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Research Article

A new tool for evaluating supply risk management

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Abstract

Paper aims: This research proposes a tool for assessing supply risk, taking into account supply chain performance criteria.

Originality: The results show that risk management can contribute to better supply chain performance when supplier selection procedures consider the risks involved and how they are related to supply chain performance criteria.

Research method: A systematic literature review (SLR) was carried out on supplier selection, performance evaluation and risk management in the supply chain. The statistical tool IRT (Item Response Theory) was used to establish the level of difficulty in eliminating the types of risks identified and associated with the supply chain performance criteria, based on the probability of each situation occurring.

Main findings: With this scale, it is possible to identify which types of risk and performance criteria are most difficult for suppliers to meet and then define a plan for mitigating the risks that are harder to eliminate.

Implications for theory and practice: Based on the tool developed, organizations have greater understanding of how risks affect the performance of their supply chain and with that knowledge they can act to minimize the effects of the risks that are most difficult to eliminate.

Keywords

Supply chain management. Performance measurement. Risk management. Supplier risk. Item Response Theory (IRT).

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1. Introduction

The selection of the right suppliers is one of the critical factors for companies' operational success, as the wrong choice can lead to costly consequences. In this sense, the lack of reliable information and the constant changes in the business environment are important sources of uncertainty when selecting suppliers (Zakeri et al., 2023). In this way, the achievement of the results sought by an organization in a supply chain will depend on the performance of its suppliers (Lima-Junior & Carpinetti, 2016), increasing concern about the selection and maintenance of suitable suppliers (Kawa & Koczkodaj, 2015).

The Covid-19 pandemic set off alarm bells around the world, as global supply chains began to have their supply flow interrupted due to movement restrictions at various times. There were shortages of basic medicines in pharmacies, the car industry had to stop production due to lack of inputs, as did the construction industry and many other similar cases. Just when it seemed that a recovery process was beginning, Russia's war against Ukraine started, again raising questions about supply problems (Duong et al., 2023; Pham et al., 2023).

This reinforces how vulnerable global supply chains are to various events - such as natural disasters, wars, terrorism, legal issues, economic and political instability, etc. - emphasizing the importance of carrying out

efficient supply risk management (Duong et al., 2023; Pham et al., 2023). Despite its significance, the risk of supply disruption has not been sufficiently considered in supplier selection procedures (Cheaitou et al., 2019). The knowledge available in the literature is still limited in this regard, with most research being qualitative or case studies (Duong et al., 2023; Pham et al., 2023). It is therefore necessary to broaden the discussion on how to quantify the degree of supply risk affecting supply chains.

In order to select the most suitable suppliers, various economic and environmental criteria must be considered in the decision-making process (Chen et al. 2016), which makes evaluating their performance a complex activity to be carried out (Mahdiloo et al., 2015). Supply chains face complexities compounded by various risks and uncertainties, and their performance will be impacted if the company does not have adequate risk management (Mukherjee et al., 2024).

The use of global supply chains brings several benefits, such as access to cheaper labor and raw materials, better financial policy, a larger product market, diversified business opportunities and government incentives. However, it also comes with the need for good supply risk management, as supply chains become more vulnerable and complex. Various risk events are interlinked in complex patterns, with one risk leading to another or influencing the outcomes of other risks (Duong et al., 2023). The greater complexity of modern supply chains also increases the risk profile and strategic tools are needed to prioritize the activities that deserve the most attention (Casado et al., 2023).

Other studies address different aspects for supplier selection, such as supply capacity, product quality, cost, company development and resilience criteria (Song et al., 2024), but do not relate risk types to supply chain performance criteria. This research therefore proposes a tool for assessing supply risk in supply chains, taking into account the performance criteria to be met by suppliers. The types of risk are associated with the performance criteria they impact and ordered according to their level of difficulty, using Item Response Theory (IRT). With this tool, companies will be able to better evaluate their suppliers, identifying those that provide the lowest risk to their performance.

The rest of this document is structured as follows. Section 2 presents a literature review on supply risks and supply chain performance. The proposed methodology is presented in Section 3. The analysis and discussion of the results are presented in Section 4. Finally, the conclusion is presented in Section 5.

2. Supply risks and supply chain performance

Efficient supply chain management encompasses the careful coordination and control of various essential activities, such as production, transportation, storage and distribution, involving the planning and control of the flow of materials, information and resources, from the acquisition of raw materials to the delivery of the final product to the consumer (Wajid et al., 2023).

Effective supply chain management makes it possible to produce and deliver products at reduced costs, helping to minimize the production time and improving overall quality (Amirteimoori & Khoshandam, 2011). In addition, close collaboration with commercial stakeholders along the chain, the adoption of advanced technologies and the continuous search for improvements and innovations are essential elements for achieving operational efficiency, adaptive flexibility and competitive advantage.

The growing evolution of globalization and new communication and transport technologies has a significant impact on supply chain management. Business challenges are becoming increasingly complex due to the need to adapt to rapid and constant market changes. In this sense, efficient supply chain management is key to ensuring greater capacity to adapt to the market (Zhang et al., 2023). Especially in relations with suppliers, since disruptions in the supply of inputs generate a cascading effect throughout the chain and, in order to minimize this vulnerability, the procurement system must contain risk mitigation strategies (Das et al., 2024).

Evaluating suppliers in a supply chain plays a key role in ensuring effective management and is an extremely important and critical aspect for companies (Ayağ & Samanlioglu, 2016). The proper choice of suppliers is essential to guarantee the quality of products and services, on-time delivery, competitive prices and compliance with environmental and social requirements. After all, high supplier performance ensures that inputs meet quality standards and requirements, positively impacting the company's results (Duong et al., 2023).

For the management of supply chains, procurement activity is particularly important, as there is an increasing dependence on suppliers that leads to the distribution of negative effects along the chain, affecting the company's ability to satisfy customer needs (Kilic et al., 2023). It is therefore important to choose suppliers appropriately and develop ways of evaluating their performance.

However, determining the right criteria for assessing supplier performance can be a complex challenge. The literature on the subject highlights the importance of a comprehensive approach that considers different key

aspects. By properly analyzing and weighting these criteria, companies can identify the suppliers that best meet their needs, set clear performance targets, continuously monitor supplier performance and promote continuous improvement in business relationships over time.

Supplier selection and evaluation should not be considered in isolation, but in conjunction with the risks involved, since risks are inherent in supply chain processes (Arslan et al., 2023; Pham et al., 2023). In addition, purchasing at risk involves important issues such as cost trade-offs, purchase value and geographical segregation (Song et al., 2024).

Risks related to suppliers can be categorized into several types. Environmental, organizational and supply chain-related (Norrman & Jansson, 2004). Supply risk, which refers to uncertainty and variability in the supply of materials or components; demand risk, related to variability and uncertainty in demand; process risk, which is related to instabilities in operational production processes (Chen et al., 2013; Kilic et al., 2023; Parast & Subramanian, 2021). Quality, delivery reliability and reduction in the percentage of returned raw materials (Modares et al., 2024).

Risk management strategies and methods can directly help to mitigate risks and improve the efficiency and effectiveness of the supply chain. By identifying and assessing supply risks, companies can adopt proactive strategies to mitigate these risks and ensure a continuous and reliable supply. However, most companies are not yet prepared to make significant investments in risk assessment. They still use conventional methods which are subjective and often cause assessment errors (Mukherjee et al., 2024).

Therefore, supplier selection, performance evaluation and risk management must be approached in an integrated manner to ensure the continuity and efficiency of the supply chain. To this end, the supplier selection and evaluation process must begin by recognizing the performance criteria to be demanded (Akcan & Güldeş, 2019). In this sense, supply risks were identified according to the performance criteria that must be met by suppliers in the supply chain (Table 1).

3. Methodology

The methodological procedures for the development of this research were divided into two stages, following the same protocol adopted by Santos et al. (2023): Stage 1 involves the definition and validation of the items; and stage 2 encompasses the elaboration of the scale, with data collection and statistical analysis using IRT. The details of each stage are shown in Figure 1.

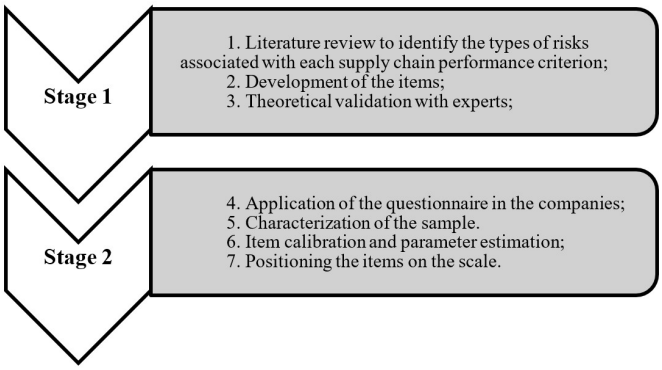

Figure 1. Scale construction steps.

3.1. Stage 1 - Definition and validation of items

The survey of the types of supply chain risks was developed through a systematic literature review, following the steps proposed by Lacerda et al. (2012). The databases chosen for the research were Scopus and Web of Science, using the keywords: "supplier performance"; "supplier assessment"; "supplier selection" AND "supply chain". The search period was limited to searches from 2000 onwards, which resulted in 6864 titles.

The selected articles were compiled in reference management software to facilitate the process of systematically selecting the literature relevant to the aim of this research. Figure 2 shows the sequence of filters used at this stage.

Table 1. Supply risks associated with supply chain performance criteria.

Performance criteria	Associated supply risk	References
Delivery	Risk of failure in the delivery process (Risk of transportation failure)	(Acar et al., 2016; Akcan & Güldeş, 2019; Alizadeh & Yousefi, 2019; Alkahtani et al., 2019; Pham et al., 2023; Zakeri et al., 2023)
Service	Risk of inefficient service	(Acar et al., 2016; Alizadeh & Yousefi, 2019; Hou & Xie, 2019; Lee et al., 2016; Imran et al., 2020; Karami et al., 2021; Kawa & Koczkodaj, 2015; Er Kara & Oktay Fırat, 2018; Li & Wang, 2018).
Logistics	Risk of suppliers offering inefficient logistics	(Akcan & Güldeş, 2019; Chatterjee et al., 2018; Chung, 2015; Pamucar et al., 2020; Pérez-Velázquez et al., 2020; Restrepo & Villegas, 2019; Tavana et al., 2017; Wang et al., 2017; Zarbakhshnia & Jaghdani, 2018).
Reliability	Risk in assuming that the reliability of suppliers is adequate	(Fallahpour et al., 2016; Mahmoudifard et al., 2018; Mohammed, 2020; Mohammed et al., 2021; Okwu & Tartibu, 2020; Pham et al., 2023).
Geographical position	Risk that the location or geographical position poses to the execution of transportation and delivery procedures	(Alizadeh & Yousefi, 2019; Dotoli et al., 2016; Ganguly et al., 2019; Kant & Dalvi, 2017; Karami et al., 2021; Song et al., 2024).
Financial stability	Risk that the financial condition of suppliers poses to the full execution of orders	(Alizadeh & Yousefi, 2019; Ashtarinezhad et al., 2018; Bouhnik et al., 2017; Diouf & Kwak, 2018, Duong et al., 2023).
Ethics	Risk in assuming that suppliers have ethical and moral values in line with the company's values	(Amindoust, 2018; Faisal et al., 2017; Ganguly et al., 2019; Kant & Dalvi, 2017; Khan et al., 2018; Pamucar & Ecer, 2020).
Health and safety regulations	The risk of doing business with companies that neglect occupational health and safety standards	(Cheaitou et al., 2019; Nikfarjam et al., 2018; Phochanikorn & Tan, 2019; Uçal Sarı et al., 2017).
Inefficient communication and coordination	The risk of hiring companies that do not have or do not practice transparent communication between those involved in the process	(Cheaitou et al., 2019; Kant & Dalvi, 2017; Sureeyatanapas et al., 2020)
Poorly trained staff	The risk of doing business with companies that don't have staff training practices	(Cheaitou et al., 2019; Chung, 2015)
Honesty of suppliers	Risk of assuming that the company will honor its commitments	(Kant & Dalvi, 2017; Su & Gargeya, 2016)
Political stability	Risk in assuming that the company's internal policy works properly and meets objectives	(Kant & Dalvi, 2017; Er Kara & Oktay Fırat, 2018)
Operational risk	Risk in assuming that operational activities are carried out efficiently and effectively	(Er Kara & Oktay Fırat, 2018; Sureeyatanapas et al., 2020)
Manufacturing capacity risk	Risk in assuming that the company is working within its production capacity and that the order placed will be delivered as agreed	(Er Kara & Oktay Fırat, 2018)
Risk of contractual commitment	Risk in assuming that the company will honor all the terms of the contract	(Er Kara & Oktay Fırat, 2018)
Catastrophic risks	The risk of hiring companies that don't have disaster contingency plans.	(Er Kara & Oktay Fırat, 2018)
Supplier country risk	Risk to which the company is subject when contracting foreign suppliers, including factors such as the company's financial situation, legal measures, etc.	(Segura & Maroto, 2017)

After reading the selected texts in full, the types of supply risks associated with supply chain performance were identified, as shown in Table 1. Based on the risks identified, a 35-item questionnaire was drawn up, with a Likert-type response scale ranging from 1 to 5. This questionnaire was sent to managers of companies in different sectors of activity to assess the relationship with its suppliers, indicating how often the supplier carries out this activity: (1) never, (2) rarely, (3) sometimes, (4) most of the time, (5) always.

To validate the items formulated for evaluating and selecting suppliers in relation to the dimension of supply risks in supply chains, five PhD experts were consulted. The PhD experts were chosen because of their research and publications on the subject of either supply chain management, supplier performance evaluation or risk assessment. Also, familiarity with the IRT and accessibility were taken into account.

Each expert was asked to analyze the consistency of the items and indicate whether they were appropriate or not. The experts were asked to suggest keeping an item if they considered it suitable or removing it if they considered it unsuitable. Each expert was asked to provide feedback for all items.

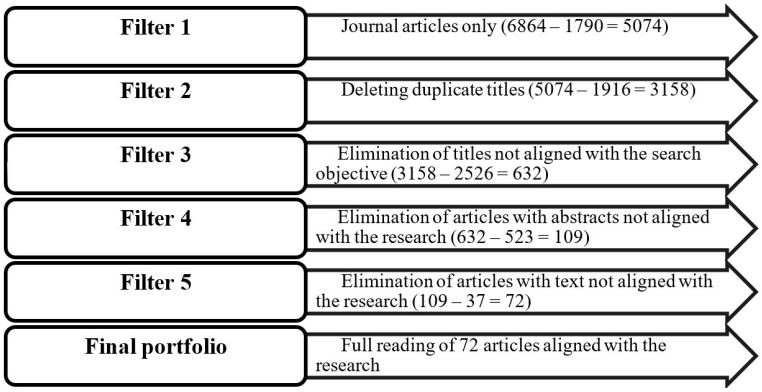

Figure 2. Filters for systematic literature selection.

In addition, the experts were asked to assess whether the items formulated were sufficient to measure supplier performance in relation to the respective aspects. They were also asked to suggest which other items could be used to assess supplier performance in relation to these aspects.

At the end of the consultation, the experts were asked whether the aspects (performance criteria) mentioned above were sufficient to assess the performance of suppliers in relation to the risk dimension. If the experts felt that they were insufficient, they were asked for additional suggestions for other relevant aspects. All the items were kept after this validation with the experts.

3.2. Stage 2 - drawing up the scale

The validated questionnaire was applied online, resulting in a sample of 167 relationships. The majority of the participating companies are micro and small, operating in industry, commerce and services.

In some items, the more often the situation indicated occurs, the lower the supplier's performance. To standardize the data in the statistical analysis, so that the higher the response on the Likert scale, the higher the performance, the responses to these items were inverted. Items 13, 18, 27, 28, 29, 30, 32 and 35 are in this condition.

The use of IRT does not imply specific sample sizes, but it is expected that each alternative will have a minimum frequency of responses to ensure a more precise positioning of the items on the scale. Although the questionnaire was administered with 5 response categories on the Likert scale, it was not possible to obtain a significant number of responses in each category in order to guarantee a good estimation of the parameters in all the categories initially presented. Therefore, due to the low frequency of responses to the different alternatives of various items, it was decided to dichotomize the items in order to obtain a more precise positioning of the information on the scale for evaluating supplier performance in the supply chain. This is because IRT models work with probability and it is not possible to define the parameters precisely with small samples.

Thus, the answers "never", "rarely" and "sometimes" were converted into "no" and the answers "most of the time" and "always" were converted into "yes". Even after dichotomizing the data, items 03, 17, 30, 32 and 35 had a response frequency of less than or equal to 5 in one of the categories and were discarded.

The two-parameter logistic model of the Item Response Theory (IRT) was used to analyze the data, with a lognormal prior for the "a" parameter of the items. By analyzing the model's fit indicators RMSEA, TLI and CFI, it was decided to exclude items with an "a" parameter below 0.9, resulting in an improvement in the respective indicators.

Once the parameters had been estimated, the items were placed on the scale. The level for fixing each category is the one where the cumulative probability is $\geq 60\%$ and with a probability $\leq 50\%$ at the immediately preceding level, considering 0.5 standard deviations between the levels. The data is originally generated on a scale (0.1).

In order to improve understanding of the results and avoid distortions of interpretation due to negative scores, the metric was changed to the (50,10) scale. This transformation of the scale does not imply a loss of information, as it is done in a linear fashion, maintaining the relationship of order and proportion between the values.

Once the positioning of the items on the scale has been defined, an interpretation is made for each level, defining what it means for a relationship to be positioned at a certain point on the scale and what the criteria are for reaching the higher levels of performance.

The dimensionality analysis was carried out using a factor analysis using the tetrachoric correlation matrix, which is suitable for dichotomized items. These analyses were carried out using the mirt and psych packages of the R software, in which it was possible to determine the dimensionality of the instrument, defining the item response model best suited to measuring the proposed latent trait.

4. Results

Parallel analysis of the tetrachoric correlation matrix generates a graph known as a scree plot (Figure 3), which represents the amount of variance explained by each component. There is a dominant factor, indicating that the data adheres to a one-dimensional model (Patil et al., 2010). In other words, the set of indicators used to manage supply risk can be represented by a single factor.

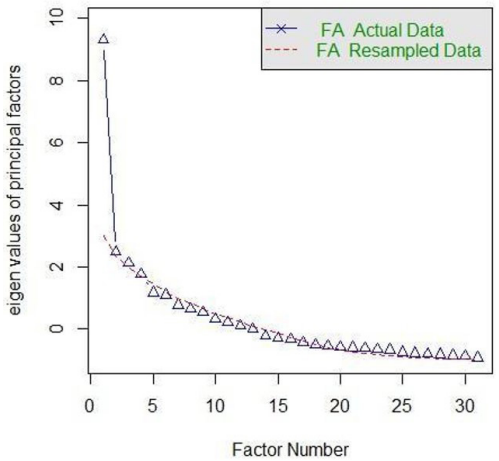

Figure 3. Parallel analysis of the tetrachoric correlation matrix.

With the data dichotomized and suitable for a unidimensional model, the two- parameter logistic model of the IRT was adjusted, obtaining the factor loadings shown in Table 2. In this analysis, items with loadings below 0.4, considered to have little information, were removed.

The item parameters were then estimated, using lognormal priori for the discrimination parameters. The model's fit indicators did not show good results. As a result, it was decided to eliminate the items with "a" parameter below 0.9 (Ledic et al., 2022), as this parameter "represents the quality of an item to discriminate respondents with different levels along the latent continuum" (Giacomelli et al., 2021). The items eliminated were 19, 23, 28, 31, 33 and 34. The final model showed an acceptable fit, as shown in Table 3.

The final parameters of the remaining items, after the adjustments described above, are shown in Table 4. The parameter "a" corresponds to the item's level of discrimination and "b" to the item's level of difficulty. The higher the value of *a*, the higher the item's ability to discriminate (Barbetta et al., 2014). As the name suggests, the difficulty parameter of each response category indicates how difficult the item's response categories are. It can be seen that most of the items have a negative b parameter, which indicates the predominance of items with a low level of difficulty.

Table 5 shows the items positioned on the scale, in ascending order of difficulty level. The first action positioned on the scale is related to operational risk, when suppliers have difficulty fulfilling their agreements due to operational failures. Positioning this item at the beginning of the scale indicates that it is a problem that occurs infrequently. Therefore, a supplier with this type of failure has a very low level of performance.

Level 25 identifies the risk of transport failure and the risk of assuming that the company will honor its commitments, which are related to the criteria of delivery performance and supplier honesty, respectively. A supplier positioned at this level fulfills what has been promised, including about the quantity previously agreed upon. It can therefore be said that the risks mentioned also occur infrequently and will only be identified in suppliers with very low performance.

Table 2. Factor analysis.

Item	F1	h2
I01	0.862	0.74310
I02	0.762	0.58096
I04	0.832	0.69178
I05	0.691	0.47690
I06	0.837	0.70000
I07	0.832	0.69252
I08	0.845	0.71457
I09	0.918	0.84326
I10	0.899	0.80829
I11	0.844	0.71183
I12	0.712	0.50738
I13	0.735	0.54005
I14		0.05115
I15		0.05453
I16		0.00106
I18		0.02705
I19	0.577	0.33322
I20	0.727	0.52874
I21	0.774	0.59945
I22		0.13604
I23	0.409	0.16720
I24	0.641	0.41109
I25	0.783	0.61248
I26	0.820	0.67310
I27		0.06520
I28	0.551	0.30357
I29	0.621	0.38553
I31	0.537	0.28796
I33	0.450	0.20223
I34	0.508	0.25842

Table 3. Model fit indicators

	RMSEA	TLI	CFI
Initial	1.108	0.892	0.901
Final	0.046	0.983	0.985

At level 30, a larger set of performance criteria is identified that need to be met, namely: delivery, level of service, reliability, health and safety regulations and poorly trained staff. Relationships positioned at this level indicate a low probability of risks of transport failure, inefficient service, problems because the supplier has not complied with the agreement or has been negligent with health and safety regulations or even dealing with poorly trained staff.

As you move up the relationship performance levels (level 35), the criteria of reliability, geographical position, communication efficiency and coordination are met. In other words, at this level the supplier meets the company's expectations, the supplier's geographical location does not interfere with transportation and delivery procedures, and the flow of information between supplier and customer meets the company's requirements.

At level 40, the supplier needs to meet logistical criteria, such as delivery time, mode of transport and load splitting, to meet the client company's needs. In addition, the company needs to know that it can count on this supplier to meet its demands properly and that it has well-trained professionals. In this way, the risks of inefficient logistics, reliability and poorly qualified work teams are reduced.

Suppliers positioned at level 50, in addition to meeting all the criteria already mentioned, present alternative plans in adverse situations, indicating a high level of reliability. And to be positioned at the highest level of the scale (level 55), the supplier anticipates possible problems and acts preventively to avoid them. Identifying the

Table 4. Item parameters.

Item	a	b
I01	1.637	-2.235
I02	1.275	-2.667
I04	1.413	-2.624
I05	1.237	0.104
I06	1.569	-1.614
I07	1.646	-1.545
I08	1.767	-1.547
I09	1.843	-2.324
I10	1.931	-1.845
I11	1.612	-1.541
I12	1.211	-0.468
I13	1.271	-2.152
I20	1.148	-2.555
I21	1.371	-1.962
I24	1.039	-1.392
I25	1.253	-2.563
I26	1.324	-2.952
I29	0.949	-3.578

level of difficulty associated with each type of risk indicates to the company where it needs to devote more effort to improving the performance of its supply chain.

An important aspect to note in this scale is that the items are cumulative, i.e. positioning at one level implies meeting the criteria presented in the previous levels. Therefore, a practical way of applying this instrument is to assess the relationship starting with the items positioned at the highest levels of the scale. A supplier that meets the criteria presented at levels 50 and 55, for example, is highly likely to also meet the previous criteria and represent a low risk to the good performance of the supply chain.

The supply chain is a dynamic system, with many uncertainties in its operations, and the lack of capacity to manage risk effectively can result in economic and financial losses, reduced product quality, delivery delays and loss of reputation (Mukherjee et al., 2024). It is therefore necessary to carry out intelligent risk management that can be updated to adapt to the reality of the market, which is constantly changing.

In this sense, the use of IRT allows the scale to be constantly revised and updated, adding new assessment items. Thus, other types of risks and performance criteria that may be identified can be assessed and included in the existing scale.

Figure 4 shows the distribution of the relationships observed on the scale. It can be seen that 37% of the relationships observed were positioned at the last level of the scale and the rest were distributed at the previous levels. The latter may have been guided by this scale to improve the performance of their relationships. Meanwhile, for the relationships positioned at the highest level of the scale, new risk indicators can be assessed that should be taken into account.

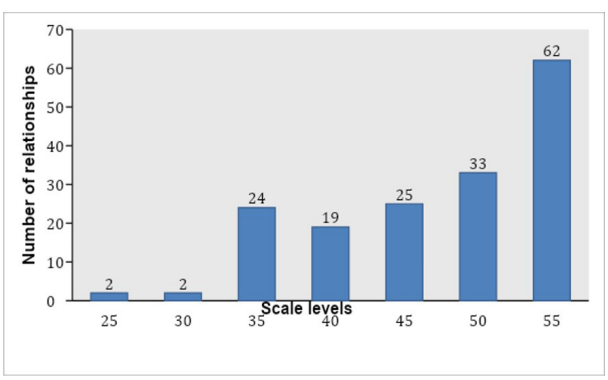

Figure 4. Positioning of relationships observed on the scale.

Table 5. Positioning of the calibrated items on the scale

Scale (50,10)	Item	Performance criteria	Type of risk	Item
20	29	Operational risk	Risk in assuming that operational activities are carried out efficiently and effectively.	The supplier company does not fulfill the agreement due to operational failures (e.g. machine breakdowns, lack of equipment and/or workers) in its processes (*)
25	2	Delivery	Risk of failure in the delivery process (Risk of transportation failure)	The supplier delivers the items in the agreed quantity
	26	Honesty of suppliers	Risk of assuming that the company will honor its commitments	The supplier company does as promised
30	1	Delivery	Risk of failure in the delivery process (Risk of transportation failure)	The supplier delivers on the day, place and time agreed in advance
	4	Service level	Risk of inefficient service	The supplier provides an adequate level of service
	9	Reliability	Risk in assuming that the reliability of suppliers is adequate	The supplier complies with the agreement with the client company
	20	Health and safety regulations	The risk of doing business with companies that neglect occupational health and safety standards	The supplier company follows occupational health and safety standards
	25	Poorly trained staff	The risk of doing business with companies that don't have staff training practices	The supplier company's staff is suitably qualified to carry out the activities
35	10	Reliability	Risk in assuming that the reliability of suppliers is adequate	The supplier meets the client company's expectations
	13	Geographical position	Risk that the location or geographical position poses to the execution of transportation and delivery procedures	The location of the supplier negatively affects the execution of transportation and delivery procedures. (*)
	21	Efficient communication and coordination	The risk of hiring companies that do not have or do not practice transparent communication between those involved in the process.	The flow of information from the supplier company to the others involved in the order fulfillment process is in line with the customer company's requirements.
40	6	Logistics	Risk of suppliers offering inefficient logistics	The logistics offered by the supplier (transportation options, delivery times) are sufficient to meet the needs of the client company
	7			The transportation options and conditions (vehicle, modal, fractional or whole load, one or more delivery cycles...) are sufficient to meet the needs of the client company
	8			The delivery options and conditions (time, schedule, packaging, place of delivery, etc.) offered by the supplier are sufficient to meet the needs of the client company
	11	Reliability	Risk in assuming that the reliability of suppliers is adequate	The client company considers that it can rely on the supplier company to meet its demands adequately
	24	Poorly trained staff	The risk of doing business with companies that don't have staff training practices	The supplier company trains its staff
50	12	Reliability	Risk in assuming that the reliability of suppliers is adequate	When there are adverse situations (not foreseen), the supplier company presents alternative action plans (e.g. compensation plan, contingency plan, flexibilization plan, etc.)
55	5	Service level	Risk of inefficient service	The supplier anticipates possible problems and acts preventively to avoid them

(*) Items with an inverted scale, where the higher the answer, the lower the level of performance.

Evaluating suppliers based on a structured method, insofar as it mitigates risks and improves supply chain performance, also reduces waste and strengthens consumer confidence (Arslan et al., 2023).

5. Final considerations

The aim of this article was to propose a tool for assessing supply risks that is associated with supply chain performance criteria. To this end, some of the performance criteria were listed and supply risks associated with them were identified. These risks were then classified according to their level of difficulty, based on the probability of each risk occurring.

Using this scale, it was possible to identify which types of risk and performance criteria are most difficult for suppliers to meet. The scale distributes 18 items into 7 levels of supply performance and relates them to the type of associated risk. Indicators associated with delivery, for example, are at the lowest levels of the scale. Thus, suppliers between levels 25 and 30 represent a low risk of failing to deliver the quantity, place and time of delivery previously agreed.

On the other hand, indicators associated with the reliability criterion appear at various levels of the scale. In this case, the supplier complying with what was agreed (item 9, level 30) is easier than presenting alternative action plans in the face of adverse situations (item 12, level 50). Thus, by evaluating the level of performance measured by the scale, it is possible to assess which criteria need to be reinforced with the supplier in order to avoid supply disruptions along the supply chain.

In general, it is hoped that the results obtained can contribute to broadening discussions on the subject studied - supplier performance in the context of supply chains - and on the applicability of IRT to deal with business problems in the field of production engineering.

Due to the limitations of the sample size and profile, some performance criteria that were included in the questionnaire were not included in the current scale, such as: financial stability, political stability, ethics, manufacturing capacity risk, contractual commitment risk, catastrophic risks, supplier country risk. This absence is due to the lack of information on these items in the relationships observed. Future research could look for supply chains with more structured relationships and higher levels of performance in order to position the other items on the scale, broadening the measurement range of the proposed tool. There is also the possibility of including new performance criteria in the evaluation tool.

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