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How the Global Initiative Report's Indicators are Related to the Strong Sustainability Concept? - A Paraconsistent Approach

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Abstract

The pressure imposed by human-dominated systems on the natural environment and the search for more balanced social systems are current concerns worldwide. Among scales of attention and shared responsibilities, companies are also in the radar of and interested in to be more sustainable. An efficient way in disclosing information on companies' sustainability is through sustainability reports, such as the global reporting initiative (GRI) framework. Although recognized as an important alternative, the GRI is receiving criticisms about its ability in accurately express the meaning of sustainability. This work applies the paraconsistent annotated evidential logic (PAEL) on opinions of experts in the sustainability theme to verify whether the GRI indicators are aligned to the concept of 'strong' sustainability. A survey applied to twenty-two experts from different field areas, backgrounds and work experiences on sustainability-related issues provided their beliefs and disbeliefs, in a quantitative way, about the ability of each of the 91 GRI indicators in expressing sustainability. Results show high dispersion (coefficient of variation $>30\%$) among the experts opinions for 77 of the GRI indicators, in which the social category appears with the worst performance with its total 48 indicators with high dispersion. This is an indicative of different understandings by experts about the meaning of sustainability concept and/or the meaning and reach of GRI indicators in achieving sustainability. The PAEL reports that all three categories (economic, environmental and social) fall into the 'paracomplete' region of the Cartesian unitary square's graph, indicating an inconclusive result about whether these three categories are able to capture and/or express the concept of strong sustainability. The overall performance (barycenter with beliefs of $\mu = 0.26$ and disbeliefs of $\lambda = 0.17$) also fall into the paracomplete region, rejecting the initial hypothesis that GRI may show strong sustainability. Recognizing the increasing importance of sustainability reports, this work contributes in identifying and suggesting improvements to the GRI developers on indicators that may better represent the strong sustainability and achieve its main goals. GRI's framework should be based on a clear sustainability model and provide through a simple, fast and understandable way, information about the purposes of each indicator. Focus for improvements should be especially directed to: EC4-6; EN18, 20, 21 and 34; LA2, 4, 5, 7, 8, 11, 12, 14; SO3-8, 11; PR1-5, 7-9; HR3, 8-10.

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1 Introduction

Since the 60's, Hardin (1968) warned that the advance of social and economic crises was resulting in an increase of inequalities between the industrialized and less industrialized countries, which is in accordance with Daly and Cobb (1994), who describe the financial crises as a consequence of pushing growth beyond the Earth's biophysical limits. Because goods and services provided by the natural capital are finite and a right common to all people, the risk in exhausting these commons and the extinction of natural capital storages deserves shared responsibility (Lloyd, 2007; Giannetti et al., 2019a, Ulgiati et al., 2019) in all scales and regions of the world. In this sense, companies have been making efforts to minimize environmental risks to avoid disorderly actions that compromise sustainable development agendas. With greater effort after the publication of the Bruntland report (WCED, 1987), the United Nations has been highly mobilized to recognize its responsibility for setting short, medium and long-term goals for a sustainable world, such as recent proposition of the 17 Sustainable Development Goals (UN, 2020).

Although considering the current advances on the recognition of co-responsibilities between society and companies regarding a more rational use and maintenance of natural capital, Kolk and Van Tulder (2010) emphasized the need to disclose programs where companies act positively towards a better societal development. According to Hassini et al. (2012), during the 2000s, companies have been considering more often the environmental impacts of their businesses decisions to achieve a better sustainable performance for their activities. However, Bjron et al. (2017) revealed that only a small fraction of companies are seriously considering the ecological limits in their decisions, because most companies understand commitments in the sustainable management of their operations as a risk, due to the difficulty in estimating costs and forecasting budgets about unexpected demands for environmental impacts. At the same time, the increase in new investors and regulators in the financial market is pushing companies, governments and international organizations to provide sustainability indicators, and the disclosure of company's sustainability reports has become the best business practice of this century (Bradford et al., 2017).

Among the several approaches for disclosure, a large number of companies has published the sustainability report according to the Global Reporting Initiative (GRI) framework, seeking standardized measures to disclosure their performance on sustainability issues (Chen and Bouvain, 2014). According to Bebbington et al. (2009), the GRI sustainability report has its origin under the concept of corporate social responsibility report (Carroll, 1999), based on the theory of stakeholders (Adams, 2002), legitimacy approach (Deegan, 2002), and institutional theory. The concept behind the GRI's sustainability report (GRI, 2020a) "is a report published by a company or organization about the economic, environmental and social impacts caused by its everyday activities", presenting "the organization's values and governance model, and demonstrates the link between its strategy and its commitment to a sustainable global economy". The GRI (2020a) understands that "sustainability reporting can help organizations to measure, understand and communicate their economic, environmental, social and governance performance, and then set goals, and manage change more effectively".

Companies worldwide have been disclosing their sustainability activities through GRI's report, and the literature provides examples of positive results from this practice, including the increase of transparency, credibility and comparability of reports (Alazzani and Wan-Hussin, 2013), and on the existing positive correlation between sustainability degree and financial performance (Aggarwal, 2013; Ansari et al. 2015; Yang et al., 2019). Although the undeniable advances of GRI framework towards a clearer and more objective structure containing representative indicators for more accurate results, the scientific literature is plentiful with studies criticizing GRI's structure and efficiency to achieve its primary goals in long term (among others, Marimom et al., 2012; Boiral, 2013; Menichini and Rosati, 2014; Barkemeyer et al., 2015; Bernard et al., 2015; Morioka and De Carvalho, 2017; Steinhöfel et al., 2019). Two works are here presented in detail, since they are considered mostly important to sustain the goals of this present study. The first one was published by Fonseca et al. (2014), who provided a constructive critique on the GRI G3 version calling attention to some negative aspects such: failing in increasing comparability and transparency, being incapable to instill within organizations deep values

and practices of sustainability development, privileging a narrow and instrumental approach detrimental to sustainability development, holding an understanding of sustainability performance too constrained, and affecting how organizations and societies perceive sustainability. The second work, from Journeault et al. (2020), discussed how GRI G3.1 technocratic guideline frames the sustainability reporting discourse and leaves aspects of organizational sustainability performance in shadows. Additionally, these authors stated that, since these guidelines are ontologically driven by a Western view of nature, they silence alternative ontologies in organizational sustainability performance reporting. According to Bradford et al. (2017), some still gray aspects of GRI framework can lead to misunderstands by stakeholders about the way in which companies are disclosing their sustainable-oriented activities.

In face of all these evidences, there is a doubt on whether the GRI framework can provides sufficient and precise subsidies to support a discussion on companies' 'strong' sustainability. It is worth noting that adjective 'strong' characterizing sustainability implies a steady state, which requires limits for the human scale (population and economic growth) coupled with the strengthening of technological progress that would reduce the flow of matter and energy to anthropic productive systems (Daly, 1995; Costanza et al., 1991; Ekins et al., 2003). Since the definition of sustainability allows the establishment of different conceptual models as backbone, it is difficult to establish a criterium rooted in scientifically quantitative approaches to verify whether the GRI indicators can reflect strong sustainability. Inconsistencies occur naturally in the description of the real world, regardless of context. In this sense, despite all the existing subjectivities, the best alternative is to listen experts who work or research on topics related to sustainability. An effort in this direction was proposed by Menichini and Rosati (2014) that used a Fuzzy-AHP approach to assess which GRI indicators have major relevance for disclosing corporate social responsibility reports. However, expert opinions were oriented based on companies strategic planning instead of evaluating whether the GRI express sustainability. According to Giannetti et al (2009), the experts' opinion on indicators able to express the meaning of sustainability often includes subjectiveness, which is a result of unfamiliarity on the theme or even due to vague or conflicting information, and this leads to distorted opinions that compromise the objectivity of the analysis. This subjectiveness claims for a logic thinking different from the classic one, once the latter cannot, at least directly, deal with a set of vague, subjective or inconsistent information. Hence, the paraconsistent annotated evidential logic appears as an alternative tool for the task (Abe, 1992; Costa et al., 1999; 2207; Carvalho and Abe, 2011; Da Silva Filho, 2011).

According to Arruda (1989) and D'Ottaviano (1990), the paraconsistent logic deals with contradictions in a discriminating way. Different from the classical logics that refuse contradictions, the paraconsistent logic refuses the principle of non-contradiction or, in other words, it refuses that a proposition cannot be true and false in the same sense at the same time. Paraconsistent is a logic that can support inconsistent and non-trivial theories, which is advancing specially on the artificial intelligence and logic programming in the computing sciences disciplines. Among the large range of derived methods from the paraconsistent logic, the paraconsistent annotated evidential logic (PAEL) is particularly useful to the different issues concerning the management theme, supporting decisions that could hardly be based under classical logic.

This work uses the paraconsistent annotated evidential logic to assess whether the GRI indicators are aligned with the concept of 'strong' sustainability. The following initial hypothesis is established: the GRI indicators express the meaning and reach of strong sustainability. The GRI quantification is carried out by considering the opinion (based on degrees of beliefs and disbeliefs) of experts in sustainability issues, whose judgement can be affected by several drivers such as their work field, company's activity, the sense of community established around the company, and internal stakeholders. The experts make value judgments about the GRI indicators they consider more or less aligned with sustainability, and then PAEL is applied to assess whether the initial hypothesis can be accepted.

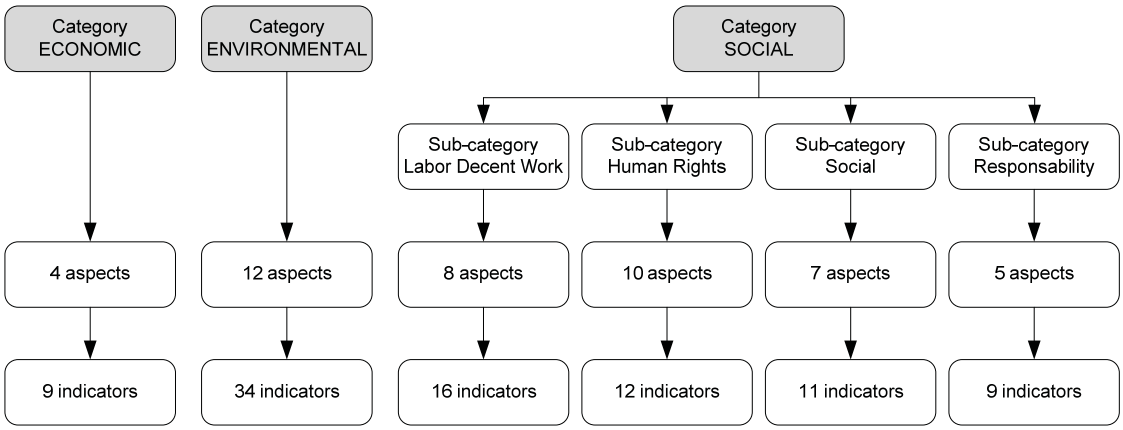

Fig. 1 Framework indicators of GRI G4.

2 Methods

2.1 The global reporting initiative (GRI) framework

GRI reporting has evolved towards higher quality standards of disclosing and accuracy to better represent the sustainability aspects of companies. Initiated in 1997, the GRI has crossed different versions including G1, G2, G3, G3.1, G4, and the most updated GRI Standards, always seeking for reporting principles such as materiality, stakeholder inclusiveness, sustainability context, completeness, balance, comparability, accuracy, timeliness, clarity, and reliability. Launched in 2016, the GRI Standards attempt to overcome some shortcomings and misunderstandings of previous versions largely criticized in the scientific literature. For this reason, the previous GRI G4 version was taken as baseline to assess whether and how the updated GRI Standards achieved their main objectives. The assumption is consistent because most indicators (89 from 91) existing in the GRI G4 are still present in the GRI Standards framework (GRI, 2020b), and 83 indicators have their exact new correspondent indicator. This ensure that discussions draw in this study focused on the previous GRI version are valid also for the current and updated GRI version. From this point, the GRI G4 will be named simply as GRI to avoid excess of unnecessary information along text.

GRI's framework is organized into three categories, including economic (9 indicators), environmental (34 indicators) and social (48 indicators), and the social category is broken into labor decent work, human rights, social aspects, and product responsibility subcategories, totalizing 91 indicators (Figure 1).

2.2 Modeling the paraconsistent annotated evidential Logic (PAEL)

According to Costa et al. (1999), who has helped in the paraconsistent annotated evidential logic (PAEL) development and its application in Brazil, the PAEL is a particular case of paraconsistent logic in which degrees of certainty (μ) and uncertainty (λ) are assigned to each variable assessed. It presents a language with proposition of type p(μ, λ), in which 'p' is a proposition and μ, λ ? [0, 1] belongs to a real closed interval. Intuitively, μ indicates the degree of favorable evidence or degree of belief of a proposition p, while λ indicates the degree of contrary evidence or disbelief of a proposition p. In the PAEL, the term 'evidence' is used in a non-rigorous sense, as evidence does not mean 'absolute certain' because it accepts opinions (Abe, 1992; Abe et al., 2015). The PAEL method has been applied in different studies, such as environmental sciences (Giannetti et al., 2009), agriculture (Da Silva et al., 2019), computing sciences (Pimenta Junior and Abe, 2019), among other applications (Abe et al., 2019).

Each pair 'p' for belief and disbelief (μ, λ) belongs to one of the four extreme logic positions or eight non-extreme positions as spatially represented by the Cartesian unitary square (Figure 2) described as follows (Da

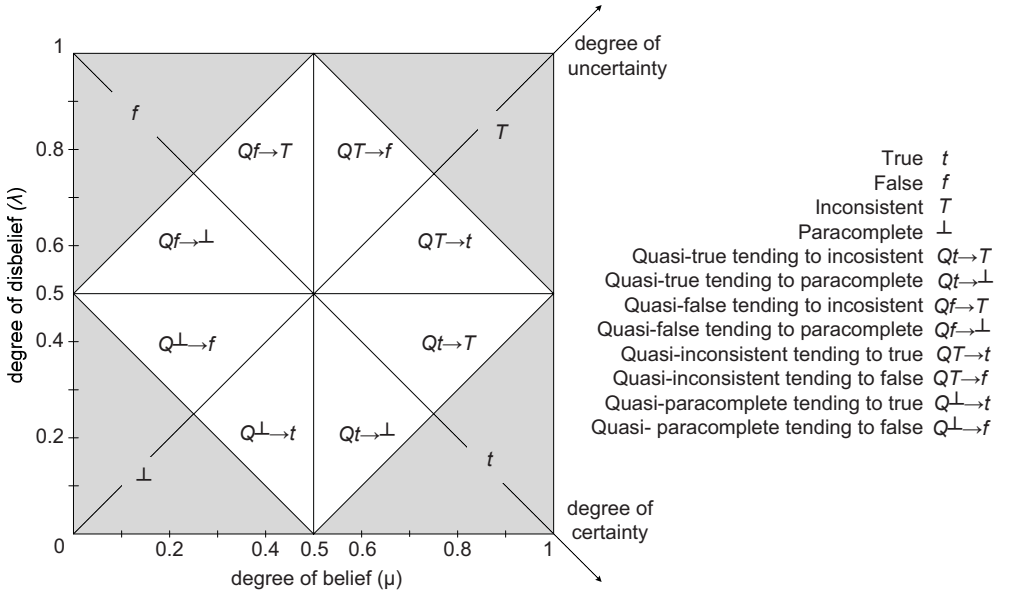

Fig. 2 Paraconsistent annotated evidential logic (PAEL) algorithm represented by a Cartesian unitary square divided in twelve regions. Source: Giannetti et al., 2009.

Silva Filho, 2011):

$p_t = p_{(1,0)} \rightarrow$ The annotation $(\mu, \lambda) = (1;0)$ assigns intuitive reading that p is true, i.e. total belief and no disbelief, represented by 'v';

$p_f = p_{(0,1)} \rightarrow$ The annotation $(\mu, \lambda) = (0;1)$ assigns intuitive reading that p is false, i.e. total disbelief and no belief, represented by 'f';

$p_T = p_{(1,1)} \rightarrow$ The annotation $(\mu, \lambda) = (1;1)$ assigns intuitive reading that p is inconsistent, represented by T;

$p_\perp = p_{(0,0)} \rightarrow$ The annotation $(\mu, \lambda) = (0;0)$ assigns intuitive reading that p is indeterminate or paracomplete (i.e., there are absence of beliefs and disbeliefs), represented by ?.

$p_I = p_{(0.5,0.5)} \rightarrow$ The annotation $(\mu, \lambda) = (0.5;0.5)$ assigns intuitive reading that p is undefined.

The level of exigency used in this work is set as 50%, which means that 0.5 is the minimum value to make a decision with 50% of certainty. This is the usual value for studies in areas as economics, geopolitics, environmental sciences, while when dealing with more restrictive disciplines such as medicine or structural engineering that demand low risk, the level of exigency can be higher than 90%.

In the PAEL's algorithm, the connectives 'OR' and 'AND' are used as a way to identify potential inconsistencies and the acceptability of experts' answers. When using the PAEL it is important to separate in advance the sample of experts in different groups of importance or expertise (Figure 3). The 'OR' operator is applied intra-groups, while the 'AND' operator is applied among the different groups. The 'OR' connective is defined by ($\mu 1$; $\mu 2$) OR ($\lambda 1$; $\lambda 2$) = (max{$\mu 1$, $\lambda 1$}; max{$\mu 2$, $\lambda 2$}), in which 'max' indicates the maximization operation. Once 'OR' is applied intra-groups, and when one of the expert's opinion is favorable, the result can be considered satisfactory. Differently, the connective 'AND' is defined by ($\mu 1$; $\mu 2$) AND ($\lambda 1$; $\lambda 2$) = (min{$\mu 1$, $\lambda 1$}; min{$\mu 2$, $\lambda 2$}), in which 'min' indicates de minimization operation. In this case, all experts must present favorable opinions to the analysis result satisfactory (Abe, 1992; Abe et al, 2015; Carvalho and Abe, 2011). This procedure is repeated, individually, for all propositions p(μ, λ), evaluated and then plotted in the Cartesian unitary square to support a decision process. For this study, each proposition p(μ, λ) corresponds to one of the 91 GRI indicators.

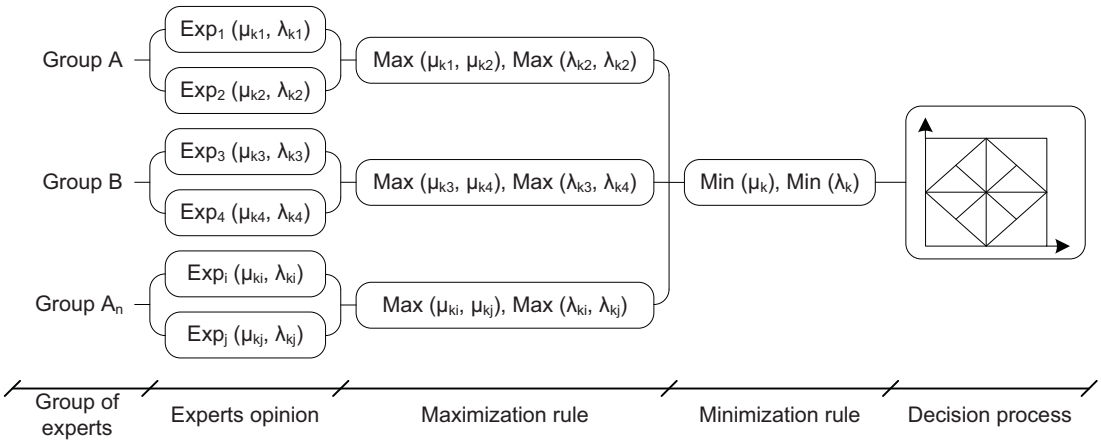

Fig. 3 Logical procedure for applying the paraconsistent annotated evidential logic. Legend: μ, degree of belief; λ, degree of disbelief; k, proposition or variable being assessed. Adapted from Carvalho and Abe, 2011.

Table 1 Groups of experts in sustainability issues that replied to the survey.

Groups	Profile of the identified expert groups
Group A	Urban ecological planning and natural ecosystems.
Group B	Sustainability assessment of production systems.
Group C	Operations and supply chain management.
Group D	Sustainable development and modeling on environmental assessments.
Group E	Industrial organization and safety.
Group F	Architecture and urbanism, regularization of land use rights for urban planning.
Group G	Portfolio analyst and business developer in the hydrocarbon industry.
Group H	Water resources modeling and rural development.
Group I	Economics in non-governmental organizations for democracy and development.
Group J	Tax sector and infrastructure for water and sanitation projects.
Group K	Management of natural resources, GIS, sustainability of production systems, risk assessment, and cleaner production.

2.3 Data source

A survey was applied during 2019 and mid of 2020 to a sample of experts in sustainability that work in companies and/or in universities or research centers. Experts were chosen according to their curriculum, papers published on sustainability issues, and their work experience in managing companies. The survey (Supplementary Material A, available through personal email) contains questions regarding the expert's perception on the relationship among the 91 GRI indicators with the concept of strong sustainability. The twenty-two experts were grouped according to their expertise, highest academic degree and their current professional position (Table 1).

Applying the PAEL based on opinions of experts in sustainability aims to verify the hypothesis that GRI indicators express the meaning and reach of strong sustainability. Once the experts' opinions must be based on their individual background (knowledge, life experience, intuition, sensibility, common sense, etc.), the twenty-two experts were requested to establish evidences 'μ' from zero (0) to one (1) about the relationship between each GRI indicator with the concept of strong sustainability. The unit represents the strongest favorable evidence or belief, while zero the weakest evidence or disbelief. The optional values were: 0.0 = none relation; 0.3 = weak relation; 0.5 = moderate relation; 0.7 = good relation; 1.0 = strong relation. Different from the traditional binomial logic, the quantitative values for chosen evidences or beliefs are not complementary to the disbeliefs values as usual in probabilistic statistics or, in other words, a + b $\neq$ 1. Thus, the contrary evidences or disbeliefs

'λ' were obtained by considering the 'amalgam' rule, i.e. by considering the complement to the maximum score established by other expert within the same group. The amalgam operation is a formal operation that, given two terms, a third term is obtained that combines as much as possible the two original terms (Ontanon and Plaza, 2010). The amalgam rule is a conceptual combination process based in cases and focused on combining possible solutions from the different information sources (deeper information in Subrahmanian 1994 and Ontanon and Plaza 2010). The establishment of disbeliefs can be considered as the main limitation of this work, however the best current available data was considered, and when more accurate data becomes available, this work can be revisited. A most appropriated approach would be inviting all the experts to take part at a one-day meeting, in which all the conceptual PAEL's characteristics are presented and discussed in detail, but this alternative was not possible because the experts who answered the survey live in different countries.

3 Results and discussions

3.1 Analyzing the dispersion of experts opinions

As the methodological approach used in this work has a degree of subjectivity since it is based on experts' opinions, it is important to verify (before applying PAEL) the dispersion degree among the provided opinions, i.e. to evaluate whether the experts have equal or similar idea about the relationship of GRI indicators with the concept of strong sustainability. Among other statistical approaches, the well-known and used coefficient of variation (CV) appears as the most appropriated one. In statistics, the CV is a normalized measure of the dispersion of a probability distribution, a measure used to quantify whether a set of observed occurrences are clustered or dispersed compared to an average value of expert opinions regarding their beliefs that GRI indicators are aligned to the concept of strong sustainability. Generally, CVs lower than 15% indicates low dispersion, between 15-30% indicates regular dispersion, and higher than 30% high dispersion.

Figure 4 shows the CV for the experts' opinions related to economic GRI indicators. It can be observed that lowest CV for all 9 indicators of economic category is $\sim$20%, while 8 indicators have a CV higher than 30%. These figures show that, with exception for EC2 ('Financial implications and other risks and opportunities for the organization's activities due to climate change') indicator, the experts have different understandings about the relationship between other indicators with the strong sustainability, with worst performance for EC4 ('Financial assistance received from government') and ERC5 ('Ratios of standard entry level wage by gender compared to local minimum wage at significant locations of operation') that obtained CV higher than 65%.

For the environmental category, Figure 5 shows that the indicator EN27 ('Extent of impact mitigation of environmental impacts of products and services') has the lowest CV ($\sim$14%), while 12 indicators have moderate dispersion from 15 to 30%, and 21 indicators have high dispersion (CV$>$30%). Worst performance is obtained by indicators EN1 ('Materials used by weight or volume'), EN4 ('Energy consumption outside of the organization') and EN21 ('NOx, SOx, and other significant air emissions'). In regard to the social category, the analysis results in even worse figures (Figure 6) because all the 48 indicators have CV$>$30%, which means that experts have different interpretations about the relationship of these indicators with concept of strong sustainability. Last positions are occupied by indicators SO6 ('Total value of political contributions by country and recipient/beneficiary'), PR6 ('Sale of banned or disputed products') and PR8 ('Total number of substantiated complaints regarding breaches of customer privacy and losses of customer data').

These results highlight that experts have divergent understandings about the GRI-sustainability relationship, mainly for the social category. Since higher CV means lower consensus among experts, those indicators located in the far left of Figures 4, 5, and 6 should receive special attention for improvement to make the GRI framework stronger in representing sustainability. It is important to say that, with exception for the EN27 indicator – the one that obtained lowest CV –, all other above-mentioned indicators with high CV are present in the current GRI Standard version.

The existing differences among experts' interpretations can be justified by many reasons, but mainly due to

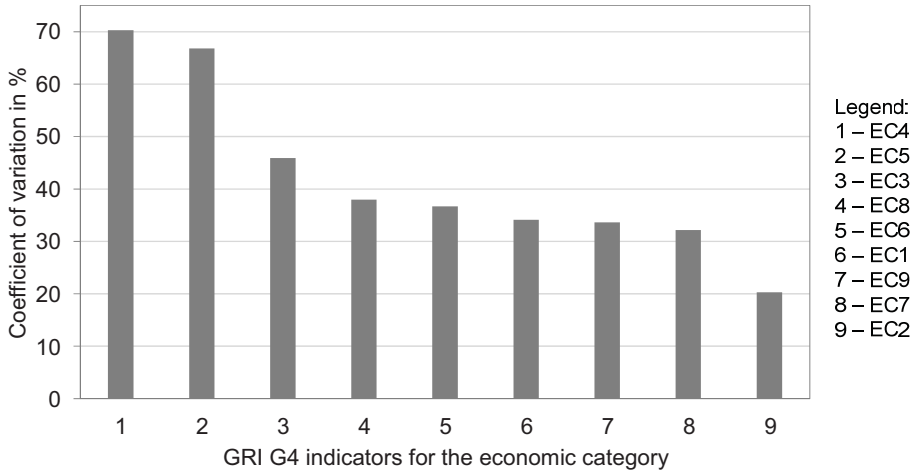

Fig. 4 Coefficient of variation (CV) for the experts' opinions on the relationship between GRI economic indicators with the concept of strong sustainability. Indicators description at Appendix A. Detailed data and calculations are presented in Supplementary Material B, available through personal email.

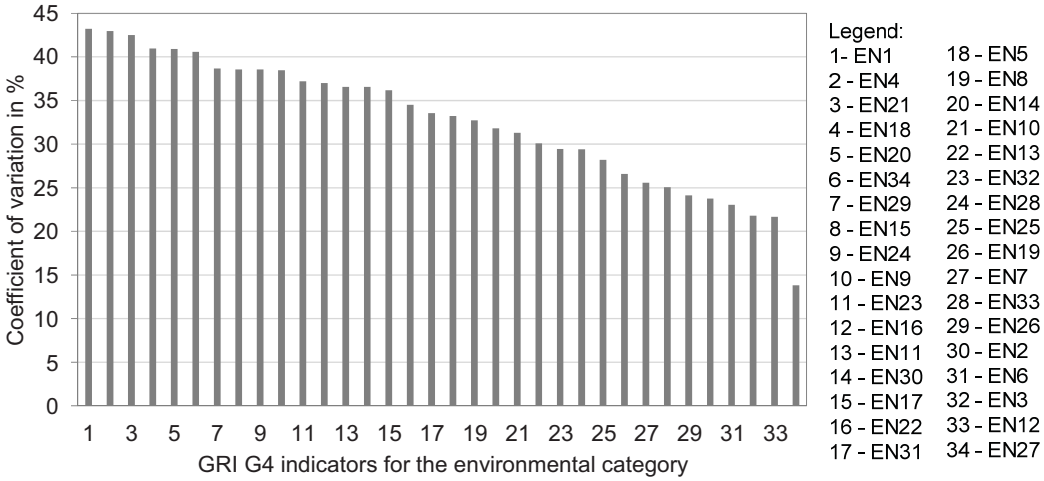

Fig. 5 Coefficient of variation (CV) for the experts' opinions on the relationship between GRI environmental indicators with the concept of strong sustainability. Indicators description at Appendix A. Detailed data and calculations are presented in Supplementary Material B, available through personal email.

their different backgrounds and understandings about the meaning of strong sustainability, as well as the lack of a better description of the meaning of GRI indicators and their reach. In an attempt to obtain more representative answers, data were modelled by considering 22 experts separated into 11 different backgrounds, and experts from different fields of sustainability-related issues were considered. Additionally, as any other scientifically rooted and well-grounded concept, the concept of strong sustainability supports a unique interpretation. These two controlled boundary conditions lead to the understanding that high dispersion among expert's opinions would not be a result of different knowledge of experts, and the existing divergences should be related to a lack of better textual presentation of GRI indicators to allow a more accurate reflection about their relationship with sustainability. Efforts should be done by the GRI developers towards better presentation of indicators, starting with those ones with higher dispersion.

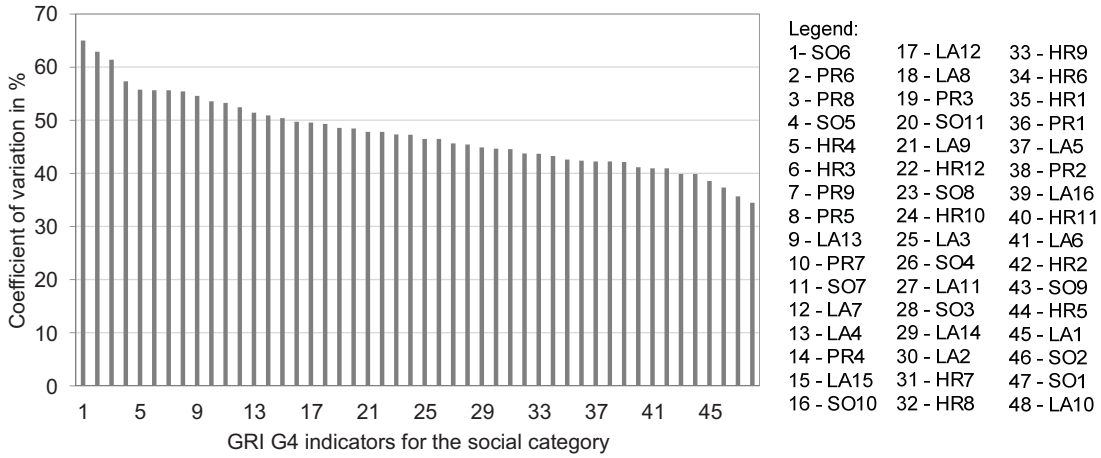

Fig. 6 Coefficient of variation (CV) for the experts' opinions on the relationship between GRI social indicators with the concept of strong sustainability. Indicators description at Appendix A. Detailed data and calculations are presented in Supplementary Material B, available through personal email.

3.2 Applying the paraconsistent annotated evidential logic (PAEL)

After applying the methodological procedures of PAEL by considering the connectives 'OR' and 'AND' with 50% for the exigency level on the opinions provided by the 22 experts, the results are presented under two approaches: (i) by considering the three categories economic, environmental and social separately; (ii) by considering the aggregated result.

Figure 7 shows the Cartesian unitary square for the economic category, including its 9 indicators and the result represented by the barycenter. All indicators are located within the 'paracomplete' region, which means an inconclusive interpretation from experts' opinion. The paracomplete performance shows that experts 'do not agree' and, at the same time, 'do not disagree' that GRI economic indicators are aligned to the strong sustainability. However, Figure 7 shows that while indicators #4, #5 and #6 are in the 'quasi-false tending to paracomplete' region, indicators #2 and #7 are 'quasi-true tending to paracomplete', and thus, the last ones have a tendency to be more aligned with the strong sustainability than the former ones. Indicators #1, #3, #8 are undefined since beliefs and disbeliefs are equal; indicator #9 is fuzzy or totally paracomplete. The aggregated result for the economic category, represented by the barycenter ($\mu = 0.31$, $\lambda = 0.30$), is located in the 'quasi-inconsistent tending to true' region, indicating that experts have not a conclusive opinion about whether the economic indicators of GRI are aligned with the concept of strong sustainability. This figures mean that efforts by GRI developers should be applied mainly on indicators EC4 (#4), EC5 (#5), EC6 (#6), and EC1 (#1) in an attempt to make them closer to the region named as true.

Figure 8 shows a different picture for the environmental category compared to the economic one. Although the general performance represented by the barycenter ($\mu = 0.43$, $\lambda = 0.02$) is still located in the paraconsistent or inconclusive region, it is closer to the true region compared to that of the economic category; the disbelief is much lower for the environmental category, as shown by the indicators distribution within the Cartesian unitary square, in which $\sim$50% of 34 indicators are located in the region named true. Especially for indicators EN10 (#10), EN19 (#19), EN27 (#27), EN28 (#28) and EN31 (#31), the experts have a conclusive belief that they belong the conceptual model of strong sustainability. However, 17 from the 34 indicators of the environmental category are located within the paracomplete region, thus experts have a non-conclusive opinion whether they can represent the strong sustainability or not. Indicator EN34 (#34) is undefined, since beliefs and disbeliefs are the same. Efforts should be done by GRI developers in improving the meaning and scope of these indicators, especially for EN18 (#18), EN20 (#20) and EN21 (#21).

Similarly to the economic category, the social category (Figure 9) also presents a paraconsistent or incon-

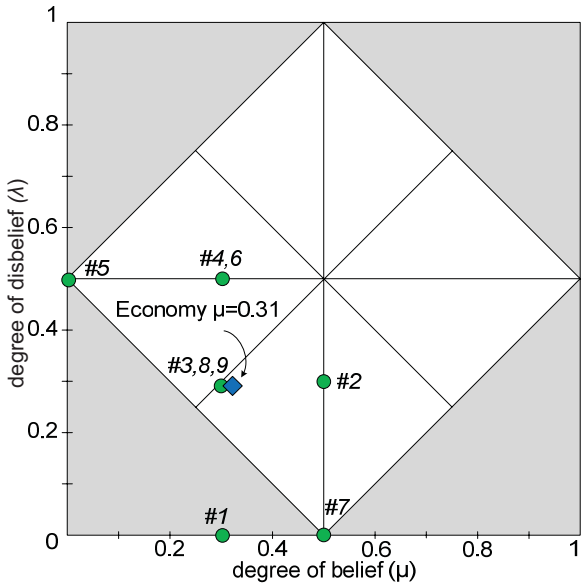

Fig. 7 Cartesian unitary square for the GRI economic category. Legend: ●, indicators for the economic category; ◆, resulting barycenter considering the 9 indicators; Please refer to Appendix A for indicators numbers #. Detailed data and calculations are presented in Supplementary Material B, available through personal email.

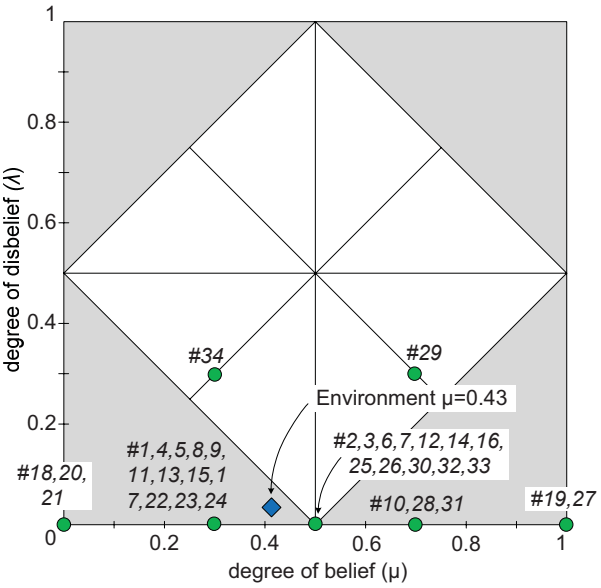

Fig. 8 Cartesian unitary square for the GRI environmental category. Legend: ●, indicators for the environmental category; ◆, resulting barycenter considering the 34 indicators; Please refer to Appendix A for indicators numbers #. Detailed data and calculations are presented in Supplementary Material B, available through personal email.

clusive result (barycenter, $\mu = 0.13$, $\lambda = 0.25$). This means that experts do not belief but also do not disbelief that social GRI indicators are aligned to the strong sustainability. The resulting barycenter in the paracomplete region is due to the large number of social indicators (29 from 48 indicators in total) located in the paracomplete region. Interesting to note that, for indicators located in the 'quasi-paracomplete tending to false' region, precisely LA #2, 4 and 12, SO #5, and PR #7 indicators, the expert's opinions almost converge that these indicators do not express the strong sustainability. Efforts should be done by the GRI developers in an attempt to move social GRI indicators closer to the 'true' region, moving in direction to indicators LA #9, 10, S #1, and HR #2, 5.

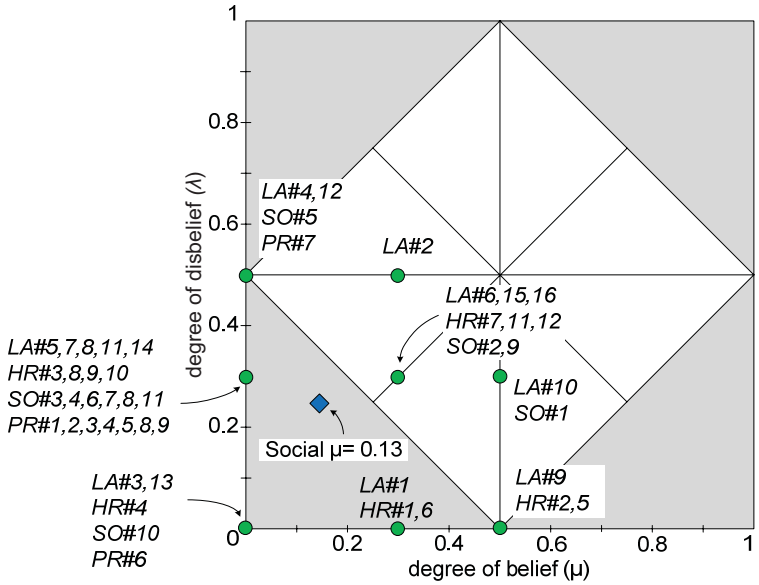

Fig. 9 Cartesian unitary square for the GRI social category. Legend: ●, indicators for the social category; ◆, resulting barycenter considering the 48 indicators; Please refer to Appendix A for indicators numbers #. Detailed data and calculations are presented in Supplementary Material B, available through personal email.

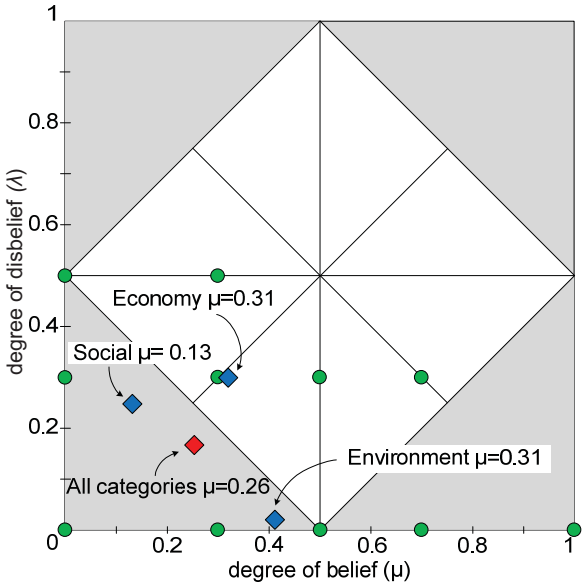

Fig. 10 Cartesian unitary square for the GRI. Legend: ●, indicators; ◆, resulting barycenter considering the 91 indicators; Please refer to Appendix A for indicators numbers #. Detailed data and calculations are presented in Supplementary Material B, available through personal email.

Finally, Figure 10 shows the overall result considering all three categories and the 91 GRI indicators. The obtained barycenter ($\mu = 0.26$, $\lambda = 0.17$) is located in the paracomplete region, indicating that experts have no conclusive opinion about the relationship between GRI indicators and the strong sustainability. Interesting to note that for the economic category, the barycenter falls very close to the undefined line where $\mu = \lambda$. Although the indicators for the environmental category presents high degree of belief and low degree of disbeliefs, the economic and social indicators presents low degree for both, leading the final aggregated result to a paracomplete region; this means a lack of conclusive evidences from experts opinions about whether GRI indicators are aligned or not to the conceptual model of strong sustainability. The existing uncertainties on the reaches

of GRI indicators emphasize its use with precaution to avoid wrong decisions that would lead companies to unsustainable development.

Rather than located in the 'false' region, which would indicate a conclusive opinion from experts that GRI indicators do not reflect the strong sustainability, the barycenter in the paracomplete region claims for efforts by GRI developers to make indicators more well defined, with aims and scope clearly presented and more aligned to the sustainability issues. The obtained results show the difficulty in identifying indicators that really express sustainability, and this goal will hardly be achieved without defining a robust conceptual model of sustainability supporting the choice of representative indicators. This model should be simple and embrace important aspects of sustainability such as the regional support in providing resources to the productive system, natural environment receiving residues for dilution, the financial health of company, and the social capital acting as labor provider and receiving the produced goods and services. Advances in this direction has been appeared in the scientific literature, among others, the work of Giannetti et al. (2019b) that proposed the five sector sustainability model (5SenSu) as an important epistemological construct supporting choices when assessing sustainability.

4 Conclusions

Experts opinion about the relationship between GRI indicators with the concept of strong sustainability reveals the existence of high dispersion (coefficient of variation $>30\%$) for 77 from the 91 indicators evaluated, including 8 from 9 economic indicators, 21 from 34 environmental indicators, and 48 from 48 social indicators. Although the opinions on the environmental category obtained better performance, the high dispersion for all categories indicates different understandings about the meaning of sustainability and/or the meaning and reach of GRI indicators in achieving sustainability. In principle, GRI framework should be based on a clear sustainability model and provide, through a simple, fast and understandable way, information about the purposes of each indicator.

After applying the paraconsistent annotated evidential logic (PAEL) on experts opinion, results showed that the resulting opinions in all three categories (economic, environmental and social) are located in the paracomplete region, indicating a non-conclusive opinion about whether the three GRI categories are able to partially capture and/or express the meaning of strong sustainability. Among the three categories, opinions on the environmental one obtained a barycenter closest to the true region, with high belief ($\mu = 0.43$) and low disbelief ($\lambda = 0.02$) for a 0.50 exigency level, indicating that improvements for this category (mainly for indicators EN18, 20, 21 and 34) would be beneficial for the GRI goals.

The opinions on the overall performance of GRI also shows a barycenter located in the paracomplete region, which means that experts have an inconclusive opinion about whether GRI is aligned to the concept of strong sustainability. The initial hypothesis of this work is then rejected. The resulting beliefs ($\mu = 0.26$) and disbeliefs ($\lambda = 0.17$) indicate that GRI needs improvements to achieve, at least, the minimum established exigency level of 0.5. GRI developers should also apply efforts focused on the following indicators: economic (EC4-6) and social (LA2, 4, 5, 7, 8, 11, 12, 14; SO3-8, 11; PR1-5, 7-9; HR3, 8-10) categories.

All disclosures on company's performance that aim pursuing alternatives for improvement towards higher degrees of sustainability are welcome and deserve to be supported. Investors, politicians, and the general society should be informed about the company's sustainability performance. This is of paramount importance nowadays due to climate change and restricted resources availability to support societal maintenance. In this sense, the GRI framework should be seen as a positive effort to achieve such important goal, in which advances on its framework should be supported by scientific studies as proposed here.

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Appendix A. Mapping GRI G4 to the GRI Standards. Based on GRI (2020b).

#	GRI G4 Indicator code	GRI G4 description	GRI Standards
1	EC1	Direct economic value generated and distributed	Disclosure 201-1 Direct economic value generated and distributed
2	EC2	Financial implications and other risks and opportunities for the organization's activities due to climate change	Disclosure 201-2 Financial implications and other risks and opportunities due to climate change
3	EC3	Coverage of the organization's defined benefit plan obligations	Disclosure 201-3 Defined benefit plan obligations and other retirement plans
4	EC4	Financial assistance received from government	Disclosure 201-4 Financial assistance received from government
5	EC5	Ratios of standard entry level wage by gender compared to local minimum wage at significant locations of operation	Disclosure 202-1 Ratios of standard entry level wage by gender compared to local minimum wage
6	EC6	Proportion of senior management hired from the local community at significant locations of operation	Disclosure 202-2 Proportion of senior management hired from the local community
7	EC7	Development and impact of infrastructure investments and services supported	Disclosure 203-1 Infrastructure investments and services supported
8	EC8	Significant indirect economic impacts, including the extent of impacts	Disclosure 203-2 Significant indirect economic impacts
9	EC9	Proportion of spending on local suppliers at significant locations of operation	Disclosure 204-1 Proportion of spending on local suppliers
1	EN1	Materials used by weight or volume	Disclosure 301-1 Materials used by weight or volume
2	EN2	Percentage of materials used that are recycled input materials	Disclosure 301-2 Recycled input materials used
3	EN3	Direct energy consumption within the organization	Disclosure 302-1 Energy consumption within the organization
4	EN4	Energy consumption outside of the organization	Disclosure 302-2 Energy consumption outside of the organization
5	EN5	Energy intensity	Disclosure 302-3 Energy intensity
6	EN6	Reduction of energy consumption	Disclosure 302-4 Reduction of energy consumption
7	EN7	Reductions in energy requirements of products and services	Disclosure 302-5 Reductions in energy requirements of products and services
8	EN8	Total water withdrawal by source	Disclosure 303-1 Interactions with water as a shared resource
9	EN9	Water sources significantly affected by withdrawal of water	Disclosure 303-2 Management of water discharge-related impacts
10	EN10	Percentage and total volume of water recycled and reused	Disclosure 303-3 Water withdrawal
11	EN11	Operational sites owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas	Disclosure 304-1 Operational sites owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas

12	EN12	Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas	Disclosure 304-2 Significant impacts of activities, products, and services on biodiversity
13	EN13	Habitats protected or restored	Disclosure 304-3 Habitats protected or restored
14	EN14	Total number of IUCN Red List species and national conservation list species with habitats in areas affected by operations, by level of extinction risk	Disclosure 304-4 IUCN Red List species and national conservation list species with habitats in areas affected by operations
15	EN15	Direct greenhouse gas (GHG) emissions (Scope 1)	Disclosure 305-1 Direct (Scope 1) GHG emissions
16	EN16	Energy indirect greenhouse gas (GHG) emissions (Scope 2)	Disclosure 305-2 Energy indirect (Scope 2) GHG emissions
17	EN17	Other indirect greenhouse gas (GHG) emissions (Scope 3)	Disclosure 305-3 Other indirect (Scope 3) GHG emissions
18	EN18	Greenhouse gas (GHG) emissions intensity	Disclosure 305-4 GHG emissions intensity
19	EN19	Reduction of greenhouse gas (GHG) emissions	Disclosure 305-5 Reduction of GHG emissions
20	EN20	Emissions of ozone-depleting substances (ODS)	Disclosure 305-6 Emissions of ozone-depleting substances (ODS)
21	EN21	NOx, SOx, and other significant air emissions	Disclosure 305-7 Nitrogen oxides (NOX), sulfur oxides (SOX), and other significant air emissions
22	EN22	Total water discharge by quality and destination	Disclosure 306-1 Waste generation and significant waste-related impacts
23	EN23	Total weight of waste by type and disposal method	Disclosure 306-2 Management of significant waste-related impacts
24	EN24	Total number and volume of significant spills	Disclosure 306-3 Waste generated
25	EN25	Weight of transported, imported, exported, or treated waste deemed hazardous under the terms of the Basel Convention Annex I, II, III, and VIII, and percentage of transported waste shipped internationally	Disclosure 306-4 Waste diverted from disposal
26	EN26	Identity, size, protected status, and biodiversity value of water bodies and related habitats significantly affected by the organization's discharges of water and runoff	Disclosure 306-5 Waste directed to disposal
27	EN27	Extent of impact mitigation of environmental impacts of products and services	Discontinued
28	EN28	Percentage of products sold and their packaging materials that are reclaimed by category	Disclosure 301-3 Reclaimed products and their packaging materials
29	EN29	Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with environmental laws and regulations	Disclosure 307-1 Non-compliance with environmental laws and regulations
30	EN30	Significant environmental impacts of transporting products and other goods and materials used for the organization's operations, and transporting members of the workforce	Discontinued
31	EN31	Total environmental protection expenditures and investments by type	Revised disclosure
32	EN32	Percentage of new suppliers that were screened using environmental criteria	Disclosure 308-1 New suppliers that were screened using environmental criteria

33	EN33	Significant actual and potential negative environmental impacts in the supply chain and actions taken	Disclosure 308-2 Negative environmental impacts in the supply chain and actions taken
34	EN34	Number of grievances about environmental impacts filed, addressed, and resolved through formal grievance mechanisms	Disclosure 103-2 The management approach and its components
1	LA1	Total number and rate of new employee hires and employee turnover by age group, gender, and region	Disclosure 401-1 New employee hires and employee turnover
2	LA2	Benefits provided to full-time employees that are not provided to temporary or part-time employees, by significant locations of operation	Disclosure 401-2 Benefits provided to full-time employees that are not provided to temporary or part-time employees
3	LA3	Return to work and retention rates after parental leave, by gender.	Disclosure 401-3 Parental leave
4	LA4	Minimum notice periods regarding operational changes, including whether these are specified in collective agreements	Disclosure 402-1 Minimum notice periods regarding operational changes
5	LA5	Percentage of total workforce represented in formal joint management–worker health and safety committees that help monitor and advise on occupational health and safety programs	Disclosure 403-1 Occupational health and safety management system
6	LA6	Type of injury and rates of injury, occupational diseases, lost days, and absenteeism, and total number of work-related fatalities, by region and by gender	Disclosure 403-2 Hazard identification, risk assessment, and incident investigation
7	LA7	Workers with high incidence or high risk of diseases related to their occupation	Disclosure 403-3 Occupational health services
8	LA8	Health and safety topics covered in formal agreements with trade unions	Disclosure 403-4 Worker participation, consultation, and communication on occupational health and safety
9	LA9	Average hours of training per year per employee by gender, and by employee category	Disclosure 404-1 Average hours of training per year per employee
10	LA10	Programs for skills management and lifelong learning that support the continued employability of employees and assist them in managing career ending	Disclosure 404-2 Programs for upgrading employee skills and transition assistance programs
11	LA11	Percentage of employees receiving regular performance and career development reviews, by gender and by employee category	Disclosure 404-3 Percentage of employees receiving regular performance and career development reviews
12	LA12	Composition of governance bodies and breakdown of employees per employee category according to gender, age group, minority group membership, and other indicators of diversity	Disclosure 405-1 Diversity of governance bodies and employees
13	LA13	Ratio of basic salary and remuneration of women to men by employee category, by significant locations of operation	Disclosure 405-2 Ratio of basic salary and remuneration of women to men
14	LA14	Percentage of suppliers that were screened using labor practices criteria	Disclosure 414-1 New suppliers that were screened using social criteria
15	LA15	Significant actual and potential negative impacts for labor practices in the supply chain and actions taken	Disclosure 414-2 Negative social impacts in the supply chain and actions taken

16	LA16	Number of grievances about labor practices filed, addressed, and resolved through formal grievance mechanisms	Disclosure 103-2 The management approach and its components
17	HR1	Total number and percentage of significant investment agreements and contracts that include human rights clauses or that underwent human rights screening	Disclosure 412-3 Significant investment agreements and contracts that include human rights clauses or that underwent human rights screening
18	HR2	Total hours of employee training on policies and procedures concerning aspects of human rights that are relevant to operations, including the percentage of employees trained	Disclosure 412-2 Employee training on human rights policies or procedures
19	HR3	Total number of incidents of discrimination and corrective actions taken	Disclosure 406-1 Incidents of discrimination and corrective actions taken
20	HR4	Operations and suppliers identified in which the right to exercise freedom of association and collective bargaining may be violated or at significant risk, and actions taken to support these rights	Disclosure 407-1 Operations and suppliers in which the right to freedom of association and collective bargaining may be at risk
21	HR5	Operations and suppliers identified as having significant risk for incidents of child labor, and measures taken to contribute to the effective abolition of child labor	Disclosure 408-1 Operations and suppliers at significant risk for incidents of child labor
22	HR6	Operations and suppliers identified as having significant risk for incidents of forced or compulsory labor, and measures to contribute to the elimination of all forms of forced or compulsory labor	Disclosure 409-1 Operations and suppliers at significant risk for incidents of forced or compulsory labor
23	HR7	Percentage of security personnel trained in the organization's human rights policies or procedures that are relevant to operations	Disclosure 410-1 Security personnel trained in human rights policies or procedures
24	HR8	Total number of incidents of violations involving rights of indigenous peoples and actions taken	Disclosure 411-1 Incidents of violations involving rights of indigenous peoples
25	HR9	Total number and percentage of operations that have been subject to human rights reviews or impact assessments	Disclosure 412-1 Operations that have been subject to human rights reviews or impact assessments
26	HR10	Percentage of new suppliers that were screened using human rights criteria	Disclosure 414-1 New suppliers that were screened using social criteria
27	HR11	Significant actual and potential negative human rights impacts in the supply chain and actions taken	Disclosure 414-2 Negative social impacts in the supply chain and actions taken
28	HR12	Number of grievances human rights impacts filed, addressed and resolved through formal grievance mechanisms	Disclosure 103-2 The management approach and its components
29	SO1	Percentage of operations with implemented local community engagement, impact assessments, and development programs	Disclosure 413-1 Operations with local community engagement, impact assessments, and development programs
30	SO2	Operations with significant potential or actual negative impacts on local communities	Disclosure 413-2 Operations with significant actual and potential negative impacts on local communities
31	SO3	Total number and percentage and of operations assessed for risks related to corruption and the significant risks identified	Disclosure 205-1 Operations assessed for risks related to corruption

32	SO4	Communication and training on anti-corruption policies and procedures	Disclosure 205-2 Communication and training about anti-corruption policies and procedures
33	SO5	Confirmed incidents of corruption and actions taken	Disclosure 205-3 Confirmed incidents of corruption and actions taken
34	SO6	Total value of political contributions by country and recipient/beneficiary	Disclosure 415-1 Political contributions
35	SO7	Total number of legal actions for anti-competitive behavior, anti-trust, and monopoly practices and their outcomes	Disclosure 206-1 Legal actions for anti-competitive behavior, anti-trust, and monopoly practices
36	SO8	Monetary value of significant fines and total number of non-monetary sanctions for non-compliance with laws and regulations	Disclosure 419-1 Non-compliance with laws and regulations in the social and economic area
37	SO9	Percentage of new suppliers that were screened using criteria for impacts on society	Disclosure 414-1 New suppliers that were screened using social criteria
38	SO10	Significant actual and potential negative impacts on society in the supply chain and actions taken	Disclosure 414-2 Negative social impacts in the supply chain and actions taken
39	SO11	Number of grievances about impacts on society files, addressed, and resolved through formal grievance mechanisms	Disclosure 103-2 The management approach and its components
40	PR1	Percentage of significant product and service categories for which health and safety impacts are assessed for improvement	Disclosure 416-1 Assessment of the health and safety impacts of product and service categories
41	PR2	Total number of incidents of non-compliance with regulations and voluntary codes concerning the health and safety impacts of products and services during their life cycle, by type of outcomes	Disclosure 416-2 Incidents of non-compliance concerning the health and safety impacts of products and services
42	PR3	Type of product and service information required by the organization's procedures for product and service information and labeling, and percentage of significant product and service categories subject to such information requirements	Disclosure 417-1 Requirements for product and service information and labeling
43	PR4	Total number of incidents of non-compliance with regulations and voluntary codes concerning product and service information and labeling, by type of outcomes	Disclosure 417-2 Incidents of non-compliance concerning product and service information and labeling
44	PR5	Results of surveys measuring customer satisfaction	Disclosure 102-43 Approach to stakeholder engagement Disclosure 102-44 Key topics and concerns raised
45	PR6	Sale of banned or disputed products	Disclosure 102-2 Activities, brands, products, and services
46	PR7	Total number of incidents of non-compliance with regulations and voluntary codes concerning marketing communications, including advertising, promotion, and sponsorship by type of outcomes	Disclosure 417-3 Incidents of non-compliance concerning marketing communications
47	PR8	Total number of substantiated complaints regarding breaches of customer privacy and losses of customer data	Disclosure 418-1 Substantiated complaints concerning breaches of customer privacy and losses of customer data

48	PR9	Monetary value of significant fines for noncompliance with laws and regulations concerning the provision and use of products and services	Disclosure 419-1 Non-compliance with laws and regulations in the social and economic area
		Non-existent on GRI G4	Disclosure 207-1 Approach to tax
		Non-existent on GRI G4	Disclosure 207-2 Tax governance, control, and risk management
		Non-existent on GRI G4	Disclosure 207-3 Stakeholder engagement and management of concerns related to tax
		Non-existent on GRI G4	Disclosure 207-4 Country-by-country reporting
		Non-existent on GRI G4	Disclosure 403-5 Worker training on occupational health and safety
		Non-existent on GRI G4	Disclosure 403-6 Promotion of worker health
		Non-existent on GRI G4	Disclosure 403-7 Prevention and mitigation of occupational health and safety impacts directly linked by business relationships
		Non-existent on GRI G4	Disclosure 403-8 Workers covered by an occupational health and safety management system
		Non-existent on GRI G4	Disclosure 403-10 Work-related ill health
		Non-existent on GRI G4	Disclosure 303-4 Water discharge
		Non-existent on GRI G4	Disclosure 303-5 Water consumption
		Non-existent on GRI G4	Disclosure 403-9 Work-related injuries