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# A Risk Model to Promote Collaborative Logistics Networks

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**Abstract.** One of the most common wastes in the transportation of goods is empty transportation. In recent years, collaborative network models have shown promising results in reducing the waste caused by empty transport. However, despite the associated benefits, adherence to these logistical models is far from the expected due to the associated risks. In order to encourage new collaborators to join collaborative networks in the freight transportation sector, this work developed a model for assessing and managing reputational risk, with the aim of making the whole process of managing collaborative networks clearer, more efficient, and more predictable. The developed model was implemented in an illustrative case study in which collaborators of a collaborative network were prioritized according to their reputation risk. The results show that the developed model enables collaborators of a network to participate in the selection of their respective partners according to their reputational risk.

**Keywords:** Reputational risk, risk assessment and management, collaborative logistics networks, partner selection, logistic sector.

## 1 Introduction

The logistics sector plays a key role in the economy. Products, goods, and services are fundamental to the growth and maintenance of a society's prosperity, therefore, negative impacts in this sector also have negative impacts on society. In particular, negative impacts on the freight transport sector have an almost immediate effect on the end consumer. This sector is highly dependent on fuel prices, which translates into rising operating costs. Indeed, the price of fuel results from two aspects: on the one hand, the relationship between supply and demand and, on the other, regulatory measures aimed at regulating the consumption of fossil fuels through ever higher taxes in order to promote environmental sustainability. In this sense, it is important to reduce waste in freight transport in order to reduce both the operating costs and the environmental footprint of the sector. In fact, reducing the sector's environmental

footprint should also be a concern for this industry, in order to promote potential relief from fuel tax restrictions.

One of the most consequential wastes in the freight sector is the empty return of a logistics mission. To reduce waste, a logistics mission optimizes delivery routes, selects the vehicle with the appropriate load capacity, and packages freight in a way that fully utilizes the available load capacity and aligns freight organization with the delivery route. However, in the return to the company for a new logistics job, the vehicle returns empty and without freight, which incurs costs. These costs can be broken down into vehicle wear and tear, fuel costs and costs for unproductive driver activities.

Recently, collaborative networks have been shown to be a solution to reduce empty vehicle waste [1]. However, despite the benefits, the adoption of this new logistics model is not as high as expected. In general, this type of collaborative network is managed by virtual companies that collect operational information from their collaborators and distribute logistics orders to them based on the information exchanged between the collaborators and the virtual company. In practice, the virtual enterprise aims to reduce idle transportation using the information at its disposal through multi-criteria decision making.

For example, if a particular collaborator in the collaborative network has an order to transport goods from the south to the north, the transport will be empty when he returns. To avoid this waste, the virtual enterprise checks if the transport of goods from north to south is performed by another collaborator. If this is the case, the collaborator who would drive empty from north to south will transport these goods. The network collaborator who placed the logistics order from north to south will receive the corresponding payment from his customer, and the collaborator who transported the goods will have a future transport credit that can be executed by another collaborator under the same conditions. This approach not only reduces waste, but also enables faster delivery of goods, which somehow promotes the link between the supplier and the end customer.

## 1.1 Industrial Need

These collaborative networks must have a large number of collaborators in order for their benefits to be more prominent, i.e., the larger the number of collaborators in the network, the more attractive it becomes to belong to the network. In this sense, the larger the number of collaborators, the less likely those collaborators will experience empty run events, and the less operational waste they will have. However, there are some operational aspects of this type of collaborative network that have caused some mistrust among potential collaborators, which is why the adoption of this logistical model has not been as expected.

The most sensitive issues are the disclosure of information to the virtual company and the possible negative impact on the satisfaction of logistics customers due to the quality of the transport services provided by third parties (other network collaborator). The exchange of operational information between collaborators is a very delicate point, since the collaborators of the network have the same field of activity and compete with each other.

It is the virtual company's responsibility to ensure that each collaborator's information is managed securely and confidentially to promote the sustainability of each collaborator, thus preventing collaborators from leaving the collaborative network. However, despite the fundamental role that the virtual enterprise plays in information management, potential collaborators find it difficult to share their operational information because of the risks involved. In addition, the execution of their logistical tasks by other collaborators can have a negative impact on reputation.

A customer portfolio is built on the basis of trust and the quality of the service provided, being necessary a customer satisfaction-based process to construct a successful portfolio which takes a long time to build. In this sense, the provision of logistics services by third party collaborators can have an impact on the reputation of the collaborator who placed the logistics order, resulting in the loss of logistics customers and consequently a decrease in the company's business volume. These fears are justified, and if there is no effective control over them, collaborators can have a negative impact that could jeopardize the survival of their company.

It is incumbent upon the virtual enterprise to develop prevention and mitigation measures to protect the interests of network collaborators in a reliable and resilient manner. However, it appears that in current models of collaborative networks in logistics, these barriers are not yet clear and effective enough to reassure both collaborators who are already part of the collaborative network and potential collaborators, especially in terms of reputational impacts, as these impacts may come not only from the virtual company but also from other collaborators in the network.

## 1.2 Research Question

Consistent with solving the industrial problem described, this work aims to develop a decision support model to help select collaborative partners in a collaborative logistics network. The purpose of this model is, first, to quantify the reputational risk that a collaborator takes when it awards a particular logistics contract to another collaborator at a particular time, and second, to allow the virtual enterprise to manage the reputational risk of each collaborator. The goal of the proposed model is not to reduce waste, because there are already models for collaborative networks proposed by several authors for this purpose [1, 2].

The problem is that the collaborative network must have a critical size, i.e., it must have a number of collaborators that allows the network to function efficiently.

However, in practice, it is difficult to achieve this number of collaborators due to uncertainties related to reputational risks, such as the impact that a particular logistics order may have on the end customer, which in turn may have an impact on the supplier and finally on the collaborator. In this sense, the proposed model aims to reassure the collaborator by providing information about the reputational risk of the other collaborators in the network. In this sense, the collaborator that places a logistics order can cancel the order if the collaborator that will execute the logistics order has a higher reputation risk. This capability makes the collaborative network much more attractive and shares decision-making responsibilities between the virtual enterprise

and its collaborators. This encourages the recruitment of new collaborators and the retention of those who are already part of the collaborative network.

### **1.3 Managerial Insights**

In practice, the model developed should make it possible to clarify the level of risk to which each collaborative network collaborator is exposed, to clarify the understanding of the prevention and mitigation barriers developed and implemented in the collaborative network, to enable each collaborator to, query the reputational risk of each collaborator in the network, enable the collaborator placing the logistics order to query the level of reputational risk of the collaborator to whom the logistics order was placed, and in this way enable the collaborator placing the logistics order to review the placement of the order.

The model described in this work allows the collaborator who places the logistics order to be involved in the selection of the network collaborator who will execute it. In this way, risks with potential impact on the collaborators of the network should be minimized. This promotes compliance of the collaborative network, increases its efficiency in reducing empty transport waste and reduces the environmental footprint of freight transport.

### **1.4 Paper Structure**

This paper is divided into 5 sections, beginning with the introduction, which describes the research context through a holistic approach, the research question, and the practical applications of the research findings. Then, the literature review briefly reviews recent work on risk assessment and risk management in collaborative networks. In the third section, the model of reputational risk is presented. In the following section, a hypothetical case study is used to illustrate the application of the model and the analysis of the results obtained. Finally, the last section presents the conclusions of the paper and future work to be conducted following this research.

## **2 Literature Review**

### **2.1 Collaborative Networks**

The first studies of collaborative networks in the literature date back to the 1990s [3]. Since then, research in this area has increased and currently includes about 60,000 scientific articles in a variety of research areas, including sociology, agriculture, medicine, engineering, and others. The benefits of this type of management and decision making are undeniable, with the most obvious benefits being resource sharing and risk sharing [4, 5].

It is interesting to note that patterns of cooperation can even be observed in nature, such as protocoooperation between animals of the same species, as in the case of ants working together to carry objects much larger than themselves, bees through task sharing, birds and fish working together to protect themselves from predators. There is also cooperation between animals of different species, also called facultative mutualism, as in the case of the crab and the sea anemone, where the crab carries the sea anemone, and the sea anemone protects the crab from predators. It appears that the survival of these species, which are endangered in some sense, depends on their ability to cooperate. Similarly, collaborative networks aim to bring companies together with a common goal, resulting in benefits that would otherwise be difficult for these companies to achieve. The increasingly demanding challenges in the modern economy threaten the survival of lower capacity companies in some ways, and the collaborative approach is a natural survival solution [6].

Because of the transversality of the concept, there are different types of collaborative networks, such as social networks, virtual organizations, virtual enterprises, and agile enterprises. Each type of collaborative network has its specifics, but there are certain basic requirements common to all types of networks that must be ensured for the proper functioning of a given collaborative network [7]. Essentially, these requirements are the sharing of information, decision making with consideration of the other participants in the collaborative network, the promotion of trust, the sharing of resources, and the application of integrative strategies.

In many situations, these requirements are compromised by a lack of trust, the adoption of inconsistent business strategies, the absence of a holistic view of business strategy, and insufficient information. These issues have hampered the effectiveness of collaborative networks, particularly the lack of trust, and have contributed to few new collaborators joining because the risk of sharing sensitive business information with third parties can threaten the survival of the organization [2]. In this sense, risk analysis and management in collaborative networks is a recurring research topic. The fundamental goal is to support the decision-making process of the network's collaborators.

For example, the literature contains work on risk analysis and risk management in collaborative networks related to open innovation [8], project management [9], information sharing [10], information management [11], and the sharing of human and material resources [12]. It can be concluded that risk analysis and risk management play a key role in managing collaborative networks.

## 2.2 Reputational Risk

Nobanee et al.[13] developed a bibliometric analysis focused on reputational risk in 2021. The study analyzes the 88 major publications that appeared between 2001 and 2020 and concludes that the amount of work done in this area is very small compared to the need and that more research needs to be done to meet existing operational needs. Indeed, a company's reputation is its most valuable asset. If this reputation is compromised, the resulting negative effects can threaten the survival of the company. In this sense, reputational risk can be considered as the damage caused to the

company if it fails to meet the expectations placed on it. Reputational risk analysis and management models can be an extremely useful tool to minimize or even eliminate these impacts and strengthen the resilience of companies that are highly exposed to this type of risk.

One of the risk factors with the greatest impact on the proper functioning of collaborative networks is also reputational risk [14]. Impacts to a particular company's reputation can lead to irreversible damage or even destruction of the company. With this in mind, companies are increasingly concerned about their image and reputation when interacting with their customers [15, 16]. In collaborative logistics networks, this interaction with the customer is lost, since the company who executes the logistics order is a company working together in the collaborative network, rather than the company that has a relationship with the customer who needs the logistics service. In this sense, companies have concerns about joining collaborative logistics networks because it could have a negative impact on their reputation.

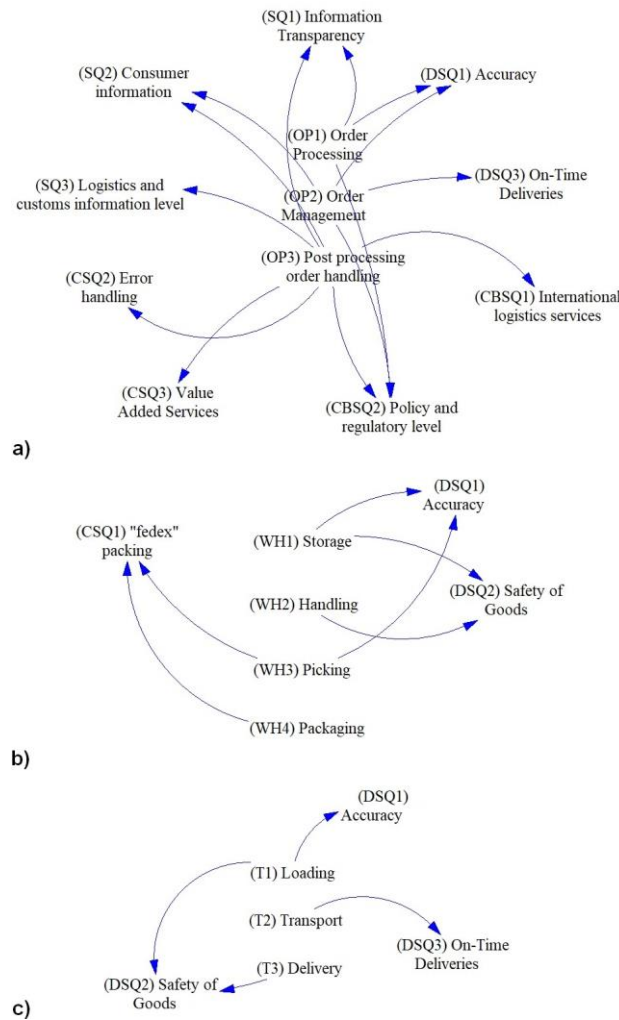
However, for collaborative networks to be effective, they must have a sufficient number of collaborators so that the benefits justify the risk taken. This indicates that there is a real need to develop models for risk analysis and risk management related to reputational risk in collaborative logistics networks[3]. There are a large number of models in the literature for reputational risk in different activity domains. However, for collaborative logistics networks, to the best of the authors' knowledge, there is no systematic and effective approach to assess and manage reputational risk. In this sense, this work aims to fill this knowledge gap and contribute to the sustainability of collaborative networks.

### 3 Reputational Risk Model for Collaborative Networks

The strategy for developing the reputation risk model is based on the analysis of supplier and customer satisfaction in the provision of the logistics service. In this sense, the development of the model begins with the identification of the most important factors in the assessment of customer satisfaction, followed by the identification of logistics operations with potential negative impact on these factors. Then, the causal relationships between customer satisfaction and logistics operations are identified. To quantify the impact of each logistics operation on customer satisfaction, an impact table is developed and later used to assess reputational risk. Then, based on causal diagrams, reliability theory, event trees, and fault trees, a mathematical expression is developed to evaluate the reputation risk of each collaborator in the network. Finally, the expression developed in conjunction with the Monte Carlo model is used to prioritize the collaborators in the network according to their respective reputation risk.

Figure 1 shows the logistical operations that affect customer satisfaction factors. These operations are divided into 3 major groups, namely OP -order processing, shown in sub-figure 1 a), WH -warehousing, shown in sub-figure 1 b), and T-transportation, shown in sub-figure 1 C).





**Fig. 1.** Causal relationships between logistical processes and factors influencing customer satisfaction. a) Causal relationships during processing b) Causal relationships during storage c) Causal relationships during transport of goods. (SQ - service quality, DSQ - distribution service quality, CSQ - customer service quality, CBSQ - quality of services provided when transporting goods abroad)

Customer satisfaction factors are divided into 4 groups, namely SQ for service quality, DSQ for distribution service quality, CSQ for customer service quality, and finally CBSQ for quality of services provided when transporting goods abroad.

Table 1 shows the impact of each customer satisfaction factor. These values were qualitatively assigned on a scale of 1 to 3. In this sense, the factor with the greatest impact has a rating of 3 and the factor with the least impact has a rating of 1.

**Table 1.** Factors that influence customer satisfaction and respective impact scores.

Area	item	<i>I</i> <sub>Score</sub>
Service quality	Information Transparency	2
	Consumer information security	3
	Logistics and customs information	1
Distribution service quality	Accuracy	2
	Safety of goods	3
	On-time deliveries	3
Customer service quality	fedex packing	2
	Error handling	3
	Value-added services	1
Cross-border service quality	International logistics services	3
	Policy and regulatory level	2

Based on the diagrams shown in Figure 1 and the classifications given in Table 1, and taking into account reliability theory, fault trees, and event trees, the expressions (Equations 1 to 3) that allow risk assessment for each of the previously mentioned groups of logistics operations were determined. In this formulation (equation(s) 1 to 3), the probability of failure of a particular collaborator in the logistics operations is represented by  $P_{FOP}$ ,  $P_{FWH}$  and  $P_{FT}$ . These probabilities were considered along with the probability of failure of prevention barriers, represented by  $P_{PB}$ , and the probability of failure of mitigation barriers, represented by  $P_{MB}$ . In addition, in this formulation, the variables beginning with "I" represent the influence that each customer satisfaction factor described in Table 1 has on overall satisfaction. The values of these variables are taken from Table 1.

$$\begin{aligned}
 OP_{risk} = & P_{FOP1} \cdot P_{PB\_OP1} \cdot (P_{MB\_SQ1} \cdot I_{SQ1\_score} + P_{MB\_DSQ1} \cdot I_{DSQ1\_score} + P_{MB\_CBSQ2} \cdot I_{CBSQ2\_score}) \\
 & + \\
 & P_{FOP2} \cdot P_{PB\_OP2} \cdot (P_{MB\_SQ2} \cdot I_{SQ2\_score} + P_{MB\_DSQ1} \cdot I_{DSQ1\_score} + P_{MB\_DSQ3} \cdot I_{DSQ3\_score} + P_{MB\_CBSQ2} \cdot I_{CBSQ2\_score}) \quad (1) \\
 & + \\
 & P_{FOP3} \cdot P_{PB\_OP3} \cdot (P_{MB\_SQ1} \cdot I_{SQ1\_score} + P_{MB\_SQ2} \cdot I_{SQ2\_score} + P_{MB\_SQ3} \cdot I_{SQ3\_score} + P_{MB\_CSQ2} \cdot I_{CSQ2\_score} + \\
 & P_{MB\_CSQ3} \cdot I_{CSQ3\_score} + P_{MB\_CBSQ1} \cdot I_{CBSQ1\_score} + P_{MB\_CBSQ2} \cdot I_{CBSQ2\_score}) \\
 WH_{risk} = & P_{FWH1} \cdot P_{PB\_WH1} \cdot (P_{MB\_DSQ1} \cdot I_{DSQ1\_score} + P_{MB\_DSQ2} \cdot I_{DSQ2\_score}) + P_{FWH2} \cdot P_{PB\_WH2} \cdot P_{MB\_DSQ2} \cdot I_{DSQ2\_score} \\
 & + \quad (2) \\
 & P_{FWH3} \cdot P_{PB\_WH3} \cdot (P_{MB\_DSQ1} \cdot I_{DSQ1\_score} + P_{MB\_CSQ1} \cdot I_{CSQ1\_score}) + P_{FWH4} \cdot P_{PB\_WH4} \cdot P_{MB\_CSQ1} \cdot I_{CSQ1\_score} \\
 T_{risk} = & P_{FT1} \cdot P_{PB\_T1} \cdot (P_{MB\_DSQ1} \cdot I_{DSQ1\_score} + P_{MB\_DSQ2} \cdot I_{DSQ2\_score}) \\
 & + \quad (3) \\
 & P_{FT2} \cdot P_{PB\_T2} \cdot P_{MB\_DSQ3} \cdot I_{DSQ3\_score} + P_{FT3} \cdot P_{PB\_T3} \cdot P_{MB\_DSQ2} \cdot I_{DSQ2\_score}
 \end{aligned}$$

Equation 4 is used to assess reputational risk, where the sum of the risks of each group identified in equation(s) 1 through 3 represents the total reputational risk. Equation 4 allows network collaborators to be prioritized according to their respective

reputational risk. These results can also be used as an indicator of the quality of each employee in the network and can be used in continuous improvement initiatives.

$$Risk_{reputation} = OP_{risk} + WH_{risk} + T_{risk} \tag{4}$$

### 4 Illustrative Case Study

This section illustrates the applicability of the model described in the previous section. To this end, we consider two network collaborators, companies X and Y. The first step in applying the model is to determine the failure probabilities for each company for both the logistic operations and the respective prevention and mitigation barriers. Tables 2 and 3 show these probabilities, taking into account the mean and the respective standard deviation. The actual collection and analysis of these data requires a separate study, which is not part of the objectives of this study and is referred to future work. With this in mind, it is assumed that the data in Tables 2 and 3 represent the performance of individual companies.

**Table 2.** Logistic process and preventive barriers failure probabilities for companies X and Y.

	Company X				Company Y			
	Normal Distribution for failures in Logistic Processes		Normal Distribution for failures in Preventive Barriers		Normal Distribution for failures in Logistic Processes		Normal Distribution for failures in Preventive Barriers	
	μ	σ	μ	σ	μ	σ	μ	σ
(1) Order Processing	0,4	0,1	0,3	0,1	0,3	0,2	0,4	0,2
(2) Order Management	0,3	0,1	0,4	0,15	0,35	0,1	0,4	0,15
(3) Post processing	0,42	0,2	0,2	0,1	0,4	0,2	0,3	0,1
(1) Storage	0,3	0,2	0,4	0,2	0,3	0,1	0,5	0,2
(2) Handling	0,4	0,15	0,5	0,1	0,35	0,15	0,6	0,2
(3) Picking	0,35	0,1	0,4	0,2	0,6	0,1	0,3	0,2
(4) Packaging	0,4	0,2	0,4	0,1	0,4	0,2	0,4	0,2
(1) Loading	0,6	0,2	0,6	0,1	0,3	0,14	0,5	0,1
(2) Transport	0,4	0,2	0,3	0,1	0,5	0,2	0,2	0,1
(3) Delivery	0,2	0,1	0,5	0,2	0,3	0,1	0,3	0,1

Normal distributions were used for the failure probabilities presented in Tables 2 through 4 because they apply relatively well to failures associated with human performance. The inclusion of the standard deviation along with the mean serves to account for the variability that is always present in the scenarios used to evaluate the failure probabilities.

To account for the variability in failure probabilities, a Monte Carlo simulation was performed, updating the average values of Tables 2 and 3 over 10000 iterations. Equation 4 was evaluated and plotted for each iteration. Based on these results, the respective average value of reputational risk and the respective standard deviation for each company were determined. Table 4 shows these results.

**Table 3.** Mitigation barriers failure probabilities for companies X and Y.

	Impact score	Company X		Company Y	
		Normal Distribution for failures in Mitigation Barriers		Normal Distribution for failures in Mitigation Barriers	
		$\mu$	$\sigma$	$\mu$	$\sigma$
(1) Information Transparency	2	0,2	0,1	0,5	0,1
(2) Consumer information security	3	0,3	0,2	0,6	0,1
(3) Logistics and customs information	1	0,4	0,1	0,3	0,1
(1) Accuracy	2	0,5	0,1	0,3	0,1
(2) Safety of Goods	3	0,3	0,1	0,3	0,1
(3) On-Time Deliveries	3	0,5	0,1	0,4	0,1
(1) "fedex" packing	2	0,3	0,1	0,3	0,1
(2) Error handling	3	0,2	0,1	0,4	0,2
(3) Value-Added Services	1	0,5	0,1	0,5	0,1
(1) International logistics services	3	0,3	0,1	0,6	0,1
(2) Policy and regulatory level	2	0,2	0,1	0,5	0,1

**Table 4.** Results for companies X and Y regarding their reputational risk.

Company X Reputational risk		Company Y Reputational risk	
$\mu$	$\sigma$	$\mu$	$\sigma$
2,73	0,63	2,90	0,81

The results presented in Table 4 cannot be used directly to prioritize companies according to their respective reputational risk, as the respective standard deviation must also be taken into account in addition to the average value of the reputational risk. With this in mind, and based on the results of the Monte Carlo simulation, the relative risk between the two companies was determined. Table 5 shows the results of this analysis. It can be seen that the probability that the reputational risk of company Y is greater than the reputational risk of company X, i.e., company X is the company with the lowest reputational risk.

**Table 5.** Relative reputational risk between companies X and Y.

>	Company X	Company Y
Company X	0	0,40
Company Y	0,58	0

The model described relates a set of logistical operations related to freight transportation to the factors that have the greatest impact on customer satisfaction. By combining this relationship, the reputational risk of a particular partner in the network is obtained, which allows ranking between pairs.

These factors for logistics operations and customer satisfaction were identified through a literature review and correlated in this paper. Although the structure of the model is predefined, it is possible to make adjustments as needed by updating equations 1 to 3 and also the scores presented in Table 1. In this sense, the described model is versatile enough to be adapted over time.

The implementation of the model in practice is simple and fast and can be implemented both in customized computer applications and in commercial software such as Excel, which means that the entire model can be automated, requiring only the introduction or updating of the information related to the failure probabilities of each network member. Capturing the probabilities of failure associated with the reality of the partner companies is critical in order to take advantage of the inherent benefits of the model described. At the beginning of the company's participation in the collaborative network, this information can be obtained through questionnaires sent by the virtual company to the newly added collaborating company. With the participation of this company, questionnaires can be sent to customers (suppliers and end customers) over time to update the failure probabilities.

## 5 Conclusions

In this article, the problem of the lack of collaborators in collaborative logistics networks is analyzed. It is shown that reputational risk is one of the main reasons for this limited accession. As a result, the efficiency of these networks is affected by the uncertainty about the potential impact on the reputation of their collaborators. In this sense, and in order to encourage the joining of collaborators to the network, this work has developed a methodology for the analysis and management of reputational risk through the theory of reliability, failure tree analysis, event trees, and the Monte Carlo method. The model developed is qualitative and allows adjustments during its application in practice. The model developed is intended to reduce uncertainty about reputational risk and allow network collaborators to participate in the selection of the network collaborator that will perform the logistical task they specify. In this way, the participation of collaborators in the network becomes more transparent, which encourages the participation of existing and future collaborators in the network which increases the size of the network, and consequently increases its efficiency. The developed model can be easily implemented in practice and can be used as an indicator of the quality of the network's collaborators. It can be used not only in the selection of the collaborator for a particular logistical task, but also as a tool for continuous improvement. In the future, it is expected that the methods for evaluating the probability of failure of each collaborator in the different areas of the model will be improved. This improvement, based on new information technologies, includes the introduction of online questionnaires for both suppliers and end users.

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