Food industry digitalization: from challenges and trends to opportunities and solutions

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Abstract: Over the last years, manufacturing companies have to face various challenges, in particular related to volatile demand and changing requirements from customer as well as suppliers. In this regard, new technological roadmaps and suggested interventions in manufacturing systems have been implemented. These solutions aim to exploit the high innovation and economic potential resulting from the continuing impact of rapidly advancing information and communication technology (ICT) in industry. In this concern, this paper explores these topics focusing on the food sector. Companies belonging to this segment are facing global challenges, which can be met with the support of the information technologies (IT). Starting from these assumptions, the overall goal of this study is to help food companies toward digitalization, with a particular focus on the design and manufacturing processes. From the methodological point of view, Case Study has been used as research method of this study. Furthermore, a questionnaire characterized by the different elements of the Manufacturing Value Modeling Methodology (MVMM) has been developed and used to gather information from companies. In this context, a framework for the digitalization process in food industry has been developed basing on the results of a preliminary literature review and of different focus groups. On completion of the aforementioned framework, a list of enabling technologies has been discussed. These represent the technological solutions for the specific food issues highlighted by the framework. Finally, a case study has been accomplished in order to test and validate the contents' framework.

Keywords: Food design, food industry, food manufacturing, Industry 4.0, PLM food.

1. INTRODUCTION

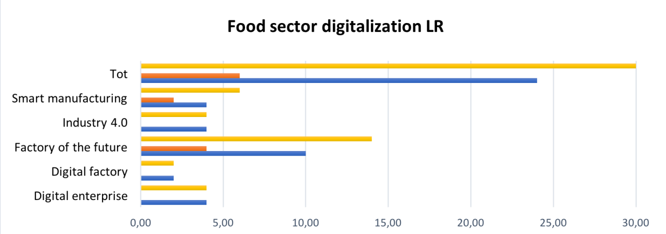
In recent years, manufacturing companies have been faced various challenges related to volatile demand and changing requirements from customer as well as suppliers. This trend has a direct impact on the value chain (Burger *et al.*, 2017). New technological roadmaps and suggested interventions in manufacturing systems such as, the German high tech strategy "Industrie 4.0" (Industry 4.0) or the Italian cluster "Fabbrica Intelligente" are implemented to overcome these challenges. These solutions aim at exploiting the high innovation and economic potential resulting from the continuing impact of rapidly advancing information and communication technology (ICT) in industry (Anderl, 2015). Industry 4.0 is a complex and flexible system, which is currently a vision for the future. Industry 4.0 presents many types of challenges and opportunities, an example is the introduction and integration of new technologies in order to improve quality, efficiency and competitiveness. According to (Khan and Turowski, 2016) "a company which fails to cope the technology challenges also face the challenge of introducing new products/services and innovation". This challenge becomes even more important for the food industry, which is considered one of the most important sector of the current economy. In fact, it is especially in this segment that is clear an increasing level of variability in terms of demand, volume, process, manufacturing technology, customer behavior and supplier attitude. So the food segment is facing peculiar global challenges that can be met with support by information technologies (IT) on a level even beyond today's advanced IT utilizations (Schiefer, 2004) and where the new paradigm of Industry 4.0 can represent an interesting evolution. Specifically, the food industry has recently changed from a supply-based approach to a demand-based approach, the so called "chain reversal", in which the consumers tell producers what they want to eat (Bigliardi and Galati, 2013) (Boland, 2008). Tastes differ – and eating and drinking are getting more individual, it means that production will be tailored to customer demand. In order to realize this vision, elements such as machines, storage systems, and utilities must be able to share information, as well as act and control each other autonomously (Thoben, Wiesner and Wuest, 2017). The result is a system in which all processes are fully integrated with equipment and decision control points. Finally, because the products are configured to respond to the preferences of individual users, production must be more flexible (Hozdić, 2015) than in the past. The overall goal of this study is helping food companies in the digitalization process evolution and transition, with a focus on the design and manufacturing phases, improving value chains over all phases of product's lifecycle. Internal and external factors, which drive the implementation of Industry 4.0 in the food sector, need to be identified. The study outcome contributes on the identification and prioritization of different steps toward an Industry 4.0 implementation in the food industry context. The research methodology is based on data collection through questionnaire, interviews and focus groups provided by Siemens expertise. The paper is structured as follow: Section 2 introduces a literature review with the aim of highlight the state of the art regarding the implementation of Industry 4.0 principles within the food industry. Section 3 describes the methodological approach used for identifying the external and internal conditions in order to realize the digitalization of the food industry; Section 4 describes deeply the aforementioned principles with the aim of a first case study. Finally, Section 5 outlines the contribution of the paper to both the scientific body of knowledge and the practical world, mentions limitations of the research, and proposes paths for further investigation of the topic.

2. LITERATURE REVIEW

In order to understand the current level of digitalization in the food sector, a literature review was conducted. The literature review has been performed following three main steps: (i) identify the keywords and the right combination; (ii) choose a source database; (iii) analyze the results. Starting from the first step, two groups of keywords have been chosen and applied to retrieve the articles of interest. The first group consists of the following keywords: "Digital factory", "Digital enterprise", "Factory of the future", "Industry 4.0", "Smart manufacturing" while the second one is composed by the following: "Food industry", "Food sector", "Food". Each keyword of the first group was then combined in the search with one of the second group, in order to expand the research results as much as possible. The searches were done separately for each keyword applied to the journals' abstracts, title and keywords in each specific search engine. Furthermore, concerning the second step of the research, two different abstract and citation databases of peer-reviewed literature have been selected: Scopus and ScienceDirect. In this regard after removing duplicates 30 articles have been collected, and carefully read the abstracts of these articles to assess criteria for relevance and exclude articles that used those words in another semantic way. After evaluation of the abstracts, 18 studies remained in the final selection of articles (the others were "out of topic"). The collected papers were systematized in terms of names of the authors, year of publication, journal title, objective, approach and characteristics. During the third step, new systematic analysis of core characteristics has been proposed to enrich them with recent academic and practitioner developments. This organization of the papers provided a summary of the recent state of the art about the digitalization in the food industry.

2.1 *First evidence*

As mentioned earlier, first analysis used separately different keywords. In the figure and table below is it possible to see the search results:



	Digital enterprise	Digital factory	Factory of the future	Industry 4.0	Smart manufacturing	Tot
Tot	4	2	14	4	6	30
Food sector	0	0	0	0	0	0
Food industry	0	0	4	0	2	6
Food	4	2	10	4	4	24

Tot Food sector Food industry Food

Fig. 1. Food sector digitalization from the literature point of view

It is possible to notice that the most cited combination of keywords is the pair "Factory of the future" & "Food". This may be related to the level of dissemination and knowledge of the word "Factory of the future" than the others. Now it is necessary to understand if this keyword is used with the meaning of "digitalization" or not.

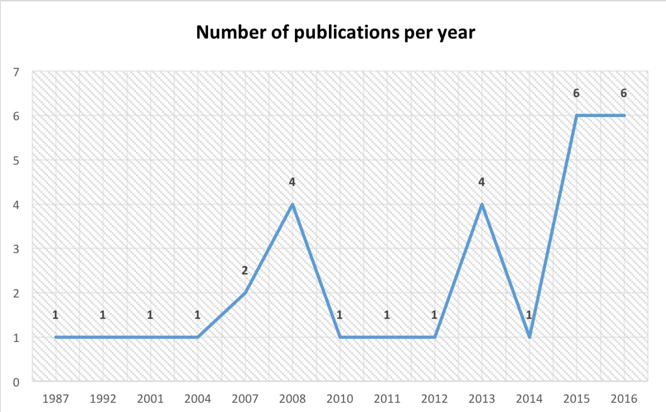


Fig. 2. Number of publication per year

As it is possible to infer from the graph, the number of publications concerning this topic start growing from the 2007 (when there is the first peak) and reached its maximum in the last two years (2015 and 2016). It is also important to highlight the presence of a second peak, in 2013 when the meaning of industry 4.0 was fully widespread on the market. Analysing the papers, 14 different trends have been found. As shown in the graph below, the most used keywords are "sustainability" and "robotics". Furthermore, 2015 and 2016 are the years with most publication and (especially in 2016) with the maximum number of topics addressed.

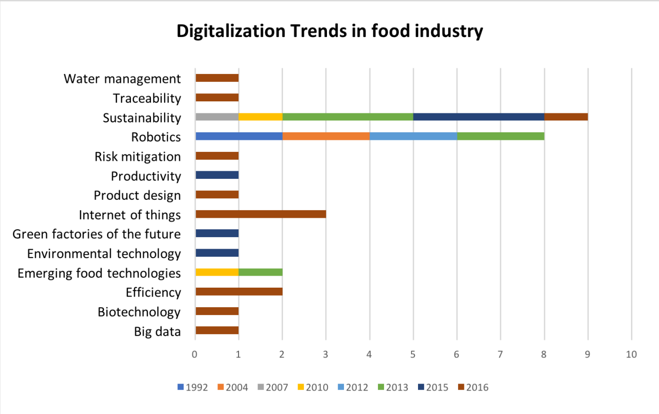


Fig. 3. Digitalization trends in food industry

In conclusion, it is possible to claim that the topic of the digitalization in the food sector starts to be studied deeper over the last two years, with the common keyword associated "Factory of the future" & "Food". Furthermore, the current digitalization trends that characterize the food sector could be recognized as "Sustainability", "Robotics" and "Internet of Things". Nevertheless, it must be said the fact that over 30 articles identified, only 18 were interesting could mean a lack of knowledge of this topic on the food sector from the scientific literature point of view. This lack represents the starting point of this paper, that try to fill this gap in proposing a conceptual model to helping food companies toward digitalization.

3. RESEARCH METHODOLOGY

Case Study (Yin, 2003) is used as a research methodology. Furthermore, Manufacturing Value Modeling Methodology (MVMM) (Tonelli *et al.*, 2016) has been utilized as a basic tool to evaluate the current state of a food company with respect to digitalization process. Basing on this model, a questionnaire with semi-structured questionnaire have been developed and submitted to managers belonging to the R&D and manufacturing company functions (characterizing the reference panel). To this concern, in order to develop each questionnaire section, interviews and focus groups have been conducted to Siemens industrial managers experts on food sector. The structure of the questionnaire follows the main steps of the model, which refers to the identification of: i) External impact factors: Trends; ii) Internal impact factor: Implications and Opportunities and iii) Solutions: Capabilities and Technologies. Each of these steps will be described in the following, reminding that the boundaries of the research are the design and the manufacturing phases. For this reason, each finding of the different model steps has been analyzed for both the phases. Results of the first case study have been described and, thanks to the identified connections between factors belonging to each model steps, some food digitalization research paths have been defined.

3.1 Manufacturing Value Modelling Methodology (MVMM)

As said in the previous paragraph, the MVMM is used for identifying which factors, external and internal, have an impact on the use of Industry 4.0 techniques for the food sector. Figure 1 shows the proposed conceptual model for the requirements definition of the food smart factory. The MVMM has three constituting blocks. The first is concerned with the definition of the external impact factors (Trends), which represent the external view. This component describes the specific environment in which company works, Trends are the changes/pressure from the business environment that make necessary a company to go through new ways of managing its business in order to maintain its value. The second is concerned with the identification of internal impact factors (Implications and Opportunities), which are used to analyze internal process, strategies and goals of the food company. Implications and Opportunities allow identifying how the company could respond to external trends. Finally, the third block concerned "Capabilities and Technologies" which are the essential practices and tools that the company needs in order to positively respond to take advantages of the changes. According to the hierarchical structure of the MVMM it is possible to identify pressure and challenges that have an impact on the company environment. And starting from these trends, define capabilities, relevant practices and tools that are essential for driving food companies in the digitalization process. Especially at this point it necessary to highlight again that these objectives highly depend on the specific scenario under study, however a set of general objectives for food industry are provided as a starting point for the assessment with the company. The goal is to offer a first set of objectives that can be discussed with the company and to sharpen the understanding in order to add more scenario specific objectives that follow the same structure and definition.

3.1.1 External impact factors: Trends

The external view represents Trends, as shown by Table 1 where manufacturing challenges that have an impact on the manufacturing environment are reported. This section gives a background on the challenges associated with the food sector. Trends focus on: direction the industry is currently taking and key change occurring in the industry.

Table 1. External impact factors: trends

External Impact Factors: Trends	Description
Environmental sustainability	Environmental sustainability refers to consuming natural resources at a rate below the natural regeneration or to consuming a substitute, generating limited emissions and not being engaged in activities that can degrade the ecosystem (Longori and Cagliano, 2014)
Focus on health and wellness	Education, healthy living and inclusion accelerate. Lifestyles that support "living well within the limits of one planet" are necessary (DiPlazza *et al.*, 2010)
Food safety and quality excellence	The food sector have led to several changes and have made food safety one of the main priorities of its policy agenda (Lehmann, Reiche and Schiefer, 2012) Safety is defined as the condition of being safe from undergoing or causing hurt, injury or loss (Mish *et al.*, 1990). The assurance of food safety is a guarantee that the food is safe from causing harm. Quality, on the other hand, is not an absolute and is defined

	as meeting agreed-upon requirements. The assurance of quality is a guarantee that agreed-upon specifications have been met. (Holleran, Bredahl and Zaibet, 1999)
Globalization vs localization	The trend of globalization has changed the ways of providing customers with products and therefore also the objects that are analyzed, be it the company, the manufacturing network, or the supply chain (Rudberg and Olhager, 2003)
Market competitiveness	The global industry is currently facing a growing increase in the competitiveness that forces companies to adopt and develop new strategies and methods of production. (Azevedo and Almeida, 2011)
Price pressure of raw materials	Over the past year, the prices of industrial raw materials have surged to all-time highs on global markets. As these raw materials are important inputs into the production process (Lehmann, Reiche and Schiefer, 2012)
Product portfolio diversification	A new trend is the mass personalization. Products are produced under the framework of mass customization and include a distinctive feature associated with the consumers such as labelling the consumers name on the products (Chen *et al.*, 2015)
Regulatory constraints	From a regulatory or consumer point of view quality refers to the basic objective requirements under the existing laws to assure that foods are safe, not contaminated or adulterated or fraudulently represented. Food quality and safety requirements are neither optional nor negotiable (Lehmann, Reiche and Schiefer, 2012)
Social Sustainability	Social sustainability refers to actively supporting the preservation and creation of skills as well as the capabilities of future generations, promoting health and supporting equal and democratic treatments that allow for good quality of life both inside and outside of the company context (Longori and Cagliano, 2014)

3.1.2 Internal impact factors: Implications

The internal influence factors are used to represent goals and strategies of the manufacturing company. Different internal influence factors could be identified as Implications and Opportunities. Implications describe the business impact on company driven by the Trends, and allow stating how the trends are affecting the company strategy. Finally, the aim of this step is to set up a goal system that should identify the important areas, which have to be addressed. Table 2 shows Implications for the digitalization of the food sector, furthermore contents are analyzed with respect to the product life cycle phases focusing on the Begging of Life (BOL) [19]: design and manufacturing.

Table 2. Internal impact factors: implications

Internal Impact Factors: Implications	**Phase**
Adoption of a global and standard solution and homogeneous KPIs	Design/Manufacturing
Comply with regulatory constraints	Design/Manufacturing
Ensure job safety and employees wellbeing	Manufacturing
Paperless Factory	Design/Manufacturing
Planet footprint and waste reduction	Design/Manufacturing
Process traceability	Design/Manufacturing
Reduce costs and improve production performance	Design/Manufacturing
Paperless Factory	Design/Manufacturing

3.1.3 Internal impact factors: Opportunities

As mentioned before Opportunities, as Implications, are used to describe the internal process of a company and allow identifying: i) response by the company to address an Opportunity or risk resulting from the Implication and ii) action taken to capture an opportunity or reduce a risk.

Table 3 shows opportunities for the food sector. Also in this case, contents are analyzed with respect to the product life cycle phases focusing on the design and manufacturing.

Table 3. Internal impact factors: opportunities

Internal Impact Factors: Opportunities	**Phase**
Automate data collection and reduce paperwork	Design/Manufacturing
Enable smooth collaboration between R&D, laboratory and production	Design/Manufacturing
Ensure efficient operator guidance all along the process	Design/Manufacturing
Global Specification Management	Design
Implement Data Visibility at Enterprise level	Design/Manufacturing
Improve production performance and share best practices	Design/Manufacturing
Job Safety and Employees wellbeing monitoring	Manufacturing
Minimize Garbage Production	Design/Manufacturing
Optimize capacity thanks to better use of available resources	Design/Manufacturing
Safety of Devices and Procedure Monitoring	Manufacturing
Send recipes and quality operative information on products	Design/Manufacturing

3.1.4 Solutions: Capabilities and Technologies

Solutions allow identifying best practice, capability and technologies which supports realizing the Opportunities. Table 4 shows for each Solution the related description in terms of process improvement and the associated technologies. The key and representative technologies selected for food sector digitalization are: Cyber physical Production Systems (CPPS); Industrial Internet of Things (IIoT); Cloud Manufacturing (CM); Big Data Analytics; Hologram and Additive Manufacturing

Cyber physical Production Systems (CPPS): CPPS is a key technology for realizing Smart Manufacturing, and it is being studied in close relationship with such technologies as:

Plug and produce: The concept follows a product-centric approach, product instances steer their own production; hence there is no need for central coordination. Production systems are composed of intelligent production units that are able to configure themselves, requiring only a minimum of engineering effort at this level. The Plug and produce approach consists of three fundamental building blocks (Jatzkowski, Adelt and Rettberg, 2016): i) Cyber-Physical Production Systems, as well as production processes, are formally modelled; ii) Concrete production workflows for products are automatically determined by matching their production plans or recipes with the production resources in a given Cyber-Physical Production System, and iii) Product instances steer their own production, which enables a CPPS to manage individualized production under volatile production demands.

Matching of skills: Matching of skills involves the following activities (Jatzkowski, Adelt and Rettberg, 2016): i) Check if there is a potential collaboration between Cyber Physical Production Equipment (CPPE); ii) Check of potential resource conflicts; iii) Check of all constraints and iv) Collect matched skills. All skills suitable for collaboration between the CPPE being plugged.

Smart products: One of the basic ideas behind Industry 4.0 is to endow products and components with embedded systems capable of collecting and communicating data and networking with each other. To this end, it is necessary to develop chips and microprocessors as well as embedded systems. These components allow, for example (Abramowicz, 2015): i) Configuration data to be stored on a component so the start-up of machinery and production equipment is accelerated, rendering manual configuration steps unnecessary and ii) Runtime data, for example from operation, to be stored on the component, thus improving the product or using the data for predictive maintenance.

Industrial Internet of Things (IIoT): Industrial Internet of Things is the industrial or the manufacturing version of the Internet of Things. It can be seen as a systematic expansion of automation and a progressive improvement of how machines communicate to each other at the manufacturing sites. IIoT mainly relates to human-object interaction. This helps users to track the sequel of events and activities as and when they occur. These devices also give users the opportunity to monitor and control their devices from a distance (Almada-Lobo, 2016).

Cloud manufacturing (CM): Cloud manufacturing (CM) is the cloud computing technology that is applied to the manufacturing area. Cloud Manufacturing is a customer-centric manufacturing model that exploits on-demand access to a shared collection of diversified and distributed manufacturing resources to form temporary and reconfigurable production lines that enhance efficiency, reduce product lifecycle costs, and allow for optimal resource loading in response to variable-demand customer generated tasking (Almada-Lobo, 2016).

Big Data Analytics: Big data generally means a data set that is inappropriate to be used by traditional data process methods due to their wide range, complex structure, and size. Therefore, technical and special systems, and methodologies, such as analysis, capture, data curation, search, sharing, storage, transfer, visualization, and information privacy, are required to perform predictive analytics, extract value from data, and seldom to a particular size of data set, among others. The realization of Smart Manufacturing requires effective visualization, analysis, and sharing of various data arising from product development and manufacturing system engineering processes to manufacturing sites to be utilized for predictions and modeling (Niesen *et al.*, 2016).

Hologram: Hologram is one of the visualization methods along with VR (Virtual Reality) and AR (Augmented Reality). Augmented-reality-based systems can support a variety of services, such as selecting parts in a warehouse and sending repair instructions over mobile devices. VR applications have been well reported in virtual prototyping, web-based virtual machining, assembly, fault diagnosis and learning, and various types of manufacturing operations. The main applications of VR and AR are in (Mourtzis *et al.*, 2016): i) robotics; ii) factory layout and iii) maintenance.

Additive Manufacturing: AM refers to a group of technologies, whose first appearance occurred in the early 80s (Sisca *et al.*, 2016) and characterized by a layer upon layer production based directly from Computer-Aided Design (CAD) data. Since its inception, AM has demonstrated a disruptive potential to develop new business paradigms, customized products and more reactive and agile supply chains (Abbink, 2015). Recently, several researchers and practitioners have followed the idea that even the food sector can use the peculiarities offered by the technology (e.g. geometry freedom, multi-material) (Godoi, Prakash and Bhandari, 2016), (Godoi, Prakash and Bhandari, 2016). Moreover, specific sectors may receive turning contribution from Additive Manufacturing Technologies (AMT) and, most likely, will be the engines for the developing of AMT in food applications (e.g. space and defense) (Pinna *et al.*, 2016). In order to support these technologies toward the company digitalization process, it is interesting to investigate the role of the Product Lifecycle Management (PLM) solution. In fact, PLM solution allow keeping information consistent and together, make teams work globally, facilitate new product ideas, product portfolio, allow the simplification of packaging and recipe specifications, managing manufacturing planning and supply chain information (Pinna, Taisch and Terzi, 2016). Such solutions make it possible for food companies to accelerate innovation, increase profits from product introductions, reduce risks, and ultimately drive competitive advantage (Terzi *et al.*, 2010).

Table 4. Solutions: Capabilities and Technologies

Opportunities	**Solutions**		**Process improvements**	
Automate data collection and reduce paperwork	Big Data Analytics	IIoT	Data collection and statistical process control	Data and data flow integrity across ERP, MES and Automation Systems
Enable smooth collaboration between R&D, laboratory and production	CPPS (Matching of skill)	Cloud Manufacturing	It emphasizes the collaboration and communication of both software developers and information technology (IT)	It aims at establishing a culture and environment, where building, testing, and releasing software can happen rapidly,

				frequently, and more reliably
Ensure efficient operator guidance all along the process	Hologram (AR,VR)		Plant personnel is guided intuitively enabling a simplified operation sequence execution	Human error reduction
Global specification management	CPPS (Smart products)	Cloud Manufacturing	Formula management	Reduces cost of regulatory compliance
Implement data visibility at enterprise level	Cloud Manufacturing	Big Data Analytics (Manufacturing Intelligence)	Enterprise data analytics	Managing plant priorities, constrains and conflicts
Improve production performance and share best practices	CPPS (Smart products)	Big Data Analytics (Manufacturing Intelligence)	Data collection and statistical process control	Performance monitoring and consistent reporting at all levels
Job safety and employees wellbeing monitoring	Hologram (AR,VR)	Big Data Analytics (Manufacturing Intelligence)	Consistent reporting at all levels	Human error reduction
Minimize garbage production	Big Data Analytics (Manufacturing Intelligence)	Additive Manufacturing	Collect data from the field	Minimization of waste production through the application of the AM technology and the reduction of the number of processing stages
Optimize capacity thanks to better use of available resources	CPPS (Matching of skill, plug and produce)	Additive Manufacturing	Production order scheduling	Time and cost savings, reducing administration, errors, scrap and rework
Safety of devices and procedure monitoring	IIoT	CPPS (Matching of skill)	Integration between primary and secondary production order execution	Monitor equipment performance
Send recipes and quality operative information on products	CPPS (Smart products)		Integration between primary and secondary production order execution	Integrated quality

4. FINDINGS: AN EMPIRICAL RESEARCH

In this section, an application of the MVMM to a real case is presented. The case study has been accomplished on a real industrial plant for the realization of the practical aspects of the food industry digitalization presented in this paper. The company is one of the main food groups and is a lead player in the baked products around the world. Basing on the MVMM model, a schedule with semi-structured interviews have been submitted to the R&D and manufacturing company managers. Figure 5 reports the results of the assessment.

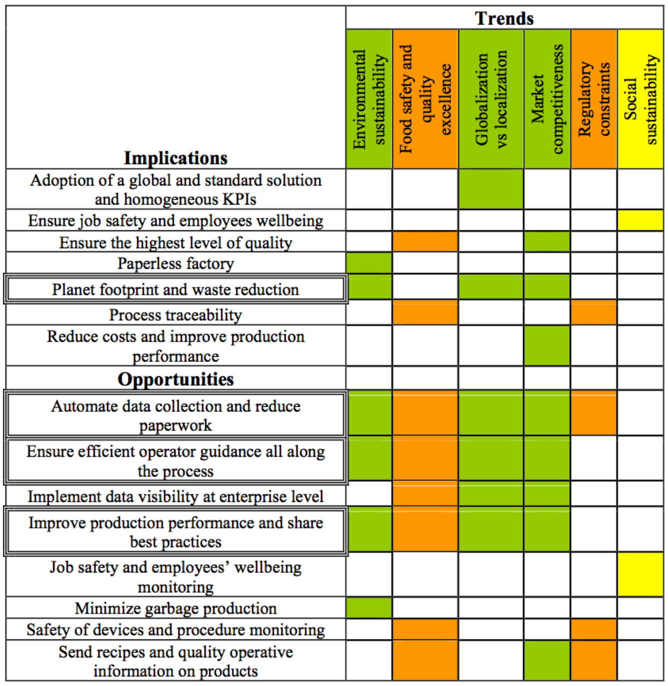


Fig. 5. Case study assessment

Starting from the company answers, it is possible to categorize these contents into three main clusters, which describe the company aim for pursuing digitalization. At this point, it is important to highlight that these main groups aren't globally valid, but they are generated by the company specific answers. The identified clusters are: i) Quality, safety and regulatory constraints: which contains Trends as Food safety and quality excellence and Regulatory constrains, that are a top priority for the company. The fast development of technology, combined with increased global competition and more stringent customer demands put strong pressures on company to improve the quality of its products and processes. Besides, food industry is a complex system in which regulations are become a critical and essential point in order to allow the company to compete in different countries; ii) Environmental competitiveness: which contains Trends as Market competitiveness, Globalization vs Localization and Environmental sustainability. The company is committed to carrying out company activities in full respect of the environment and human health. Furthermore, price for raw materials, energy and water are growing increasingly volatile (Taticchi, Tonelli and Pasqualino, 2013). The company wants to optimize its sustainability practices in order to be less exposed to these swings; iii) Social sustainability: which contains the namesake Trend, is a primary objective for the company in fact, being aware of social and ethical responsibilities towards the communities where it operates and from which it draws resources is essential.

Analyzing the answers given by the company interviewed, it is possible to detect its particular focus and interest on the "Environmental competitiveness" cluster. This fact was also confirmed by the company itself. In fact, in order to travel the digitalization path, the company decided to bet on the following trends: "environmental sustainability", "globalizations vs localization" and "market competitiveness". The company objective is to digitalize its design and manufacturing processes in order to improve its value and to be more competitive on the market. To reach these objectives, one main implication has been detected: "Planet footprint and waste reduction". Indeed, from the company point of view, in the current period, the company competitiveness depends mostly on the sustainable factor (Tonelli, 2013) both from the planet footprint and on the waste reduction, keeping in mind the lean thinking principles. In conclusion, three opportunities have been identified, helping to satisfy the implication defined. The opportunities mapped are: "Automate data collection and reduce paperwork", "Ensure efficient operator guidance all along the process" and "Improve production performance and share best practices". Starting from these considerations, the technologies enabling the digitalization process are:

Big data analytics, IIoT (for Automate data collection and reduce paperwork) can help the company use resources in a more environmentally responsible manner, improve their sourcing decisions, and implement circular-economy solutions in the food chain. Indeed, these technologies could allow monitoring quality, efficiency and traceability. It means there is the possibility to trace a food product back along its entire chain of production, from farmer's field to supermarket shelf. Therefore, the technology could be used to provide consumers with a guarantee of a product's environmental credentials. Hologram (for Ensure efficient operator guidance all along the process), VR has been used in creating product design as it provides very intuitive interaction with the designers in terms of visualization and the interfacing with downstream processes (Nee and Ong, 2013). Besides, AR application can be used for maintenance activities, in fact, suitable collaboration tools should be provided to allow remote experts to create AR-based instructions to assist on-site technicians who may need assistance. CPPS (smart product), Big data analytics (for Improve production performance and share best practices): Production processes in the CPPS based on smart products are self-organized, cooperative, and decentralized. For this scope, products are smart, they maintain information about their Bill of material (BOM) or Recipe and Bill of process (BOP). The materials of the products' BoM / Recipe use this information to steer their own production and step-wise transformation towards concrete product instances or product batches. The notion of products steering their own production also transfers to continuous production. In fact, control is needed only in case of exceptional situations and explicit human intervention like emergency shutdown, responses to severe alarms, maintenance in which operators can be supported by AR applications. Following the analysis, in the near future, the company decides to work towards the implementation of Data analytics. However, the long-term strategy includes the implementation of a pilot project based on the CPPS smart product.

5. CONCLUSIONS AND FUTURE DEVELOPMENTS

The purpose of this paper is to investigate the state of the art of the digitalization process in the food industry. For this reason, a literature review has been conducted. In the literature, the digitalization in the food sector started to gain relevance only during the last two years. It seems that this topic is still new and more research need to be conducted. This lack of research is the starting point of this paper. This paper proposed a conceptual model that supports food companies toward digitalization. The methodology used to conduct the research is the Manufacturing Value Modeling Methodology (MVMM), whole structure allows identifying the external impact factor and internal strategy that drive the digitalization process. In this context, through the performed literature review and interviews conducted with Siemens industrial managers, a framework for the digitalization process in food industry has been developed. On completion of the aforementioned framework a list of enabling technologies has been discussed, they represent the technological solutions for the specific food issues highlighted by the framework. Finally, a case study has been accomplished in order to test and validate the contents' framework. There are some limitations to the framework, the model is largely qualitative, it does not allow for detailed quantitative analysis. Besides it needs to be validated with more real case in order to verify and improve it. More tests are planned to further understand the applicability of the tool in different contexts. Finally, it is evident that this area still requires significant investigations, the framework provided could help and guide food industry to the digitalization process.

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