Digitalization and environmental sustainability: What are the opportunities?

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Abstract

This paper provides an explorative study on digitalization and sustainability from the angle of industrial firms. The paper presents case studies on application of the Triple Layered Business Model Canvas, which allowed for relevant insight into the field. The findings in this study show that companies do not capture sufficient sustainability data along their supply chain in order to conduct an overall sustainability assessment. The opportunities lies in adaptation of new technologies, which allow collecting data along each phase of life cycle of a product. Four Sustainable Development Goals by United Nations that are aligned to Industry 4.0 are addressed.

Keywords: Sustainability, manufacturing, clusters, digitalization

Introduction

Digitalization and sustainability are two terms that have gained increased attention the recent years since they are representing potential transforming forces of businesses and society. Sustainability has moved from being regulative pressure from the surroundings [illegible] sses has to relate to and implement in their activities. Sustainability is "a radical transformation towards a sustainable society" (Grin et al., 2010, Joyce and Paquin, 2016).

The fourth industrial revolution is envisioned based on innovations in technologies, smart materials and manufacturing operations. The revolution includes initiatives termed Industry 4.0, the Industrial Internet, Factories of The Future, and Cyber Physical Systems. A driving force for this development is the accelerated use of Internet of Things (IoT)-technologies (Porter and Heppelmann, 2015, IEC, 2015). Companies have common needs across sectors for optimizing operations, for managing parts and raw materials, in production, assembly, packing and dispatching. Digitalization can play a vital role in providing valuable data to help making businesses more efficient and sustainable (EMF, 2016). A relevant perspective of a sustainable development adopting digital technologies should adhere to the 17 Sustainable Development Goals (SDGs) by the United Nations (UN, 2016b, UN, 2016c). How these goals are aligned to Industry 4.0 in practice among industrial actors are still unclear (Bonilla et al., 2018). Bonilla et al. (2018) have identified four of the goals of particular relevance for Industry 4.0: Goal 7 Affordable and clean energy, Goal 9 Industry, innovation and infrastructure, Goal 12 Responsible consumption and production, and Goal 13 Climate actions. Each goal is complemented by a set of sustainability-targets and indicators to measure and drive performance towards meeting the goals (UN, 2016a).

In order to transform companies to become sustainable, a new theoretical basis is needed. Digitalization of global value chains and sustainability are however, representing separate fields of research within operation management. This paper aims at exploring the territory represented by the intersection between digitalization and sustainability, and propose a set of potential research directions.

Sustainability measurement as whole requires comprehensive data and information. However, the evidence of some studies is that part of the firms are at the stage where they are not capturing the entire data and information on their business processes. This paper aims at exploring how industries approach the expectations and needs to become more sustainable, and how digitalization may solve the challenges in this context. The study is based on in-depth studies of two companies in the maritime and marine sector in Norway (Klymenko and Nerger, 2018). In these case studies the Triple Layered Business Model Canvas (TLBCM) (Joyce and Paquin, 2016) is applied to test this tools applicability, as well as mapping the challenges for using such framework in the companies' development towards sustainability. Based on this, we discuss how digital technologies may solve some of these challenges.

Digitalization and Industry 4.0

The term digitalization has grown fast within operation management in industry as well as in academia in the past decades. Digitalization addresses the transformation of information flows and data through usage of new technologies and tools, that is, reconstruction of business processes towards more efficient. The term "Industrie 4.0" which concern digitalization in the manufacturing industry, was coined at the Hannover Fair in 2011, describing how digital technologies will revolutionize the organization of global value chains (Schwab, 2016). The term originates from a governmental high-tech strategy in Germany, promoting the computerization of manufacturing (Zuehlke, 2010). Industry 4.0 encompasses a broad range of technologies and concepts. In the context of manufacturing, Industry 4.0 focuses on intelligent products and production processes (Brettel et al., 2014). In the envisioned factory of the future, or smart factory, cyber physical systems will enable communication between machines, products and humans, vertically as well as horizontally. The products are intelligent and customized, to accommodate for the increased need for rapid product development, flexible production and increasingly complex environments (Vyatkin et al., 2007). Brettel et al. (2014) point out that the concept of Industry 4.0 is being used in different contexts, but is lacking an explicit definition. Based on a literature review, Hermann, Pentek, and Otto (2015) provide the following definition of Industry 4.0:

Industry 4.0 is a collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industrie 4.0, CPS monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPS communicate and cooperate with each *other and humans in real time. Via the IoS, both internal and cross-organizational services are offered and utilized by participants of the value chain." (Hermann et al., 2015, p. 242)*

This definition itself contains several terms and concepts, as IoT, CPS and IoS. However, the core of this definition is that items, systems and humans communicate with each other over the Internet in real time. This implies that everything is connected. The second main aspect is the development of services based on this connectedness. According to World Economic Forum, the fourth industrial revolution is being driven by extreme automation and extreme connectivity in combination with artificial intelligence (UBS, 2016). The extreme connectivity enables global and instant communication enabling new business models, which is second aspect of the fourth industrial revolution. The development of new business models is also made possible by the advances in data processing capacity enabling the analytics of "Big Data". Hence, the fourth industrial revolution encompasses a variety of enabling technologies, as CPS, IoT, Big Data, RFID, cloud computing 3D printing and blockchain (Bonilla et al., 2018).

Digitalization, sustainability and business models (BM) for sustainability

Digital technologies provide the information needed to create iterative and restorative systems enabling the companies to move towards sustainable operations and products.

Coupling IoT-enabled innovation with sustainability principles can help companies identify new business models. Some examples of areas where the ongoing digitalization have been used to move towards more sustainable operations are optimization of capacity utilization, implementation of predictive maintenance, and automation of sales and inventory management. Digitalization is seen to enable sustainable business models several areas, including (EMF, 2016):

- Knowledge of the location of assets (products, production resources, humans). Tracking to determine the location is an enabler of sharing models, and it contributes to bring down the costs of operations. This allows improved resource utilization, rapid redeploying of resources, and keeping assets in service over an extended period of time. Tracking also facilitate auditing and consolidation of records in an efficient manner reducing the costs.
- Knowledge of the condition of an asset. Sensor data can monitor environmental conditions to keep track of the performance of an asset and its use patters providing data for sustainability indicators driving their operations towards their sustainability goals.
- Knowledge of the availability of an asset. The availability data supports increased sharing of assets and development of new more sustainable business models. It promotes the shift towards a more service-oriented economy, for example in energy systems, data about usage and demand of energy at a given location and a given point in time enable more efficient usage of the energy.

Digitalization can be identified as one of the enablers of sustainability in terms of improving resource efficiency, manufacturing performance and as an opportunity to establish accessible data system and obtain flexible and smart use of data through application of information technology. Another contribution of digitalization is strengthening firms' ability to respond on internal and external uncertainties and changes (Gürdür et al., 2019).

There is a growing literature exploring how Industry 4.0 related technologies could contribute to achieving the sustainable goals. According to de Sousa Jabbour et al. (2018), Industry 4.0-associated technologies have the unique potential to unlock environmentally-sustainable manufacturing, however there are few emerging works providing insights into these two fields. Stock et al. (2018) have recently published a relevant study addressing this issue. Based on a literature review and expert interview, Stock et al. (2018) qualitatively assess “the potential of industrial value creation in Industry 4.0 in terms of it contribution to the shift towards sustainable value creation for sustainable value creation” (p. 255). The point of the departure for this study is the United Nations’ 17 SDGs and the characteristics of Industry 4.0, which in this paper are referred to as Cyber Physical Systems (CPS), Cloud Computing, and Digital Twin & Digital Shadow. The study assesses the macro and micro potential. The macro potential encompasses business models and value creation network and product life cycle. The micro potential covers quantity of materials used, shared of reused, remanufactured and recycled materials total amount of waste, energy consumption, use of renewables, energy efficiency, greenhouse gas emissions, water use emissions of pollutants and noise, working conditions, information and transparency, and utilization of data. For some of these indicators, specific technologies are given, as RFID and 3D-printing. The above study gives some relevant suggestions of how Industry 4.0 related technologies may facilitate sustainability. However, little attention is devoted of what are the main challenges of the industry, and how technology may accommodate these. In order to shed light on this, we need to introduce a tool that companies can use in the process to address sustainability goals, called the Tripe-Layered Business Model Canvas.

The Triple-Layered Business Model Canvas

The literature suggests a vast number of frameworks and methodologies on sustainability. Some scholars propose various business models, for instance business models for sustainability, circular business models (Schaltegger et al., 2012, Bocken et al., 2014, Joyce and Paquin, 2016). The TLBMC, first introduced in 2016, belongs to the field of sustainable business model. A business model (BM) is a conceptual model that integrates coherence of processes and information necessary for value creation of a firm (Teece, 2010), and the TLBMC tool integrates business model innovation with sustainable business model development. The TLBMC integrates sustainability as part of their business models across three layers: economic layer based on the original business model canvas, environmental layer based on a life cycle approach and social layer based on a stakeholder view. It designed to address three dimensions of sustainability based on the original business model Canvas (Osterwalder et al., 2005).

The TLBMC describes how the company generates economic, environmental and social values. The template of the Environmental layer is presented at the Figure 1. According to Joyce and Paquin (2016), there are horizontal and vertical coherences between each layer. In horizontal coherence of TLBMC, each of three layers is being examined separately, while the vertical coherence combines the value creation of the three canvas layers (Lozano, 2008).

The Economic layer is directed to assessment of nine interdependent components, such as customer value proposition, segments, customer relationship, channels, key resources, key activities, partners, cost and revenues.

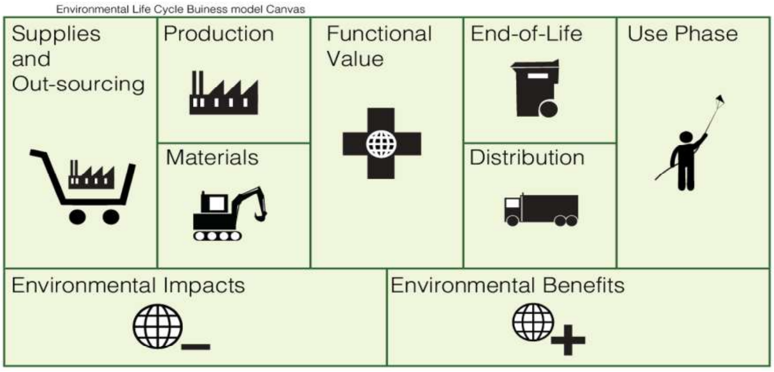

Figure 1. The Environmental layer of the TLBMC (Joyce and Paquine, 2016)

According to the framework, the Environmental layer is based on a life cycle perspective of environmental impact. The layer assesses environmental benefits and environmental impacts of the company. Moreover; as business model canvas evaluates how revenues outweigh costs, the Environmental layer aims to assess where the company's highest environmental impacts compared to environmental benefits that can be a potential area for implementation of sustainability-oriented innovations (Joyce and Paquin, 2016). Due to this approach, organizations might search for environmentally oriented solutions, especially when its environmental impacts are large. The TLBMC does not use the entire approach of the LCA. However, it provides a perspective of the LCA while integrating it to the environmental phase of the business model. The Environmental layer consists of nine components, which together give the holistic view on environmental performance of the company.

The Social layer explores the social impact of an organization on its stakeholders. The stakeholders may include employees, shareholders, customers, suppliers, community, government, interest groups, media, etc. The template is based on the original business model canvas with a stakeholder approach.

Similar baseline can be drawn at the perspective of UN SGDs. The seventeen SDGs as well as TLBMC are based on the Triple bottom line concept (Elkington, 1997). These are directed to enhance economic, social and environmental value creation. However, the framework of SDGs is broader in scope and can be relevant for different groups of stakeholders (private households, businesses, cities, industries).

Design/methodology/Approach

The issues addressed in this paper are explorative in their nature, and hence call for an open and explorative approach. Initially, we address the evidence for sustainability measurement and the role of digitalization from industrial perspective by presenting the case study of two Norwegian firms. Furthermore, the UN SDGs are presented with relevance to digitalization and Industry 4.0. Finally, the discussion of findings provides the overview of current extent and solutions for data availability and information flow issues along the value chains with respect to sustainability assessment.

The companies of the case study

The methodology of the TLBMC was applied on two companies from marine and maritime industries (Klymenko and Nerger, 2018). The companies were selected based on their practices and focus towards sustainability. Company A is a maritime mechanical equipment suppliers and it is one of the leading firms in Western Norway. The company holds control over the whole value chain that involves various activities starting from design, manufacturing, marketing and after-sales service for maintenance and repair. The production facilities are located in the region. From a sustainability angle, the firm focuses on providing maintenance, upgrade service for the equipment in order to extend the lifetime of equipment. The product range includes environmentally friendly products with lower energy consumption, low noise and vibration.

Company B is a fishing company that provide catching, processing and delivery of fish fillets. It uses a eco-friendly factory trawlers with hybrid propulsion and low NOx emissions. The company focuses on sustainable harvesting techniques that minimizes emissions and utilize 100% of the fish and aims to provide a high degree of transparency as all fish caught are traceable. Both companies are categorized as small and medium-sized companies representing two different and important industries in Norway. Consequently, the selection of companies provides for comparison, and for in-depth insight into different types of companies.

Findings of the study

The studies of the two companies show that the economic layer of the original business model canvas were proven sufficient for both cases (Klymenko and Nerger, 2018). Not surprisingly, most information related to economy, consisted of straightforward facts that can quickly be revised by managers. Unlike the economic layer, the data collected for the social and environmental parts did not completely fulfill these two corresponding layers. Some components of the social layer were difficult to define and measure, for instance, social value, scale of outreach and social impacts. The study of Joyce and Paquin (2016) suggests limited and brief description of the elements of the layers. Thus, some additional sources were applied in order to develop the insight of the components and indicators, for instance, Guidelines for social life cycle assessment of products (Life Cycle Initiative at UNEP, United Nations Environment Programme, 2009). Finally, the data and information for the environmental layer provided a generalized understanding of the impact. The study revealed, however, that there is a lack of data on greenhouse gas (GHG) emission for distribution, energy requirements during the operation, etc.

The case of company A emphasize the differences regarding product types, as this have impact on the following manufacturing, energy consumption for product use, and finally the environmental impact. Unlike the study described by Joyce and Paquin (2016) where the TLBMC framework was applied on Nespresso capsules, the products in company A was very complex. The complexity led to challenges in applying the TLMBC framework. Nevertheless, company A produces several kinds of product units and some of them identified as environmentally friendly products, that have lower energy consumption, low noise and vibration. The interviews revealed that company A does not have a single storage of data and information. The data is distributed according to the organizational structure of the firm and separate pieces of data belong to specific department or to responsible of those employees. Consequently, there is a lack of a systematic approach to information storage, where the data can be organized in accessible and structured way. Sustainability from the perspective of the TLBMC, is directed towards detailed review of all business processes, starting from raw materials delivery by suppliers, along the manufacturing, logistics, warehousing, towards customer use, and finally finishes at the end of use stage. The challenge with availability and easy access to data and information made it difficult to map the different elements in the TLBMC, which is a key to complete sustainability evaluation.

The case of Company B differs in terms of shorter value chain, which is integrated in one vessel. According to Ziegler et al. (2016), fuel use is the main driver to greenhouse gasses (GHGs), eutrophication or depletion of abiotic resources. The fishing phase consumes most fuel and contributes 75% - 79% of GHGs. In this case, fishing is one of the central activities of the company. However, information about fuel consumption and emission NOx were not available at the company. General information about consumption level came from the ship building company in Spain. Hence, the data collection time was significantly longer than initially planned. To apply life cycle approach to the environmental layer, it is imperative to take a broader view on the entire life cycle. For fishing companies, suppliers include firms who provide packaging material, processing factory manufacturers, fuel providers, and vessel maintenance companies among others. In this case, the conduction of a more comprehensive sustainability assessment was limited due to the absence of necessary information about suppliers that are part of the product's life cycle and hence are contributors to the emission level of the product. Generally, where the company has control over its value chain, it was possible to obtain sufficient data and information to conduct the sustainability assessment, however, when it comes to suppliers and distributors less relevant data was available. As a result, a more thorough sustainability assessment would require more time and information from distributors and suppliers.

To visualize the understanding of data and information availability from the case study across the layers, the summary of information received is presented in Table 1.

Table 1. Data and information collected for the Environmental Layer for companies A and B

(grey)	Data available
(green)	Partly available data
(blue)	No data

Environmental layer	Company A	Company B
Supplies and Outsourcing		
Production	Energy consumption Waste for recycling, hazardous waste	Estimated fuel consumption
Materials		Information about reduction of pollutants from supplier
Functional Value	One type of mechanical system	1 kg fresh frozen fish
End-of-Life		
Distribution		
Use Phase		
Environmental Impacts	Electricity use in production facilities Data on noise and vibration Hazardous waste	NO_x production Disposal of packing material
Environmental Benefits	ISO 14001 Three environmentally friendly products Waste for recycling and further processing	Reduction of NO_x (2016-2017) 100% use of fish Modern trawler prevents catching of small fish which secure future stock

Exploring the interrelations between digitalization and sustainability measurement, the findings reveal on high data requirements especially for the environmental layer of the TLBMC. Based on the case study example, the information collected partly fulfill the requirements for production phase analysis for both companies A and B. For company A data on energy consumption in production facilities for 2012-2017 was received. The analysis showed a reduction in energy use in the last years. However, the cause for this decrease is not quite clear. According to the findings in company B, the resulting data consisted information on fuel used for catching, processing, freezing on the vessel, and storage/freezing after taken from the vessel per 1 kg of fish. The information for material phase for company B provides particular insight on packaging materials. Although, the first common issue for those companies is absence of the information from the suppliers, for instance, environmental impact from raw materials supply and logistics. Furthermore, customer use and end of life stages are not at the main scope of the businesses. As a result, the responsibility for the product impact often ends when the supplier role finishes. At the same time, the information flow on business activities generally are not completely shared between supplier firms across the value chain.

Hence, based on the data and information collected during the interviews and secondary data assessment, the environmental impacts and benefits are not addressing the entire impacts and benefits of the activities of the companies A and B. Consequently, the result estimated in the study provides limited findings.

The result shows that important data and information are not available or even not accessible for the companies. Firstly, there is a lack of supplier materials information. Both case companies receive general data and information about resources and materials they supply. However, there is no complete information flow from supplier to buyer firm. Bonilla et al (2018) underlines the principle of Industry 4.0 to promote real-time shared information through supply chain tiers that can help companies to understand patterns of consumption and increase transparency of a product information. Another essential phase for sustainability assessment is use phase and end of life of a product, which also defined as lacking of data. Industry 4.0 fundamental technologies can help in resolving this gap. First is cyber-physical systems (CPS), which establishes connective and communicative solutions that allows sufficient information exchange and control between humans, machines and products (Bonilla et al., 2018). According to Bonilla et al., (2018), the second is Internet of Things (IoT), which is essential for data mining and recording, and directed to information exchange from physical things to Internet. The collection of data and information is carried out through installed sensors, actuators and communication technologies. In fact, digitalization and novel emerging technology solutions are crucial for industrial sustainability, which is directed to redesign for value creation in sustainable production and consumption.

Digitalization and the SDGs

Drawing on the study of Bonilla et al (2018) and the findings from the case study above, we address the collaborative linkage between Industry 4.0 components and SDGs. The SDG 7 Affordable and clean energy is directed to ensuring access to affordable, reliable energy and particularly improvement of industrial energy efficiency (UN, 2016 b). As an illustration, the case studies of companies A and B reveal on importance of assessing energy consumption along the whole life cycle of a product. Technology for monitoring and data collection is crucial for further adjustments in energy efficiency of a product. In the same way, the SDG 9, which aims to enhance innovation and sustainable industrialization, can be flourished by digitalization in order to define weak and potential stages for sustainability improvements. The case study underlines the lack of tools for systematic data and information collection at the stage of supply materials, production and material phases, thus, it lead to the lack of complete sustainability assessment. Finally, the SDG 12 Responsible consumption and production, which requires data and information from use phase of a product as well as manufacturing phase in order to make further improvements. The actions towards contribution to SDG 13 Climate actions, aims to assess COx, NOx emissions, hazardous waste and other chemicals that have negative impact on environment and climate change overall. Thus, the initial stage towards sustainable development is in reliable technologies for critical assessment of today's impact, followed by further sustainability-oriented decisions.

Discussion

The concept of sustainability is a transdisciplinary field by nature. Whether it is sustainability evaluation through variety of tools such as sustainable business models, or whether it is assessment through indicators of SDGs, one and the other requires accurate and detailed data and information. According to the study findings, the example of case study of the TLBMC application underlines that sustainability is a data- and information-demanding area. The study indicates that examined companies are at the stage where they are not capturing entire data and information along the supply chain. Consequently, it is more difficult to conduct overall sustainability assessment.

However, gathering data is not enough for holistic pictures of sustainability measurement. It follows that the data should be processed and transformed into information and knowledge categories. When evaluating some of the SDGs indicators, the process relies on available data, preferably in time-series, accessible and timely updated (Bastianoni et al., 2019). Schaffartzik et al. (2015) propose that the data and information in form of macro- and micro-economic aggregates are historically easier to report and it is more sufficient than the information and data reported in physics-based units, as most of the environmental dimension data is.

High data requirements for sustainability measurement underlines how important the focus on digitalization of the businesses is. Digitalization from the perspective of business model for sustainability can be defined as a procedure to create a common system for storage of data and information, its processing and structuring, and approach to the effective interpretation of data crucial for business model redesign and sustainability assessment. An important contribution of the study is that it through these case studies show the importance of data availability is for both sustainability measurement in general and for application of the TLBMC in particular.

Conclusion

The paper presented an explorative study on digitalization and sustainability from the angle of industrial firms, and a case study on application of the TLBMC for two companies. The results show that the companies do not capture enough sustainability data along their supply chain in order to conduct an overall sustainability assessment. Thus, this also indicates that the companies do not have enough information on their operations to manage their processes in a way that enable them to move towards their sustainability goals. The opportunities lies in adaptation of new technologies, which allow collecting data along each phase of life cycle of a product. Industry 4.0 has brought beneficial changes towards digitalized infrastructure and essential for sustainability assessment.

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