fulfill consumer expectations, supply chain managers will examine not only advancing technology developments but also their optimal integration into the design and operation of future digital businesses. To that aim, researchers (as Sharma and Timmermans [42]) anticipate that by 2023, 86 percent of organizations focused on innovation and future success

will have invested adequately in high technology for the digital, sustainable growth of corporate infrastructure.

The term "digital transformation" has been increasingly popular in recent years, and it will have a significant influence on the evolutions indicated by the application of the concepts of "Society 5.0" and "Industry 5.0" According to authors like Gezgin et al., 2017 [43], the digital transformation of the supply chain (both holistically and at the component level) reveals an appropriate strategy and policies on how digital technologies and applications (both existing and to be acquired) will improve the level of services, costs, agility and storage, as well as changes (of an organizational and procedural nature) required to achieve operational excellence.

Therefore, the digital technological advance (determined by the digital transformation) in the efficient operation, adapted to the new requirements of the supply chain management, represents a strategic objective determined mainly by: the need to bring closer to customers both production companies and those distributing through new business models, which would allow a growth potential through the superior capitalization of resources; increasing the complexity of products and services in accordance with the requirements and behavior of consumers and users; the need for digital interfaces evolved in the activities of supplier relationship management and customer relationship management; the continuous increase in competition determined by the new emerging companies that have implemented the digitalized business models; optimizing the processes of information and data analysis, increasing the visibility inside the SCM components and as such for efficient acceleration of all input–output flows in/from the business system; increased possibilities to anticipate, prevent, avoid and counteract functional interruptions within the SCM; developing the personnel training—both management and on execution—of all specific actions through the use of new, hyper-digitized and automated technologies [44].

2.3. Determinations and Classifications of High-Performing Organizations Using Digital Supply Chain Management

If we previously emphasized the recommended factors about the necessity to enhance functional supply chain management by raising the level of digitization, we will now provide similar facts on the recognition of digital SCM performance among globally categorized organizations.

Due to the superior performance obtained through supply chains, Gartner (mentioned in [45]) has globally classified in 2021 (based on the size of the "composite score" obtained in at least seven of the ten years evaluated), as "examples of excellence", five companies depending on the fulfillment of the strategic objectives regarding digitalization, agility, resilience, robustness, transparency, business ethics, etc. They were located as follows: Apple; Amazon; McDonald's; P&G; and Unilever [45].

In addition to the mentioned companies, for the efficient operation of the supply–delivery chains, Gartner classified in 2021 (mentioned in [45]), based on the determined Composite Score, another twenty-five renowned companies. According to our analysis of individual performance, the following essential elements were encountered differently and were taken into account in the evaluation: digitization; agility; resilience; innovation; investments in new technologies; sustainability; the importance and value of customers; energy saving; production efficiency; warehouse management; packaging recycling, etc. Based on the mentioned classification, it results that the first ten places were located, according to the individual values of the Composite Score, with these companies: Cisco Systems = 6.37; Colgate-Palmolive = 5.58; Johnson & Johnson = 5.22; Schneider Electric = 5.07; Nestlé = 4.41; Intel = 4.40; PepsiCo = 4.37; Walmart = 4.23; L'Oréal = 4.05; Alibaba = 3.90.

According to the conception of the Gartner investigators (mentioned in [45]), the formula for determining the Composite Score included as elements: Peer Opinion; Gartner Opinion; Three-Year Weighted ROPA (ROPA = operating income/net property, plant, equipment, inventory); Inventory Turns; Three-Year Weighted Revenue Growth; ESG Component Score; and 2020 data used where available. Each of these elements was weighted by

a predetermined percentage and the individual determinations were calculated, resulting in the final value for each company analyzed and evaluated.

Following our analysis of the information and data published by Gartner (mentioned in [45]), it results that the inclusion of the best-performing companies (worldwide) in the top 25 in 2021 according to the performance obtained in their supply chains is relevant for other companies primarily for:

- Achieving the objectives appropriate to its own digitization;
- Achieving the necessary parameters of agility and resilience to face any risks and challenges in business;
- Investments in new technologies for innovation and sustainability [46].

All of this will determine for SCM (of the interested companies) flexibility, robustness, elimination or avoidance as much as possible of vulnerabilities and achieving success in the business of the future, even in the conditions of complex crisis profiled on the short and medium-term horizon.

3. Materials and Methods

The requirement to expose a high scientific content in the study prompted us to employ a number of appropriate research methods to gather the essential information and data, as well as their logical, eloquent and beneficial relationship to get the anticipated research outcomes, as specified.

3.1. Research Methods

In order to capture the whole picture of the challenges under discussion, this study employed a mixed approach in which broad theoretical knowledge on the strengthening of digital supply chain management was integrated, analyzed and connected, using scientific research methods such as observation, analysis, comparison, induction, deduction, interpretation and case study.

The research process determined us to use, with a certain overlap, two of the mentioned methods, namely induction and deduction. In using the specific method of induction, we conducted extensive reviews of the international literature to identify the concepts used and case studies in order to collect information relevant to the research. Using the deduction-specific method, we verified the concepts treated based on additional literature, using the phenomenon analysis to present our own opinions on the topic and finding solutions to the issue of strengthening supply chain management in response to economic development vulnerabilities under the impact of current challenges, disturbances and threats. At the same time, the results obtained by using the deduction method allowed us to formulate mathematical relations, the case study, as well as the appropriate conclusions and proposals.

By using the other methods, namely observation, analysis and comparison, we have identified some aspects and concrete theoretical relationships looking at the further evolution of digital supply chain management, given the role and importance of new digital technologies with a special impact on increasing agility, its resilience and robustness.

3.2. Research Results

Depending on the objectives of our scientific research, we considered that in this framework we should highlight, as results obtained, first the theoretical considerations directly related to the practical part of the study, supported by relevant figures and mathematical relationships that reflect elements of the consolidation of the digital supply chain management. Next, we conducted a case study of a hypothetical situation that reflects the possibility of selecting an adequate solution for the acquisition, installation, verification and full operation of a smart digital system to effectively consolidate the mechanism of digital supply chain management.

3.2.1. Relational Considerations Regarding the Consolidation of the Digital Supply Chain Management

The vulnerabilities caused by the present crises, in our opinion, indicate that the success of digital supply chain management is directly reliant on the holistic resilience of this mechanism. The main determinants of the digital supply chain management resilience are presented in Figure 4. Therefore, the engagement of the evolved digital capabilities of the supply chain must determine, according to our assessment, its uninterrupted functionality under the conditions of adequate and continuous management of risk factors. In critical situations, the capabilities related to automated and robotic systems must allow avoiding as much as possible the action of disruptive factors in the operation of the digital supply chain, but also the return in a short time to the initial functional parameters [47,48].

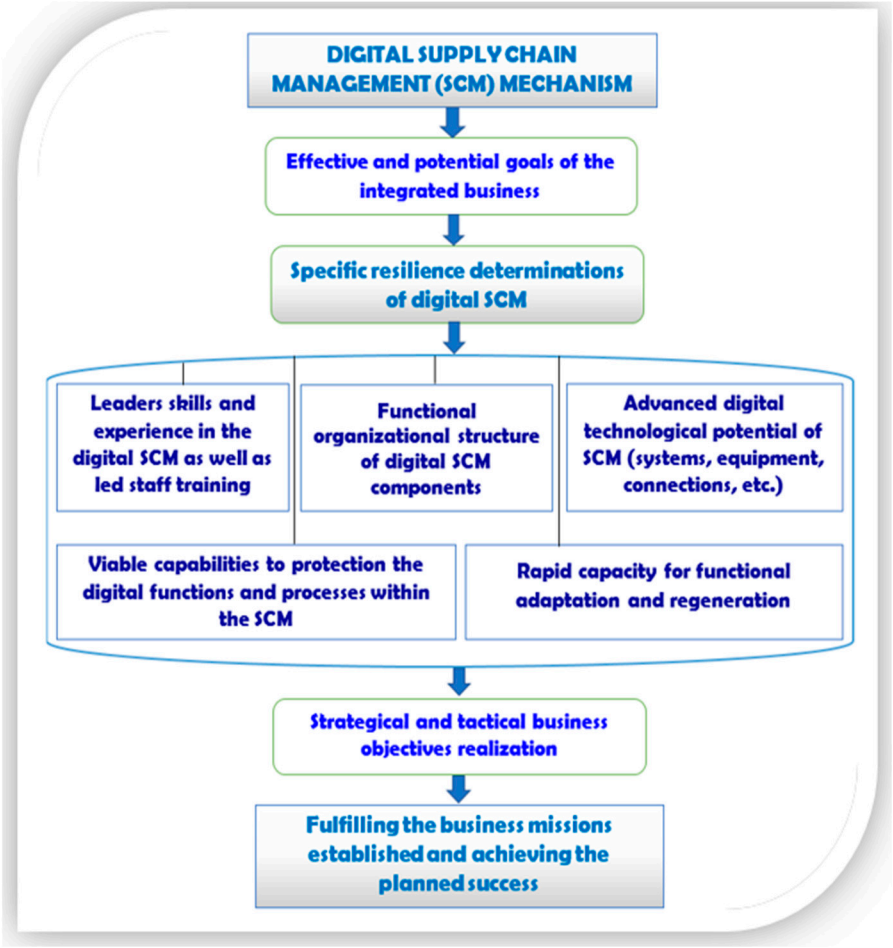

Figure 4. Determinants of the digital supply chain management resilience.

Continuous market demands and turbulences in recent years have resulted in the development and modernization of modern supply chain infrastructure to install smart digital technology, which are and will be systemically integrated with intelligent automated platforms, complex ERP (which can integrate other platforms, such as EDI, ECR, B2B, etc.) [5].

In this evolving functional digital framework, an appropriate scientific approach to supply chain management is needed to highlight increased flexibility and resilience in line with the vulnerabilities and economic threats posed by the current conflicts. This desideratum is possible, precisely by understanding the intelligent and feasible operation of the digital supply chain to respond continuously, effectively and efficiently to the new challenges generated by economic disturbances and crises, as shown in Figure 5.

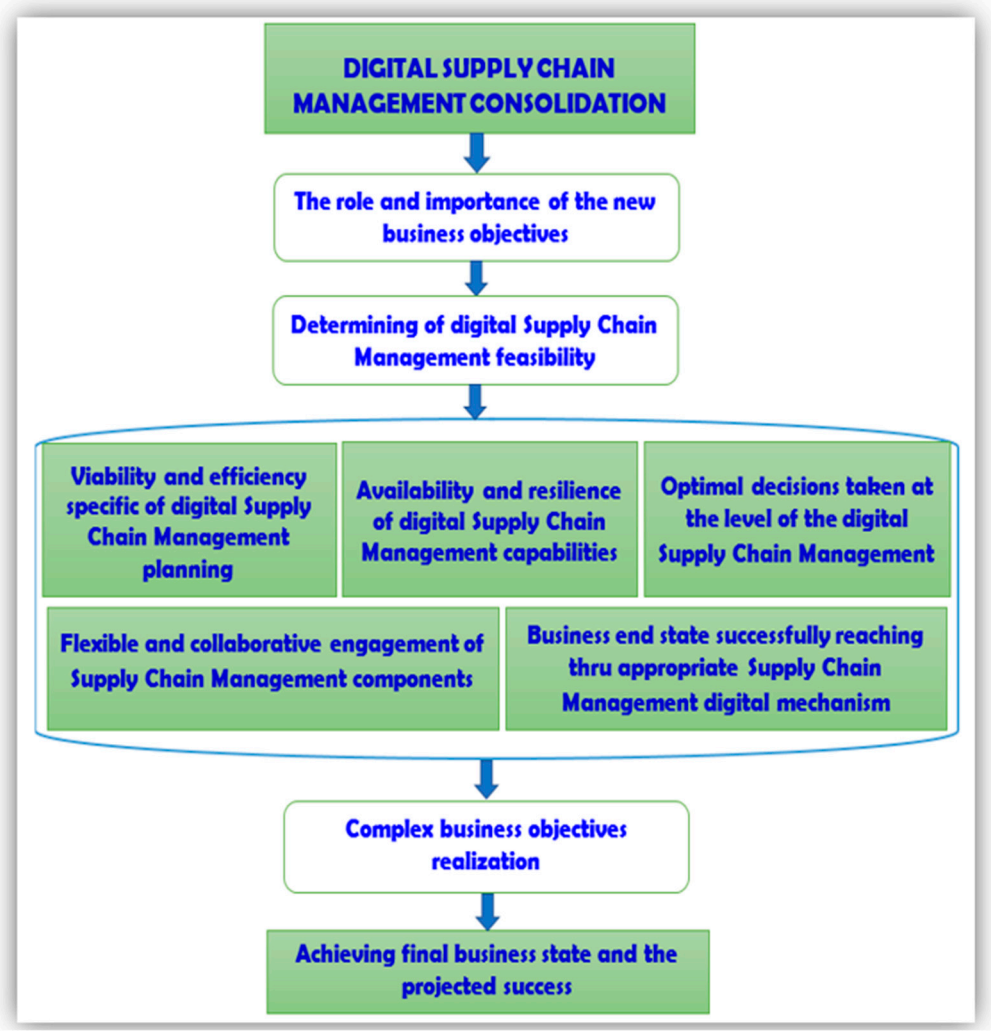

Figure 5. The business success determination through consolidated functional processes within digital supply chain management.

To fulfill the exact requirements of present and prospective consumers, the evolved and complex mechanism of digital supply chain management requires the application of ideas with a major role, connected and interdependent in the effective operation of the business system. According to Gartner researchers (mentioned in [45]), global economic changes and transformations show that in order to achieve future business performance goals, digital supply chain management must be configured by implementing those options that will determine and enable the agility, sustainability and resilience necessary for systemic operation in inefficient conditions, even if it is be disrupted or interrupted. The result, according to the mentioned researchers, is an advancement of "digital maturity", within the management of the supply chain, over a period of several years (3 to 5), through the continuous adoption of new technologies, focused mainly on IT [49].

Agility in the supply chain reveals the ability of partner companies in the business system to perceive and respond quickly (according to the quick concept of "sense and response") to functional changes through reconfigurations in the mechanism of collaborative employment of resources to provision [50]. From our point of view, to achieve the agility adequate to the modern supply chain management, it is necessary to continue its intelligent digitization to reach the parameters of efficient operation and cyber protection of operations performed at the level of partner companies and integrated in the digital operating system of that business (Figure 6).

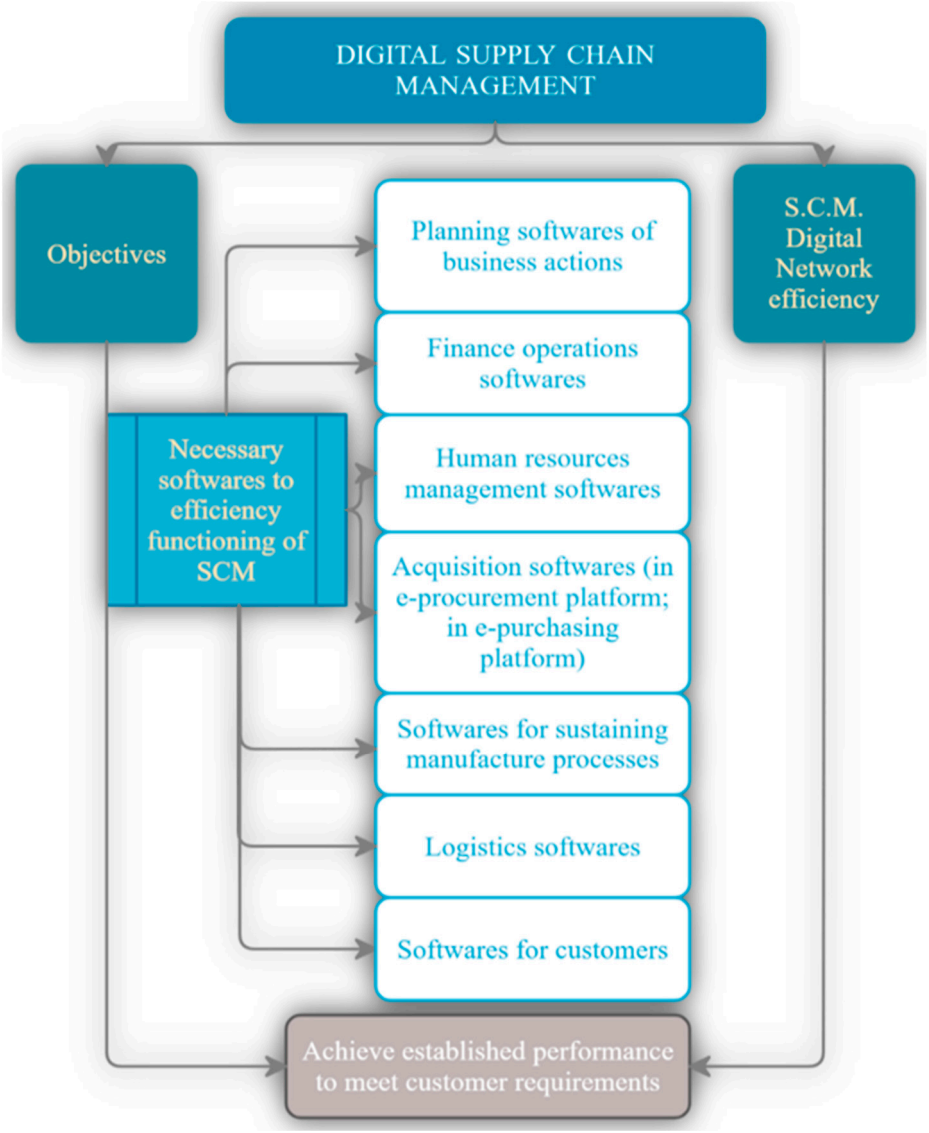

Figure 6. Intelligent digital tools for optimal supply chain management.

It is obvious that the efficient functioning of the digital supply chain management requires the efficient engagement of a consolidated system of interdependent systems, meant to design and realize digital transaction flows, efficient and continuous, for the full and beneficial satisfaction of current and potential customer requirements. To this end, authors like Kechagias et al., 2021 [51], point to the need to implement a systemic thinking philosophy for the implementation, especially in high-risk conditions, of the functions and operations specific to production companies in digital supply chains.

In the current socio-economic developments, the realization, acquisition and installation in an organized way by companies of evolved, sustainable and resilient digital capabilities determine an increased potential for the management of the supply chain that allows it to reduce as much as possible the risks of interruption of direct and reverse flows from the business system [15]. Of particular importance in this regard is the implementation of evolved digital traceability within the digital supply chain, as shown in Figure 7.

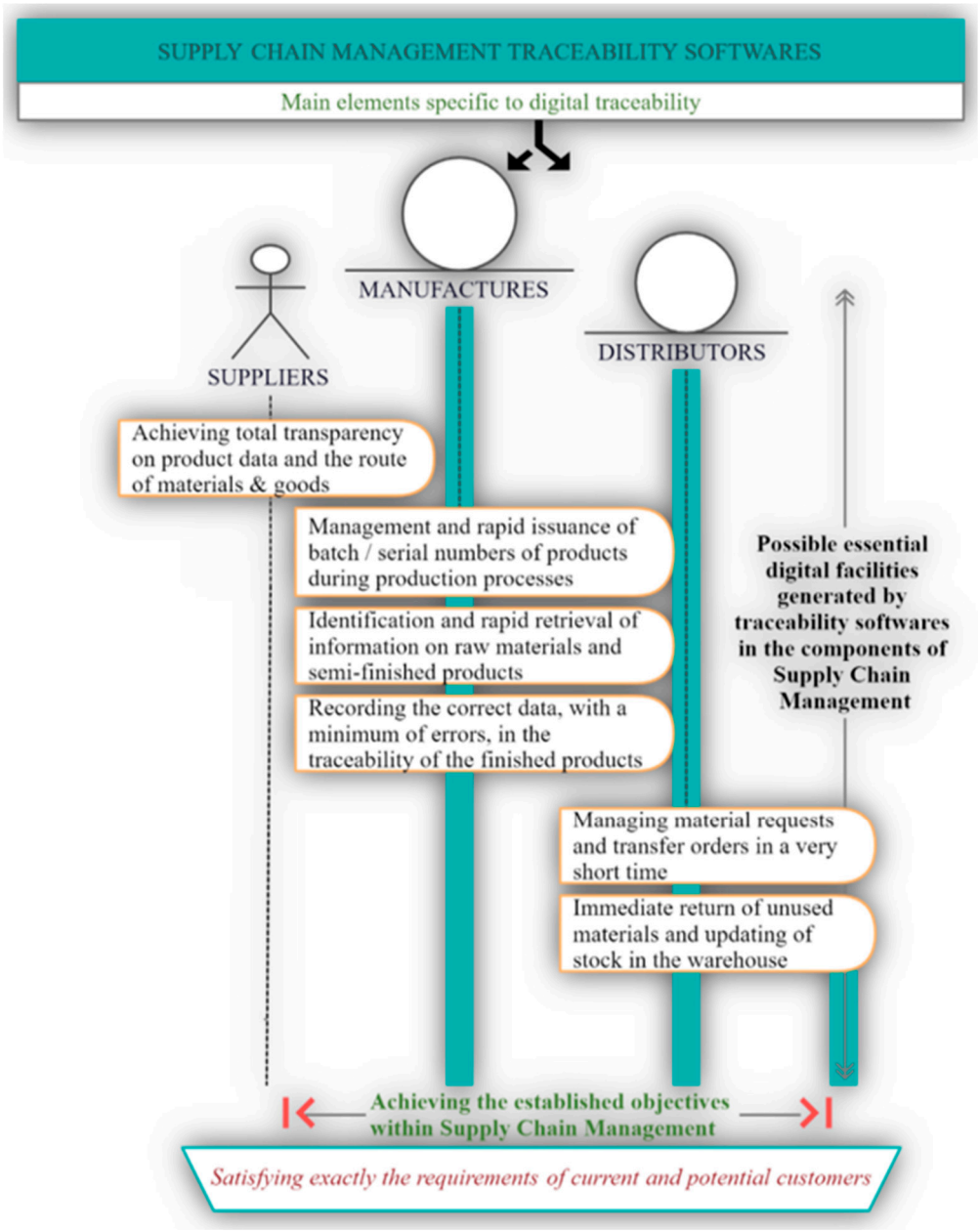

Figure 7. The importance traceability for increasing the visibility within Supply Chain Management.

For example, Johnston [52] found that the reduction in the supply (due to risk factors) of large, listed companies, leads to a 10% reduction in equity (measured by the share price). This disruption in the supply chain has an impact on the market balance, as it causes an average reduction in sales of approx. 7%, an increase in the level of costs by 11%, but also an increase of up to 14% in the level of stocks. It is clear that timely investment in smart IT technologies will lead to increased digital facilities, which will allow increased opportunities to employ alternative sources of supply, immediate order fulfillment and customer loyalty.

The impact of the ongoing development of digital technologies with connections to robotics, automation and information and communication technology (ICT) that are direct and integrative will make it easier to design and develop procedures for the strengthening of the digital CSM through a "integration-information-performance" mechanism [53], which will allow the creation of visions centered on the acquisition, effective utilization and adequate realization of finished products and their distribution at optimal times, consistent

with the immediate demands and urgencies of current and potential consumers and users. For this reason, changes will be made to the digital CSM that will increase functional performances through the dependent use of cyber–physical production systems, highly intelligent communications, big data, artificial intelligence etc., all of which are closely related to the unique characteristics of smart business, virtual reality and the viability of the environment [54].

Therefore, in the management of the digital supply chain, there is a need to continuously increase the functional potential of the component systems, to facilitate their resilient operation by preventing the risk of interruptions due to disruption caused by shortages of material and energy resources, also considering the consequences of conflict relations and economic bottlenecks generated by the war in Ukraine and beyond.

We suggest that from a managerial standpoint, a consolidated digital supply chain enables a number of facilities that primarily aim at: setting objectives, developing strategies, policies, plans and programs in accordance with opportunities, emergency situations and ensuring process and operation resilience (internal and between business partners); the design and implementation in a much more evolved and efficient form of specific managerial functions; facilitating decision-making processes both within each partner company and at the level of the entire business system; a quick holistic approach for managers within the business system by immediately and continuously updating data and information from the dashboards, necessary to manage and monitor all operations planned and actually carried out within the SCM components; increasing the visibility and efficiency of material and value flows inside and outside the business system etc.

We will provide some comments on information management integrated into digital consolidated SCM in the following sections.

3.2.2. Considerations Regarding Appropriate Information Management within Consolidated Digital SCM

The consolidated digital SCM facilities allow continuous flows of information, finances and commodities, which determines a very well-coordinated management and execution mindset in order to minimize loss-generating syncopes in customer relations, as a result of the immediate non-fulfillment of their requirements.

Intelligent technologies, integrated into the system of digital strengthening of SCM, involve qualified and multi-skilled professionals both in the field of ICT and in the specific economic field of evolved digital SCM.

This economic-technical (or technical-economic) relationship is absolutely useful for the effective design and development of the mentioned flows. In this sense, particularly important, within the consolidated digital SCM, are customer relationship management (CRM) and supplier relationship management (SRM; as can be seen in Figure 8). As a result, one may talk broadly of an existing consolidated digital SCM-specific information management system with two essential components (which must be compatible and very well interconnected): (a) upstream—from suppliers (sub-suppliers) to producer (producers); (b) downstream—from the producer (producers) through distributors to the final customers (individual or organizational). To this end, there are smart, digital and automated modes of communication, relationship, transmission and receipt of logistical, financial, production, distribution and other information for and between the two mentioned essential components.

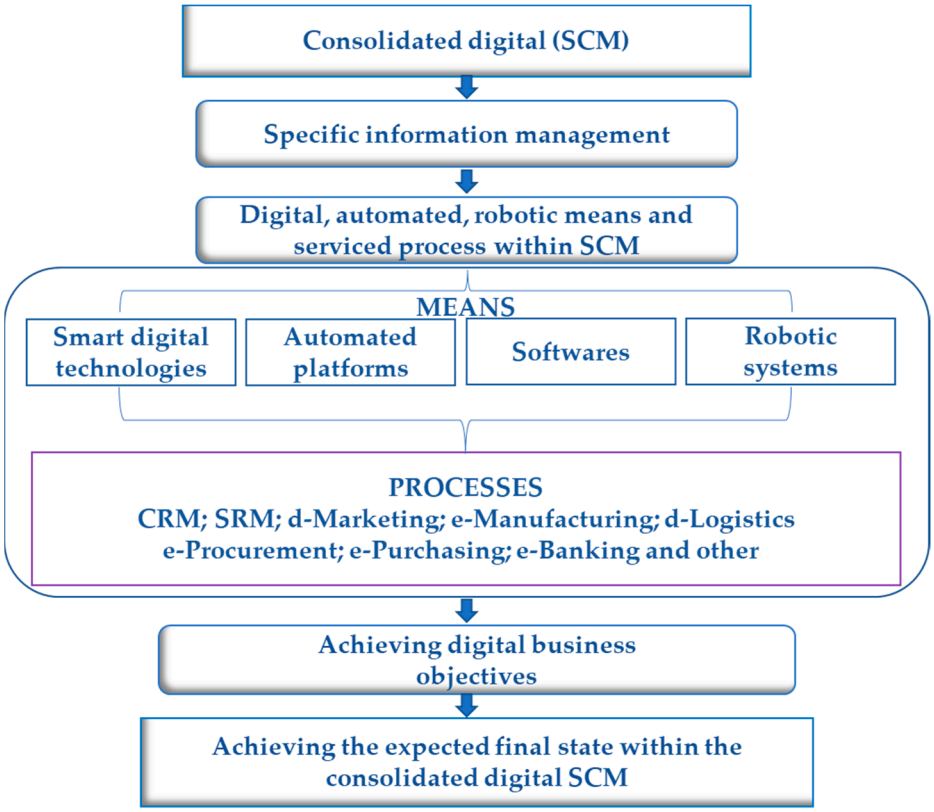

Figure 8. Information management elements integrated in the consolidated digital SCM.

The particular aspects of the realization of continuous information flows and circuits within the evolved digital SCM involve intelligent technological systems, automated platforms (such as ERP, EDI or specific e-Commerce), software and robotic systems intendend for complex operations. These determine and allow connected and interconnected digital processes (with the digital level given by the abbreviations d. or e.) for example d-Marketing, d-Manufacturing; d-Logistics, e-Procurement, e-Purchasing, e-Banking (specifically transactional) and other—as shown in Figure 8. Along with automated platforms and computers, robots, software, storage media and means of connecting and establishing networks are required for the operation of the entire information system specific to the consolidated digital SCM, with the realization of all the facilities of communicating, relating and transacting throughout the evolved digital supply chain.

All of these elements, which are distinctive to the consolidated digital SCM, must be organized, managed and controlled in order to make better use of digitization directly related to automation and robotization, so that the required agility, sustainability, robustness and resiliency parameters are met for the successful operation of a complex business system (according to the modern SCM).

3.2.3. Proposed Mathematical Relationships to Strengthen Digital Supply Chain Management

Based on the above, we appreciate that digitalization increases the resilience and agility of the supply chain system in adequate risk management conditions. Therefore, we consider that the effect of continuous and efficient digitization (expressed in value), necessary to strengthen the management of the supply–delivery chain (Dce.SCM) is determined by several essential impact factors, such as:

- Digital business facilities achieved through digital consolidated SCM (Fa.; for example, the surplus (value) resulting in turnover determined in a certain period of time, as a result of digital transformation);

- The average value level of the digitization achieved within the SCM, resulting by summing the value levels of each component (Dav; represents a constant resulting from the ratio of the two value states of the system, ie: high digitized SCM/lower digitized SCM; it reflects the expenses (efforts) made in order to strengthen the digital SCM);
- The value level of losses related to all risks manifested in the operation of the digital consolidated SCM in local, zonal or global environments (Ll; for example, some interruptions in the operation of new digital systems, with an impact on the performance of digitally consolidated SCM).

Therefore, according to our analysis and evaluation, the following relation results:

$$Dce.SCM = Fdb \times Dav - Ll \quad (1)$$

For example, if the efficiency of the previous digitization is assessed inside the digitally consolidated supply–chain management "*M*" after the development of the planned business over a period of 1 year, the following may occur:

- The income obtained in 2021, Ic1/2022 = 1.4 billion EUR (the digital transformation of SCM takes place);
- The income obtained in 2022, Ic2/2022 = 2.1 billion EUR;
- Value of technological systems/previous digitization, Vts1 = 130 million EUR;
- Value of technological systems/digital consolidation, Vts2 = 270 million EUR;
- Associated risks, Ll = 0.
- The elements in formula (1) presented above have the following configuration:

$$Fdb = Ic2 - Ic1 \quad (2)$$

$$Dav = Vts1/Vts2 \quad (3)$$

According to what was stated, the formula is further refined.

$$Dce.SCM = (Ic2 - Ic1) \times Vts1/Vts2 - Ll = (2.1 - 1.4) \times 0.270/0.130 - 0 = 0.70 \times 2.07 = 1.01 \text{ billion EUR} \quad (4)$$

The mathematical result explains that the new digital system enabled an increase of approximately 44.28 percent (determined on the basis of the following relationships of highlighting and verification of the resulting percentage surplus value: (a) 1.01: $0.7 \times 100 - 100$ or (b) $1.01 - 0.70 = 0.31$; result: 0.31: 0.70×100) over the surplus of income obtained within the digital SCM "*M*" in 2022, a value found within the total income obtained (of 2.4 billion EUR).

Recognizing that revenue and profit are primarily generated by the production and distribution components of the digital supply–delivery chain, it is essential to reduce all expenses as much as possible. The realization of the digital consolidation of the SCM will contribute significantly to this framework, as evidenced by the percentage highlighting of the outcome of our previously presented example.

At the same time, we believe that the requirements of society 5.0 and industry 5.0 will determine the continuous digitalization of supply chain management, thus facilitating not only its efficient operation but also increasing specific resilience (*SRincr*) by ensuring the overall achievement of the following factors:

- Important improvement of the parameters of functional *agility* (speed and flexibility) (*Ifa*) within the SCM processes;
- Adequate increase in the visibility of the operations (*IVO*) specific to the efficient functioning of the SCM components;
- The functional association (high-performance and complementary) of digitalization with the robotization of artificial intelligence and the Internet of Things (*FA*), all technologically integrated within the evolved processes, specific to the SCM components;

- The possibility of avoiding or diminishing the effects of disturbing factors (*Pa/ddf*) on SCM components;
- Rapid recovery of some value losses (because of the action of some disturbing factors) and the return in a short period of time to the initial functional performances (*Rrl*) of SCM. Based on the presented, we highlight the following relationship:

$$SRincr = f\,(Ifa + IVO + FA + Pa/ddf + Rrl) \quad (5)$$

According to our assessment based on the presented facts, in the management of the digital-intelligent supply chain, the performance (*P*) can be expressed by the relation:

$$P = Ab \times M \times R \quad (6)$$

where:

- *Ab*–the abilities of the staff in the management and execution subsystems, both at the higher level of the digital SCM and at the level of each component company. In turn, the mentioned abilities can be expressed as follows:

$$Ab = Q \times (K + S + Exp) \quad (7)$$

The elements of the relationship represent *Q*-qualification; *K*-knowledge; *S*-skills; *Exp*–the experience. The relationship has the expected effect in the conditions where the objectives and performance indicators are adequately described in the job description. However, this can be achieved when: *the qualification* is based on a relevant formative side accompanied by multi-qualification; *the knowledge* must be in line with the requirements of the position and continuously updated; *the skills* involve skills, clarity and positive and innovative justification of the effort made with efficiency to carry out the assigned tasks; *experience* denotes successful practices in previous functions and the accumulation of added value in professional activities, which allows new high-performance developments in one or more functions that will be occupied later. We believe that the role and importance of abilities (*Ab*), as a fundamental element within mentioned formula for determining performance (P), is given by the individual value of the acquired level of the component sub-elements. Therefore, within the consolidated digital SCM, the weighting of skills (*Q*) with the group resulting from the combination of knowledge (*K*) with skills (*S*) and experience (*Exp*) determines, for an employee, a beneficial action power resulting from an individual professional aspect characterized by: efficiency and effectiveness; adequate collaboration—internal and external; intelligent, proactive, innovative and productive thinking; prolonged effort in situations imposed by the performance of certain work duties (natural; urgent; anticipatory etc.); smart management and leadership that continuously engages a mix of resources (human, material, financial, informational) etc.
- *M*-the pecuniary and non-pecuniary motivation of the management and execution staff within the digital SCM.
- *R*-the resources committed for the efficient operation of SCM in win-win terms, for the digital SCM components and for the clients of this business system.

3.2.4. Case Study on the Selection and Implementation of the Optimal and Timely Solution, Needed to Strengthen the Digital Supply Chain Management

Given the current economic demands, we appreciate that high-performance supply chain management (SCM) needs viable and efficient smart digital technologies. For this purpose, in the elaborated case study, we will analyze three hypothetical solutions for the acquisition and implementation of an advanced technological (digital) system, necessary for the functional consolidation of a digital supply chain, where several eligibility criteria will be considered, each having established the standard individual importance in a 100 points, as follows: (a) price = 15 points; (b) agility = 17 points; (c) sustainability = 18 points;

(d) robustness = 20 points; (e) resilience = 30 points. The assigned team of specialists (commission) at the SCM level was formed to plan and carry out an appropriate procurement procedure in order to select the optimal digital technological solution after comparing the offers of the companies interested in selling, in accordance with the requirements imposed by the specified eligibility criteria, taking into account the value data from Table 1. Below we present the phases of the case study.

Table 1. Results of the evaluation (in points) on eligibility criteria and decision options.

Decisional Alternatives (Solutions)	Evaluation Results in Points/Eligibility Criteria				
	Price (Ps; P)	Agility (As; A)	Sustainability (Ss; S)	Robustness (Rbs; Rb)	Resilience (Rss; Rs)
The standard evaluation established for each criterion (Ps, As, Ss, Rbs, Rss) according to its importance, in 100 points	15	17	18	20	30
V1	11	15	16	16	22
V2	13	16	17	18	25
V3	15	17	18	20	30

(a) Initial details

The general manager and the managerial staff of SCM "*M*" took the decision to reconfigure the digital mechanism inside the business system, by identifying, testing and purchasing another new and intelligent one, in a period of 6 months. To that purpose, the team (commission) (with IT professionals from the partner firms) created three cost options based on the prices supplied and negotiated with the suppliers of the technical components.

The organizational need of SCM "*M*", which imposed the procedure from a managerial point of view to identify, select and implement an optimal solution for strengthening the management of the digital supply–delivery chain, is based on the following hypothetical elements (determined following the study of some works published by experts from McKinsey [8,41,43] and Forbes [40,50]): the level of annual income (total) and profit obtained within the SCM; observable flaws in the operation of SCM components; achieving a digital transformation would allow an increase in value performance by approx. 7–10% annually, as a result of the quick satisfaction of customer requests; the recovery of the investment could be achieved in a period of 3–5 years (and even earlier); the existence of the necessary qualified personnel, with development possibilities (multi-qualifications; new personnel etc.); the sufficiency of the spaces required for the installation of new digital technologies and the needs for reconfiguration.

(b) Data for analysis, comparison and decision

b1. Following the comparison of the offers of the supplier companies, based on the established eligibility criteria, in order to select the optimal decision-making solution, for the acquisition and installation and verification of the proper functioning of the digital intelligent system within SCM "*M*", the data in Table 1 resulted.

b2. In order to convert the evaluation results (according to Table 1) into final values (by summing the individual arithmetic values on eligibility criteria), for the three decision alternatives, we consider useful the following formula:

$$Pji = P/Ps + A/As + S/Ss + Rb/Rbs + Rs/Rss \quad (8)$$

where: *Pji* = final arithmetic value for each decision alternative (solution); *P/Ps* = assessed price/standard assessed price; *A/As* = assessed agility/standard assessed agility; *S/Ss* = assessed sustainability/standard assessed sustainability; *Rb/Rbs* = rated robustness/standard rated robustness; *Rs/Rss* = assessed resilience/standard assessed resilience.

The final arithmetic values obtained (*Pji*), by which the three decisional variants are separated, are highlighted in Table 2.

Table 2. Individual and final arithmetic values obtained according to eligibility criteria and decision options.

Decisional Alternatives (Solutions)	Individual Evaluation Values/Eligibility Criteria and Final Values					
	Price (P/Ps)	Agility (A/As)	Sustainability (S/Ss)	Robustness (Rb/Rbs)	Resilience (Rs/Rss)	Final Arithmetic Values of V1, V2, V3 (Pji)
V1	0.73	0.88	0.88	0.80	0.73	4.03
V2	0.86	0.94	0.94	0.90	0.83	4.47
V3	1.00	1.00	1.00	1.00	1.00	5.00

b3. Following the analysis of the costs involved in procuring and implementing the intelligent digital IT system, the managerial staff of SCM "*M*", having all the necessary information, received the disposition to build an adequate decision tree for the eloquence of procuring and implementing the designed technological solution [53,54]. This methodological framework will result in the efficient decision to acquire the technological components of the mentioned digital intelligent system, based on the primary value data (expressed in EUR) related to each of the three decisional alternatives considered (possible acquisition and implementation variants), according to Table 3.

Table 3. Highlighting the primary value data (in EUR) for each decisional variant (solution) of acquisition considered.

Decision Variants (Solutions) (for Technological Components Acquisition of the Intelligent Digital System)	Smart IT Equipment Costs (Million EUR)			Assessment of the Costs Necessary to Make the Decision to Purchase and Implement a Smart Digital System Necessary for the SCM "*M*" Functional Consolidation (Million EUR)	
	Favorable Conditions	Average Conditions	Unfavorable Conditions	High Costs	Low Costs
V1	160			690	330
		142		590	270
			145	450	190
V2	170			850	600
		143		670	350
			139	500	270
V3	162			590	340
		145		490	240
			141	350	170

Note: The data considered and inserted in the table, on the three solution options, are based on the investment value, about 7% of the level of annual income obtained within the SCM "*M*" (which is about 10 times higher than the level of the average cost resulted from the sum and division by 3 of the maximum costs, evident in the three solution variants). For the three solution variants (V1–V3), the data in the table were determined according to the prices offered, at the same quality level, by the suppliers for the components of the intelligent technical solution to be selected and implemented. The favorable conditions, average conditions and unfavorable conditions evident in the table (by variant, for each type of cost) reveal the value level of the facilities offered by the suppliers (delivery conditions; transport; handling; installation; maintenance; craftsmanship, etc.) included in each of the existing cost categories for each type (high costs; low costs), as specified in the organizational procurement documentation. All of this (based on the decision to select the optimal variant) will serve as the foundation for determining the cost level for the acquisition and implementation of a smart digital system suited for the functional consolidation of digital SCM "*M*."

b4. Probabilities of occurrence of the event "j" (costs) following the development of studies (research) specific to the acquisition, installation and functional verification of the intelligent digital system, necessary to increase the functional performance within the SCM "*M*": high costs = 0, 4, low costs = 0.6.

b5. Probability of manifestation "i" for each decision node in each decision-making variant (E_mD_i), following the evaluation of the specific costs of acquisition, installation and functional verification of the specified digital smart system: $E_mD_1 = 0.3$; $E_mD_2 = 0.2$; $E_mD_3 = 0.5$.

b6. The formula for the decision tree method: the determination of the mathematical expectation, for each decision-making alternative, represents the stage in which the expected values are estimated for each possible combination between the alternatives and the states of nature, which requires the application of the following formula [55,56]:

$$E_{m_i} = \sum_{i=1}^{m} p_j \cdot R_{ij} \quad (9)$$

in which: p_j = probability of manifestation of the event "*j*"; R_{ij}= result obtained by variant "*i*" influenced by event "*j*"; E_{m_i} = mathematical expectation in the decisional node "*Di*" or for the decisional variant (*Vi*).

The optimal variant is the decisional variant with the highest mathematical expectation, i.e.:

$$Vopt. = max. E_{mi} \quad (10)$$

Therefore, according to the specific method of implementation, the construction of the decision tree is based on: the three decision variants (V1–V3); risk nodes (R1–R3); decisional nodes (D1–D9); end nodes (E1–E18).

(c) Requirements set to be addressed

c1. Determination of mathematical expectation (E_{m_i}) for each decision node (D_i)

The probabilities of the manifestation of the "*j*" event (costs) following the development of the studies (research) necessary for the procurement, installation and functional verification of the intelligent digital system: high costs = 0.4, low costs = 0.6. Next, the individual value of the mathematical expectation (E_mD) for each decision node (D) is determined. By performing the operations, it results:

$$\begin{aligned}
&E_mD_1 = (690 \times 0.4) + (330 \times 0.6) = 276 + 198 = 474 \text{ million EUR};\\
&E_mD_2 = (590 \times 0.4) + (270 \times 0.6) = 236 + 162 = 398 \text{ million EUR};\\
&E_mD_3 = (450 \times 0.4) + (190 \times 0.6) = 180 + 114 = 294 \text{ million EUR};\\
&E_mD_4 = (850 \times 0.4) + (600 \times 0.6) = 340 + 360 = 700 \text{ million EUR};\\
&E_mD_5 = (670 \times 0.4) + (350 \times 0.6) = 268 + 210 = 478 \text{ million EUR};\\
&E_mD_6 = (500 \times 0.4) + (270 \times 0.6) = 200 + 162 = 362 \text{ million EUR};\\
&E_mD_7 = (590 \times 0.4) + (340 \times 0.6) = 236 + 204 = 440 \text{ million EUR};\\
&E_mD_8 = (490 \times 0.4) + (240 \times 0.6) = 196 + 144 = 340 \text{ million EUR};\\
&E_mD_9 = (350 \times 0.4) + (170 \times 0.6) = 140 + 102 = 242 \text{ million EUR}
\end{aligned} \quad (11)$$

c2. Determination of mathematical expectation (E_m) for each decision variant (V_i)

The probability of manifestation "*i*" for each decisional node from each determinant decisional variant (E_mD_i) following the study of the offers: $E_mD_1 = 0.3$; $E_mD_2 = 0.2$; $E_mD_3 = 0.5$. By performing the operations, it results:

$$\begin{aligned}
&E_mV_1 = (474 \times 0.3) + (398 \times 0.2) + (294 \times 0.5) = 142.2 + 79.6 + 147 = 368.8 \text{ million EUR};\\
&E_mV_2 = (700 \times 0.3) + (478 \times 0.2) + (362 \times 0.5) = 210 + 95.6 + 181 = 486.6 \text{ million EUR};
\end{aligned} \quad (12)$$

E_mV_3 = (440 × 0.3) + (340 × 0.2) + (242 × 0.5) = 132 + 68 +121 = 321 million EUR.

c3. Establishing the optimal decisional variant with the highest mathematical expectation (Vopt).

In terms of costs, the optimal option is the decision option with the lowest mathematical expectation:

$$Vopt. = min.\ E_mV_i \quad (13)$$

$$Vopt. = min.\ (368.8; 486.6; 321) = 321.0 \text{ million EUR, } ie\ V3 \quad (14)$$

c4. Construction of the decisional tree can be seen in Figure 9, where:

- V1–V3, are the three decisional variants;
- R1–R3, are the risk nodes, where some random events take place (favorable, average or unfavorable conditions), determined by the costs of acquisition, installation and verification of the operation of the technological components of the digital intelligent system;
- D1–D9, decisional nodes, where the intervention of the deciding manager will take place, who will opt for one of the three decisional variants (V1–V3);
- E1–E18, represent final nodes in which the costs of acquisition and functional implementation of the elements of the intelligent digital system are measured.

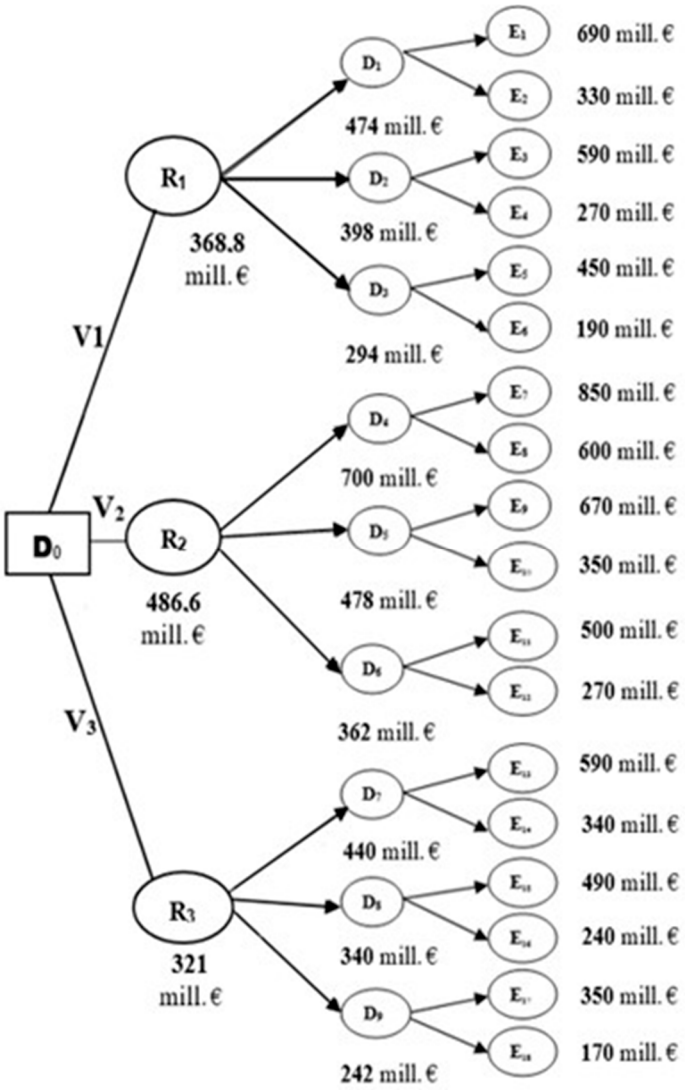

Figure 9. Decision tree results according to the created hypothetical situation.

Based on the presented results, following the confirmation of the results obtained in points b1–b6 and c1–c4, the company responsible for supply chain procurement will proceed to the procurement procedure (following other analyses and evaluations), contracting and receiving the technological components of the desired digital smart system from the supply chain manufacturer "J.", which could coincide with the optimal decisional variant resulting from the analysis, V3. The company will then receive, install, test for functionality and make any required modifications.

The presented case study is relevant for several reasons, including: the new status of the practical approach; the ease of understanding and applicability at any time in terms of reconfiguration and adaptation to the concrete situation; the economy of human, material and financial resources in the specific processes of identifying, selecting and implementing an optimal and timely solution required to strengthen the management of the digital supply chain; and the contribution to the company's profitability (annual turnover; annual income; annual profit, etc.) arising from the digital transformation achieved as a result of the mentioned solution's implementation.

4. Findings

Through our research we have revealed information and data for the development of the efficient functioning of digital supply chain management, a process that involves and requires both intelligent digital technologies and adequate skills for the management and execution from within this business complex mechanism.

Our research demonstrates that the challenges, vulnerabilities, threats, changes and current and future crises of the business environment (zonal, national, continental and global) determine that modern management applied in the digital supply chain becomes increasingly efficient by reconfiguring it structurally and functionally based on more relevant performance indicators, allowing it to increase the required agility, resilience, sustainability and feasibility. At the same time, we highlighted through the content of the research that the transformation of digital supply chain management must have a value—focused on increasing business performance, while minimizing risks through a complex understanding of customers, including consumers and end-users (individual and organizational). In full accordance with the above, we believe that the changes determined by strategies and policies established by the supply chain management must be effective in obtaining economic results through full collaboration between partner companies integrated into the digital business system, as well as between them and beneficiaries of manufactured and/or delivered products. This systemic interaction between the components of digital supply chain management (according to the beneficial digital transactional concept "end-to-end"), as well as between them and organizations in the external environment is possible through the acquisition, installation, verification and use of new digital technologies and, implicitly, by increasing the potential for obtaining the capitalization of information and business data by the marketing structures, sales, product development-innovation, etc.

To attain the goal of effective digital supply chain management, a new mindset and professional behavior on the part of management and execution factors are necessary. These factors must design and achieve new performance levels in the management of the digital supply chains, which are located in markets that are in constant competition.

Based on the purpose and objectives of this research and the selected sources used to build the scientific content, we did not develop an engineering side that involves theoretical and practical approaches related to smart technologies and related industries, nor a profile SCM. Instead, we explored specific concepts in order to highlight digital consolidation and improve the economic functional performances of the supply chain management under consideration.

According to what is highlighted in the content of the study, as a result of our sustained effort, we have developed relational considerations regarding the consolidation of the digital SCM, based on agility, sustainability and robustness as determining factors in achieving and augmenting its high-performance functioning, as well as on achieving

feasibility and the resilience necessary to ensure its viability. The results of our research can assist both SCM managers and other business people to identify, procure and implement the smart technology solutions needed to transform the existing digital supply chain management into a new, strengthened, much better performing form that will provide continuous added value to any complex business system.

5. Limits of Research

The requirements imposed by the specific policies and strategies of "Industry 5.0" and "Supply Chain Management 5.0", which have been adopted since 2021 [57,58], have determined a series of positive transformations in several fields of activity with results expected to be superior but with a number of constraints that must be considered. From our point of view, they are mainly aimed at: the limited flow of information in collaborative processes between companies that have moved to SCM 5.0, due to the secrecy related to the modernization of processes and operations to achieve superior business results; fierce competition, on new grounds, between digital supply chains is driving sustained digital transformation efforts for companies in digital business systems to consistently achieve superior results, which require increased attention in publishing reports and balance sheets on own activities and economic results; the need to increase functional resistance, as a result of the effects of the pandemic and especially as a result of the ongoing conflict in Ukraine; and respecting the entities' specific data protection parameters in reference to regional, national, continental and worldwide competitors.

Therefore, due to the aforementioned limitations, we were unable to approach the problem of enhancing the management of the digital supply chain in a more comprehensive manner, as neither the vast specialized literature we examined revealed data and information developed in the aforementioned sense, nor were we able to identify other more elaborate sources particularly on the profile side of case studies.

Despite its advantages, the study has several limitations: First, in the case study, the decision tree technique was utilized to select and apply the most effective and timely solution necessary to boost digital supply chain management. Although a decision tree model is highly intuitive and easy to explain to technical teams and stakeholders, it generates instability if a small change in the data results in a substantial change in the structure of the decision tree. Second, the background to this case study is built on the knowledge and experience of a team of CSM-level specialists, and it may occasionally disclose subjective intents that could influence the outcomes of a possible analysis.

6. Conclusions

Based on thorough literature research, the paper intended to clarify and analyze the determinants driving supply chain consolidation. The fundamental theoretical contribution of the research is the construction of a theoretical framework to define relational considerations regarding the consolidation of digital supply chain management, as well as the proposal of mathematical relationships to strengthen digital supply chain management. The empirical section includes a case study on the selection and implementation of the best and most timely solution for strengthening digital SCM.

The contributions of this paper are based on the obtained results; first the theoretical considerations directly connected to the practical part of the study, supported by relevant figures and mathematical relationships that reflect elements of the digital supply chain management consolidation. Following that, we conducted a case study of a hypothetical situation that reflects the possibility of selecting an appropriate solution for the acquisition, installation, verification and full operation of a smart digital system to effectively consolidate the digital supply chain management mechanism.

The continuous transformation of digital supply chain management aims to increase the visibility, agility, sustainability and resilience of this business system through forecasting, planning, scheduling, organizing, training, coordination, control–evaluation and regulation of all processes and actions specific to functional components, appropriate to internal

and external organizational environments. In this context, smart digital technologies are needed to enable systemic and subsystem integration (internal and external) of personalized information and data in full compliance with the requirements of new business models, imposed by the evolving requirements of current and potential consumers and users. To achieve the mentioned desideratum, a new mentality and new professional conduct on the part of the management and execution factors are necessary, which must design and achieve new performances within the digital supply chains, located in continuous competition in various markets and market segments.

The development of the digitalization of the structural components of the supply chain management aims at achieving an adequate integration between technologies; for example, between advanced digital systems and automated platforms used within the respective business system. In this way, it turns out that the limitations of existing technology are overcome by developing advanced planning, as well as more effective relationships with external partners. Therefore, the processes of digital supply chain management are augmented and perfected through the efficient use of advanced technological applications; artificial intelligence; robots; predictive analysis, etc. All of these are directly correlated with the abilities of the established staff to design and carry out the processes involving intelligent digitization in the supply chain management of the future. At the same time, we appreciate that the leaders of the supply chain are those who must constantly analyze and evaluate the dependence between the skills of human resources employed and evolved digitization, implemented based on results planned and achieved by business system components.

Therefore, the strong point of our study highlighted the need for continuous transformation and functional consolidation of digital supply chain management in order to increase the visibility, agility, sustainability and resilience of this business system through forecasting, planning, programming, organization, training, coordination, control–evaluation and regulation of all processes and actions specific to the functional components, appropriate to the internal organizational and external environments. In this context, we have highlighted the need for smart digital technologies that allow systemic and subsystem integration (internal and external) of personalized information and data in full compliance with the requirements of new business models, imposed by the evolving requirements of current and potential consumers (users).

The findings confirm the previous research (such as [11,12,35] and others) and point to the fact that digital SCM provide agility, flexibility, security and openness, which aid in achieving superior performance in these highly competitive, complex global marketplaces.

The study's practical implications refer to the fact that it could be valuable for documentation analysis and assessment, including important highlights, in order to develop new forecasts and scientific breakthroughs in the field of intelligent and efficient digital supply chain management operations. This study assists managers in identifying the essential technologies employed in the transformation of traditional supply chains to digital supply chains. It especially helps practitioners and managers with insight by defining digital SCM as a holistic concept and giving a conceptual framework for its analysis. With the aid of this framework, managers can examine the process by which their organization, which is a link in a supply chain, becomes aware of environmental disturbances, understands their significance and potential effects, determines the available planned or unplanned options and chooses an appropriate course of action.

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