Smart technologies and environmental management. Exploratory research from Italy

By Andrea Chiarini, Federico Brunetti and Nicola Cobelli

University of Verona, Italy, Department of Business Administration

Abstract

Purpose

The main purpose of this paper is to analyse the impact of smart technologies on environmental performance, trying to understand the differences between manufacturing and service companies.

Methodology

This research used an exploratory study based on semi-structured interview with 10 experts.

Findings

It seems that several smart technologies have a relevant impact on environmental performance especially in the manufacturing sector. While for service industry the impact seems rather limited.

Practical implications

Findings can be very useful for companies belonging to both manufacturing and service industry. Companies that are interested in implementing these smart technologies can now realise whether or not they could impact on environmental performance.

Originality/value

Smart technologies have been studied particularly for the manufacturing industry. The literature lacks of applications dedicated to service industry and environmental performance.

Keywords

Smart technologies; environmental performance; manufacturing sector; service sector.

1. Introduction

Since 2011 the fourth industrial revolution has introduced several cyber or smart technologies mainly used to improve products and processes. Technologies such as smart sensors, RFID, smart vehicles, cobots and robots, smart human interfaces and artificial intelligence, to name but a few, are catching on in different kinds of manufacturing and service industries. These technologies are not just used to reduce costs increasing productivity and quality, but in the last years they have also been employed to reduce and prevent environmental impacts as well as monitor environmental aspects. The literature review shows, for instance, several environmental applications in terms of waste management, air and soil pollution

monitoring and energy consumption reduction. However, smart technologies have been used so far only for a small part of their potential. Companies are even looking for kinds of applications which have not been developed yet. Therefore, this exploratory research wants to enlarge the debate concerning smart technologies and environmental management trying to correlate the most used technologies with their current and potential applications.

The main objective of this paper is to investigate the impact of smart technologies on environmental management performances, comparing the differences between manufacturing and service industry. The paper is based on a semi structured questionnaire which has been administered to 10 managers. Smart technologies are typically connected with Industry 4.0 (I4.0) which represents the so-called fourth industrial revolution and was first coined in Germany and launched in 2011 by the German Federal Government (Kagermann et al. 2011). So far, several authors have dealt with smart technologies and their impacts on environmental management mainly regarding manufacturing processes. In this light we noticed a lack of studies dedicated to service industry, smart technologies and environmental performances. There are several smart technologies connected with I4.0 which are capable of autonomously exchanging information, activating actions and making decisions and controlling each other independently (Kagermann et al. 2013). Among these smart technologies probably we can easily find something that positively affects environmental performances. Specifically, we analysed technologies such as are RFID, Automated Guided Vehicles, Augmented Reality, Smart Sensors, Smart maintenance, Robot and Cobot and the internet of Things (IoT).

In this light, this exploratory qualitative research contributes to the debate concerning how to improve environmental
performance in both manufacturing and service context, answering these research questions:
Is there a specific connection between smart technologies and the environmental performance?
What are the differences between manufacturing and service industry?

2. Literature review

The concept of sustainable development first appeared at the UN Conference on the Human Environment held in Stockholm (Rogers et al., 2008). There are several definitions of sustainable development. An interesting definition that insists on maintaining a balance between profit, planet, and community has been given by the EPA (2003): “Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations.” In the manufacturing sectors, sustainability aims to create manufactured products which use processes and practices that maximize profits, minimize negative environmental impacts, conserve natural resources and energy, and are safe for employees, consumers, and communities (NACFAM, 2012). Hence, achieving sustainability in different sectors requires a complete view covering not only the product/service and the processes involved in its production, but also the entire supply chain and the realisation systems (Faulkner and Badurdeen, 2014).

Over time, sustainability has been implemented through several different systems concerning environmental management, health and safety management as well as social responsibility management (Qi et al., 2013). For this purpose, smart technologies have been analysed as possible way for improving environmental performance.

Through a first literature review we identified some smart technologies which can be investigated for their impacts on environmental performance. Industry 4.0 for instance is a structured and complex model of many technologies connected with each other over the so-called IoT. The number of possible technologies and systems connectable and integrable is uncountable and subject to a rapid and continuous evolution. We tried to categorise them according to the current literature review, especially linked to the possibility of affecting environmental performance in different sectors. Hermann et al. (2016) analysed 51 papers dedicated to industry 4.0 and tried to categorise the most important elements of Industry 4.0.

According to the authors, the most quoted and studied elements are cyber-technologies, followed by the IoT, Smart Factory, Internet of Services, Smart Products, Machine-To-Machine, Big Data and Cloud.

The consulting firm PwC (2016) carried out the most global survey so far about smart technologies with no less than 2,000 companies in 26 countries involved, collecting data from different kinds of manufacturing industries. According to the results of this research, we have 11 mainly contributing smart technologies which are mobile devices, the IoT platforms, location detection technologies, advanced human-machine interfaces, authentication and fraud detection, 3D printing, smart sensors, bid data analytics and advanced algorithms, multilevel customer interaction and customer profiling, augmented reality/wearable, cloud computing.

Other authors (Jeschke et al., 2017; Dalenogare et al., 2018) classified smart technologies using the three main advantages introduced by Industry 4.0, vertical integration, horizontal integration and end-to-end engineering. According to Dalenogare et al. (2018), the vertical integration is the integration between the production and the management levels, the horizontal integration the integration between production processes and suppliers, while the end-to-end engineering is the integration of product design in the whole value chain from product development until after-sales. In this way, Dalegoner et al. (2018) listed a combination of new and more consolidated technologies such as CAD/CAM, integrated engineering systems, digital automation with sensors, flexible manufacturing lines, Manufacturing Execution Systems (MES) and Supervisory control and data acquisition (SCADA), simulation and analysis of virtual models, bid data collection and analysis, digital product systems, additive manufacturing, 3D prototyping, cloud service. There are also authors (Rüßmann et al., 2015; Romero et al., 2016) who, in addition to the above-mentioned technologies, highlighted how smart technologies relies on new autonomous and collaborative robots which can help and assist workers instead of just substituting them like in the past.
In this literature we tried to find some traces of impacts on environmental performance and then we combined the technologies discussed by the different authors creating the below Table 1 where the technologies are grouped avoiding to refer to specific single technological items and apparatuses. In this way technologies can sometimes be considered as a combination of different other technologies creating a more complex system. For instance, we put together the integrated engineering systems and the CAD/CAM creating the Product Data Management and Product Life Management (PDM/PLM) system.

As a first result from this literature review, we can see how smart technologies are mainly affecting environmental performances in manufacturing. Table 1 recaps the smart technologies potentially involved in environmental management.

Table 1 – Industry 4.0 smart technologies potentially involved

Technology/System
MES/SCADA
PDM/PLM
Big data collection and analysis
Artificial Intelligence
3D printing, additive manufacturing
Smart products and customer interaction
Digital automation with sensors and smart sensors
COBOT and AMR/AGV
Augmented Reality (AR)
RFID

Concerning service industry, we were able to find just some papers dedicated to smart technologies applied to reduce energy consumptions (Haikara and Teyssier, 2020). Apparently, it seems that smart sensors, big data and artificial intelligence are the most used technologies to reduce energy consumptions, both in manufacturing and service industry.

3. Methodology

The semi-structured questionnaire is a qualitative approach which typically involves interviews that have some explicit structure but are not completely structured. Such inquiry usually employs systematic, iterative coding of verbal data written in a memoire (Grbich, 2013). In this way, the developed semi-structured questionnaire contains four open questions to cover and discuss each research question. For instance, the first research questions were turned into the following open question:

Do you think that there a specific connection between smart technologies and environmental performances in manufacturing companies?
What are the most involved smart technologies in order to improve environmental performances?
And similarly, we asked:
Do you think that there a specific connection between smart technologies and environmental performances in service industry?
What are the most involved smart technologies in order to improve environmental performances?

The interviews were carried out with a panel of experts using a Delphi method. The latter consists of two, three rounds of interviews (Robinson, 1991; Walker and Selfe, 1996) with interviewees who are considered experts of the sector. There is no strict rule for the number of experts; Linstone (1978), who is considered one of the most important scholars in the field of Delphi methodology, suggested that a suitable minimum panel size is 7. A panel of 10 consultants with similar characteristics have been chosen:

- At least 10 years of experience in environmental management
- A good knowledge regarding the new I4.0 smart technologies
- Experience in terms of smart technology implementation

In the first round the semi-structured questionnaire was circulated among the 10 experts in order to collect their opinions and suggestions on the four open questions. This round generated o lot of information that was analysed, labelled and grouped using thematic content analysis (TCA). An adequate TCA depicts the thematic content of interview transcriptions by identifying common subjects in the texts (Creswell, 2013). TCA works using the following pattern:

- Highlighting in the text notes which are relevant to the topic of the research
- Initially coding each distinct unit of meaning
- Grouping similar codes creating more focused categories
- Labelling categories.

4. Discussion and findings

With reference with the tools listed in Table 1, we found different levels of effects on environmental performances for the manufacturing context.
Starting from the use of a MES and/or a SCADA, our respondents believe they are very important. The MES can measure key performance indicators such as the overall equipment effectiveness (OEE), number of failures, stoppages, delays, as well as can trace down products monitoring the quality of the logistic flow. However, unless the MES can be modified for specifically measuring environmental indicators of the shop-floor, it does not affect the possibility of improving environmental performance.
PDM/PLM could affect environmental performance as long as they are designed for this purpose. The PDM/PLM should include features like design to environment, environmental characteristics of the product and end-of-life product management. Especially the PLM should trace down the product once it is in use, monitoring and collecting data and information concerning consumptions, environmental aspects and impacts as well as its interactions with other products or more complex systems.
According to the respondents, Data stores have continued to grow exponentially and big data has become increasingly challenging. Now they are realising that Big Data management involves putting the right people, procedures and technologies in place to ensure the accuracy, security and quality of large stores of data. At the beginning companies implemented complex and expensive pieces of software for analytics and cyber-security. They have, in this way, collected big data from products in the markets and from production

processes. However, the data are mainly about product performance, especially related to reliability, and process performance such as productivity, quality, cycle time and machine parameters. The respondents think that only in a second time companies understood how important could be collecting data, big data, from sensors and equipment dedicated to environmental performance. For instance, data concerning energy consumptions, raw materials used for the products, waste produced as well as consumptions of water and gas. Big data could also be collected directly from the products in terms of pollution. For each new product the company could even measure the quantity of CO2 and other chemicals released in atmosphere. However, the respondents declared some difficulties in developing specific pieces of software to analyse environmental big data and provide environmental patterns and trends. Artificial intelligence is surely to key to develop analytics to analyse big data finding patterns and makig decisions regarding how to improve environmental performances.
Strictly connected with big data analysis and cloud storing, 3D additive printing is another interesting tool linked to Industry 4.0 which could have a relationship with environmental performance. The respondents stated how several companies have implemented 3D printers, for instance dedicated to plastic prototypes or metallic components. The 3D printers can help designers in reducing prototyping times, making products and components more customised. However, a part from a saving of raw materials and electricity for making the prototype there are no other relevant savings connected with environmental performance. Moreover, the above-mentioned savings of raw materials and electricity can be considered not so significant from an economic point of view. Instead, artificial intelligence is considered by the respondents a smart technology very effective to reduce energy consumption. Lastly RFID can be implemented in several different applications concerning the identification and traceability of the different kinds of waste; in this way RFID could be relevant for recycling and reusing affecting the so-called circular economy.
Table 2 recaps the smart technology and the effect on environmental performance for manufacturing industries.

Table 2 – Effects of smart technologies on environmental performance (manufacturing sector)

Smart technology	Possible effect on environmental performance
MES/SCADA	Low
PDM/PLM	Moderate
Big data collection and analysis	Moderate
Artificial Intelligence	High
3D printing, additive manufacturing	Low
Smart products and customer interaction	High
Digital automation with sensors and smart sensors	High
COBOT and AMR/AGV	Moderate
Augmented Reality (AR)	Low
RFID	High

On the other hand, the respondents considered many of the smart technologies above mentioned not so relevant for service industry. First of all, they ruled out all the typical manufacturing technologies such as MES, PDM/PLM, 3D printing, smart products, COBOT and AMR/AGV. As a consequence, according to the respondents, just a few technologies could actually affect environmental performances in service industry. This is particular significant for services such as consultancy, finance, real estate, public offices, etc. Among them surely big data and artificial intelligence, even if they believe are just confined in energy consumption reduction. Similarly, to the manufacturing context, RFID could be employed for waste management, although the impacts, according to respondents can be classified as moderate. Indeed, for services like education, consultancy, software development and others where the company manages a very limited number of physical products, waste management is not a problem so perceived.

5. Conclusions

Conclusions demonstrate how smart technologies can really help companies in improving environmental performance. However, there are differences between the manufacturing sector and the service one. We found that in the manufacturing sector technologies such as artificial intelligence, smart products, smart sensors and RFID have a positive high effect on environmental performance, while others have a moderate and low effect.
On the other hand, we found very few technologies which can have a positive impact for service industry. It seems that artificial intelligence can affect just energy consumption and RFID could be used to manage waste in terms of recycling and reusing.
This research has some implications. First of all is based on a qualitative inquiry and just on the opinions of 10 experts. We need to validated these hypotheses using quantitative methods.

References

Dalenogare, L.S., Benitez, G.B., Ayala, N.F. and Frank, A.G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. International Journal of Production Economics (204), 383-394.

Environmental Protection Agency – EPA. 2003. Lean Manufacturing and the Environment. EPA100-R-03-005. Available at: http://www.epa.gov/lean/environment/pdf/leanreport.pdf (accessed on 02 June 2022).

Faulkner, W. and Badurdeen, F., (2014). Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance. Journal of cleaner production, 85(2), pp.8-18.

Hermann, M. Pentek, T. and Otto, B., (2016). Design Principles for Industrie 4.0 Scenarios. In Proceedings of the 49th

Hawaii International Conference on System Sciences (HICSS). January 2016, Koloa, HI. http://www.inovasyon.org/pdf/bcg.perspectives_Industry.4.0_2015.pdf, (accessed 10 July 2022).

Haikara, V., and Teyssier, A. (2020). Digitisation of services, and sustainability.

Jeschke, S., Brecher, C., Meisen, T., Özdemir, D., Eschert, T. (2017). Industrial Internet of Things and Cyber Manufacturing Systems, Springer, Berlin.

Kagermann, H., Wolfgang, W. and Helbi, J., (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Available at: www.plattform-i40.de/finalreport2013, (accessed 20 June 2022)

Lofland, J. and Lofland, L.H., (1995). Developing analysis. Analyzing social setting, Wadshorth Thomson, Los Angeles

Nacfam. (2012). Getting to Green Through “Lean and Clean” White Paper. Findings and Recommendations of the Lean & Clean Project, Improving the Environmental Performance of Small and Mid-Sized Manufacturers: Washington, DC.

PwC., 2018. (2016). Global Industry 4.0 Survey. PwC Research & Insights. Available at: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf (accessed 20 June 2022).

Romero, D., Stahre, J., Wuest, T., Noran, O., Bernus, P., Fast-Berglund, Å. and Gorecky, D. (2016). Towards an operator 4.0 typology: a human-centric perspective on the fourth industrial revolution technologies. in

proceedings of the International Conference on Computers & Industrial Engineering (CIE46). October 2016, Tianjin, China), 1-11.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P. and Harnisch, M. (2015). Industry 4.0: The future of productivity and growth in manufacturing industries. Boston Consulting Group.