Sustainability Assessment of Manufacturing Organizations Based on Indicator Sets: A Formal Concept Analysis

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Abstract. Organizations are struggling to survive in today's competitive market. They are mostly obliged to meet customers' expectations and demand for sustainable products from one side and comply with governmental rules and regulations regarding energy, resources, materials, etc. on the other side. Therefore, measuring their sustainability performance and trying to keep up with the competitors is essential for their future development. Consequently, organizations' perception of operational sustainability can reveal their strategies on how to be sustainable, endeavouring the three pillars of economic, environmental and social. The present work investigates the role of indicators' choice and their meaning for sustainability assessment of manufacturing organizations. To this point, an analysis is conducted on the sustainability assessment of 100 manufacturing organizations using GRI indicators for assessing their sustainability state. A Formal Concept Analysis was run to look over the indicators and their interpretations to reach a given degree of sustainability of the organization.

Keywords: Sustainability assessment · Sustainable organization · Indicator-based sustainability assessment · Formal Concept Analysis

1 Introduction

Companies across the world are facing with elevated expectations of customers on one hand and increasing prices for materials, energy and compliance on the other. Therefore, the sustainability target seems to become a vital opportunity and has changed face from a show-off achievement to a competitive imperative and a must-have in today's market. However, the pressure made the manufacturing organizations think about ways, tools and methodologies to assess the level of sustainability in the whole manufacturing system. Therefore, it is safe to say that Sustainable Assessment of manufacturing operations is one of the essentials of sustainable development in an organization. The concept of sustainability assessment is introduced to offer new perspectives to impact assessment geared toward planning and decision making on sustainable development [1].

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Sustainability assessment is defined as a methodology that can help decision-makers and policy-makers decide what actions they should take and should not take in an attempt to make society more sustainable [2]. Sustainability Assessment (SA) is known to be a complex task and conducted for supporting decision making and policy in a broad environmental, economic and social context [3]. Various methods of assessment have been accomplished through the literature so far, trying to find a way for companies to assess their sustainability state, help the companies choose between sustainable solutions, define and solve problems on the way to sustainability and identify potential solutions. Among all methods, assessment through adopting indicators are increasingly recognized and it is known to be a tool for policymakers to convey performance information in environmental, economic, social and development field [4]. Sustainable development indicators, in general, can serve to assess and evaluate the performance, provide trends on improvements plus warnings in case the corporate is facing a drop off in features of sustainability and provide information to decision makers [5, 6]. Therefore, the choice of indicators inside organizations can represent the priorities of the organization and to define strategic and political goals as well as its objectives [7]. Accordingly, the aim of this study is to get deep into the definition of the indicators applied for sustainability assessment to pave the path to the comparison of organizations on their strategies toward assessing their sustainability status. To serve this purpose, an analysis has been conducted on the sustainability reports of 100 manufacturing organizations and a Formal Concept analysis (FCA) was run on the results to get deep into the definition and choice of indicators by the organizations. The rest of the paper will discuss the analysis procedure and its sample. Furthermore, the FCA results will be discussed. Finally, the conclusion and the future work is presented.

2 Analysis

The abundance of the sustainability indicators created a huge confusion for manufacturers when it comes to indicators selection and sustainability assessment [8]. In order to increase the reliability and effectiveness of the indicators, several standard sets, guidelines and frameworks have been introduced by international initiatives. To serve the purpose of the study, an analysis on sustainability reports of organizations which use a defined and standard set of indicators needs to be run. A study of the existing sets of indicators is here performed to clarify the differences between the sets and raising the awareness on the applicability and adjustability of the indicators. The study, as represented in the following, will be led to choosing a standardized set of indicators.

2.1 Review of the Standard Sets of Indicators

In the literature, standard sets of indicators are presented. For the present work, the sets were studied and analysed according to the fulfilment of the following criteria: **(1) Level of Application:** As the aim of the study clearly stated, the assessment needs to be done throughout the whole organization. Therefore, the tools which are not appli-

cable or adaptable for the factory levels were excluded from the study. **(2) Cross-Industry Comparison:** The chosen set of indicators needs to have generic applicability to enable the decision makers to make a comparison between various organization without limitation. Thus, the product/process- specific sets limit the general use of the proposed study. **(3) Holistic View over Sustainability:** as mentioned before, the assessment of progress toward sustainable development should consider the well-being of social, ecological, and economic sub-systems, the tools which are specified on just one feature, i.e. environmentally focused ones, might limit the assessment in the proposed study and will not be considered.

Table 1. Indicators' set review

Indicator set	Description	Reference	Level of Application	Holistic View			Cross-Industry Comparison
				Social	Environmental	Economic	
GRI	Global Reporting Initiatives	[14]	Organization Level	Y	Y	Y	●
DJSI	Dow Jones Sustainability Index	[15]	Organization Level	N	N	Y	▲
ISO 14031		[16]	Organization Level	Y	Y	Y	○
IChemE	The institution of Chemical Engineering	[17]	factory Level	Y	Y	Y	○
LCSP	The Lowell Centre for Sustainable Production	[18]	Organization level	Y	Y	Y	●
UNCSD	UN Commission on Sustainable Development	[19]	Country Level	Y	Y	Y	●
FPSI	Ford of Europe's Product Sustainability Index	[20]	Product Level	Y	Y	Y	○
GM MSM	General Motors Metrics for Sustainable Manufacturing	[21]	Product Level	Y	Y	Y	▲
NIST	National Institute of Standard and Technology Sustainable Manufacturing Indicator Repository	[22]	Organization/Process/Product Level	Y	Y	Y	●
OECD	Organization for Economic Co-Operation and Development (OECD) Sustainable Manufacturing Toolkit	[23]	organization level	N	Y	N	●

Note: Y=YES; N=NO; ● = Covered; ▲= Covered with the limitation ; ○ = Not Covered

As shown in Table 1, tools like GRI, NIST and LCSP appear to meet all our needs. However, NIST is not an open source set of Indicator anymore and LCSP considers a limited and generalized assessment. Therefore, GRI seemed to be an effective selection of standard indicators based on the needs of the study. Indicators of GRI which are related to the three dimensions of sustainability are available through the website (https://www.globalreporting.org/standards/gri-standards-download-center/).

2.2 The Sample of 100 Organizations

Among the verified sustainability assessment reports available on the website (https://www.globalreporting.org/reportregistration/verifiedreports#), the first 100 manufacturing ones related to the years 2016 and 2017 were chosen regardless of the size, country and the field of activity. The reports were all inspected for GRI indicators they encompass in three traditional sustainability dimensions: economic, environmental and social.

2.3 FCA on GRI Indicators

As previously indicated, the organization's reports were studied and the GRI indicators related to the three traditional sustainability dimensions were scrutinized. Then, each dimension was analysed separately with the help of Formal Concept Analysis (FCA). Formal Concept Analysis (FCA) as a clustering technique was chosen to assist the interpretation of the indicators used for sustainability assessment within the organizations. FCA is a branch of lattice theory [9] and it is best used for knowledge representation, data analysis and information management. It detects conceptual structures in data and consequently extraction of dependencies within the data by forming a collection of objects and their properties [10, 11]. FCA is able to visualize and represent knowledge by exploring the relationship between objects and is known to be effective for data analysis and association rule extraction [12, 13].

Based on the set of data given by FCA, GRI indicators were categorized in a formal context in which the regularity of the indicators' choice by the organizations was shown. Having Access to these kinds of result, made it possible to analyses the tendency of the organizations toward the definition of sustainability knowing what indicators have been adopted the most and with what frequency in each dimension. Consequently, the most practiced combinations of the indicators were shown. However, for only one dimension like environmental, more than 15000 combinations were exposed. The wide range in the formal context and the limitation of the space, restricted the present study only upon results of the application of the indicators alone and in two-indicator combinations that are shown in Figs. 1, 2 and 3.

In each figure, solo indicators are shown as circles whose size varies based on the number of the organizations that have applied them in the analysis. Therefore, the bigger the circles are, the more frequent the indicators appeared in the analysis. The scale of the size of the circles is fixed, therefore all indicators in all three dimensions are comparable. On the other hand, if the indicator was applied in the sustainability report of the organization in company with another indicator, the two were connected with a line. The thickness of the line shows the frequency of the application of the two

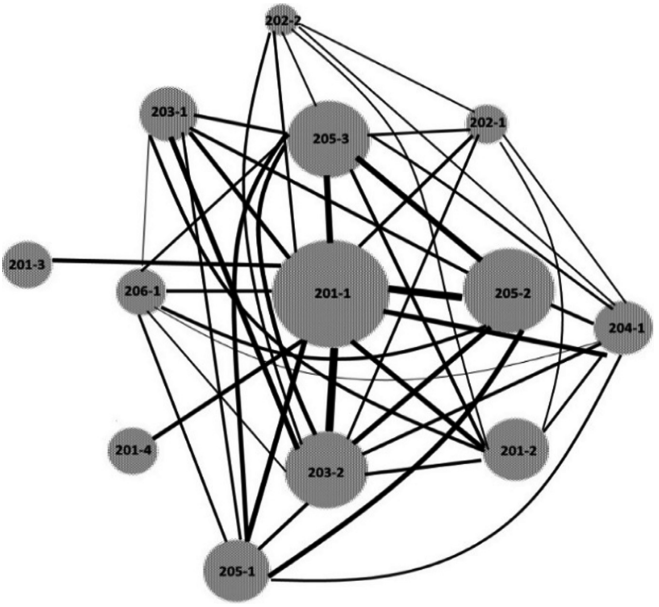

Fig. 1. Economic GRI indicators

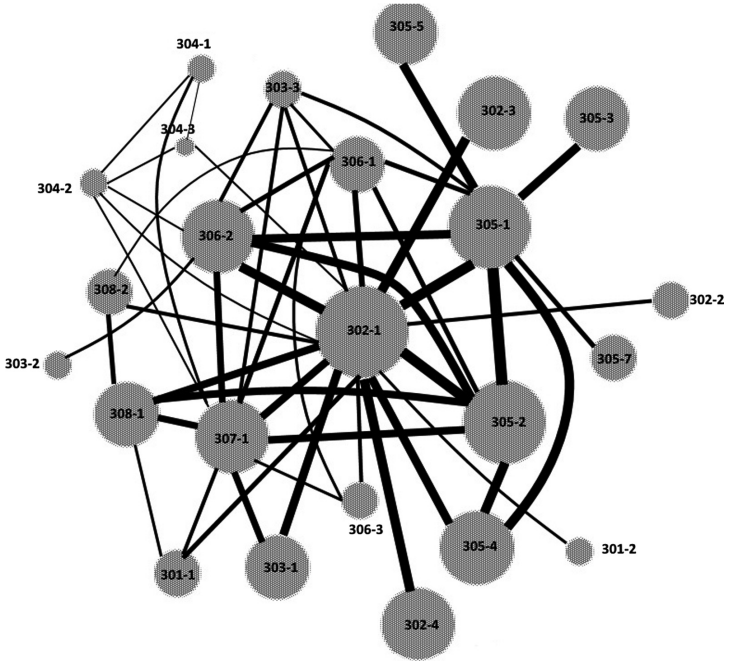

Fig. 2. Environmental GRI indicators

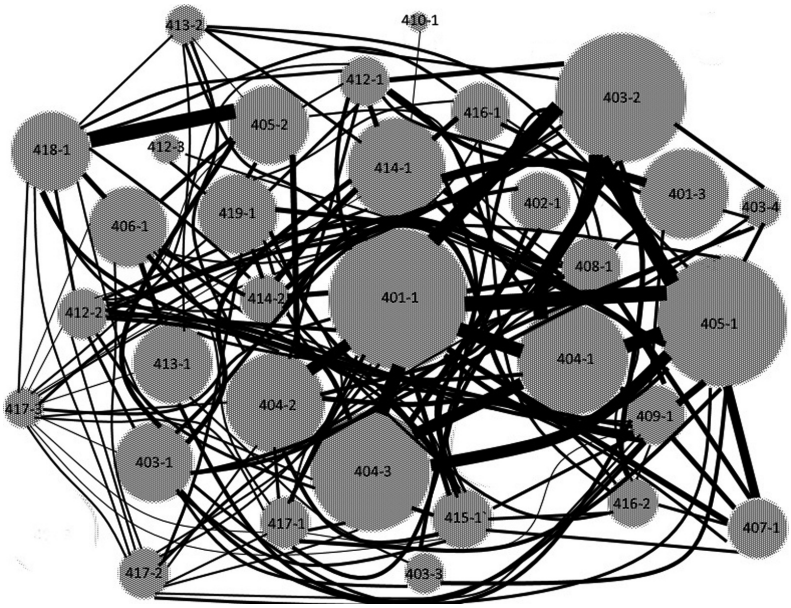

Fig. 3. Social GRI indicator

indicators in comparison with the rest of the two-combination indicators in the same dimension. In better words, the thicker the connection line is, the more the two connected indicators were used in the assessment process of the organizations. The position of the circles and the length of the connection lines speak for no meaning and are fully accidental.

2.4 Results and Discussion

Looking through the economic dimension (Fig. 1), the indicator "direct economic value generated and distributed" (201-1), was ranked as the first with a significant difference from the second one. However, the vast meaning of the indicator can be a justification of its highly ranked application since it contains all three aspects of direct economic value generated (revenues), economic value distributed (operating costs, employee wages and etc.) and economic value retained. On the other hand, the rest of the economic indicators are practiced with smaller differences in frequency of the application which can be the representative of the tendency toward interpreting economic sustainability as costs and profit. In addition, the second-most-used indicator was surprisingly "Communication and training about anti-corruption policies and procedures" (205-2) which is known as both a social and economic value in sustainability definition and it was employed more than "Significant indirect economic impacts" (203-2). The other two anti-corruption indicators, (205-3, 205-1) come next and before "other indirect economic impacts" or "procurement practices" that can be a sign of propensity of organizations toward the concept of anti-corruption. Nonetheless,

indicators related to "market presence" which seemed to be an interesting topic were positioned at the end of the ranking list. As concerns the combinations, it is clear that the combinations with the indicators related to "direct economic value" and "anti-corruption" (all its three indicators) be the ones with the highest position among all. However, the two-indicator combination of (201-1 and 205-2) stood first with an evident difference from the second one which is the combination thought to be the first: direct and indirect economic value (201-1, 203-2). The observation reconfirms the importance of anti-corruption when it comes to economic sustainability in an organization.

Considering the environmental dimension of sustainability (Fig. 2), "Energy Consumption within the organization" which is represented by the indicator (302-1) stood out while the "GHG emission" with two indicators of (305-2) and (305-1) came closely after. However, the difference between the third place (305-1) and the fourth (307-1) and forward is clearly notable. On the other hand, it is observed that most of the indicators at the top of the ranking are the ones related to topics of "energy" (energy consumption, energy intensity, reduction of energy consumption, etc.) and "GHG emissions" (Direct and Indirect GHG emission, GHG intensity, Reduction of GHG emission, etc.) which displays the most representative concepts of environmental sustainability in the organizations. Indicators covering "waste management" like (306-2), (306-1) and the ones for the "water" like (303-1) were among the highest ranked ones which put an emphasis on the importance of this categories on the concept of environmental sustainability in an organization. However, indicators like (301-2), (304-1), (304-3) relating to the categories of "material" and "biodiversity" were placed at the bottom of the list but it does not imply a lack of importance or their ineffectiveness toward sustainability since the shortage can be related to the field of the organizations participated in the analysis. The combination of direct and indirect GHG emissions and their combination with energy consumption within the organization were the most used ones as it was expected. However, although waste management was not the at the top of the list of solo indicators, its combination with GHG emission came rather high in the ranking.

Inspecting the social dimension (Fig. 3), the most noticeable fact is the closeness of the frequency of the indicators and also how repetitive the thickness of the lines is which itself can express that how selective the social dimension is, and the choice can thoroughly differ based on the objective of an organization. However, it is seen that three indicators which deal with "employees", "diversity and equal opportunities" and "injuries" were the ones with the most concentration on with negligible differences. Nevertheless, the indicator (401-1) which stood at the top of the list, covers the new employees and their turnover, gender, age and region, so it is relatively vast in terms of what it covers regarding the characteristics of employees. The same goes for the next indicator, (403-2), which examines the "occupational health and safety" inside the organization and it encompasses types of injury, injury rate (IR), occupational disease rate (ODR), lost day rate (LDR), absentee rate (AR), and work-related fatalities, for all employees, with a breakdown by gender and region. On the other hand, the next topic with a bit of difference in frequency is "training and education". Yet, these prominent topics reveal the importance of the employees, their safety and health and non-discrimination in terms of employment in reaching sustainability from a social point of

view. In addition to these topics, indicators representing social screening of suppliers (414-1), incidents of non-compliance with laws and regulation (419-1), and operations with local community engagement (413-1) also attracted a good deal of attention to themselves. Subsequently, looking through the combination of the indicators, it can be detected that employees and their related issues are the ones that are the most depictive of social sustainability in an organization.

As seen above, the economic and environmental indicators, seem to be more straightforward than the social ones. In other words, unlike economic and environmental, no indicator can be strictly called as the representative of the social dimension. all indicators have been chosen to reach sustainability in the manufacturing organization while the difference in the frequency of the choice is almost negligible. The approach the organizations took toward social sustainability, can speak for the irregularity in defining sustainability from the social point of view while the other two dimensions are mostly approached the same.

3 Conclusion and Future Work

The paper focuses on indicator-based sustainability assessment in manufacturing organizations and tries to scrutinize the meaning of the choice of indicators by the organizations. The study starts with a survey on available indicators set provided for sustainability assessment to choose the most responsive one according to the defined criteria. Among all sets, GRI was elected as the indicator source of the assessment throughout the organizations. Furthermore, 100 organizations were inspected on their choice of GRI indicators for assessing their sustainability status. The result of the analysis was then interpreted by Formal Concept Analysis (FCA) to investigate the strategies of the organizations toward sustainability and help decision makers define a more sustainable strategy for the organization considering the trends. Nevertheless, the future work of the present study can focus on comparing the painted picture of sustainability by the manufacturers to the assumed concept of sustainability delineated in the literature.

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