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Industry 4.0 tools in innovative European firms: exploring their adoption and communication features through content analysis

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Abstract

Industry 4.0 is a popular topic in management literature, but it is also an interdisciplinary subject, maintaining a strong engineering connotation. Firm decision-making processes are more and more affected by Industry 4.0 which has introduced numerous tools that benefit and greatly support business activities. In this domain, the focus of this paper is the information made available to stakeholders on Industry 4.0 tools in use through a content analysis of the Annual Reports of the main European innovative firms (from the top ten of the Boston Consulting Group ranking). The analysis seeks to highlight how firms describe and qualify these tools in terms of impact (risk, strategy or environmental), the perspective used in illustrating them (mana gerial or engineering) as well as the temporal orientation of the information provided (present, past, future or none). Results show that innovative European firms pay attention and use these tools, in different ways and for different purposes. The paper has both theoretical and managerial implications. From a theoretical point of view, it contributes to study and further the literature on Industry 4.0 and its instruments, while from a managerial perspective, it gives a better understanding of how these innovative tools can be communicated to external stakeholders, especially investors.

Keywords: Industry 4.0, innovative firms, content analysis, Annual Report.

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1. Introduction

Industry 4.0 represents a recent but widely investigated topic in literature [1]. These studies began in the engineering domain then rapidly expanded to the managerial field exploring various issues: from production techniques to strategies, as well as social impacts [2-4]. Over the years, numerous authors have focused, in particular, on the analysis of technologies developed in the field of Industry 4.0 [5-9].

A detailed and extensive review of the literature regarding Industry 4.0 and related technologies is provided by Oztemel and Gursev [10] who list and describe all contributions concerning tools introduced into firm activities. From this analysis, it emerges that, although the characteristics of these tools are well-established and have already been investigated, there is still not an overall or shared vision of them to guide firms in their adoption. Innovative tools are often analyzed alone, habitually in a single firm or considering just a specific sector [10].

However, in the domain of Industry 4.0 tools, none of the studies have focused on how their use is communicated to external stakeholders, especially investors. In the light of this, the paper aims at an initial exploration of this issue, seeking to understand whether and how firms communicate to investors the Industry 4.0 tools adopted, focusing on innovative firms which are the most active in using them and on analysis of the kind of impact (risk, strategy or environmental), perspective used in illustrating them (managerial or engineering), temporal orientation of the information provided (present, past, future or none). Indeed, the research questions put forward are:

- RQ1: what tools are used and mentioned by firms in their Annual Reports?
- RQ2: what are the features of the communication made about these instruments?

Following this goal, the paper begins with a description of the methodology adopted, i.e. content analysis. The results and the discussion follow. Finally, the paper will draw its conclusions, including theoretical and managerial contributions, as well as limitations and future avenues of research.

2. Methodology

The sample of firms investigated was taken from the Boston Consulting Group ranking of the "2019 most innovative companies". From this list the first ten European firms were selected.

The European companies, among worldwide ones, were selected because, in application of the international accounting standards, they have to draw up a particularly detailed annual report which places emphasis on the activities carried out under various profiles. Table 1 shows the selected firms, their position in the European and World rankings, their Country of origin and their activity.

Table 1. Firm sample

Firms	Eu	World	Country	Activity
Adidas	1	10	Germany	Sports Clothing
Basf	2	12	Germany	Chemical
Siemens	3	16	Germany	Engineering
Bayer	4	24	Germany	Pharmaceutical
Allianz	5	26	Germany	Insurance
Bmw	6	27	Germany	Automotive
SAP	7	28	Germany	Software
Philips	8	29	Holland	Electronics
Royal Dutch Shell	9	30	Holland	Gas Production
Axa	10	31	France	Insurance

The content analysis [11] applied to perform this study is widely used and accepted in social sciences. It is based on searching a set of keywords in a selected document, which in this particular case is the Annual Report of the selected firms (it is precisely in this document that European firms must illustrate tools used in their activities, analyzing them under different profiles, please see above).

For each firm, the last Annual Report available (2018) was downloaded and a database was created to report the results of the keyword search. Keywords in this case are represented by the main Industry 4.0 tools retrieved from literature [6-8, 12-15]: Internet of Things, Artificial Intelligence, Machine Learning, Big Data, Cloud, Blockchain, Augmented reality, Advanced Robotics, Cyber-physical systems.

The first goal of the analysis was to understand the impact of these tools on risks, strategy and environment as communicated in the Annual Reports of the selected innovative firms. In general, those aspects are highlighted in the framework suggested by the IASB [16] with the purpose of improving corporate communication. IASB (2010) emphasizes the disclosure of risk factors and business strategy: "that type of commentary will help users of the financial reports understand, for example: (a) the entity's risk exposures, its strategies for managing risks and the effectiveness of those strategies" [16] (p. 14].

Given this first goal of the paper, it is also important to understand the perspective with which these tools are communicated, whether from a managerial or an engineering point of view. Indeed, even if this study is based on managerial literature and so is more interested in the first aspect, Industry 4.0 tools almost always pertain to the engineering domain so it is important to understand which perspective is preferred in communicating them; this is relevant from an audience point of view.

The third goal refers to the state of implementation of these innovations by firms, thus the temporal orientation of the information given to stakeholders (i.e., present, past or future). The research was structured following the methodological steps suggested by Beattie, McInnes and Fearnley [17] and Jones and Shoemaker [18] considering that the text unit of a sentence containing a single piece of information is the object of observation.

Indeed, first of all the keywords were searched, then the information, enclosed in the phrase containing the keyword, was classified into three different categories (risk, strategy or environmental impact), then perspective (managerial or engineering) and finally temporal orientation (present, past, future or none) were extracted.

The hypothesis assumed in this paper is that the frequency of the keywords is an indicator of the interest in Industry 4.0 tools, so the frequency of the keyword in terms of absolute value and percentage was considered [19-20].

3. Results

The results are divided into two sections.

The first presents just the frequencies of the keywords in the Annual Reports.

The second section shows the results relating to the analysis of the sentences in which the keywords are contained in order to answer the two research questions above.

3.1. Keyword frequency

From the 10 Annual Reports analyzed a total of 109 keywords were extracted. Table 2 shows results by individual keywords (in descending order) and firms.

Table 2. Keyword details per firm*

KEY WORD	FIRM								Total	%
	BASF	*SIEMENS*	*BAYER*	*ALLIANZ*	*BMW*	*SAP*	*PHILIPS*	*AXA*		
Artificial Intelligence	0	5	4	0	1	13	10	11	44	27%
Machine Learning	2	0	0	0	3	17	2	1	25	15%

Internet of Things	1	2	0	0	0	11	1	0	15	9%
Cloud	0	1	0	0	0	4	5	2	12	7%
Blockchain	0	1	0	1	0	6	0	0	8	5%
Big Data	1	0	0	0	0	3	0	0	4	2%
Augmented reality	1	0	0	0	0	0	0	0	1	1%
Total	5	9	4	1	4	54	18	14	109	67%

* for space reasons, the column of Adidas and Royal Dutch Shell and the line of Advanced Robotics and Cyber-physical systems has been eliminated as there are no references to any keyword.

3.2. Analysis of the details of the sentences

The analysis of the sentences in which the keywords are contained has been structured in three different levels of investigation. In the first, as shown in Table 3, each sentence was analyzed to understand the kind of impact attributed to the use of the various tools.

Table 3. Classification of sentences

Classification	n.	%
Strategy	103	94%
Risk	5	5%
Environmetal	1	1%
Total	109	100%

The second level of analysis (Table 4) involved the study of the thematic orientation of the sentence, distinguishing between managerial and engineering perspectives.

Table 4. Perspective of sentences

Perspective	n.	%
Managerial	79	72%
Engineering	30	28%
Total	109	100%

Finally, as shown in Table 5, a third level of analysis made it possible to focus attention on the time zone of the sentence in which the keyword is contained.

Table 5. Temporal orientation of sentences

Temporal orientation	n.	%
Present	40	37%
Past	36	33%
Future	32	29%
None	1	1%
Total	109	100%

The results obtained were then analyzed by focusing on individual keywords (please see Table 6), on the perspective of analysis by each tool (see Table 7) and finally (Table 8) underlined the temporal orientation for each keyword.

Table 6. Details for keywords

Keyword	Classification						
	Risk	%	*Strategy*	%	*Environ.*	%	*Total*
Artificial Intelligence	2	5%	42	95%	0	0%	*44*
Machine Learning	0	0%	25	100%	0	0%	*25*
Internet of Things	0	0%	14	93%	1	7%	*15*
Cloud	3	25%	9	75%	0	0%	*12*
Blockchain	1	13%	7	88%	0	0%	*8*
Big Data	0	0%	4	100%	0	0%	*4*
Augmented reality	0	0%	1	100%	0	0%	*1*

Table 7. Perspective details for keywords

Keyword	Perspective				
	Management	%	*Engeneering*	%	*Total*
Artificial Intelligence	35	80%	9	20%	*44*
Machine Learning	18	72%	7	28%	*25*
Internet of Things	14	93%	1	7%	*15*
Cloud	6	50%	6	50%	*12*
Blockchain	5	63%	3	38%	*8*
Big Data	4	100%	0	0%	*4*
Augmented reality	1	100%	0	0%	*1*

Table 8. Temporal details for keywords

Keyword	Temporal orientation						
	Present	%	Past	%	Future	%	Total
Artificial Intelligence**	15	34%	13	30%	15	34%	44
Machine Learning	14	56%	7	28%	4	16%	25
Internet of Things	5	33%	4	27%	6	40%	15
Cloud	3	25%	6	50%	3	25%	12
Blockchain	1	13%	5	63%	2	25%	8
Big Data	2	50%	1	25%	1	25%	4
Augmented reality	0	0%	0	0%	1	100%	1

** for space reasons, the column of the temporal classification "none" has been eliminated. This classification only includes "Artificial intelligence" for a frequency of 1 (2% of the sample).

4. Discussion

From the first analysis of the results obtained, it is possible to affirm that most of the firms analyzed (8 out of 10 firms of the sample), refer to one or more Industry 4.0 tools.

As was conceivable, the firm that mostly refers to details and aspects related to the tools of Industry 4.0 is SAP (54 keywords, 50% of the frequency) which operates in the software sector and is therefore closely linked to technological innovations.

Follows Philips (18 keywords, 17% of the entire frequency) that operates in the electronic field. Interesting is the third position occupied by Axa, a firm that operates in the insurance field with 14 keywords (13% of the entire frequency).

This result is very interesting because it makes us aware of how, even in service-industry firms, Industry 4.0 tools can take on considerable importance [21]. Therefore, this shows how Industry 4.0 tools, initially designed for the production sector, are also intensifying in services [22]. Significant interest also emerges for the chemical and pharmaceutical sectors, with Basf and Bayer (respectively 4 and 5 of the instances). Looking more in-depth at firm Annual Reports, some interesting considerations emerge, for example for Axa. In its Annual Report it is stated that a new ad hoc working group, the Advisory Board of independent experts has been created for the understanding and effective and efficient use of artificial intelligence systems and in particular for data protection and ethical aspects. SAP, on the other hand, highlights the influence of artificial intelligence in business revenues. In this regard, it states that "calculates that enterprises using this technology made 21% of their revenue with it in 2018" (SAP Annual report 2018 p. 81).

SAP also provided a precise forecast of the future development and diffusion of the use of blockchain affirming that "blockchain will be another growing technology over the next years […] It estimates that by 2021, nearly a third of all manufacturers and retailers globally will be using blockchain technology to build digital trust and establish prominent in-industry value chains, thus reducing transaction costs by 35%" (SAP Annual report 2018 p. 124). These examples are very interesting in that they underline that these tools are reaching even more firms and sectors; there is an empirical awareness of their potential, also in terms of prospective data. Coming to the first research question put forward:

RQ1: what tools are used and mentioned by firms in their Annual Reports?

Results show that the most used innovative tool for firms is Artificial Intelligence (44 instances, 40% of the sample).

This result is in line with what the literature says about Industry 4.0 and its application [10]. SAP, Philips and Axa are the firms that mostly use this tool in their activities.

The application of Artificial Intelligence in Philips is very interesting for the realization of medical instruments, precision diagnosis, clinical decision support; it grants an improvement in living conditions of patients with chronic diseases.

On the other hand, in the case of Axa, Artificial Intelligence is useful in supporting data prediction for insurance purposes and in creating and updating databases in combination with the potential of Big Data.

Scrolling down the list of industry 4.0 tools, Machine Learning (25 instances, 23% of the sample) emerges.

The results of Machine Learning are certainly attributable to the long history of this tool.

The first references in literature date back to the 90s [23-24] and have since been implemented and expanded with the advent of Industry 4.0. Machine Learning appears as a versatile tool adaptable to use in different sectors of activity. In their Annual Report most of the sample firms recall the core business and how Machine Learning contributes to its development.

The Internet of Things deserves a special mention in that it is third for the number of recurrences (15 instances, 14% of the sample). Compared to the previous tools analyzed, the history of the Internet of Things is certainly more recent.

The first studies date back to the 2000s [25-26] and have since deepened and expanded with the advent of Industry 4.0 [27].

However, almost all of these occurrences can be found in the SAP Annual Report (11 instances, 73% of the total). In describing the various innovation tools, SAP considers the Internet of Things as a "key to our strategy" and underlines its use in various areas (smart cities, consumer knowledge, business model etc.).

SAP, Philips and Axa are the firms with the greatest interest in these Cloud (12 instances, 11% of the sample) and Artificial Intelligence. SAP emphasizes how it is actively collaborating with government agencies to create "reasonable framework conditions" for the application of Cloud solutions, thus underlining both the public and private scope of this tool. For the other tools (Blockchain, Big Data and Augmented reality), results are not yet clear while no firms report the use of Advanced Robotics and Cyber-physical systems. The lack of this indication in the Annual Reports does not lead, however, to affirm the non-use or knowledge of these tools by the firms.

At this point it is interesting to shift the attention to the more specific communication features of these tools; thus, coming to the second research question:

RQ2: what are the communication features of these instruments?

As stated in the methodology (please see section 2) and highlighted in the results (please see section 3.2), the sentences containing the keywords have been classified to extrapolate some characteristics attributed to Industry 4.0 tools.

The results clearly show how these tools are presented in the Annual Reports mainly as strategic aspects for firms (103 instances, 94% of the sample). Not to be overlooked, however, are some hints at two very interesting aspects: risk and environmental impact.

As regards risk, 5 instances are identified (5% of the sample) in which some potential difficulties or problems for firms deriving from the application of Industry 4.0 tools are highlighted. In this regard, Siemens with reference to Internet of Things and Cloud Computing, as well as Axa for Artificial Intelligence, Big Data and Blockchain highlight possible risks related to both competitors and core business.

Indeed, firms underline that these innovations could bring advantages to more experienced and skilled competitors or even create difficulties for the core business if firms are unable to follow and keep up with innovation.

In the Axa Annual Report it is stated that “if we are not effective in anticipating the impact on our business of changing technologies, such as driverless cars, drones, connected devices, artificial intelligence or robot advisors, our ability to successfully operate our business may be impaired” (Axa Annual Report 2018 p. 174). Axa also stresses the risk associated with managing sensitive data.

With reference to Cloud solutions, Axa states that "may in the future be subject to unauthorized intrusions, such as physical or electronic breaking, cyber-attacks, unauthorized tampering or other security breaches".

SAP, on the other hand, mentions the environmental impact, underlining that "Cities are facing growing populations and aging infrastructures. SAP solutions for the Internet of Things can help manage and monitor resources so that cities can run more sustainably and help citizens enjoy more enjoyable, safer lives”.

This single reference, however, clearly highlights another issue closely connected to the potential of Industry 4.0 tools: sustainability.

It should be pointed out, however, that this theme has not been found in the Annual Reports, as firms generally draw up a specific document called "Sustainability Report" in which the impacts of Industry 4.0 on sustainability can be illustrated. Finally, another interesting reference was made by SAP on social impact.

The report states that "SAP is also looking at the ethical and societal implications of the latest advances in technology, such as artificial intelligence, and is contributing to the public debate about these subjects".

The topic is not further investigated in any other case, but reveals a possible social impact and an opportunity for Industry 4.0 tools to be applied.

Coming back to the specific characteristics of industry 4.0 when communicated, the second level of analysis has made it possible to highlight that there is a prevalence of managerial information relating to Industry 4.0 tools in the Annual Reports (79 instances, 72% of the sample) rather than in engineering ones.

This suggests that this topic is now widely communicated by firms using a managerial language and following entrepreneurial dynamics while tool details are viewed as purely engineering information (30 instances, 28% of the sample).

The last aspect analyzed is the time zone to which the Industry 4.0 tools are collocated.

The analysis shows that there is a substantial uniformity of references between present, past and future (present 40 instances 37%, past 36 instances 33% and future 32 instances 29% of the sample).

The slight prevalence of present-oriented considerations allows us to speculate that Industry 4.0 tools are a concrete reality in the strategies and behavior of firms. The statements referring to the past confirm the application and attention already dating back several years (generally firms speak about one or two years earlier than 2018). While the information referring to the future expresses a projected interest in future applications and continuous development in the use of Industry 4.0 technologies.

5. Conclusion

From the analysis of the results emerging from the content analysis it is possible to underline that the most innovative European firms pay attention, also from a communication point of view, and use these tools to some extent.

Obviously, as pointed out, the level of attitude and application varies according to the sector to which the analyzed firms belong, but service industries are also now using this technology which initiated in firm production departments.

There is a greater emphasis by firms in sectors traditionally closer to technology and innovation, even if other sectors (for example, services, in our sample, insurance ones) are starting to approach numerous Industry 4.0 tools. Some of the considerations extrapolated from the Annual Reports show a strong versatility of the innovative tools of Industry 4.0.

In many cases the same tool can adapt to different needs and contexts.

Finally, it can be seen that although Industry 4.0 initiated in the engineering field, it has largely developed and practically been triggered into managerial language. In speaking of Industry 4.0 it can therefore be said that two souls, engineering and management, coexist, which although having clearly different application aspects, are essential to each other.

After all, this research work has both theoretical and managerial implications.

From the literature point of view, the paper contributes by providing a vision of Industry 4.0 tools from the perspective of firms and their institutional communication, especially on behalf of investors. It begins to fill this gap in the literature by providing a practical and comprehensive view of the concrete use of tools by firms, even if the sample could be broadened in future research.

From a managerial point of view, the paper is of interest and can support managers and entrepreneurs in understanding how Industry 4.0 tools are applied as well as their features and/or fallouts communicated by other firms. This could be useful respectively for choosing the most deemed tools in light of the results expected and already reached by other firms but also to create an ad hoc communication strategy to stakeholders and especially investors, being inspired by other firms able to profit from this opportunity. Managers can evaluate the application of these tools in different areas and functions of the firm to support the achievement of objectives and to improve the overall efficiency of the activities carried out.

The paper can also guide managers in choosing the most appropriate investments to make in the new technologies of Industry 4.0.

The paper has some limitations related to the applied methodology. In fact, the analysis of the content of the Annual Reports is affected by a certain degree of subjectivity due to the considerations made by the authors. At the same time the choice of keywords, albeit based on considerations emerging from the literature, could represent a simplification and therefore a limitation of the search.

Obviously, also the number of firms involved in the analysis represents a limitation, together with the fact that the sector in which they operate could not be considered due to the number of firms included in the sample. Future avenues of research could consider widening the sample of firms and also considering their adoption and

communication strategies also in the light of the sector in which they operate. Moreover, the same methodology could be applied to the Sustainability Reports of firms in order to also evaluate the potential reflection of Industry 4.0 tools on sustainability.

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