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Supply Chain Integration, Quality, and Knowledge Management in the Aerospace Industry*

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Abstract

In recent years, Supply Chain Integration (SCI) has gained attention in academic and empirical research. However, SCI has little consensus on conceptualizations, definitions, and dimensions. This research aims to analyze how quality management and knowledge management contribute to integrating the supply chain and participate in solving some of this misleading analysis of the aerospace industry in Queretaro, Mexico. To evaluate the influence of the variables, the structural equation modeling was used using the partial least squares approach (SEM-PLS). A census was made of the 48 firms in the aerospace industry through an interview with the firm's executives. The model results show that knowledge management positively and significantly influences supply chain integration. Information and knowledge acquisition, both internally and externally, are essential for firms to improve their performance. Firms also must develop quality management systems that involve all the participants to integrate into global supply chains.

Keywords: Supply chain management; Structural Equation Modelling; Supply Chain Quality integration; competitive advantages; knowledge management.

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Integración de la cadena de suministro, gestión de la calidad y el conocimiento en la industria aeroespacial

Resumen

En años recientes, la integración de la cadena de suministro (SCI) ha atraído atención en términos académicos y empíricos. Sin embargo, la integración de la cadena de suministro tiene poco consenso en la conceptualización, definiciones y dimensiones. El objetivo de la investigación es analizar la contribución de la gestión de la calidad y la administración del conocimiento a la integración de la cadena de suministro en la industria aeroespacial en Querétaro, México. Para evaluar la influencia de las variables, se utilizó el Modelamiento de Ecuaciones Estructurales con el enfoque de Mínimos Cuadrados Parciales (SEM-PLS). Se elaboró un censo a las 48 firmas de la industria aeroespacial que conforman el universo de estudio mediante una entrevista a los ejecutivos de las firmas. Los resultados del modelo muestran que la administración del conocimiento tiene una influencia positiva y significativa en la integración de la cadena de suministro. La información y la adquisición de conocimiento, tanto en el medioambiente interno como en el externo, son esenciales para el desempeño de las empresas. Las firmas deben crear sistemas de administración de la calidad, las cuales involucren a todos los participantes para lograr su integración en las cadenas de suministro globales.

Palabras clave: Administración de la cadena de suministro; modelamiento de ecuaciones estructurales; integración de la calidad de la cadena de suministro; ventajas competitivas; gestión del conocimiento.

1. Introduction

Now, in business, organizations have moved from competing against each other to competing for supply chain against supply chain (Deng et al, 2020). In this situation, supply chain management has become an essential topic of study for all stakeholders, academics, and executives. Fierce global competition has motivated firms to reconsider supply chain integration as a prominent topic in management (Ayoub et al, 2017).

Pursuing supply chain integration (SCI) offers advantages for organizations that achieve this practice, such as attaining cost advantages, improving operational and business benefits, and maintaining competitive advantages (Flynn et al, 2010).

One of the implications that affect the integration of the supply chain is how organizations manage knowledge based on three aspects: how knowledge is generated, retained, and transferred (Sudhindra et al, 2020). Knowledge creation and transfer are fundamental to the integration of the supply chain. For example, creating knowledge is necessary to foster collaborative relationships between suppliers and customers. In the same sense, the importance of the relationship with customers and suppliers and mutual trust between them, such as the investment of joint projects, knowledge sharing, and sharing of responsibilities between the participating firms (Chión et al, 2019).

Quality management has become a fundamental topic given the complexity surrounding today's supply chains, where compliance with the requirements of the firms involved is demanded (Weckenmann et al, 2015). However, there is still a need to develop a framework for quality management in supply chains. A few studies show that companies that manage jointly improve their performance within the supply chain. In this sense, supplier participation and selection as a functional strategy in supply chains positively influence chain performance. Finally, quality management activities within supply chains significantly and positively affect firm performance (Quang et al, 2016).

Based on the above aspects, the article analyzes how quality and knowledge management contribute to integrating the aerospace industry's supply chain in Queretaro, Mexico. To achieve this objective, a structural equation model was designed using the partial least squares approach (SEM-PLS) based on a 19-item instrument.

The research structure is as follows: Section two reviews the literature, explaining the variables of supply chain integration and its relationship with quality management and knowledge management. Section three is the methodology, which describes how the model was built, the study universe, the statistical analysis, and the software used. The fourth section presents the results of the model and their discussion. The last section is the conclusions of the article and the references reviewed.

2. Theoretical Issues of the study

For this purpose, the conceptual elements that support the study will be detailed.

2.1. Supply Chain Integration (SCI)

Supply chain integration (SCI) has become a term that has attracted much attention in academia and business (Leuschner et al, 2013). SCI with customers and suppliers allows companies to improve communication and data exchange, which helps improve products and material flows throughout the supply chain. Likewise, it will enable companies belonging to the supply chain to access various resources or capabilities by sharing knowledge among members and improving the firms' innovation (Yang et al, 2021)

SCI is defined as an extension of the commitment between customers and suppliers. It is the activities related to coordinating (physical) product flows between the supply chain members, where transactions include material movements, procedures, and process optimization without neglecting information flows (Ayoub et al, 2017; Vanpoucke et al, 2017).

The SCI aims to reduce the barriers that prevent the coordination, control, and communication of the relationships, activities, functions, processes, and locations of the different actors in the supply chain (Sundram et al, 2020). SCI means cooperation between the manufacturer and partners of the supply chain to develop an efficient and effective movement of materials, resources, parts, and information that are valuable to the customer quickly and at a low cost (Flynn et al, 2010).

In the SCI, two factors are identified: the first one is collaboration, and the second one is coordination. The first collaboration factor starts with customers and extends back to the firm's activities, and integration is necessary internally and externally. In contrast, the second point is the coordination of the delivery of physical products to customers and the coordination of information from customers to the firm (Frohlich & Westbrook, 2001). The integration of information is considered important (Shukor et al, 2021), and how the flow of data related to the demand, production, sales, forecasts, performance, deliveries, and inventories is measured, while information must be transmitted in real time, in an accurate, reliable, meaningful and helpful manner (Gu et al, 2021).

Another component of SCI is organizational integration. This component seeks to generate long-term relationships based on trust between the members of the supply chain by creating close relationships (Prajogo & Olhager, 2012), is considered a strategic and valuable resource of the firm and positively influences operational performance and communication within the supply chain, allowing overcoming turbulent environments and increasing the delivery of goods and services (Khanuja & Jain, 2019).

Organizational integration can be enhanced when SC partners make mutual planning, engage in functional cooperation, share information, and work together to ensure on-time delivery and meet customers' needs (Ayoub et al, 2017). Long-term relationships are achieved by sharing responsibilities and developing common planning through joint investments (Sudusinghe & Seuring, 2022).

Also, logistics integration refers to the bundle of operational activities and practices that entail flow (materials, information, or products) and coordination between supply chain actors (Vanpoucke et al, 2017). Logistic integration is a dynamic supply chain capability that helps minimize the build-up inventory, improve asset utilization rate in transportation and warehousing, and reduce cost (Danese et al, 2020).

Logistics integration reduces delivery times, reduces costs, improves overall service, and improves the competitiveness of supply chain participants. To achieve logistics integration, it is necessary to consider the role of information transfer and standardization of logistics activities of supply chain members (Prajogo & Olhager, 2012).

2.2. Quality management and supply chain integration

Historically, quality has been controlled internally by organizations. However, in recent times, it has spread to inter-organizational processes such as supply chains, and because of its complexity, new requirements have been demanded that members must meet (Weckenmann et al, 2015). One of the main advances within this section was the development of the Supply Chain Quality Management (SCQM) construct, which involves the coordination and integration of supply chain quality management systems (SCQM), where consists of the coordination and integration of business processes by participants to measure, analyze and continuously improve products, processes, and services for the creation of value and satisfaction of intermediate and final customers (Chau et al, 2021).

Huo et al, (2014: 38) coined the

term supply chain quality integration (SCQI), which is defined as integrating quality management among upstream suppliers, downstream customers, and functional units within an organization. Firms try to incorporate quality into the supply chain. One way to improve it is to recognize the critical success factors, such as materials flow, quality systems, and maximizing data sharing with SC partners (Chau et al, 2021).

Empirically, research mentions that quality management is significantly related to the strategic selection of the supplier, its participation role, and the firm's performance (Pizzichini et al, 2023). Another factor in improving quality in the supply chain is leadership used in four practices: stakeholder involvement, continuous improvement, innovation, and strategic planning, so internal and external integration of supply chain practices is affected by supplier quality and compliance with supplier requirements (Lim et al, 2022).

In another sense, commitment, adaptation, communication, trust, and collaboration among supply chain members positively affect overall performance (Li, 2021). Also, firms that perform better than those that do not are a consequence of the quality management practices that the firms implement.

The improvement in all phases of the supply chain reduces costs, increases resource utilization, and improves process efficiency. Also is analyzed the relationship between the different dimensions of the SCQM model and the impact on the firms, concluding that managers have to look outside the firms to benefit from collaboration, integration, and communication among the members of the supply chain (Abdallah et al, 2023).

2.3. Knowledge management and supply chain integration

Knowledge management is a specific, systematic, and organizational process for creating, transferring, integrating, and increasing the associated knowledge of a unit applied to other units (Chuang et al, 2013). Based on this definition, four phases of knowledge management are identified: creation, transfer, storage, and application of knowledge within the supply chain integration.

Collaborative relationships with customers and suppliers must be established to generate applicable knowledge. In this sense, defining roles and responsibilities, forming joint projects on research and development issues, and emphasizing exchanging specialized knowledge are considered critical factors. KM processes guarantee that when the right people receive the proper knowledge at the right time and use it in the right way, different businesses will be improved (Madhavaram et al, 2024)

Storage is another factor in the relationship between supply chain integration and knowledge management. A strategic orientation towards knowledge accompanied by a learning-focused culture directly affects knowledge retention and storage. However, the relationship between supply chain integration and storage has been little studied, and there is a significant gap in the literature (Farooq, 2023).

Creating and storing knowledge would be unimportant if the knowledge is not executed, so knowledge transfer allows firms belonging to a supply chain to manage the knowledge generated and stored. If the information is contextualized correctly and the participants know how to apply it, the inter and intra-firm process is extended. It creates value among supply chain participants (Ayoub et al, 2017).

Firms that develop a knowledge-based strategy positively impact overall chain performance, so investing in knowledge-related strategies is recommended. However, the fundamental factor for improving supply chain integration through knowledge management lies in the trust among the supply chain members (Hult et al, 2007).

3. Methodological considerations

To achieve the proposed objective of the research and based on the literature review, it was chosen to use a structural equation model with partial least squares under the designed 19-item instrument whose foundations are found in the literature research (Frohlich & Westbrook, 2001; Koçoğlu et al, 2011; Prajogo & Olhager, 2012).

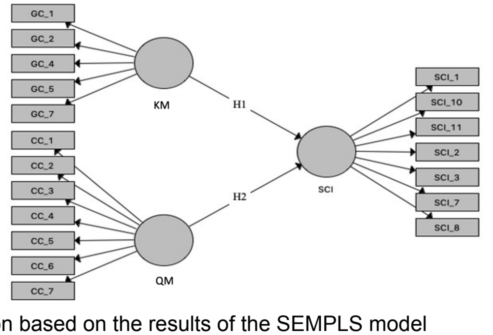
The instrument was applied to 48 aerospace industry executives in Querétaro, Mexico, through direct interviews during the Mexico Aerospace Fair 2021 (FAMEX).

Structural equation modeling with partial least squares (SEM-PLS) is a statistical technique that allows the calculation of a set of equations that measures the concepts (measurement model) and the relationships between them (structural model) employing concepts that are not directly observable (latent variables) (Fornell & Larcker, 1981).

SEM-PLS models have gained attention in research contexts for analyzing data and defining complex models. The development of software (SmartPLS, Adanco, and WarpPLS) or packages in R (SEMinR, cSEM, and semPLS) and the growing development of methodological papers such as Confirmatory Composite Analysis, Heterotrait-Monotrait approach or conditional mediation analysis has helped the diffusion and use of SEM-PLS analysis (Ciavolino et al, 2022).

The proposed model also illustrates the hypotheses raised in this research. Hypothesis 1 (H1) mentions that knowledge management positively influences supply chain integration (Diagram 1). Hypothesis 2 (H2) stipulates that quality management positively influences supply chain integration.

Diagram 1
Proposed structural equation model



Source: Own elaboration based on the results of the SEMPLS model

The structural equation model was assessed through the SmartPLS Software version 4.0.1.2 (2024). The assessment of the structural equation model consists of two phases (Henseler et al, 2015):

The evaluation of the measurement model, i.e., measuring how the latent variables behave, this step consists of the assessment of reliability through Cronbach's Alpha and the composite reliability measure (ρA), the external loads of the indicators, and the AVE (Average Variance Extracted) and the Heterotrait-Monotrait (HTMT) ratio that measures the discriminant validity.

Evaluation of the structural model: in this step, the collinearity is measured as the first measure, then the explanatory power of the model through the R^2, followed by the predictive power with the *PLSPredict* indicator and the measurement of the path coefficients. Finally, the hypothesis test is performed, and the coefficients, the *t* or *p* values, and their significance are evaluated.

4. Supply chain, quality and knowledge management in aerospace industry: Results of statistical analysis

The first evaluation of the model is the composite reliability (ρA) and the average variance extracted (AVE) and Cronbach's alpha, where the expected results must be higher than 0.50 to be satisfactory, and the constructs generated are valid. In the case of the research, it is observed that the observed indicators are higher than this expected value, so these variables are valid. These results are shown in Table 1.

Table 1
Reliability assessment

	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
KM	0.78	0.85	0.533
QM	0.898	0.92	0.624
SCI	0.853	0.888	0.534

Source: Own elaboration based on the results of the SEMPLS model

Discriminant validity is measured by the HTMT ratio, an estimate of the correlation between the proposed constructs (Henseler et al, 2009). This ratio should be less than 1, preferably less than 0.85. When these values are exceeded, a discriminant validity problem occurs, and the constructs should be eliminated (Hair et al, 2017). Table 2 presents the results of the HTMT ratio, which shows no discriminant validity problem with any of the constructed variables since all have values below the limit, so it is possible to continue evaluating the model.

Table 2
HTMT Ratio

	KM	QM
KM		
QM	0.658	
SCI	0.753	0.567

Source: Own elaboration based on the results of the SEMPLS model

The next step of the structural model evaluation is to determine the R^2 of the model along with the collinearity. The R^2 shows the variance of supply chain integration using quality and knowledge management. The result indicates that these two variables explain 43.4% of supply chain integration. This result is considered a moderate effect (Hair et al, 2017).

Regarding collinearity (VIF), the values were below the limit of 5 (Henseler et al, 2015), so the model does not have a collinearity problem. The path coefficients show the strength of the relationship between the constructs. They can have values between -1 and +1. The closer to 1, the greater the relationship. In this case, the knowledge management relationship is 0.514, while the quality management relationship is lower at 0.218. the results of the evaluation of the structural model are shown in Table 3.

Table 3
Evaluation of the structural model

Path	Path Coefficient	Collinearity (VIF)	t-value	p-value
H1: KM→SCI	0.514	1.459	3.451***	0.001
H2: QM→SCI	0.218	1.459	1.340	0.180
Construct	R2 Coefficient			
SCI	0.437			

Source: Own elaboration based on the results of the SEMPLS model
Notes: The t- and p-values were derived from the bootstrapping procedure with 5000 subsamples.
Abbreviations: SCI, supply chain integration. KM, knowledge management. QM, quality management.
*p<0.1 **p<0.05 ***p<0.01

Regarding statistical significance, only the relationship of knowledge management→ supply chain integration was significant at 0.01, so H1 is accepted. In contrast, the relationship of quality management→ supply chain integration is not significant, so H2 is rejected.

The results of the *PLSpredict* include the *Q^2predict* coefficient of the key's endogenous construct indicators. *Q^2predict* has to be higher than 0 to have predictive power and is compared with the Root Media Square Error (RMSE) or Mean Average Error (MAE) value with the LM value of each indicator if the RMSE or MAE is lower than LM_RMSE or LM_MAE contributes to the predictive power. If the minority of the indicators are below the LM, the model has a low predictive power. If most indicators are below, it shows a medium predictive power; if all indicators are below the LM, the model has a high predictive power (Shmueli et al, 2019). The results of the *PLSpredict* are shown in Table 4.

Table 4
PLSpredict results

Q2 Predict	RMSE	MAE	LM RMSE	LM MAE
SCI_1	0.102	0.750	1.11	0.943
SCI_10	0.246	0.540	0.842	0.663
SCI_11	0.207	0.507	0.775	0.627
SCI_2	0.140	0.599	0.900	0.741
SCI_3	0.246	0.625	0.840	0.657
SCI_7	0.045	0.620	0.972	0.757
SCI_8	0.199	0.665	0.874	0.726

Source: Own elaboration based on the results of the SEMPLS model

The results of Table 4 show that all indicators used to measure supply chain integration, using RMSE and MAE, are below the lower limit of both measures. With this information and using the parameters proposed by Shmueli et al. (2019), the model has a high predictive power.

Based on the statistical analysis results, it was found that the indicators that have the most significant influence on the measurement of supply chain integration are the relationship between customers and suppliers and the trust between them. Both characteristics are achieved in the long term, and this increase in integration positively affects the firm's performance and subsequently increases the performance of the supply chain in general (Frohlich & Westbrook, 2001).

In this sense, supply chain partners must rely on downstream and upstream suppliers to increase supply chain integration, and collaboration must be used in all the supply chain processes (Madhavaram et al, 2024).

Knowledge management and the effects of supply chain integration highlight the importance of knowledge creation, which is formed through information gathering by firms and knowledge application. Managers have to be capable of improving a culture of knowledge development in their supply chains to ensure success (Hult et al, 2007).

The collection of information has become one of the primary activities for supply chains to integrate, as well as transforming this collection into knowledge that firms can use. However, the firms can use the knowledge generated (Koçoğlu et al, 2011). However, the knowledge generated can only be used when it is shared and transferred with the other participants in the supply chain (Hult et al, 2007), which influences logistical integration and information integration (Prajogo & Olhager, 2012).

Quality management in this research is measured with the acquisition of quality certifications whose importance for the aerospace industry is vital, so the firms that participated in this research have several quality certifications necessary to operate within this industry (for example, ISO 9000 series or AS9100). Although quality management was not significant, verifying that products are of sufficient quality is essential to the firms within the operational areas. These certifications allow them to integrate into a supply chain more efficiently.

Quality is related to direct supply chain integration, increasing market share, and preference for suppliers with certification, indicating the importance of quality in achieving supply chain integration. Empirical results corroborate that having quality management practices through quality systems and quality certifications improves firm performance, better meets customer needs, and facilitates supply chain integration (Lotfi et al, 2013).

5. Conclusions

Knowledge management has positively and significantly impacted supply chain integration. Information and knowledge acquisition are essential for firms to improve their performance. New knowledge is found in all the firm environments, both internally and externally. Firms that have formal processes to identify and locate it generate competitive advantages.

Existing tools allow correct codification and protection of the knowledge created and acquired by firms; nevertheless, this must be adapted to their unique features. Artificial intelligence is a tool that allows the application to exploit knowledge and achieve competitive advantages.

Efficient information technologies in the supply chain also influence integration. Information shared between clients and suppliers must be considered to improve the firms' resource and planning operations. This allows for trust and collaboration between clients, manufacturers, and suppliers, improving supply chain performance.

Quality management is also a vital variable in any industry. Quality certifications from governments and non-government organizations allow firms to integrate global supply chains correctly. However, the evidence obtained in this research does not assess the established hypothesis. In this case, refocusing on how quality management is operated in industries is essential.

Regarding the aim of the research about the contribution of knowledge and quality management to supply chain integration, it considered the importance that the creation and execution of knowledge in the supply chain has a significant impact on supply chain integration, mainly in developing long-term relationships, involving trust and collaboration between supply chain partners. In quality management, firms must keep creating quality management systems to be considered by Original Equipment Manufacturers as their supplier, and firms can integrate global supply chains.

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