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Abstract: Manufacturing organizations are facing the urge to adopt new strategies like sustainability to be able to respond to the market and customer's demand for sustainable products due to the scarcity of the natural resources or government policies. To serve this purpose, the main questions risen are "How sustainability is defined through its dimensions? and What sub-dimensions can denominate sustainable manufacturing? Focusing on the questions, this study is cantered by a systematic literature review based on sustainability, its dimensions and subdimensions to investigate sustainability in manufacturing and the domains on which manufacturers can act on to be more "sustainable". Although the literature is more focused on the three traditional dimensions of sustainability namely: environmental, economic and social, a more detailed look through the dimensions is needed to help manufacturing organizations sketch their own sustainable strategies on more specific issues. The study of the dimensions led to a hierarchy of importance for the traditional three, in which environmental dimension of sustainability showed to be conspicuous. Therefore, the dimension was chosen for the further analysis conducted by Formal Concept Analysis (FCA) on its sub-dimensions to explore the trends in their combination by manufacturers while trying to reach sustainability.

Keywords: Sustainable Manufacturing; Sustainability; Production Organization; Sustainability Dimensions; Formal Concept Analysis

1. Introduction

Manufacturing enterprises are forced by several increasing challenges such as resource depletion, economic stagnation, human being pursuing higher life quality and stricter regulations and banning policies. Sustainable manufacturing has intended to empower the companies to cope with such challenges and guide them to stand out in the competitive market today. Therefore, manufacturers are now tending to reset to manufacturing processes and manufactured products that minimize environmental impacts while considering social and economic dimensions. On the other hand, Jawahir et al. (2014) insisted on the need for having an expanded look at sustainable manufacturing as he stated that: *"sustainable manufacturing at product, process and system level, must demonstrate reduced negative environmental impacts, offer improved energy and resource efficiency, generate minimum quality of waste, provide operational personnel health while maintaining and/or improving the product and process quality with the overall life cycle cost benefits."*

Sustainable manufacturing aims at creating a future in which 100% of products are recyclable, manufacturing causes zero impact on the environmental and complete disassembly of a product at its end of life is routine (Rachuri, Sriram, & Sarkar, 2009). To make this vision come true and to move in that direction, companies need to reply to a series of questions: How sustainability is defined through its dimensions? and What sub-dimensions can denominate sustainable manufacturing? Considering the questions, companies will be able to understand the scope and goals of sustainability regarding to their own field and also will detect the means which serve the purpose of reaching sustainability in a manufacturing organization (Arena et al., 2009). To investigate the first question, which is the focus of the present study, it is needed to delineate the domain on which sustainability can act on and define its strategies.

The term sustainability has been used interchangeably with sustainable development. In spite of the introduction of sustainable development, the World Commission on Environment and Development (WCED, 1987) made nearly 30 years ago, there is still no single agreed-upon definition for sustainability. The same definition by WCED has been used the most and widely by manufacturers, engineers, economists and others as a working definition of sustainability: *"development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs"*. This definition is compatible with several other interpretations of sustainability throughout the literature (Voinov & Farley, 2007). The definition made by the U.S Department of Commerce (DoC) for sustainable manufacturing paves the path to move from sustainability to sustainable manufacturing: *"the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities and consumers and are economically sound"* (Huang & Badurdeen, 2017). Corresponding to this definition and based on (Uva et al., 2017), sustainability is known as a delicate balance between the economic, environmental and social health of a community, nation and of course the earth. However, the concept of sustainability needs to be more than the traditional three dimensions (namely: economy, society, and the environment) and this classification for the domains of sustainability seems to be too broad and more delineation is needed to help manufacturers identify more specific issues on which they can act to be more "sustainable". To win over the purpose, the paper tries to organize the literature on sustainability in manufacturing, looking through its dimensions and sub-dimensions in order to get a detailed view of sustainable manufacturing.

The work is structured as the following: the literature review methodology will be described in sections 2. The samples will be introduced in section 3 and the applied criteria for the content analysis comes after in section 4. Section 5 starts with an analysis of the papers so that the sustainability dimensions, their sub-dimensions and the groupings of sustainable manufacturing are explored by applying Formal Concept Analysis (FCA). The results will be discussed in section 6. Finally, conclusions and future works are described.

2. Systematic Literature Review

2.1. Method of research

The study is formed by a systematic literature review on sustainable manufacturing and the domains of sustainability in manufacturing organizations. To do so, the questions from the abovementioned sequence must have been answered through the work: "How sustainability is defined through its dimensions? and What sub-dimensions can denominate sustainable manufacturing?" To that aim, papers were identified by means of a structured keyword search on major databases and publisher websites (Scopus, Elsevier ScienceDirect, Web of Science). Keywords such as "manufacturing" and "manufacturing system" were combined (using AND) with sustainability-related ones, such as "sustainable/sustainability", "sustainable development" and "sustainable manufacturing system". All the searches were applied in "Title, Keyword, Abstract" field. First, there were two issues excluded from further analysis as they seemed bias from the scope of the research, due to the dissimilarity of interests and distant from the authors' aptness zone: (1) chemical product manufacturing process and (2) manufacturing by renewable energy. However, it is highly important to note that the focus of the study was on statistical data, therefore, business-oriented papers (i.e. (Gurtu, Searcy, & Jaber, 2016)) and the papers which investigate sustainability in a global level (i.e. (Gurtu, Searcy, & Jaber, 2017))were also decided to be considered out of scope and be excluded from the search.

A content analysis was conducted to systematically assess the papers. The material collection has been already described which is by means of the literature search and the reduction mode mentioned above. For the analysis itself, a set of criteria was used at first for describing the sample. The respective content analysis is outlined as the following sectors.

2.2. Samples and descriptive analysis

The overall sample considered in this study is 115 papers (published up to March 2018 as in the Reference section). The time distribution of the papers published is shown in figure 1.

A small fluctuation can be seen between 2001 and 2012 in the number of papers, however, the sharp growth appeared on 2013 with gradual changes to the current years, rationalizes the rise of the importance of the topic of sustainability in recent years.

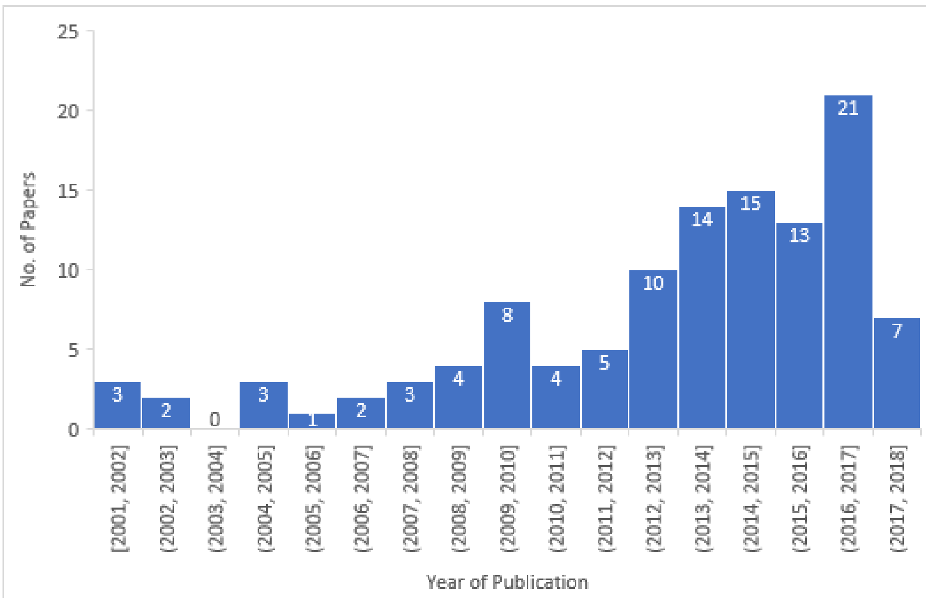

Figure 1. Time distribution of the papers in the sample

2.3. Criteria applied in the context analysis

The criteria for the content analysis can be established based on whether the analysis performed in the paper is deductive or inductive (Seuring, 2013). In the present work, the aim is to generalize research findings in sustainable manufacturing to a certain extent and get to the essence of sustainability in a manufacturing organization. Therefore, the choice of the criteria was mostly deductive, however, in some cases, the criteria could only be established during the process of the review and after digging into the concept. However, the dominant choice for the criteria in the study was sustainability dimensions and the sub-dimensions. The papers were assessed based on the authors' choice on which dimension of sustainability as economic, environmental and social (or any other dimensions) they made the discussion.

3. Analysis of papers

3.1. Analysis of the dimensions

WCED (1987) identified three components of sustainable development as social, economic, and environmental. Within its 2005 World Summit Outcome report, the United Nations (2005) declares social development, economic development, and environmental protection as ‘three pillars’ of sustainable development that are ‘interdependent and mutually reinforcing’ (Faezipour & Ferreira, 2011). However, these three were not the only aspects analysed through the literature but were the most popular ones. Other aspects like technology has been discussed through the literature (as examples see (A. Balkema, Preisig, Otterpohl, & Lambert, 2003; M.F. Hassan et al., 2017; Joung, Carrell, Sarkar, & Feng, 2013)) and the authors believed that technology is a pertinent element of the sustainability concept. Marika Arena et al., (2009) mentioned that without a continuous technology development and evaluation, the modern industrialized world cannot survive. Indeed, technology was considered in some works to check whether it can deal with existing social and environmental threats. Among the papers analysed for the present study, other aspects like energy (S. Li, Mirlekar, Ruiz-Mercado, & Lima, 2016a), efficiency (Ruiz-Mercado, Gonzalez, & Smith, 2014a), manufacturing (Harik, El, Medini, & Bernard, 2015), quality((C. Li, 2013; Lye, Lee, & Khoo, 2001) and performance management (Joung et al., 2013) were also observed. Nevertheless, the majority of the works were applying the traditional three aspects as social, environmental and economic with a distance from the other aspects (Figure 2).

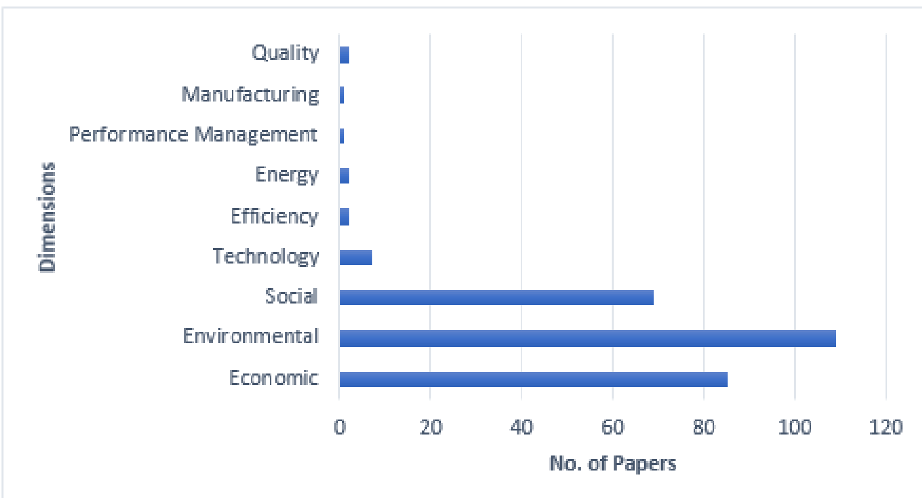

Figure 2. Sustainability dimensions observed in analysed papers

The three dimensions, also known as the Triple Bottom Line (TBL), have been covered through the literature of sustainability assessment allowing comprehension of each line separately and along with their integration. A detailed look at the papers regarding TBL and other dimensions is shown in table 1. On the other hand, wide usage of the TBL in sustainability assessment justifies its further application. However, classifying the concept of sustainability into three groups of economic, environmental and social is too broad for further analysis of the papers and it makes it difficult to operationally support companies select a specific strategy (Marika Arena et al., 2009). Therefore, it’s been decided to go into detail in analysing the TBL and trying to divide them into micro levels and sub-dimensions based on the analysed papers. The division was done inductively though. It started with a suggestion on (Marika Arena et al., 2009) and was revised during the coding. A stipulated look for each dimension and the sub-dimensions are presented as the following.

Table 1. Sustainability dimensions throughout the literature

Reference	Year	Environmental	Social	Economical	Technology	Efficiency	Energy	Performance Management	Quality
(Li, Mirlekar, Ruiz-Mercado, & Lima, 2016)	2016	●		●		●	●		
(Santucci & Esterman, 2015)	2015	●							
(Varsei, Soosay, Fahimnia, & Sarkis, 2014)	2014	●	●	●					
(Ramos, Gomes, & Barbosa-Póvoa, 2014)	2013	●	●	●					
(Choi & Shen, 2016)	2016	●	●	●					
(Rezvan, Azadnia, Noordin, & Seyedi, 2014)	2014	●	●	●					
(Holton, Glass, & Price, 2010)	2010	●	●	●	●				
(Aydin, Mays, & Schmitt, 2014)	2014	●		●					
(Loucks, D. P. 1997)	2014	●	●						
(Ruiz-Mercado, Gonzalez, & Smith, 2014)	2012	●		●		●	●		
(Shin & Colwill, 2017)	2017		●						
(Rachuri, Sriram, & Sarkar, 2009)	2009	●	●	●					
(Mani, Larborn, Johansson, Lyons, & Morris, 2016)	2016	●							
(Krajnc & Glavič, 2005)	2005	●	●	●					
(Smith & Ball, 2012)	2012	●							
(Chen, Thiede, Schudeleit, & Herrmann, 2014)	2014	●	●	●					

Reference	Year	Environmental	Social	Economical	Technology	Efficiency	Energy	Performance Management	Quality
("Assessing the sustainability performances of industries - ScienceDirect," n.d.)	2005	●	●	●					
(Baumgartner & Ebner, 2010)	2010	●	●	●					
(Gunasekaran & Spalanzani, 2012)	2011	●	●						
(Eastlick & Haapala, 2012)	2012	●	●	●					
(Kremer et al., 2016)	2015	●		●					
(Mani, Madan, Lee, Lyons, & Gupta, 2014)	2014	●							
(AlKhazraji, Saldana, Donghuan, & Kumara, 2013)	2013	●							
(Aizstrauta, Celmina, Ginters, & Mazza, 2013)	2013	●	●						
(Smetana, Tamásy, Mathys, & Heinz, 2016)	2016	●	●	●					
(Arena et al., 2009)	2009	●	●	●	●				
(Balkema, Preisig, Otterpohl, & Lambert, 2003)	2003	●	●	●	●				
(Haanstra, Toxopeus, & van Gerrevink, 2017)	2017		●	●					
(Huang & Badurdeen, 2017)	2017	●	●	●					
(Jayal, Badurdeen, Dillon, & Jawahir, 2010)	2010	●	●	●					
(Lu et al., 2011)	2011	●	●	●					
(Jawahir et al., 2006)	2006	●	●	●					
(Justin J. Keeble et al., 2003)	2003	●	●	●					
(Veleva & Ellenbecker, 2001)	2001	●	●	●					
(de Silva, 2009)	2009	●	●	●					
(Krajnc & Glavič, 2005)	2005	●	●	●					
(Feng & Joung, 2010)	2010	●	●	●					
(Clarke, Zhang, Gershenson, & Sutherland, 2008)	2008	●		●					
(Sutherland, Jenkins, & Haapala, 2010)	2010	●		●					
(Mani et al., 2013)	2013	●							

Reference	Year	Environmental	Social	Economical	Technology	Efficiency	Energy	Performance Management	Quality
(Haapala, Rivera, & Sutherland, 2008)	2008	●	●	●					
(Faulkner & Badurdeen, 2014)	2014	●	●	●					
(Videira, Antunes, Santos, & Lopes, 2010)	2010	●							
(Joung, Carrell, Sarkar, & Feng, 2013)	2013	●	●	●	●			●	
(Dewulf et al., 2015)	2015	●	●	●	●				
(Moldavska, 2016)	2016	●	●	●					
(Despeisse, Ball, Evans, & Levers, 2012)	2012	●							
(Lanz et al., 2014)	2014	●	●	●					
(Halog & Manik, 2011)	2011	●	●	●					
(Uphoff, 2014)	2014	●	●	●					
(Bertoni, Hallstedt, & Isaksson, 2015)	2015	●		●					
(Garretson, Eastwood, Eastwood, & Haapala, 2014)	2014	●	●	●					
(Long, Pan, Farooq, & Boer, 2016)	2016	●	●	●					
(Eastwood & Haapala, 2015)	2015	●	●	●					
(Wang, Zhang, Liang, & Zhang, 2014)	2014	●	●	●					
(Garbie, 2015)	2015	●	●	●					
(Jayawickrama, Kulatunga, & Mathavan, 2017)	2017	●	●	●					
(Hapuwatte, Badurdeen, & Jawahir, 2017)	2017	●	●	●					
(Maginnis, Hapuwatte, & Jawahir, 2017)	2017	●	●	●					
(Badurdeen & Jawahir, 2017)	2017	●	●	●					
(Yan & Feng, 2014)	2014	●	●	●					
(Koren, Gu, Badurdeen, & Jawahir, 2018)	2018	●	●	●					
(Kuik, Nagalingam, & Amer, 2011)	2011	●	●	●					
(Jawahir & Bradley, 2016)	2016	●	●	●					
(Gao & Wang, 2017)	2017	●	●	●					

Reference	Year	Environmental	Social	Economical	Technology	Efficiency	Energy	Performance Management	Quality
(Badurdeen et al., 2009)	2009	●	●	●					
(Zhao, Perry, & Andriankaja, 2013)	2013	●							
(Rondini, Tornese, Gnoni, Pezzotta, & Pinto, 2017)	2017	●							
(Onat, Kucukvar, Tatari, & Egilmez, 2016)	2016	●	●	●	●				
(Kluczek, 2016)	2016	●	●	●					
(Ramos, Ferreira, Kumar, Garza-Reyes, & Cherrafi, 2018)	2018	●							
(Joglekar, Kharkar, Mandavgane, & Kulkarni, 2018)	2018	●	●	●	●				
(Hegab, Darras, & Kishawy, 2018)	2018	●	●	●					
(Chaim, Muschard, Cazarini, & Rozenfeld, 2018)	2018	●	●						
(Inman & Green, 2018)	2018	●							
(Kaur, Sidhu, Awasthi, Chauhan, & Goyal, 2018)	2018	●							
(Das, 2017)	2017	●	●	●					
(Chakravorty & Hales, 2017)	2017			●					
(Zhou & Yao, 2017)	2017	●		●					
(Sunk, Kuhlang, Edtmayr, & Sihn, 2017)	2017	●		●					
(Falck et al., 2017)	2017		●						
(Diaz & Marsillac, 2017)	2017			●					
(Masmoudi, Yalaoui, Ouazene, & Chehade, 2017)	2017	●		●					
(Keivanpour, Ait-Kadi, & Mascle, 2017)	2017	●		●					
(Golini, Moretto, Caniato, Caridi, & Kalchschmidt, 2017)	2017	●	●	●					
(Thirupathi & Vinodh, 2016)	2016	●	●	●					

Reference	Year	Environmental	Social	Economical	Technology	Efficiency	Energy	Performance Management	Quality
(Govindan, Jha, & Garg, 2016)	2016	●	●	●					
(Dhavale & Sarkis, 2015)	2015	●		●					
(May, Stahl, Taisch, & Prabhu, 2015)	2015	●							
(Bentaha, Battaiä, & Dolgui, 2015)	2015	●							
(Dubey, Gunasekaran, & Chakrabarty, 2015)	2015	●	●	●					
(Harik, El, Medini, & Bernard, 2015)	2015	●	●	●					
(Altmann, 2015)	2015	●		●					
(Romli, Prickett, Setchi, & Soe, 2015)	2015	●	●	●					
(Garbie, 2014)	2014	●	●	●					
(Li, 2013)	2013	●		●					●
(Garbie, 2013)	2013			●					
(Kim, Park, Hwang, & Park, 2010)	2010	●							
(Quariguasi, Walther, Bloemhof, Van, & Spengler, 2010)	2010	●		●					
(Calvo, Domingo, & Sebastin, 2008)	2008	●							
(Mouzon, Yildirim, & Twomey, 2007)	2007	●							
(Bevilacqua, Ciarapica, & Giacchetta, 2007)	2007	●		●					
(O'Brien, 2002)	2002	●		●					
(Lye, Lee, & Khoo, 2001)	2001	●		●					●
(Anvari & Turkay, 2017)	2017	●	●	●					
(Ries, Grosse, & Fichtinger, 2017)	2017	●							
(Keivanpour & Ait, 2017)	2017	●							
(Lake, Acquaye, Genovese, Kumar, & Koh, 2015)	2015	●							
(Tsai et al., 2015)	2015	●							
(Xing, Wang, & Qian, 2013)	2013	●		●					

Reference	Year	Environmental	Social	Economical	Technology	Efficiency	Energy	Performance Management	Quality
(Heidrich & Tiwary, 2013)	2013	●							
(Dai & Blackhurst, 2012)	2012	●	●	●					
(Roy et al., 2014)	2014	●	●	●					
(Bradley, Jawahir, Badurdeen, & Rouch, 2016)	2016	●	●	●					
(Rosenthal, Fatimah, & Biswas, 2016)	2016	●							

3.1.1. Environmental sub-dimensions

Environmental dimension helps companies measure the environmental aspect of sustainability performance in manufacturing and products. Concentrating on sustainability, it is obvious that the environmental dimension has been targeted the most: about 94% of the analysed papers referred to environmental dimension alone and alongside the other two; among which about 55% of the analysed papers tried to cover all the three dimensions simultaneously. However, most of the analysed papers address environmental issues in sustainability in similar categories. It was plotted that, sustainability in manufacturing processes, was the most targeted area in terms of environmental assessment and was carried on by measurement of energy, material, water and other resources used, throughout the processes involved in the life cycle of the product. Getting through the papers, studied issues from the environmental point of view can be categorized in four main groups: “Emission”, “Pollution”, “Resource Consumption” and “Biodiversity”. The first group can be described as the emissions from the manufacturing process include by-products, auxiliary materials used in the manufacturing products, waste energy, and wastewater, while “Pollution” is harmful substances released to the environment by a manufacturing process or organization, “Resources” on the other hand, can consist of raw materials, consumable tools, energy, and packaging materials used in a manufacturing process. Finally, the latter encompasses the variety of life at all levels of the organization, from genetic diversity within a species to diversity within entire regions or ecosystems (Joung et al., 2013). Acknowledging the four groups, the sub-dimensions “water”, “material”, “carbon footprint”, “emissions”, “waste”, “biodiversity”, “landfill”, “transport”, “resource” and “energy” seemed to be the dominant ones as they assess thoroughly the environmental dimension of sustainability.

However, some of the works that discussed environmental dimension of the sustainability are as the following: (Mahesh Mani, Larborn, Johansson, Lyons, & Morris, 2016) used Discrete Event Simulation (DES) in combination with Life Cycle Assessment (LCA) to make more rigorous environmental decisions and to reach sustainable manufacturing processes. Material and resource usage were aggregated downstream in the product life cycle to discover, analyse and improve hotspots and bottlenecks. The E3012-16 standard was used as a guideline to collect information on the inputs, resources, products and process information that are transformed into the desired outputs. The same sub-dimensions were used by (Leigh

Smith & Ball, 2012) to reach sustainable manufacturing by applying Process Flow Modelling. A suitable approach is created by mapping the life cycle of material, energy and waste process flow which are counted as the inputs of the physical resources and the outputs of the facility. A set of guidelines is also prepared to aid the analysis of the manufacturing systems with the help of the process flow through which a quantitative analysis is enabled by detailed insights within the system and assists with the identification and selection of environmental efficiency improvements. The efficiency within the manufacturing system can be measured financially and in terms of carbon emissions. Mani, Madan, Lee, Lyons, & Gupta (2014) tried to characterize sustainability in processes from the environmental point of view by addressing energy usage, emissions, water, waste and carbon footprint. On the other hand, Kremer et al. (2016) pointed both economic and environmental issues across product supply chain aiming at optimizing cost, carbon footprint, product quality and delivery reliability by considering geographical influence. Social and environmental dimensions were studied both by (Loucks, 1997) to quantify trends in the sustainability of systems. Like many others, water, waste, land and other resources were the main environmental matters to be assessed by the authors. See (A. J. Balkema, Preisig, Otterpohl, & Lambert, 2003; Feng & Joung, 2010; Keeble, Topiol, & Berkeley, 2003; D. Krajnc & Glavič, 2005) as some other examples in which the same environmental sub-dimensions as the ones mentioned above alongside different ones in economic and social were studied.

3.1.2. Economic sub-dimensions

The economic feature will help manufacturing companies to measure the economic aspect of sustainability performance in manufacturing and products. Unlike environmental references, the economic dimension was addressed by diverse elements. The sub-dimensions by which sustainability was assessed were more dependent on how sustainable manufacturing was conceptualized and in what level it was assessed. Almost no paper targeted economic dimension alone, it was covered alongside the other two dimensions though (73% of the papers). For the papers covering the product or process level, measurements like investment, product quality, profitability, innovation, transportation, R&D were considered (see (Baumgartner & Ebner, 2010; Jayal, Badurdeen, Dillon, & Jawahir, 2010) and (Lu et al., 2011) as examples); while on the system level, direct and indirect cost, profit, net cash flow, economic development and penalty cost, were the main concerns (see, e.g., (Angappa Gunasekaran & Spalanzani, 2012) and (Huang & Badurdeen, 2017)). Nevertheless, based on the National Institute of standards and technology (NIST)(Thompson, 2011), the areas to study sustainability from an economic point of view in manufacturing can be divided to three main groups: "Profit", "Manufacturing costs" and "Investment". "Profit" subcategory aims at measuring revenue and profits attributable to the manufacturing of products. "Manufacturing Cost" subcategory covers the cost of manufacturing and can include costs of material, labour, tooling, equipment depreciation, energy consumption, water consumption, packaging, delivery, environmental protection (solid waste management and water treatment), and recycling. The third group, "Investment", measures the investment performance in a manufacturing company.

However, some of the works discussed economic dimension of the sustainability are as the following: Ramos, Gomes, & Barbosa-Póvoa (2014) designed a multi-objective, multi-depot periodic Vehicle Routing Problem (VRP) with inter-depot routes to model a reverse logistic plan in order to balance costs with environmental and social issues. The model's economic objective is to minimize the total distance travelled by vehicles which include inbound distance, outbound distance and also a possible extra distance as it is allowed to have vehicles based at one depot to perform closed routes from and to another depot. By applying the classic VRP and generating routes for vehicles, not only the total distance travelled by vehicles will be minimized but also the CO2 emissions and the working hours of the drivers will be decreased to the minimum amount possible. 33 economic indicators were introduced alongside 106 Energy, efficiency and environmental ones by Ruiz-Mercado et al. (2014) to measure the process performance. Based on the achieved performance evaluation, design modifications are suggested to reach the desired or increased sustainability goals. However, the economic indicators covered processing costs (capital cost, manufacturing cost), process input costs (raw material cost, utility costs) and process output costs (waste treatment costs). To reach the indicators, a conversion of flow and energy mass to monetary units (like raw material, product and utility cost) accompanied by the process and operating costs was needed. In addition, the equipment, operating conditions, and goods and services required for all manufacturing steps have to be reflected in terms of costs, such as manufacturing and capital costs. On the other hand, production cost, initial time set, and energy saving were the economic categories (P. Rezvan, Azadnia, Noordin, & Seyedi, 2014) decide to cover to reach sustainability through a fuzzy evaluation of the process elements.

Conclusively, based on what has been observed through analysing papers and also considering groupings made by NIST and (Marika Arena et al., 2009) the sub-dimensions of “profit maximization”, “manufacturing cost optimization”, “market image”, “logistic cost”, “investment” and “indirect economic” impacts seemed the ones incapable of covering all the detailed classifications in the literature.

3.1.3. Social sub-dimensions

The social dimension which was studied in 78% of the papers, seemed to be the most conflicted one among all and was named the most problematic one due to its qualitative nature. Based on NIST, the social dimension has been designed for measuring employee, customer, and community well-being affected by manufacturing activities and products of a manufacturing company. It groups the dimension into three main sub-dimensions of Employee (employee well-being, such as health, safety, security, career development, and satisfaction, in a manufacturing facility), Customer (customer well-being, such as health and safety, affected by manufacturing and manufactured products) and Community (community well-being, such as health, safety, and human rights, affected by manufacturing and manufactured product).

However, the diversity of the measurements and interpretation of the social dimension in sustainable manufacturing was vast and they were pointing out a wide range of responsibilities from employment, to distribution to customer health and satisfaction. For instance, Huang & Badurdeen (2017) indicated that at the system level corporate safety, personnel health, societal impact of the product and even functional impacts need to be considered. On the other hand, Lu et al. (2011) mentioned education and training, customer satisfaction, employee safety and health are the ones to be measured. Damjan Krajnc & Glavič (2005) introduced an overall sustainability index by aggregating indices from different sustainability dimensions to make the process of decision making and comparison between companies easier. From social point of view, categories were studied that could reflect the attribute of the company to the treatment of its own employee, suppliers, contractor and customers and also its impact on society. Therefore, categories like health and safety of personnel (fatal accident rate, injury frequency, fatalities), "social and community investment and employment rate were studied to reach social sustainability. Issues like Employment (average wage) and occupational health and safety (acute injuries, lost work days and chronic illnesses) were covered by (Dane D. Eastlick & Haapala, 2012) as it proposes a Design for Manufacturing (DoF) case followed by a decision-making process to support component design for sustainable manufacturing. The authors try to relate process and product design variables to selected sustainability indicators with the help of decomposing manufacturing processes and developing related mathematical expressions to assign input variable to output streams. Consequently, design choices will be related to sustainability indicators and it gives the opportunity to evaluate sustainable alternatives based on manufacturing process variations. From social perspective, the work covered employment rate along with safety and health of the personnel. To (Pouyan Rezvan, Azadnia, Noordin, & Seyedi, 2014) the most important social issue was product responsibility while some papers like (A. Balkema et al., 2003; Jayal, Badurdeen, Dillon, & Jawahir, 2010a; Lu et al., 2011) insisted on considering End of Life Management (EOL) of the products as a social issue as well.

To cover all discussed issues, and based on the scope of the study, “labour practice/working condition”, “diversity and equal opportunities”, “relations with the community”, “social policy compliance”, “safety and health”, “customer satisfaction”, “product responsibility” and “education” were the ones chosen as the final social sub-dimensions to assess sustainable manufacturing. Table 2 shows the sub-dimensions of sustainability in the analysed papers.

Table 2. Sub-Dimensions of sustainability

Reference	**Environmental Subdimensions**										**Economic sub-dimension**						**Social Sub-dimension**									
	water	**material**	**carbon footprint**	**Emissions**	**waste**	**Biodiversity**	**landfill**	**transport**	**Resource**	**energy**	**Profit Maximization**	**Manufacturing cost optimization**	**Market Image**	**Logistics cost**	**Investment**	**Indirect Economic Impacts**	**labour Practice/working Condition**	**diversity and equal opportunities**	**relations with the community**	**social Policy Compliance**	**safety and health**	**Customer Satisfaction**	**socio-economic**	**Product Responsibility**	**Education**	**human rights**
(Mani, Larborn, Johansson, Lyons, & Morris, 2016)	•	•			•					•																
(Eastlick & Haapala, 2012)	•	•	•	•	•					•							•				•					
(Mani, Madan, Lee, Lyons, & Gupta, 2014)	•		•	•	•					•																

Reference	Environmental Subdimensions										Economic sub-dimension						Social Sub-dimension									
	water	material	carbon footprint	Emissions	waste	Biodiversity	landfill	transport	Resource	energy	Profit Maximization	Manufacturing cost optimization	Market Image	Logistics cost	Investment	Indirect Economic Impacts	labour Practice/working Condition	diversity and equal opportunities	relations with the community	social Policy Compliance	safety and health	Customer Satisfaction	socio-economic	Product Responsibility	Education	human rights
(Varsei, Soosay, Fahimnia, & Sarkis, 2014)	●			●	●					●	●	●					●			●		●		●		●
(Holton, Glass, & Price, 2010)	●	●			●					●			●	●			●		●	●	●					
(Chen, Thiede, Schudeleit, & Herrmann, 2014)	●	●		●	●	●			●	●	●				●		●				●				●	
(Labuschagne, Brent, & van Erck, 2005)	●			●		●			●	●	●									●			●			
(Smetana, Tamásy, Mathys, & Heinz, 2016)	●				●				●	●				●						●						
(Balkema, Preisig, Otterpohl, & Lambert, 2003)	●				●					●		●												●		
(Huang & Badurdeen, 2017)	●	●		●	●				●	●	●	●				●	●				●	●		●		
(Lu et al., 2011)	●	●			●					●		●		●		●	●			●	●			●	●	
(Justin J. Keeble et al., 2003)	●			●				●	●	●	●		●	●	●			●		●		●		●	●	
(Aydin, Mays, & Schmitt, 2014)	●											●														
(Ruiz-Mercado, Gonzalez, & Smith, 2014)	●	●	●	●	●				●	●	●	●				●										
(Loucks, D. P. 1997)	●	●			●	●			●								●					●	●	●		

Reference	Environmental Subdimensions										Economic sub-dimension						Social Sub-dimension									
	water	material	carbon footprint	Emissions	waste	Biodiversity	landfill	transport	Resource	energy	Profit Maximization	Manufacturing cost optimization	Market Image	Logistics cost	Investment	Indirect Economic Impacts	labour Practice/working Condition	diversity and equal opportunities	relations with the community	social Policy Compliance	safety and health	Customer Satisfaction	socio-economic	Product Responsibility	Education	human rights
(Joung, Carrell, Sarkar, & Feng, 2013)	●	●		●	●	●			●	●	●	●			●		●				●	●		●	●	●
(Faulkner & Badurdeen, 2014)	●	●		●	●			●	●	●		●				●	●				●					
(Videira, Antunes, Santos, & Lopes, 2010)	●			●		●		●	●	●																
(Mani et al., 2013)	●		●	●	●		●			●																
(Lanz et al., 2014)	●	●		●	●	●		●		●	●	●	●		●	●	●	●	●	●	●			●	●	●
(Halog & Manik, 2011)	●			●	●				●	●	●		●				●			●	●					●
(Garretson, Eastwood, Eastwood, & Haapala, 2014)	●			●	●		●			●		●									●					
(Long, Pan, Farooq, & Boer, 2016)	●			●	●					●	●		●		●		●		●		●					
(Eastwood & Haapala, 2015)	●	●		●	●		●		●	●		●				●					●					
(Wang, Zhang, Liang, & Zhang, 2014)	●			●	●				●	●	●	●				●			●		●					
(Garbie, 2015)	●	●		●	●	●			●	●	●		●		●		●		●		●	●			●	●
(Roy et al., 2014)	●	●		●	●					●		●				●					●			●		

Reference	Environmental Subdimensions										Economic sub-dimension						Social Sub-dimension									
	water	material	carbon footprint	Emissions	waste	Biodiversity	landfill	transport	Resource	energy	Profit Maximization	Manufacturing cost optimization	Market Image	Logistics cost	Investment	Indirect Economic Impacts	labour Practice/working Condition	diversity and equal opportunities	relations with the community	social Policy Compliance	safety and health	Customer Satisfaction	socio-economic	Product Responsibility	Education	human rights
(Koren, Gu, Badurdeen, & Jawahir, 2018)	•	•		•	•					•		•				•		•			•					
(Joglekar, Kharkar, Mandavgane, & Kulkarni, 2018)	•								•	•		•					•			•						
(Hegab, Darras, & Kishawy, 2018)	•				•					•		•									•					
(Chaim, Muschard, Cazarini, & Rozenfeld, 2018)	•	•		•	•	•			•	•								•		•	•	•				•
(Chakravorty & Hales, 2017)												•				•										
(Zhou & Yao, 2017)										•																
(Falck et al., 2017)																	•									
(Diaz & Marsillac, 2017)											•	•		•		•										
(Masmoudi, Yalaoui, Ouazene, & Chehade, 2017)										•		•														
(Keivanpour, Ait-Kadi, & Mascle, 2017)					•						•															
(Golini, Moretto, Caniato, Caridi,				•	•				•	•	•	•	•				•		•	•	•	•			•	

Reference	**Environmental Subdimensions**										**Economic sub-dimension**						**Social Sub-dimension**									
	water	**material**	**carbon footprint**	**Emissions**	**waste**	**Biodiversity**	**landfill**	**transport**	**Resource**	**energy**	**Profit Maximization**	**Manufacturing cost optimization**	**Market Image**	**Logistics cost**	**Investment**	**Indirect Economic Impacts**	**labour Practice/working Condition**	**diversity and equal opportunities**	**relations with the community**	**social Policy Compliance**	**safety and health**	**Customer Satisfaction**	**socio-economic**	**Product Responsibility**	**Education**	**human rights**
& Kalchschmidt, 2017)																										
(Govindan, Jha, & Garg, 2016)		•		•	•			•			•			•		•	•						•	•		
(Dhavale & Sarkis, 2015)			•	•											•											
(May, Stahl, Taisch, & Prabhu, 2015)										•																
(Dubey, Gunasekaran, & Chakrabarty, 2015)		•	•	•	•				•					•		•	•					•				
(Harik, El, Medini, & Bernard, 2015)	•			•	•				•	•		•				•	•	•	•		•	•		•		•
(Altmann, 2015)		•	•	•				•				•		•		•										
(Romli, Prickett, Setchi, & Soe, 2015)	•	•	•							•		•		•		•				•				•		
(Li, 2013)		•									•	•		•		•										
(Kim, Park, Hwang, & Park, 2010)		•		•																						
(Mouzon, Yildirim, & Twomey, 2007)										•																
(Bevilacqua, Ciarapica, & Giacchetta, 2007)			•	•						•						•										

Reference	Environmental Subdimensions										Economic sub-dimension						Social Sub-dimension									
	water	material	carbon footprint	Emissions	waste	Biodiversity	landfill	transport	Resource	energy	Profit Maximization	Manufacturing cost optimization	Market Image	Logistics cost	Investment	Indirect Economic Impacts	labour Practice/working Condition	diversity and equal opportunities	relations with the community	social Policy Compliance	safety and health	Customer Satisfaction	socio-economic	Product Responsibility	Education	human rights
(O'Brien, 2002)		●		●	●					●		●		●		●										
(Anvari & Turkay, 2017)	●				●				●			●		●		●		●	●		●	●			●	
(Ries, Grosse, & Fichtinger, 2017)			●																							
(Lake, Acquaye, Genovese, Kumar, & Koh, 2015)	●	●	●		●		●		●	●																
(Tsai et al., 2015)			●																							
(Xing, Wang, & Qian, 2013)		●		●	●					●	●					●										
(Heidrich & Tiwary, 2013)	●	●	●	●	●		●	●	●	●																

3.2. Analysis of the sub-dimensions

Getting through the sub-dimensions, a more profound investigation of their choice and their grouping was called for. Thereof, papers were categorized based on the number of sustainability dimensions they cover, if they study one dimension only, two dimensions or all three traditional together as shown in figure 3. Among 115 papers studied for the dimensions of sustainability, 3, 24 and 2 papers covered economic, environmental and social dimensions alone which represent 3%, 21%, and 2% respectively. The stood-out percentage of environmental, shows the inclination of the organizations while practicing sustainability as a solo dimension. In better words, when it comes to defining sustainability only through one dimension, organizations are more tending to lean on environmental side rather than the other two dimensions.

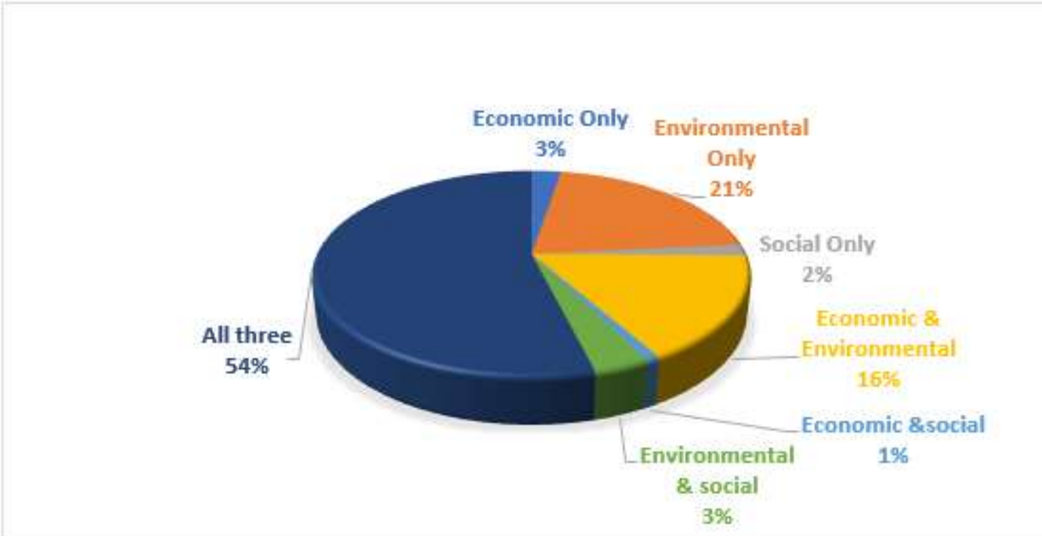

Figure 3. The percentage for the coverage of the three-traditional sustainability dimensions

Through investigating the sub-dimensions of sustainability in the papers, it was observed that almost all of the environmental sub-dimensions have been considered and there is a little variation in the number of times each has been studied. Sub-dimensions like “energy” and “emissions” are iterated the highest (63% and 44% respectively), the diversity in the frequency of the usage in other sub-dimensions is not noticeable though (see figure 4). On the other hand, all of the papers which study sustainability only from the economic point of view, pointed out “cost” (manufacturing and indirect) as an inevitable criterion to reach sustainability. Half also considered “logistics cost” and “profit” while “market image” and “investment” were ignored as shown in figure 5. This leads the mind to the idea that economic sustainability is mostly believed to be cost-centric while other factors are with no doubt as important and deserve more attention. As for the social dimension, it seems that what makes an “image” and an “output” of the manufacturing organizations matters the most. Factors like “customer satisfaction”, “relations with community” and “social policy compliance” grabbed the most attraction among all the others (figure 6). This observation can point out the tendency to relate organizational policies to more social ones and the effort to make these two more and more connected. However, no clear conclusion can be made here due to the little number of papers as the sample.

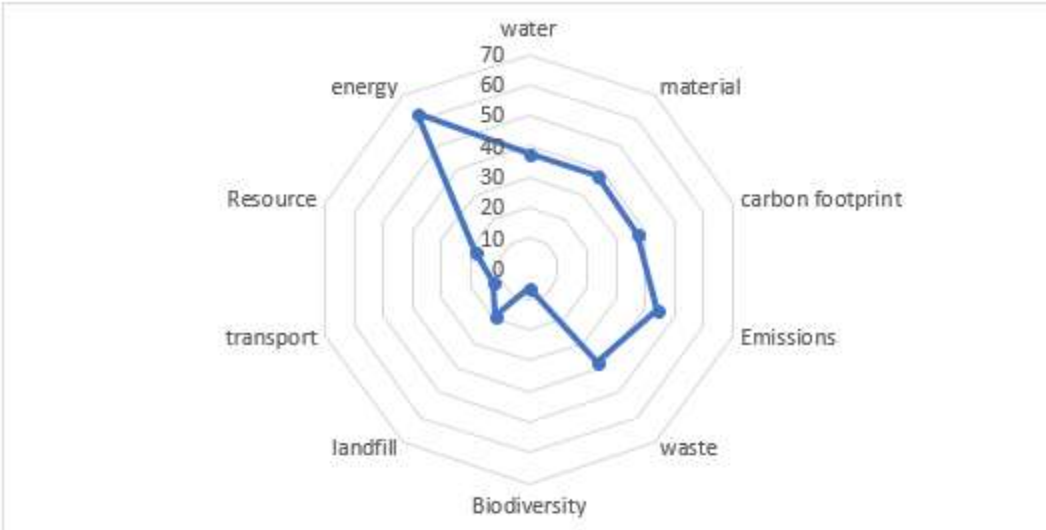

Figure 4. Sub-dimensions of sustainability in papers studying Environmental as a solo dimension

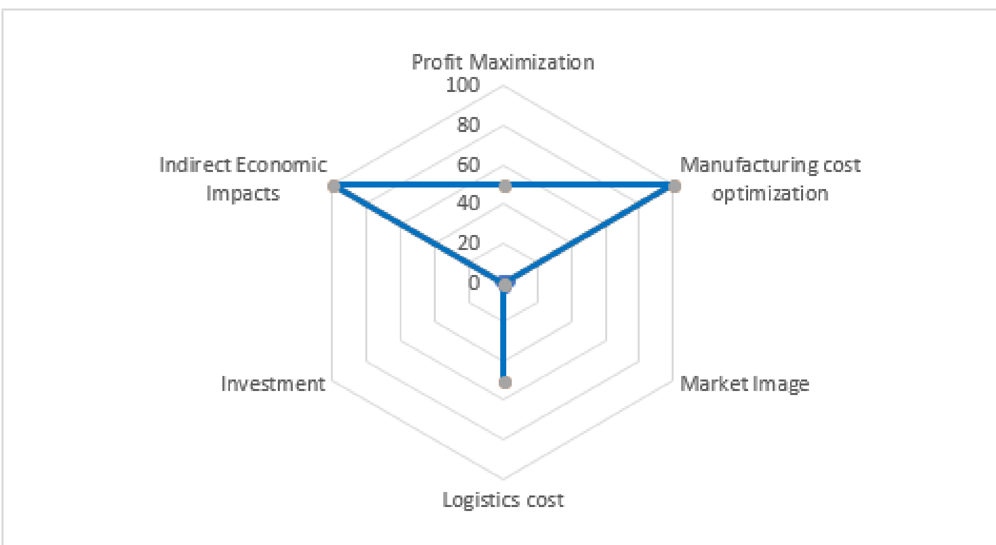

Figure 5. Sub-dimensions of sustainability in papers studying Economic as a solo dimension

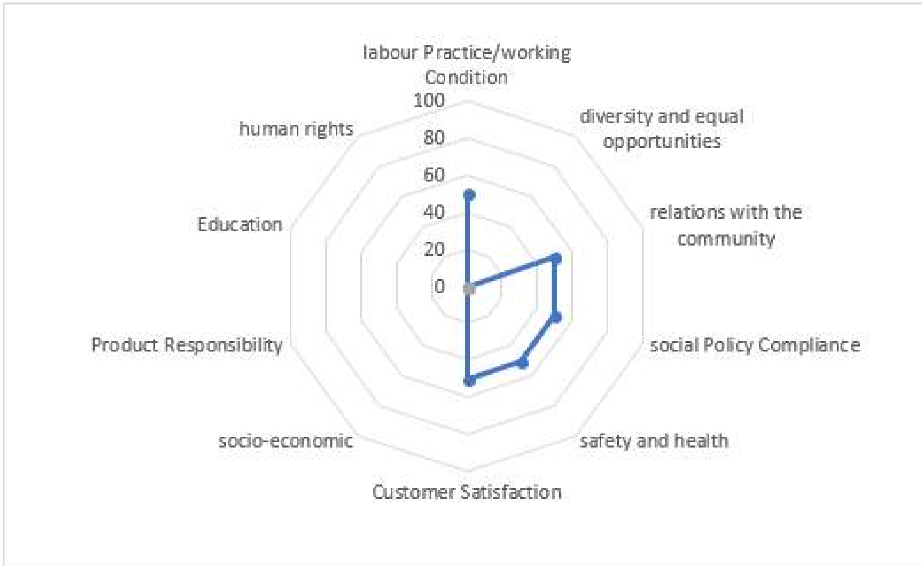

Figure 6. Sub-dimensions of sustainability in papers studying Social as a solo dimension

19 papers out of 115 (about 17%) covered environmental and economic dimensions simultaneously while the number is relatively high comparing to the other combinations of two dimensions: 1% and 3% for economic-social and environmental-social combinations respectively. As it is apparent, the combination of economic-environmental is the most popular one among the three, and the same observation for the solo dimensions was repeated: from an economic point of view, cost was the centre of attention while environmental sub-dimensions had more variation. Subsequently, the same patterns were observed among the papers covering all three dimensions together which served the majority, 54%, which itself shows the urge felt to study sustainability from all three traditional points of view.

3.3. FCA on the environmental dimension

As it is evidently noticed, the environmental dimension was the one studied the most alone and alongside others. As the observation showed, dealing with even one sub-dimension from the environmental dimension, was considered as sustainability among manufacturers who practice sustainable manufacturing. Therefore, it was decided to deepen into the dimension and its sub-dimensions while they have been considered for reaching sustainability. Hence, Formal Concept Analysis (FCA) as a clustering technique was chosen to scrutinize the usage of the sub-dimensions and to discover the hidden relations between them. FCA is a branch of lattice theory (Wille, 1982) 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 (Mezni & Sellami, 2017; Wajnberg, Lezoche, Massé, Valtchev, & Panetto, 2017).

FCA method starts with the input data in a form of a matrix, in which each row represents an object from the domain of interest, and each column represents one of the defined attributes. If an object has an attribute, a mark (e.g. symbol "●") is placed on the intersection of that object's row and that attribute's column. Otherwise, the intersection is left blank. The matrix is called the "formal context" on which the analysis will be performed. For the present study, the rows with at least one environmental sub-dimension in table 2 are used as the “formal context”. FCA method results in two sets of output data : The first set gives a hierarchical relationship of all the established concepts in the form of line diagram called a concept lattice, while the second one gives a list of all found interdependencies among attributes in the formal context (Škopljanac-Mačina & Blašković, 2014). The second set is used for the analysis and the results will be represented consecutively in table 3.

Table 3. FCA results for environmental sub-dimensions

Sub-dimensions studied	No. of Papers
{energy}	52
{Resource}	30
{Resource; energy}	25
{transport}	10
{transport; energy}	7
{Biodiversity}	11
{Biodiversity; energy}	8
{Biodiversity; Resource}	9
{Biodiversity; Resource; energy}	7
{waste}	51
{waste; energy}	40
{waste; Resource}	25
{waste; Resource; energy}	21
{waste; landfill; energy}	8
{Emissions}	48
{Emissions; energy}	35
{Emissions; Resource}	22
{Emissions; Resource; energy}	20
{Emissions; transport}	9
{Emissions; transport; energy}	6
{Emissions; Biodiversity}	9
{Emissions; Biodiversity; Resource}	7
{Emissions; waste}	36
{Emissions; waste; energy}	30
{Emissions; waste; Resource}	19

Sub-dimensions studied	No. of Papers
{Emissions; waste; Resource; energy}	17
{Emissions; waste; landfill; energy}	7
{carbon footprint}	16
{carbon footprint; energy}	8
{carbon footprint; waste}	7
{carbon footprint; Emissions}	11
{carbon footprint; Emissions; energy}	6
{carbon footprint; Emissions; transport}	3
{carbon footprint; Emissions; waste}	6
{material}	41
{material; energy}	29
{material; transport}	7
{material; transport; energy}	5
{material; waste}	35
{material; waste; energy}	27
{material; waste; Resource}	18
{material; waste; Resource; energy}	15
{material; waste; landfill; Resource; energy}	6
{material; waste; Biodiversity}	8
{material; waste; Biodiversity; energy}	6
{material; waste; Biodiversity; Resource}	7
{material; waste; Biodiversity; Resource; energy}	5
{material; Emissions}	28
{material; Emissions; transport}	6
{material; Emissions; waste}	26
{material; Emissions; waste; energy}	21
{material; Emissions; waste; Resource}	15
{material; Emissions; waste; Resource; energy}	13
{material; Emissions; waste; transport}	5
{material; Emissions; waste; transport; energy}	4

Sub-dimensions studied	No. of Papers
{material; Emissions; waste; landfill; Resource; energy}	5
{material; Emissions; waste; Biodiversity}	6
{material; Emissions; waste; Biodiversity; Resource}	5
{material; carbon footprint}	7
{material; carbon footprint; waste}	5
{material; carbon footprint; waste; Resource}	4
{material; carbon footprint; Emissions}	5
{material; carbon footprint; Emissions; transport}	2
{material; carbon footprint; Emissions; waste}	4
{material; carbon footprint; Emissions; waste; Resource}	3
{water}	36
{water; energy}	33
{water; Resource}	20
{water; Resource; energy}	18
{water; Biodiversity}	8
{water; Biodiversity; Resource}	7
{water; waste}	30
{water; waste; energy}	28
{water; waste; Resource}	16
{water; waste; Resource; energy}	14
{water; waste; landfill; energy}	5
{water; Emissions; energy}	24
{water; Emissions; Resource; energy}	15
{water; Emissions; transport; energy}	5
{water; Emissions; transport; Resource; energy}	4
{water; Emissions; Biodiversity; energy}	7
{water; Emissions; Biodiversity; Resource; energy}	6
{water; Emissions; Biodiversity; transport; energy}	2
{water; Emissions; Biodiversity; transport; Resource; energy}	1
{water; Emissions; waste; energy}	21

Sub-dimensions studied	No. of Papers
{water; Emissions; waste; Resource; energy}	12
{water; Emissions; waste; landfill; energy}	4
{water; carbon footprint; energy}	7
{water; carbon footprint; waste; energy}	6
{water; carbon footprint; waste; landfill; energy}	3
{water; carbon footprint; Emissions; waste; energy}	5
{water; carbon footprint; Emissions; waste; landfill; energy}	2
{water; material}	19
{water; material; energy}	18
{water; material; waste}	18
{water; material; waste; energy}	17
{water; material; waste; Resource}	11
{water; material; waste; Resource; energy}	10
{water; material; waste; landfill; Resource; energy}	3
{water; material; waste; Biodiversity}	6
{water; material; waste; Biodiversity; Resource}	5
{water; material; Emissions; waste; energy}	13
{water; material; Emissions; waste; Resource; energy}	9
{water; material; Emissions; waste; transport; energy}	3
{water; material; Emissions; waste; transport; Resource; energy}	2
{water; material; Emissions; waste; landfill; Resource; energy}	2
{water; material; Emissions; waste; Biodiversity; energy}	5
{water; material; Emissions; waste; Biodiversity; Resource; energy}	4
{water; material; Emissions; waste; Biodiversity; transport; energy}	1
{water; material; carbon footprint; energy}	5
{water; material; carbon footprint; waste; energy}	4
{water; material; carbon footprint; waste; Resource; energy}	3
{water; material; carbon footprint; waste; landfill; Resource; energy}	2
{water; material; carbon footprint; Emissions; waste; energy}	3
{water; material; carbon footprint; Emissions; waste; Resource; energy}	2

Sub-dimensions studied	No. of Papers
{water; material; carbon footprint; Emissions; waste; landfill; transport; Resource; energy}	1

As mentioned above, FCA helped to display the links between the environmental sub-dimensions in the papers through the definition of attributes. Therefore, it was possible to see the combination of the sub-dimensions and their regularity of appearance in the literature. Looking through table 3, which is the knowledge extracted and interpreted from the FCA result, it is noticed that three sub-dimensions of "energy", "waste" and "emission" are the ones been used the most alone and alongside the other sub-dimensions. While these three dominate, "transport" and "biodiversity" were placed at the end of the ranking list as shown in figure 7. However, the conclusion may be due to the domain of study and the focus of attention in the analysed papers and it does not reduce the importance of the low ranked sub-dimensions. Considering the top three, their combination with other sub-dimensions also stand out: "waste-energy", "emission-waste", "emission-energy", "material-waste", "emission-waste- energy", "water-waste-energy", "material-waste-energy" and "material-emission-waste" were the most applied ones among all of the two-factor and three-factor combinations. However, the fact that these three positioned as the highest, does not force the idea that any combination of them does the same, for instance, "carbon footprint-waste", "transport-energy", "material-carbon footprint-waste" and "material-carbon footprint-energy" were the least used ones among the double/triple combinations although they included one of the top three (see figures 8 and 9). Anyway, combinations of more than three sub-dimensions were not considered due to lack of concentration of the sub-dimensions and the divergence of the concepts. Nevertheless, there is no paper covering all 10 subdimensions simultaneously, only one paper (Heidrich & Tiwary, 2013) hosted 9 out of 10 of the environmental sub-dimensions as shown in table 3.

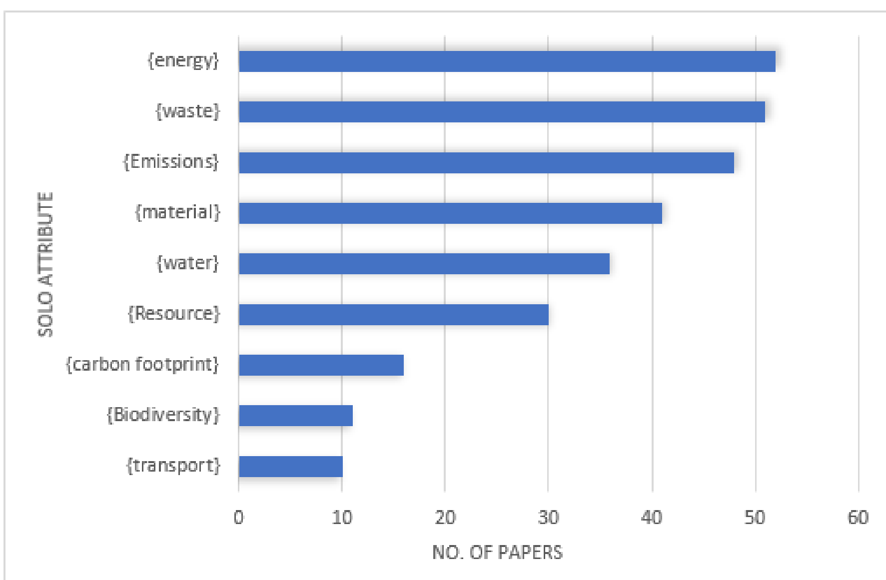

Figure 7. Solo Combination of Environmental Sub-dimensions

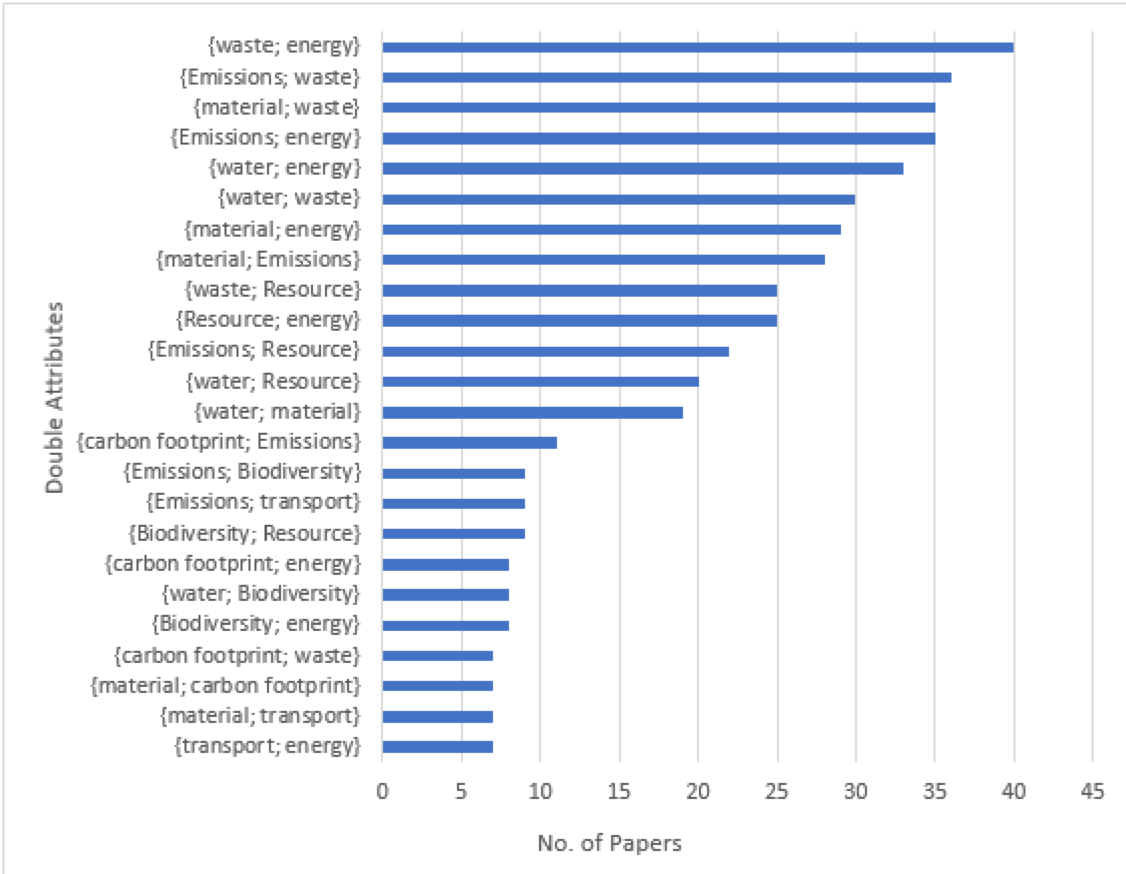

Figure 8. Double Combination of Environmental Sub-dimensions

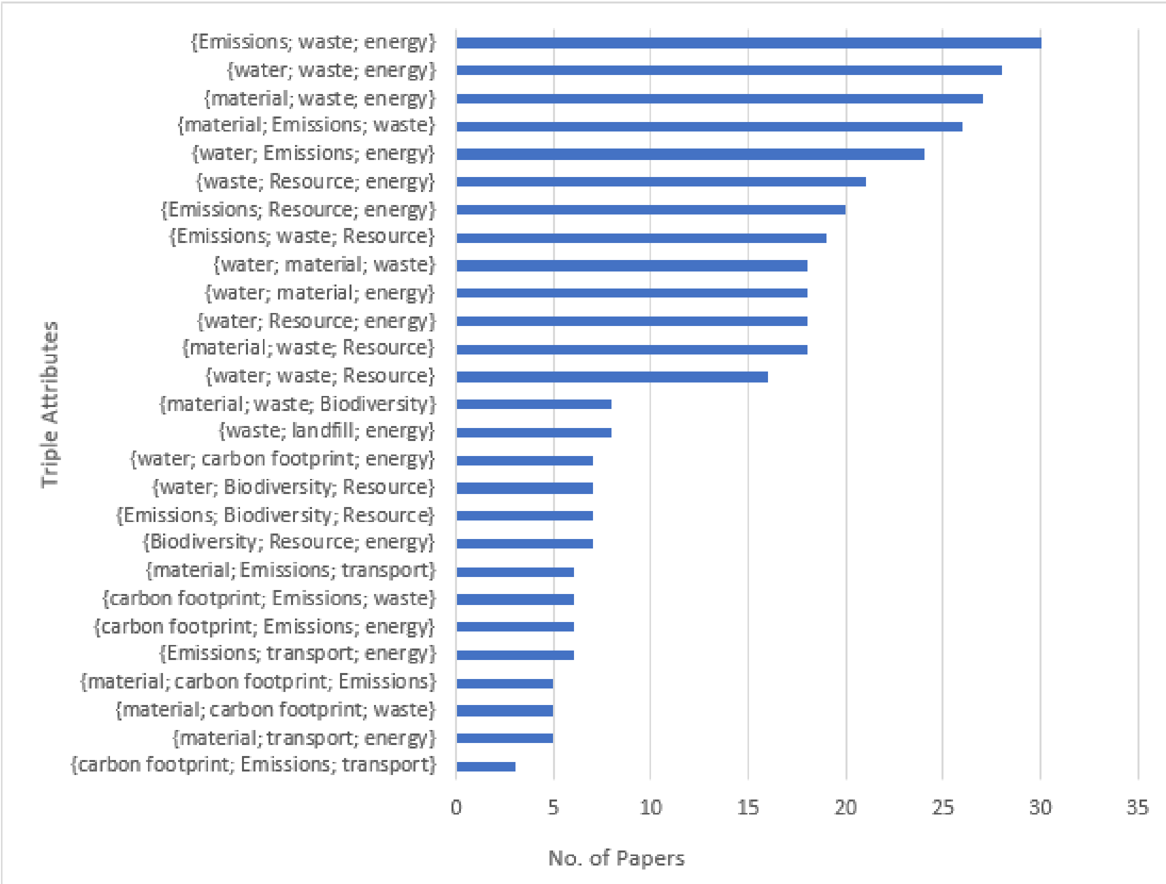

Figure 9. Triple Combination of Environmental Sub-dimensions

Concluding all, it can be noted that the concepts like energy consumption and efficiency, GHG emissions and management of waste, are the ones that held the meaning of sustainability even on their own and without being accompanied by other dimensions of sustainability. By way of explanation, it can be concluded that the mentioned concepts have drawn many attentions by the manufacturers and were recognized as sustainability representatives and were particularly recognized to be effective enough in leading an organization toward sustainability and help them decrease the catastrophic environmental impacts and reach sustainability.

4. Discussion on the 3 sustainability dimensions in Sustainable Manufacturing

Through the application of FCA, it was observed that there is a hierarchy of the importance among the three traditional dimensions of sustainability. At the top, Environmental dimension stands, which itself can represent and justify sustainability on its own. Then the other two, economic and social come based on the frequency of the study. However, getting through the literature, it was shown that environmental is the dimension which can be sufficient to reach sustainability while the other two were more optional. However, among the three studied dimensions, the social dimension is mentioned mostly to be the most difficult and also the least discussed dimension among the three. The most inconvenience though is due to the inability to accurately quantify a number of qualitative indicators (Smullin, 2016).

Exploring the sub-dimensions, the environmental dimension is mostly focusing on gas emissions, energy, water, and resource depletion. Yet, many papers stay vague about the kind of environmental impacts taken into account; they lack an explanation of what "an impact" means and how big it should be to be called "an impact". Some specify the environmental impacts of a particular product (e.g. automotive industry, chemicals, etc) or supply chain process and mention how to deal with them, mostly by looking at the particular sub-dimensions mentioned previously (e.g. water withdrawal, emissions, waste generated, resource depletion and etc) and offering guidelines to practitioners on how to deal with them. On the other hand, and in the economic dimension, "total" cost-based or decision-related cost and revenue approaches dominate. This does not really capture how proactive manufacturing organization strives to achieve sustainable manufacturing. Therefore, widening the economic area to something more than the total cost or net profit can be a good contribution.

Based on the abovementioned, it can be concluded that dimensions like "environmental" and "economic" are mostly exercised by a defined set of sub-dimensions. In other words, sustainability in these dimensions are most likely to be reached through well-known channels of sub-dimensions like "energy", "emission" and "profit", the ones that stood at the top of the rankings with a noticeable difference. On the other side, social dimension of sustainability was practiced with different sub-dimensions and with scattered frequency of the application which can be related to the fact that how social sustainability is approached and defined by different manufacturers. Consequently, it can be noticed that there are sub-dimensions in "economic" and "environmental" that are recognized as the representatives of the dimension which means "economic" and "environmental" sustainability are with less diversity in definition while the same conclusion cannot be made for the social dimension since the application of the sub-dimensions were not concentrated.

As the final observation and as it was shown previously, 54% of the analysed papers insisted on considering all the three dimensions simultaneously. Seuring (2013) also mentioned that the new move is to integrate all the three rather than finding a trade-off between them. However, in the review (Mohd Fahrul Hassan et al., 2016) and (Marika Arena et al., 2009) provided 10 and 27 papers (respectively) out of 60 were dedicated to integration of the three pillars and considering them all simultaneously; which can be an endorsement to have a holistic view through sustainability by considering all the three traditional pillars.

5. Conclusion and Future Work

The paper does a systematic literature review on sustainability dimensions and sub-dimensions in order to extract knowledge for manufacturing organizations who want to practice strategies to be more "sustainable" to stay competitive in the market today and also be responsive to the demand of both customers and the government for sustainable products and preservation of natural resources. The main question risen here is to find out "How sustainability is defined through its dimensions? and What sub-dimensions can denominate sustainable manufacturing? Going through the dimensions of sustainability in manufacturing, it was observed that among social, technological, economic, environmental, technology, efficiency and performance management, the traditional three namely: Economic, Environmental and social, also known as the Triple Bottom Line (TBL), were the ones with the most concentration on. On the other hand, this classification for the domains of sustainability seemed to be too broad and more delineation was needed to help manufacturers identify more specific issues on which they can act. Therefore, a research on the sub-dimensions of sustainability was run inductively to explore the essence of sustainability in a manufacturing organization. It was observed that there is a hierarchy of the importance among the three traditional dimensions of sustainability. At the top, Environmental dimension stands, which itself can represent and justify sustainability on its own. Then the other two, economic and social come based on the frequency of study. However, getting through the literature, it was shown that environmental is the dimension which can be sufficient to reach sustainability while the other two were more optional. Additionally, it was noted that among the three studied dimensions, the social dimension is mentioned mostly to be the most difficult and also the least discussed dimension among the three. The most inconvenience though is due to the inability to accurately quantify a number of qualitative indicators. Based on the findings of the study, an FCA analysis was conducted on the environmental sub-dimensions to analyse their clustering and grouping throughout the literature and knowledge was extracted on the context of the trend in a combination of environmental sub-dimensions and their usage regularity.

Ultimately, the contribution was in the analysis of the dimensions and the environmental sub-dimensions of sustainable manufacturing focusing on the scientific domain throughout the literature. However, as a future work, the same concepts will be investigated in manufacturing domain in practice by means of a benchmarking to explore the possible gap(s) between industrial point of view toward sub-dimensions of sustainable manufacturing and the ones in the literature.

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