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Operational Risk and Corporate Sustainability Relationship Using Case-Based Reasoning

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Abstract. This research seeks to contribute to the literature by classifying the operational risks to which companies are exposed and that have an impact on the results of sustainability through taxonomy. This study begins with a systematic literature review that covers 103 documents to build the theoretical constructs and establish the taxonomy; from this, the relationship among the constructs is established through reasoning based on 100 business cases. The results show a relationship between operational risks and corporate sustainability in aspects that generate this link, such as causes and consequences. From this, it is concluded that operational risks could affect corporate sustainability given that, based on case-based reasoning, we found relationship patterns linked by the economic, social, and environmental consequences and temporary effects on companies. The major contribution of this work lies in the proposed classification of operational risks regarding corporate sustainability and the establishment of their relationship. The findings of this study allow the management to classify the operational risk related to sustainability to carry out comprehensive risk management in companies, looking at the effects that this generates in the long term. The main limitation of this research was that the results of the connections can change depending on the analyzed case. In addition, the CBR case base includes many sectors of the economy, which is why it provides heterogeneous results. It was identified that the relationship can change if a sectoral analysis is performed.
Key words: corporate sustainability, operational risks, sustainability drivers, case-based reasoning (CBR), taxonomy.

Introduction

The literature has shown that corporate risk has an impact on businesses (Jensen *et al*., 2012); it has been studied by many authors as the materialization risk influencing companies' results by means of the benefit–cost relationship (Fatemi & Luft, 2002), either through superior performance (Cancellier & Salum, 2011) that is reflected by decreased exposure, by a reduced impact, by legislative incentives, or even by achieving the maximization of yields, in the case of investment portfolio risks (caused by the correct application of diversification theory). It can also be studied from a point of view in which the materialization of risks can lead companies to poor performance, fines, sanctions, and even bankruptcy (Ortiz-de-Mandojana *et al*., 2011). Despite the fact that these studies show the importance of evaluating the incidence of risk for the business, there is no holistic vision from the point of view of corporate sustainability.

Sustainability studies have included factors related to different dimensions (economic, social, and environmental) (Lozano, 2008), but it is important to carry out a holistic analysis that leads to standardized measurement processes allowing us to assess and measure corporate sustainability levels (Montiel & Delgado-Ceballos, 2014). Although diverse topics have been addressed, such as corporate social responsibility, the business relationship with the environment, business performance, the participation of stakeholders in sustainable development, and strategic decisions, among others, it was identified that in these studies, risk has not been widely explored. This is, however, necessary, since risk management can be used to identify and control threats and opportunities implied in the transition of

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companies towards sustainability (Schulte & Knuts, 2022).

There are authors who link corporate sustainability with risk (Shafiq *et al*., 2017), since companies are exposed to inherent risks in the development of their activity (Kouloukoui *et al*., 2019), which could prevent them from meeting the fundamental sustainability pillars (Patel *et al*., 2020). It is known that operational risk affects businesses, but there is no holistic vision, such as the one proposed by sustainability. This highlights the need to manage the different risks to which a company can be exposed, including operational risks.

This research paper aims at classifying and listing the operational risks that have an impact on corporate sustainability results. For this, the article presents a systematic literature review of 103 documents. Once the classification of the two theoretical constructs is obtained, the relationship between them is established through the reasoning methodology based on 100 business cases. Finally, this article contributes to the literature by explaining the relationship between corporate sustainability and business performance (Goyal *et al*., 2013) from the drivers, guidelines, and characteristics that govern sustainability (Lozano & von Haartman, 2018); in this way, the originality of this work lies in the proposed classification and connection between operational risks and corporate sustainability. To address the research, Section 2 of this article explains the methodology used, followed by Section 3, which presents the results; then, Section 4 provides the discussion. Finally, the conclusions are presented in Section 5.

Materials and Methods

The research consists of a sequential methodology of two qualitative techniques. The first consists of a systematic literature review through an inductive exercise with a bibliometric phase and a content analysis to constitute the taxonomy of risk and sustainability. Subsequently, the empirical relationship between risk and sustainability is established through a case-based reasoning analysis. The development of this study's stages is explained below.

Taxonomy for the Identification and Theoretical Classification of the Operational Risk Components and Corporate Sustainability

The research project began with a systematic literature review, through a bibliometric analysis and subsequently a content analysis. It began with the bibliometric analysis, taking samples from Scopus and applying data export as the data collection technique (title–abstract–keywords). After this, a content analysis was carried out, selecting the documents with the Prism method (Moher *et al*., 2009), and, with these, information processing was carried out aiming at explaining the following points to the reader:

- The holistic vision of corporate sustainability.
- The operational risk management.

From the data collected, information processing was carried out. Based on this analysis, a classification of corporate sustainability and operational risks was made. Studies that described taxonomic representations were also included; reviewing the existing records was used as a data collection technique. Through inductive reasoning, the following question was answered: How can we classify the operational risks that are related to sustainability aspects?

Taxonomies are structures that connect concepts through typification, i.e., concept specialization relationships. These structures are fundamental to the modeling of conceptual domains and have a central organizing role in areas such as knowledge representation, ontology engineering, and object-oriented modeling, as well as knowledge organization in data science (Batista *et al*., 2022). Taxonomies and structured representations of concepts have always played an important role in various contexts. With these, sorting can be developed given a set of domain-specific concepts. This helps in analyzing and classifying theoretically derived factors, as well as factors from empirical research (Horne & Fichter, 2022).

For the development of taxonomies, there are different techniques for progressive grouping based on the similarity of objects; however, researchers have found that there is little guidance on how to build high-quality taxonomies, which is why there are authors who adopt the existing methodologies, such as Onto-Clean and the ontology-based conceptual modeling language OntoUML. This is how some authors have managed to present a guideline for the main good practices to correctly build taxonomies (Batista *et al*., 2022); this paper is based on this guideline.

In order to build its taxonomy approach, we began this research by developing an understanding of the different methodologies, analyzing the recommendations of authors based on their experience, taking future recommendations from these studies, and, thus, proposing the taxonomy for the present work.

This research intends to classify corporate sustainability and operational risks in order to operationalize each of the variables and clearly define the approach to be used in the study. For this, taxonomic representation examples used by other authors have been considered; these include previous studies on operational risks and corporate sustainability including taxonomy as the analysis technique. These have evidenced that there is not a standardized method of representing the classifications in these research

works and that, on the contrary, there is a diversity of presentations displayed by other authors. They have carried out their classification processes using tables, diagrams, clusters, graphs, process maps, clustering algorithms, neural networks, association rule learning, and trees/hierarchies of classes and subclasses, among others. On the other hand, this paper presents its taxonomy based on the creation of trees and the hierarchy of classes and subclasses as a sorting methodology (Zhu *et al*., 2020). It thus shows the results of the classification under a data qualitative approach; first, it presents the sustainability classification and then the risk classification.

Structuring the Correlation between Operational Risks and Sustainability Aspects through the Case-Based Reasoning Methodology

The theoretical framework and the taxonomy make it clear that the classification must incorporate both theoretical constructs. For this, the paper establishes the relationships between the classification of corporate sustainability and the classification of operational risks through the development of reasoning based on cases. We used a base of 100 cases, found in Appendix A, where the qualitative information was processed using Web Scraping as a data collection technique. In order to create the case base, interpretative synthesis was used as a data collection technique. Then, the data analysis and findings were obtained.

To establish the relationship between operational risks and corporate sustainability, the literature review is taken as theoretical evidence. The explicit connection between these two theoretical constructs is established through the relationship between taxonomies. To establish the connection, the case-based reasoning (CBR) analysis methodology is used. An analysis of experiences (a fact that occurred in the past) and reusing the experiences of materializing operational risks are used to obtain empirical evidence on the factors that can be taken as a reference. Accordingly, we proceed to collect the information and create the case database. For this, other authors who have already established this type of relationship with this methodology are taken as a reference, linking different theoretical constructs through historical connections.

To list the 100 cases, a detailed description of the selection criteria and the procedure for their analysis is provided below:

(I) Identification of operational risk cases: the search was performed for companies that have historically had an operational risk materialized in the company.
(II) Description of the operational risk event: this shows the event that occurred in the company that led to the materialization of the operational risk.
(III) Year of occurrence: this indicates the year in which the materialization of the operational risk occurred.
(IV) Type of operational risk: according to the occurrence, the classification of the operational risk is performed.
(V) Consequences: inductive reasoning is used to indicate the consequences presenting risks on corporate sustainability.

Once the case database is documented, the empirical link between operational risk and sustainability is established. For this, the variables defined in the taxonomy are assigned to each of the cases depending on the consequences of each risk; thus, an explanation of risk cases and their consequences is obtained.

Finally, the theoretical model is contrasted with empirical validation to explain the similarities and differences between them; then, the conclusions of the analysis are presented.

Results

In order to build the taxonomy approach, this research conducted a bibliometric analysis that was raised with the Scopus database. The information was collected by applying the "Citation Pearl Growing" method (Schlosser *et al*., 2006), using, in the search equation, the main themes "Sustainable*" and "Risk". The main studies analyzed through the co-authorship networks are included; with these, an analysis of the correlations and co-occurrences that are presented in the literature was performed using the Scopus database. These were filtered and processed in the VOSviewer tool, as presented in Figure 1.

The resulting network presents the knowledge map of corporate sustainability and business risks, where the relationship of co-occurrences is found; it reveals the existence of seven clusters where the most relevant keywords are identified in the bibliographic records. From this, the most distinguished cluster is the one that includes sustainable development issues, followed by the risk management cluster and then sustainability. In addition, there are other clusters that refer to economic development issues, risk perception, environmental impacts, and strategic decisions.

As shown in Figure 2, all the clusters generate a relationship among them and allow us to approach the topics that have been studied in the literature, with the most relevant concepts in this field. Table 1 below shows the terms with the most frequent appearance in the VOSviewer® tool.

After identifying the existing knowledge map between corporate sustainability and operational risk, the analysis of the keywords presenting the greatest co-occurrences and the selection of documents for content

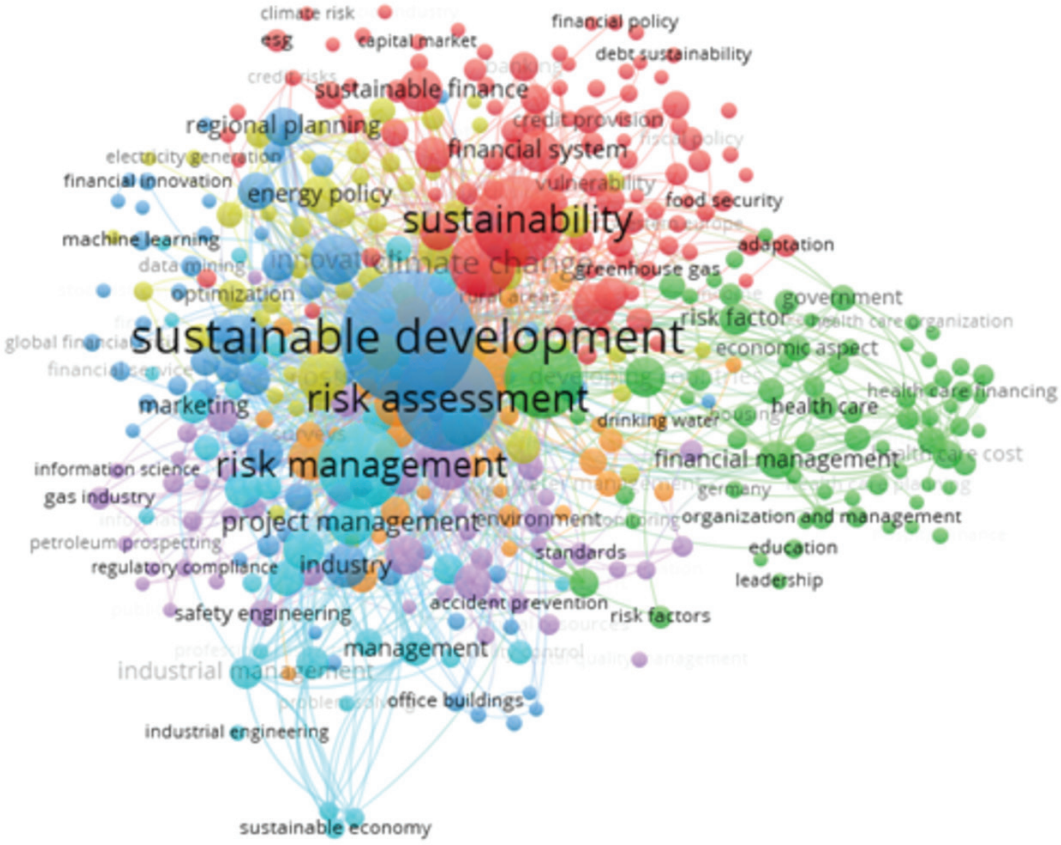

Figure 1. Knowledge map.

Source: Own elaboration in VOSviewer.

Table 1

Most relevant co-occurrences

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Sustainability	Economics	Sustainable Development	Costs	Environmental Impact	Risk Management	Decision Making
Climate Change	Developing Countries	Risk Assessment	Energy Policy	Environmental Protection	Project Management	Economic And Social Effects
Risk	Financial Management	Innovation	Financial Sustainability	Environmental Management	Public Policy	Planning
Sustainable Finance	Risk Factor	Information Management	Risk Perception	Health Risks	Risk Analysis	Economic Analysis
Financial System	Health	Industry	Cost/Benefit Analysis	International Trade	Industrial Economics	Laws And Legislation

Source: Own elaboration.

analysis is performed. For this, the Prism method is implemented with the topics of interest. Figure 2 presents the process for filtering the documents.

From the filtered documents, the content analysis was carried out. It shows the results of the sections proposed by the methodology. The documental analysis findings are shown below:

Sustainability has been widely defined by different authors; however, few of them have committed to identifying the variables or sustainability factors that are related to the business system. The classification of corporate sustainability begins by understanding the work proposed by authors who explicitly show the relationship of the corporate system with sustainability,

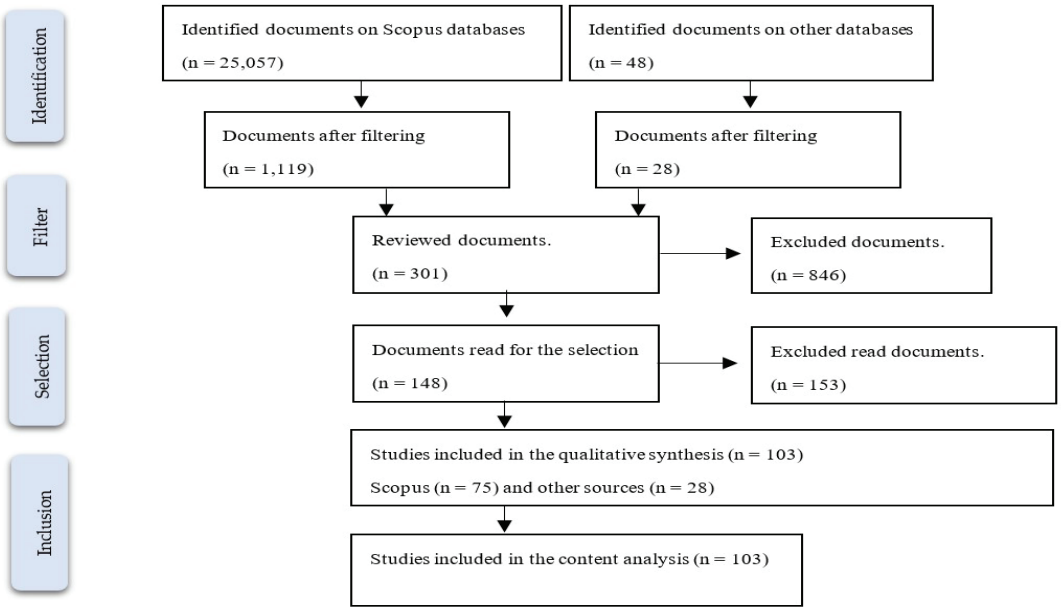

Figure 2. Implementation of the Prism method for document selection, where n is the number of documents.

Source: Own elaboration.

where the following classifications are focused on the results of their research. Lozano (Lozano & von Haartman, 2018) proposes drivers of sustainability that explain the economic, social, and environmental results from internal, external, and connection drivers. These are grouped by clusters according to corporate interests; they include in the internal drivers, economic factors, culture, and leadership. Within the external drivers, there are regulatory and political factors, customers, collaboration, awareness, and the pressure from interested parties. Within the connection drivers, there are the connection markets, crises, reports, and reputation.

Likewise, authors such as Lüdeke-Freund (Lüdeke-Freund *et al*., 2018), classify sustainability from a taxonomy proposing a "Triangular Analysis", which is composed of the connection of the three domains of results (economic, social, and environmental), where groups of employers are connected with the means of creating value in a company. Among these, there are the price and income patterns, financing, eco-design, closing the cycle, the supply chain, donations, access provision, the social mission, service and performance, cooperative activism, and the community platform. Each of these factors has different associated characteristics that form groups and patterns for corporate value creation. Along with this research, (Alonso-Martinez *et al*., 2021) show a taxonomy of sustainable business models describing archetypes divided as follows:

(I) Environmental (to maximize material and energy efficiency; to transform waste into valuable inputs; to substitute with renewables and natural processes);
(II) Social (providing functionality through pay-as-you-go instead of product ownership, adopting a managing role, fostering self-sufficiency);
(III) Economic (to reuse resources for society/ environment; to develop sustainable expansion solutions; creation of inclusive value).

Alternatively, Horne and Fichter (Horne & Fichter, 2022) establish a taxonomy that is divided into three levels, a micro level, a medium level, and a macro level, where there are internal variables (the natural environment, policies and regulations, the sociocultural environment, the business ecosystem, technology, industry, and the market) and external variables (the work team, the vision and strategy, company processes, resources, products and services, and positioning). Other authors refer to a taxonomy only composed of social dimensions, or taxonomies of environmental dimensions, and, finally, other authors only classify sustainability variables around economic performance.

According to the previous authors, scientific research proposes sustainability taxonomies where economic, social, and environmental components are discussed (Seay, 2015); later, the temporal factor is introduced in the analyses (Lozano, 2015), In addition,

it is found that in the sustainability–corporate system relationship, there is a great diversity of factors in these previous studies, where strong relationships cannot be identified. They are also limited; thus, there is a search for indicators associated with drivers in financial databases, sustainability standards, reports, and sustainability guides worldwide to obtain the indicators associated with these. Different sources, such as the GRI, the Dow Jones Sustainability Index, and Bloomberg, were used.

In accordance with the information obtained from the theoretical and empirical evidence, the classification of sustainability is carried out according to the grouping methodology. This classification takes, as its first level of grouping, sustainability drivers (economic, social, environmental, temporal); they present the theoretical standards that were evidenced in the literature review. Next, there is Level 2, which takes as a reference the sustainability indicators used in Bloomberg's financial reports (Bloomberg L.P ®, 2023), and, finally, Level 3 is based on the Dow Jones Sustainability™ World Index (The Dow Jones Sustainability World Index Guide, 2012) and the GRI (Global Reporting Initiative, 2023) standards; they were classified by assigning them a mnemonic item for ease of location. Below, Figure 3 presents the classification and each of its components.

Next, we present the mnemonics that were assigned to the variables for the classification of corporate sustainability.

***Classification of environmental components*:** E1 Energy consumption, E2 Operational eco-efficiency, E3 Electricity generation, E4 Transmission and distribution. A1 Water and effluents, A2 Transmission and distribution, A3 Effluents and waste, A4 Risk related to water.GD1 Emissions, GD2 Environmental compliance. M1 Materials, M2 Transmission and distribution, M3 Emissions. EI1 Emissions, EI2 Environmental compliance. GE1 Climate change governance, GE2 Biodiversity, GE3 Climate strategy, GE4 Operational eco-efficiency. PA1 Environmental compliance, PA2 Environmental footprint, PA3 Biodiversity, PA4 Environmental evaluation of suppliers, PA5 Environmental reports.

***Classification of social components*:** EM1 Employment, EM2 Attraction and retention of talent, EM3 Health and safety at work. DS1 Employee–employer relationships, DS2 Diversity and equal opportunities. CAP1 Training and education, CAP2 Human capital development. CC1 Non-discrimination,

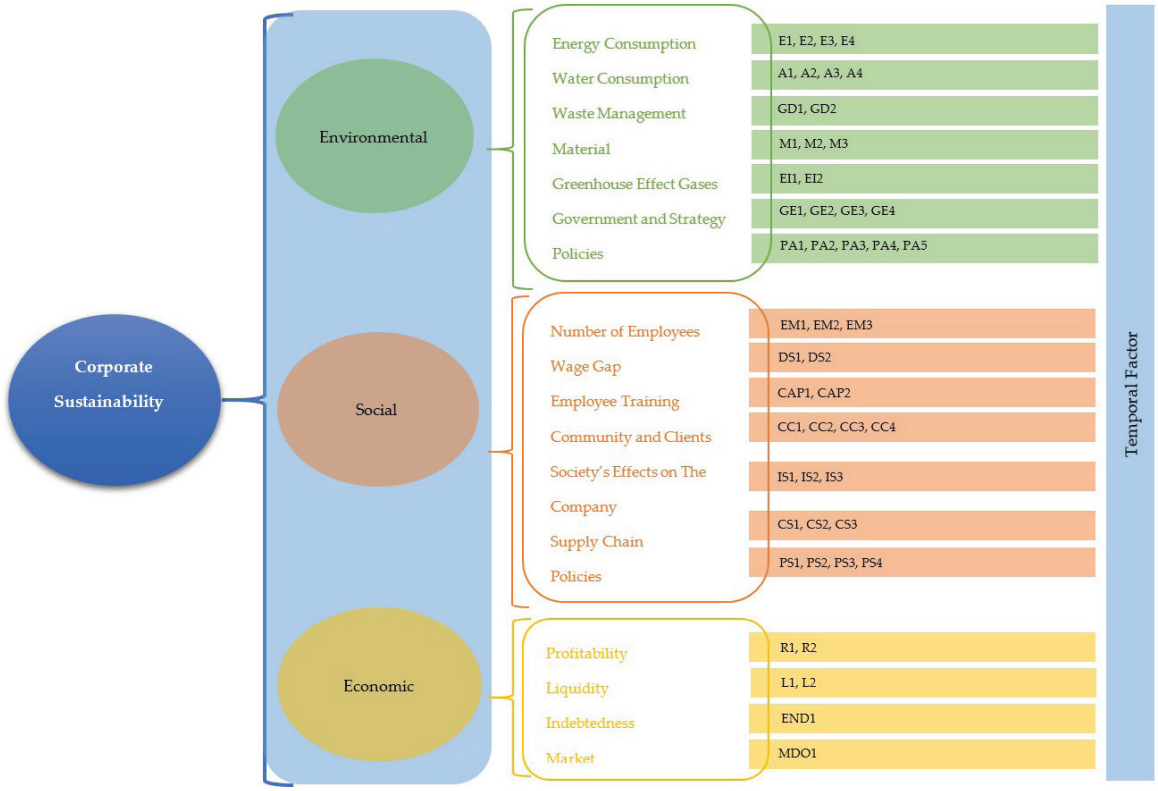

Figure 3. This figure shows the taxonomy of corporate sustainability according to the interpretation obtained from the literature review and the information taken from the sustainability and financial information bases.

Source: Own elaboration.

CC2 Social assessment of providers, CC3, Local communities, CC4 Contribution to health outcomes. IS1 Freedom of association and collective negotiating, IS2 Child labor, IS3 Forced or compulsory labor. CS1 Social assessment of providers, CS2 Socioeconomic compliance, CS3 Supplier standards. PS1 Rights of indigenous peoples, PS2 Public policy, PS3 Indicators of labor practices, PS4 Social reports.

***Classification of economic components*:** R1 Economic performance, R2 Indirect economic impacts. L1 Customer relationship management, L2 Risk and crisis management. END1 Business opportunities and financial services/products. MDO1 Presence in the market.

Once the corporate sustainability classification is obtained, the operational risk is studied, where us found that research evidences that there is a disengagement between risks and corporate sustainability (Hawkins & Weber, 2015); it is argued that sustainability should be seen as a separate and isolated issue involving the business strategy, legal environment, economics, accounting, corporate finance, marketing, and international business (Stubbs & Cocklin, 2008).

The foregoing is also explained by studies that suggest that a "negative aspects" report can endanger corporate legitimacy if the stakeholders perceive that the company is not aligned with social norms and values. In addition, many scholars question the effectiveness of sustainability reports; they argue that reporting can mislead sustainability decision-makers, or even can mask unsustainable practices. Despite the fact that these studies highlight the disconnection between business management and corporate sustainability, this paper's challenge was to establish the classification and connection of operational risks with corporate sustainability. This relationship has been identified through different authors; they state that risk management supports decision-making aimed at reducing the adverse effects of risk factors. Alternatively, this research adopts a different perspective on operational risks. This paper intends to raise awareness among the readers about the effects that the materialization of risks can produce on companies. As a result, these effects might act against or in favor of sustainability. This research work's vision is in line with studies affirming that risk management helps decision-making aimed at reducing the adverse effects of risk factors.

To better understand the risk management process, it must be noticed that it includes identification, measurement, control, and monitoring activities; it is important to quantify the total risk exposure level faced by companies. The former leads to the identification of potential losses or the generation of added value.

This demonstrates that the materialization of risks is linked to administrative planning since it determines how objectives can be modified in the short or long term; risk management is a relevant topic in the business world, necessary to estimate the value and level of risk to which companies are exposed; a discipline that helps to establish decision strategies against risks results from this.

Although there are guidelines that provide instructions for risk management and they show good practices (such as those presented in Table 2), the risk management performance evaluation process is complex and difficult. Most of these difficulties can be attributed to the fact that the impact of losses

Table 2

Risk management guidelines

Guideline	Description	Reference
As / NZ 4360 (Australian/New Zealand Standard)	This provides a general guideline for risk management, which can be widely used in different sectors.	(Chen, 2018)
ISO (International Organization for Standardization)	This is an international standard on risk management practices, also called "Risk Management—Principles and Guidelines".	(Gjerdrum & Peter, 2011)
COSO (Committee of Sponsoring Organizations	This helps organizations to design and implement internal control based on the shifting business and operating environments.	(Power, 2005)
Basilea	This standard describes the framework for risk-based capital requirements.	(Hernández Barros, 2015)
Solvencia	This establishes the minimum capital requirements to cover the risk in companies.	(Gatzert *et al*., 2012)

Source: Own elaboration.

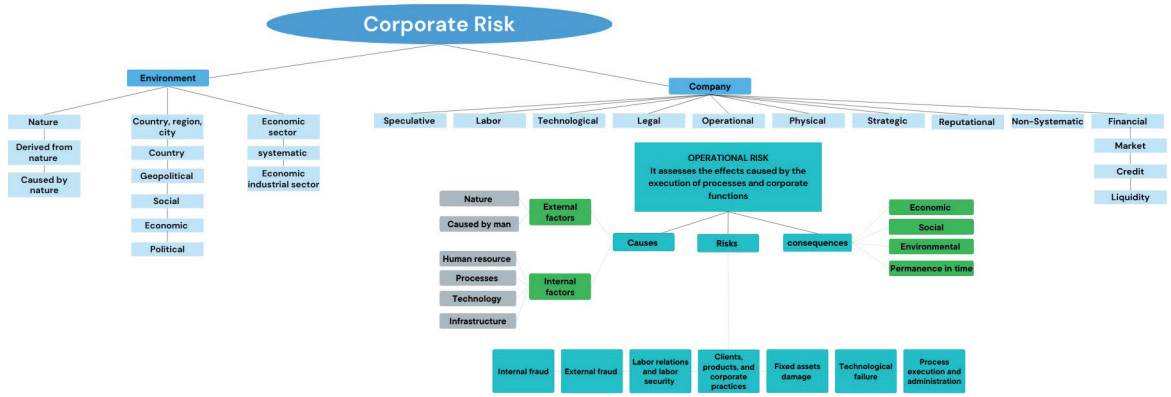

Figure 4. This figure shows the taxonomy of operational risks according to the interpretation obtained from the literature review and the information taken from the Basel Committee.

Source: Own elaboration based on Basilea, 2004 and Mejía Quijano, 2013.

prevented or reduced by risk management practices cannot be easily measured.

In these guidelines, it is evident that one of the branches in studying corporate risk is operational risk. It is defined as the risk of loss resulting from internal processes, people, and inadequate, failed systems or external events, which must be identified, measured, controlled, and monitored. This is due to the fact that risk is inherent to almost every activity, both daily and industrial; so, the definition, in this context, can be understood as the possibility of an operation-derived event occurring that affects corporate objectives.

For the development of the taxonomy, first, it is required to understand the classification of business risks proposed by Mejia (Mejía Quijano, 2013), who explains that companies are exposed to environmental risks and to those coming from the company itself; the latter are classified into different classes, such as non-systematic risks, reputational risks, pure risks, speculative risks, strategic risks, operational risks, financial risks, legal risks, technological risks, labor risks, and physical risks. Then, the operational risks are classified into the "risks generated by the company". Therefore, this research takes this general classification to establish their importance within a company.

Once the operational risks in the corporate system have been identified, an analysis of the classification of operational risks is carried out. The literature review had identified that there are different international standards providing this input. In this research work, the classification proposed by the Basel Committee (Basilea, 2004) has been used as a reference. It is divided into 3 levels, and, for this research, Level 1 is taken. This level classifies the operational risk as internal fraud, external fraud, labor relations and job security, clients, products and business practices, damage to physical assets, technological failure, and the execution and administration of processes.

In accordance with the current categorization, interpretation–description is used as a data analysis technique so that the interpretation and connection of business risks with operational risks is carried out. This is established through the tree or hierarchy of classes and subclasses methodology (Zhu *et al*., 2020). Figure 4 presents the classification of operational risks used in this research.

Once we have obtained the taxonomy of corporate sustainability and the operational risks, the relationship between them is established. The next section explains the results of the relationship through empirical analysis to test the relationship between the theoretical constructs.

Research that covers the existing body of knowledge on these issues found that sustainability becomes relevant as an alternative to traditional short-term and for-profit approaches to company management, since it holistically balances the economic, environmental, and social problems in the current generation and for future generations. This supports the fact that companies are exposed to risks, inherent to the development of their activity; these could lead to a failure to achieve the fundamental pillars to becoming sustainable (Patel *et al*., 2020). It also highlights the need to manage the operational risks to which a company can be exposed because, during the development of their activities, companies can generate operational risks that are mainly based on business action. This can affect business sustainability, which is why authors point out that companies, in their strategies, need to integrate sustainability and risk management so as to reduce possible losses and impacts and obtain opportunities derived from the sustainability agenda.

Figure 5. This figure hierarchical ranking the risks according to the number of matrix events.

Source: Own elaboration.

Based on the taxonomy proposed in the previous section, empirical validation is performed through an analysis based on the CBR methodology. For this research work, 100 cases of the materialization of operational risks were used. Data from the cases were collected via the web scraping methodology. The search for cases with "close-to-materialization operational risks" was conducted using this methodology (its search variable was the materialization of operational risks).

Once the data from the cases were collected, an interpretative synthesis was carried out. With this, the empirical connections among the materialization of the risks, their causes, and their consequences were established.

The cases are analyzed from the three components suggested by integrated risk management (causes, risks, and consequences). The results are shown in Figure 5, where, in terms of risk, it is evident that the risk with the most materialization is internal fraud, followed by clients, products, and corporate practices; this is followed by fixed assets damage, process execution and administration, external fraud, technological failures, and finally labor relations and labor security. The numbers shown in the graph are the number of cases corresponding to the classification of each risk.

In addition, an analysis of the cases by their consequences shows that the most relevant impact is the economic impact, followed by the social impact, the environmental impact, and finally the impact of permanence over time (Figure 6). The numbers shown in the graph are the number of cases corresponding to the classification of each impact.

Based on the relationship presented between the case database and the causes and consequences of operational risks, this study proceeded to evaluate the effects of the operational risks on corporate

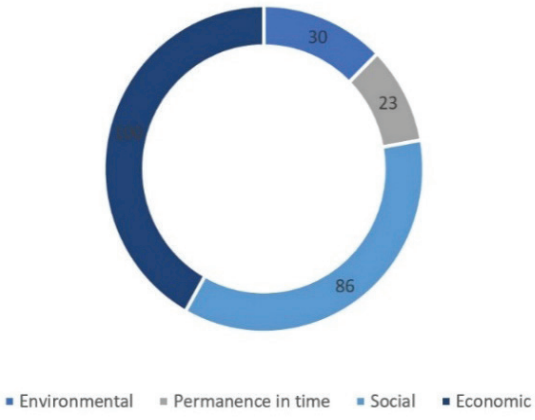

Figure 6. This figure ranks of the impacts analyzed in the cases.

Source: Own elaboration.

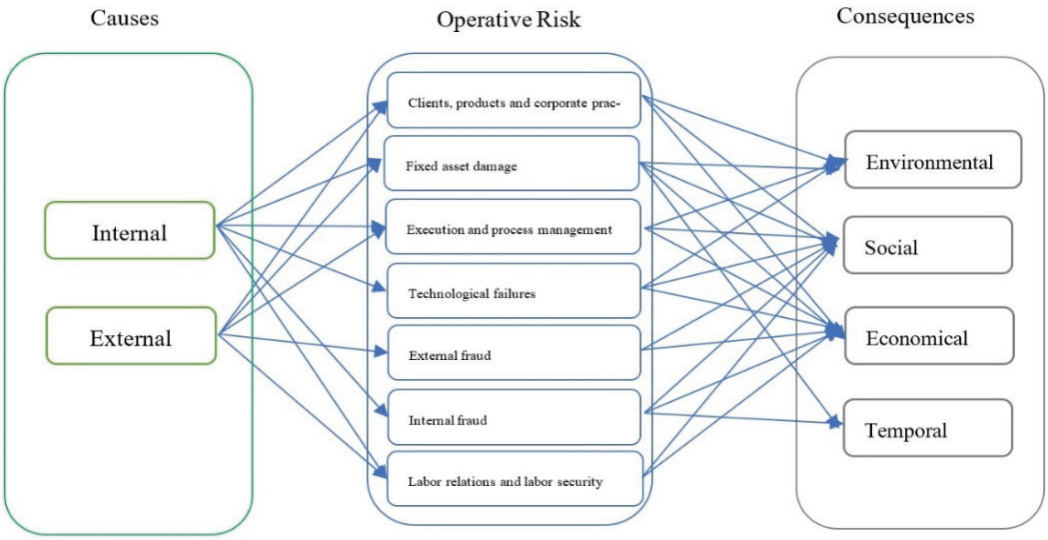

Figure 7. This figure shows the relationship between the classification of operational risks and corporate sustainability based on the analysis and interpretation carried out using the case-based reasoning methodology.
Source: Own elaboration.

sustainability factors; we found an explicit connection between these two theoretical constructs, where the connection shown in Figure 7 was established.

The relationships presented by the analyzed cases illustrate that there is a link between the operational risks and corporate sustainability; the connections can be established through causes, risks, and consequences. The Table 3 presents a general summary of the relationships found.

Based on the above results, a contrast is established with the theoretical relationships presented by other authors, and the similarities and differences between the theoretical and the empirical model, which are presented in the discussion section. Below, the discussion is presented based on the literature review and the case-based approach developed in this research.

Discussion

The literature review shows that, in the relationship sustainability corporate system (Lozano & von Haartman, 2018), there is a great diversity of factors (Horne & Fichter, 2022); among these, it was not possible to identify strong relationships to classify sustainability. Moreover, studies that have already examined these factors are limited (Lau *et al*., 2018). This is why reports were explored to approach the variables used in the classification (Batista *et al*., 2022). Alternatively, operational risk is well defined and there are guidelines that provide information on risk classification depending on the type of risk to be analyzed.

The seminal documents explaining the origin of these issues (through the elements of the business system, such as operations and processes, management

Table 3

Summary of the relationships between operational risks and corporate sustainability.

Connections	Environmental	Social	Economical	Temporal
Internal fraud		✓	✓	✓
External fraud		✓	✓	
Labor relations and labor security		✓	✓	
Clients, products, and corporate practices	✓	✓	✓	
Fixed asset damage	✓	✓	✓	✓
Technological failures	✓	✓	✓	✓
Process execution and administration	✓	✓	✓	✓

and strategy, organizational systems, procurement and marketing, and evaluation and communication) allow (Lozano, 2012) us to approach the connection, since the business activity per se entails operational risks. These are inherent to the business operations, the risk theory classifies it according to the cause or the consequence that it can generate (Inés *et al*., 2018), and, according to this classification, the link between the operational risks and sustainability can be created.

Based on this theoretical baseline, this article developed the linkage of different theories relating each of the elements of the corporate system with risks and subsequently linking corporate sustainability. As a result of this, the theoretical model shown in Figure 3 was presented, where the theoretical link is established from the theories and risk guidelines; this was later empirically validated with case-based reasoning.

The empirical validation made it possible to confirm the links established from the literature review to configure the taxonomy proposed in this research. Thus, the originality of this article lies in the establishment of the classification and connection of operational risk management and sustainability. When contrasting the theoretical findings with the empirical validation, it is found that, in both cases, there are explicit connections between risks and sustainability through the causes and consequences of operational risks. From this contrast, the following similarities and differences between the theoretical model and the empirical model are evident.

About similarities, both models show the existence of a relationship between the operational risks and corporate sustainability through internal and external causes. Also, both models show the existence of a relationship between the operational risks and corporate sustainability through the consequences that are linked to the sustainability guidelines with environmental, social, economic, and temporal impacts. And, both models can adopt the classifications suggested by the literature review. As far as differences are concerned, it can be concluded that the empirical model shows that the materialization of operational risks has an impact on some aspects of sustainability, but not necessarily on all of them, while, in the theoretical model, this cannot accurately be validated. It was also possible to conclude that the empirical model shows that both the internal and external causes do not generate all types of risks, while, in the theoretical model, this relationship cannot be distinguished. And finally, the theoretical model provides more information on risk classification since it is based on taxonomic representations; the empirical model does not allow for depth on other classification levels. Based on the contrast between the theoretical model and the empirical model, the conclusions of the research are presented below.

Conclusions

In the development of this research, new means of approaching operational risks are presented. When relating them to sustainability, a framework emerges, and it shows a relationship with operational risk management considering the externality problems that traditionally affect companies. It also shows effectiveness in the interpretation of operational risks based on corporate sustainability; this answers the research question, namely "how can we classify the operational risks that are related to sustainability aspects?" It was identified that connections between the causes, risks, and consequences can be established, and based on these findings, it is concluded that operational risks could affect corporate sustainability based on the connections presented in this research.

Through empirical validation, it is evident that the effects are specific to each risk and that these should not be generalized. The main limitation of this research was that the results of the connections can change depending on the analyzed case. In addition, the CBR case base includes many sectors of the economy, which is why it provides heterogeneous results. It was identified that the relationship can change if a sectoral analysis is performed.

Future research should consider that, in the risk management process, once the identification process is completed, the risks must be measured to quantify the degree of operational risk in companies. The measurement of operational risk evaluates the probability of later experiencing financial losses in an organization; they are managed through detection/supervision, mitigation/management, or optimization techniques. Through these, they are finally monitored and controlled. This is why it is important to further advance the process risk modeling, monitoring, and control to attend to the risk management process as exposed by theory and finally to characterize the sample in order to generate sectoral studies that show more compelling patterns.

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Appendix A

Operational Risk and Corporate Sustainability Relationship Using Case-Based Reasoning

Table A1

Base of 100 research cases

Case N°	Company	Case	Year	Causes	Operative risk Level 1	Consequences Level 1			
1	British Petroleum	Explosion at the Gulf of Mexico	2010	Internal	Damage to physical assets	Economic	Social	Environ-mental	
2	Enron	Irregular practices	2001	Internal	Internal fraud	Economic	Social		Perma-nence in time
3	Mattel	Lead in toys	2006	Internal	Clients, products and corporate practices	Economic	Social	Environ-mental	
4	Barings Bank	Fraud with financial derivatives	1995	Internal	Internal fraud	Economic	Social		Perma-nence in time
5	Toyota	Brake errors	2010	Internal	Clients, products and corporate practices	Economic	Social		
6	Samsung	Samsung Galaxy Note 7 explosion	2016	Internal	Clients, products and corporate practices	Economic	Social	Environ-mental	
7	Parmalat	Fraud and falsification of financial information	2003	Internal	Internal fraud	Economic	Social		
8	Societe Generale	Fraud with financial derivatives	2008	Internal	Internal fraud	Economic	Social		

9	Vodafone Deutschland	Data theft	2013	External	External fraud	Economic			
10	Volkswagen	System to deceive pollution emission controls	2015	Internal	Clients, products and corporate practices	Economic	Social	Environmental	
11	Xerox	Hidden accounting maneuvers	2000	Internal	Internal fraud	Economic			
12	Waste Management	Accounting manipulation	1998	Internal	Internal fraud	Economic			
13	Kmart	Accounting manipulation	2001	Internal	Internal fraud	Economic			
14	Tyco	Fraudulent maneuvers	2001	Internal	Internal fraud	Economic			
15	Olympus	Accounting manipulation	2014	Internal	Internal fraud	Economic			
16	Lehman Brothers	Accounting manipulation, derivatives, greed, excessive leverage	2008	Internal	Internal fraud	Economic	Social		Permanence in time
17	Madoff Investment Securities (BMIS)	Scam—pyramid scheme	2008	Internal	Internal fraud	Economic	Social		Permanence in time
18	Daiwa Bank	Irregular operations in the bond market	1995	Internal	Internal fraud	Economic			
19	Sumitomo Bank	Trading copper contracts with unrecorded losses in three years	1996	Internal	Internal fraud	Economic			
20	Allied Irish Bank	Falsification of bank statements and documents	2002	Internal	Internal fraud	Economic	Social		
21	National Westminster (Natwest)	Incorrect valuation of option contracts and swaptions	1997	Internal	Internal fraud	Economic	Social		Permanence in time
22	WorldCom Inc	Accounting frauds and appropriations of funds	2002	Internal	Internal fraud	Economic	Social		Permanence in time
23	Allianz, Lloyd´s, AXA, Berkshire Hathaway, others	Terrorist attacks against the Twin Towers	2001	External	Damage to physical assets	Economic	Social	Environmental	
24	Windsor Building	Windsor building fire caused loss of profits for businesses	2005	Internal	Damage to physical assets	Economic	Social	Environmental	
25	Imar Bank	False financial statements	2003	Internal	Internal fraud	Economic	Social		Permanence in time
26	SolarWinds	Hidden malicious code that sent software updates to its 18,000 customers	2021	External	External fraud	Economic	Social		
27	Colonial Pipeline	Cyber-attacks against vital U.S. infrastructure	2021	External	External fraud	Economic	Social		
28	Garmin	Global downtime of company services due to ransomware cyber attack	2020	External	External fraud	Economic	Social		
29	Capcom	Ransomware attack that stole sensitive corporate documents, as well as confidential customer and employee information	2020	External	External fraud	Economic	Social		

30	Canon	Ransomware attack of 10 Tbytes of data and stolen databases	2020	External	External fraud	Economic	Social		
31	Twitter	An employee received money for allowing attackers to use certain management tools that were only accessible to company personnel	2020	Internal	Internal fraud	Economic	Social		
32	Microsoft	Windows XP source code and Windows Server 2003 source code leaked	2020	Internal	Process execution and administration	Economic			
33	Marriott Hotels	Security breaches with theft of personal and financial data of 500 million customers	2018	External	External fraud	Economic	Social		
34	AT&T	Software update bug crashed network	1990	Internal	Technological failures	Economic	Social		
35	European Space Agency	A computer crash while trying to convert data from 64-bit to 16-bit format led to the explosion of the Ariane 5 rocket	1996	Internal	Technological failures	Economic		Environmental	
36	Airbus	Airbus A380 delayed due to software incompatibility issues	2006	Internal	Technological failures	Economic			
37	Dell, Matsushita, Sony, Lenovo, Acer	Laptop explosion was a battery issue	2006	Internal	Technological failures	Economic	Social	Environmental	
38	Samsung	Samsung's Galaxy Fold breaks when bent	2019	Internal	Clients, products and corporate practices	Economic	Social		
39	CDMX Subway (Mexico)	Collapse of CDMX subway line 12	2021	Internal	Damage to physical assets	Economic	Social		
40	Sriwijaya Air	Sriwijaya Airplane crashes into Indonesian sea, leaving 62 dead, due to throttle lever failures	2021	Internal	Damage to physical assets	Economic	Social	Environmental	
41	Starlink	Geothermal storm wiped out 80% of the satellites launched	2022	External	Damage to physical assets	Economic		Environmental	
42	Ever Given	Mega container ship Ever Given stuck in Suez Canal	2021	Internal	Damage to physical assets	Economic	Social	Environmental	
43	Baninter	Defaulted as a result of embezzlement	2003	Internal	Internal fraud	Economic	Social		Permanence in time
44	Petrobras	Embezzlement scandal		External	External fraud	Economic	Social		
45	Demae-can	Platform failures, a system error generated refunds or cancellation of payments	2018	Internal	Technological failures	Economic			
46	United Airlines	Disembarking of passengers due to ticket overbooking	2017	Internal	Clients, products and corporate practices	Economic	Social		
47	VanCamp's	Alert on a batch of tuna that had a higher mercury level than established in the regulations	2017	Internal	Clients, products and corporate practices	Economic	Social		

48	Hennes and Mauritz (H&M)	Controversy due to advertising that had a message that was considered racist around the world	2018	Internal	Clients, products and corporate practices	Economic	Social		
49	Telstra	Massive service outage throughout the country	2015	Internal	Technological failures	Economic	Social		
50	Capital One	Hacker gained access to 100 million customer accounts and bank credit card applications	2019	External	External fraud	Economic	Social		
51	BMW	52 fires broke out in South Korea in automobiles of German automaker BMW	2018	Internal	Clients, products and corporate practices	Economic	Social	Environmental	
52	Facebook	Facebook was implicated in a 267 million data breach	2018	External	External fraud	Economic	Social		
53	Rappi	A protest was made due to changes in the rappi application	2020	Internal	Labor relations and labor security	Economic	Social		
54	Luckin Coffe	Luckin Coffee used affiliated entities to place huge online orders of coffee that were never delivered to inflate its sales volumes	2020	Internal	Internal fraud	Economic	Social		Permanence in time
55	Clorox	Withdrawal from the market of all Poett brand antibacterial liquid cleaners	2020	Internal	Clients, products and corporate practices	Economic	Social	Environmental	
56	Postobón	Sanction for inadequate information and misleading advertising of one of its products	2020	Internal	Clients, products and corporate practices	Economic	Social		
57	Wakashio	It ran aground on a coral reef off Mauritius Island with more than 4,000 tons of oil	2020	Internal	Damage to physical assets	Economic	Social	Environmental	
58	Famsa Bank	Granted loans to related persons of the group in excess of regulatory limits	2020	Internal	Process execution and administration	Economic	Social		
59	Wirecard	Increased accounts with fictitious funds through irregular operations in the Philippines	2020	Internal	Internal fraud	Economic	Social		Permanence in time
60	Ecopetrol	Attacks on the Caño Limón pipeline.	2020	External	Damage to physical assets	Economic	Social	Environmental	
61	ZOOM Inc	"Zoombombing" cyber attacks, infiltrating and sabotaging active videoconferences	2020	External	External fraud	Economic	Social		
67	Odebrecht	Bribes	2016	Internal	Internal fraud	Economic	Social		Permanence in time
63	Interbolsa	Bankruptcy of the company	2012	Internal	Internal fraud	Economic	Social		Permanence in time

64	Arianespace	A spacecraft that was sent to be placed into orbit took an unexpected course, veering off course and subsequently failing the mission	2020	Internal	Process execution and administration	Economic		Environ-mental	
65	Satyam Computer Services	Financial reporting fraud	2009	Internal	Internal fraud	Economic	Social		
66	Petrobras	Embezzlement scandal	2014	Internal	Internal fraud	Economic	Social		
67	Goldman Sachs	Fraud	2009	Internal	Internal fraud	Economic	Social		
68	BCCI	Fraudulent activities of BCCI at the international scale	1991	Internal	Internal fraud	Economic	Social		Perma-nence in time
69	Ericsson	International business corruption	2019	Internal	Process execution and administration	Economic	Social		
70	Siemens	Corruption	2008	Internal	Internal fraud	Economic	Social		
71	HealthSouth	Accounting scandal	2003	Internal	Internal fraud	Economic	Social		
72	WorldCom	Fraudulent maneuvers	1999	Internal	Internal fraud	Economic	Social		Perma-nence in time
73	Global Crossings	Bankruptcy of the company	2002	Internal	Internal fraud	Economic	Social		Perma-nence in time
74	Bernie Madoff	Stock fraud	2008	Internal	Internal fraud	Economic	Social		Perma-nence in time
75	Diamond Foods	Financial reporting fraud	2012	Internal	Internal fraud	Economic	Social		Perma-nence in time
76	Garment industry Mexico, Sri Lanka, China, and Cambodia	Workplace harassment	2020	Internal	Labor relations and labor security	Economic	Social		
77	U.S. work-ers	Discrimination of em-ployees based on "race, color, religion, sex"	2018	Internal	Labor relations and labor security	Economic	Social		
78	British Retail Con-sortium	Workers suffered from threats and verbal abuse	1995	Internal	Labor relations and labor security	Economic	Social		
79	Mining sector	Women's exclusion	2020	Internal	Labor relations and labor security	Economic	Social		
80	Energy sector	Accidents and deaths	2015	Internal	Labor relations and labor security	Economic	Social		
81	Community Innovation Survey	Corporate failure—in-novation	2020	Internal	Technological failures	Economic	Social		Perma-nence in time
82	ACI, IATA, IACA, Airbus, and Boeing	Vulnerability and critical-ity for terrorist attacks	2011	External	Damage to physical assets	Economic	Social	Environ-mental	
83	IT Compa-nies	Accidental destruction of data and backups	2018	Internal	Technological failures	Economic	Social		

84	Vladimir Ilyich Lenin	Nuclear power plant accident	1986	Internal	Process execution and administration	Economic	Social	Environmental	Permanence in time
85	Upper Big Branch	Underground explosion—coal dust explosion	2010	Internal	Process execution and administration	Economic	Social	Environmental	
86	Imperial Sugar	Explosion	2008	Internal	Process execution and administration	Economic	Social	Environmental	
87	Port Wentworth	Industrial dust explosion	2010	Internal	Process execution and administration	Economic	Social	Environmental	
88	Imperial Foods	Industrial fire	1991	Internal	Process execution and administration	Economic	Social	Environmental	
89	Piper Alpha	American oil rig explodes and kills 167 men	1988	Internal	Process execution and administration	Economic	Social	Environmental	
90	L'Ambiance Plaza	Collapses due to structural deficiencies	1987	Internal	Process execution and administration	Economic	Social	Environmental	
91	Buffalo Creek-Pittston Coal Company's	Dam collapse	1972	Internal	Process execution and administration	Economic	Social	Environmental	
92	Triangle Shirtwaist Factory	Fire trapped more than 500 workers	1911	Internal	Damage to physical assets	Economic	Social	Environmental	
93	Pemberton Mill.	Industrial accident	1860	Internal	Damage to physical assets	Economic	Social	Environmental	Permanence in time
94	Washburn Mill	Flour dust causing an explosion	1878	Internal	Damage to physical assets	Economic	Social	Environmental	Permanence in time
95	Fraterville Coal Mine	Coal mine explosion	1902	Internal	Damage to physical assets	Economic	Social	Environmental	Permanence in time
96	Nestlé	Cultural adaptation	2018	Internal	Clients, products and corporate practices	Economic	Social		
97	Air France, British Airways, Iberia	Price decision	2021	Internal	Clients, products and corporate practices	Economic	Social		
98	Burger King	Controversial ad campaign	2011	Internal	Clients, products and corporate practices	Economic	Social		
99	Royal Ahold	Failed strategy, an accounting scandal, the firing of professional management, and litigation filings	2003	Internal	Internal fraud	Economic	Social		Permanence in time
100	Pepsi	Reputational damage due to advertising campaigns	2017	Internal	Clients, products and corporate practices	Economic	Social		

Source: Own elaboration.