REFLECTIONS OF UNDERSTANDING SMART INDUSTRY

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ABSTRACT

This chapter reflects on the understanding of the phenomenon known as Smart Industry, Industry 4.0, fourth industrial revolution, and many other labels. It does so by reflecting on the issue of terminology, as well as the existing diversity regarding the description of the phenomenon. The issue of meaning is addressed by assessing the results from Culot, Nassimbeni, Orzes, and Sartor (2020) and Habraken and Bondarouk (2019) which are, subsequently, used to develop a workable description. Findings from the two assessed studies raise the question of whether a workable construction of the phenomenon is to be understood as the key technologies or the distinctive developments? A question without a definitive answer, but I will present my view by taking inspiration from the manner in which the prior industrial revolutions are commonly understood. This leads to a, still multifaceted though, more focused understanding of the phenomenon. The insights, formulated proposition and developed model stemming from the reflection of terminology and meaning of the phenomenon helps move the current technology-related phenomenon forward. They assist with the establishment of well-documented papers. A critical aspect if we aim to understand how management will look like in the era of this phenomenon.

Keywords: Smart Industry/Industry 4.0; terminology; meaning; model; fourth industrial revolution; smart manufacturing

What started out as a German initiative to strengthen the competitiveness of the German manufacturing sector resulted in a global phenomenon which has received an increasing amount of attention over the past years; a development that has been documented both in words and numbers. But contradictory to its popularity, the understanding of the phenomenon is surrounded by ambiguity. For not only did the interest in the phenomenon

Smart Industry - Better Management
Advanced Series in Management, Volume 28, 5–18

ISSN: 1877-6361/doi:10.1108/S1877-636120220000028002

grow, so did the number of labels and meanings related to the phenomenon. Given the impracticality behind this combination (i.e. popularity and ambiguity), the confusion and lack of conceptualization of the phenomenon has received attention by scholars. With a recent study being the systematic literature review by Culot et al. (2020), the authors assessed definitions for the phenomenon, that is Industry 4.0 and similar concepts, in academic as well as non-academic articles. In light of the findings from this systematic literature review, the proposition written in the dissertation by Habraken (2020, p. 136) and the importance of establishing a more stable foundation from which to work with regarding the current phenomenon, this chapter reflects on the understanding of the phenomenon from both a terminology and meaning perspective. By reflecting on noticeable issues that are at play, steps can be constructed that will help move the phenomenon forward. In other words, this chapter does not offer specifics when it comes to the question of management in the era of the current phenomenon. The combination of novelty and diversity surrounding the phenomenon makes how management will look like in this era a topic that requires time and, importantly, well-documented efforts. In contrast, this chapter offers insights that will assist with the creation of answers to the question of management in the era of the current phenomenon. It does so by reflecting on the notion of the label the fourth industrial revolution and the existing yet unnecessary diversity in labels which creates an integration challenge, both of which address terminology, and the multifacets of the phenomenon as well as the topic of workability which are both grouped under the understanding of meaning. But first the understanding of terminology is addressed.

UNDERSTANDING OF TERMINOLOGY

Made in China 2025, Make in India, Advanced Manufacturing, Smart Manufacturing, Factories of the Future, Industrial Internet, Industrie 4.0 (translations like Industry, Indústria & Pramonė 4.0), or… Smart Industry. They are all examples of, likely many more, labels that currently exist to highlight a phenomenon that is also often referred to with the term the fourth industrial revolution. Before turning to the apparent diversity, I first want to focus attention on the notion of the fourth industrial revolution.

Fourth Industrial Revolution

To start, let it be clear that the phenomenon in question can bring about fundamental changes (i.e. be disruptive). From this point of view, the terminology of a fourth industrial revolution is definitely appropriate. However, it is relevant to consider that a revolution is also tied to the concept of speed, as visible in understandings of the word 'revolution' – 'are *fast*, disruptive and destructive' (Blanchet, Rinn, Von Thaden, & De Thieulloy, 2014, p. 7) – and the word 'industrial revolution', 'a *rapid* major change in an economy…' ('Industrial Revolution', n.d.). When one takes this lens into account, the fit appears to become less suitable. The prior sentence includes the word 'appears' for, as Madsen (2019) points out, there is 'relatively little evidence on I4.0 adoption rates in different parts of the world' (p. 14). In addition, what is considered fast in this context is open to different interpretations. Consequently, a definite outcome regarding the speed of this phenomenon cannot be made. Nonetheless, available data do not hint at the phenomenon being a fast development.

For example, in 2016, two years after the introduction of Smart Industry in the Netherlands, only 15% of the respondents in a Dutch survey among entrepreneurs

indicated to have heard of the term Smart Industry (Smetsers & Borst, 2017).[1] Within the same survey conducted in 2020, still 72% of the respondents stated to never have heard of the term or, having heard of it but not knowing what it is (Vegter, Witvliet, & Reinhartz, 2020). Though it is possible that companies have Smart Industry elements in place while being unfamiliar with the terminology, this is expected to be an exception rather than the rule; especially with the phenomenon being promoted at national and regional level as well as by platforms such as the Dutch Chamber of Commerce (KvK). The fact that respondents only represent small and medium sized enterprises (SME's), that is companies up to 50 employees, in addition cannot be used as a justification for the results since firms up to 50 employees account for 99% of all Dutch businesses in 2019, according to Statistics Netherlands (CBS) (2021). They make up the bulk of the economy and must therefore be considered when it comes to the speed of the revolution. The mention of barriers for adopting Smart Industry, like lack of time and investment budget, in the 2016 and 2020 survey further signals that the phenomenon does not have the speed associated with a revolution. The presence of barriers even transcends the Netherlands as can be understood from publications like Moktadir, Ali, Kusi-Sarpong, and Shaikh (2018) or Orzes, Rauch, Bednar, and Poklemba (2018). Lastly, results predate COVID-19, excluding it as an explaining factor.

To conclude, the phenomenon does not appear to be fast or rapid. Neither should that be a goal in and of itself. Technology needs to serve a purpose, and not be introduced because it is available. However, from a terminology perspective, the applicability of the label fourth industrial revolution can be questioned when adding speed to the equation. From solely a disruption standpoint, the term is understandable. As its predecessors, the term fourth industrial revolution indicates the presence of a major change. Whether we need a separate term to stress this fact, especially with the number four embedded in labels such as Industry 4.0, is another discussion.

Diversity of Labels

Having addressed the essential distinction in the interpretation of the word revolution, I turn to the existing diversity in labels used to denote the phenomenon. For some labels the overlap with the initial, German terminology Industrie 4.0 is relatively clear and interchangeability can therefore be easily assumed. Other labels are more unique and, as a result, give the impression that the label represents something different; in other words, not related to the Industrie 4.0 phenomenon. But based on the following evidence, the distinction signalled by the use of unique labels can be considered a pretence:

> You should not bring a German term like Industrie 4.0 to the Netherlands. We don't really like German labels, it must always sound a bit English, and if you give it an original name it seems as if you invented something new. As if you invented it yourself. Then of course it is very smart to call it Smart Industry. (A quote from a Dutch Smart Industry expert; from the study discussed in Habraken & Bondarouk, 2019)

> Implementing advanced manufacturing technology services/Industry 4.0… (Sentence on the website of the National Institute of Standards and Technology, that is part of the US Department of Commerce[2])

> In response to the recent global reindustrialization tide and Germany's high-tech strategy Industry 4.0, the State Council of China announced the Made-in-China 2025 Plan in May 2015 and Both Industry 4.0 and Made-in-China 2025 focus on the new round of industrial revolution and employ manufacturing digitization, CPS, IoT, and intelligent manufacturing. (Li, 2018, pp. 67–68)

> The analysis [a systematic literature review of academic studies providing a definition of Industry 4.0 and similar concepts] underlined how very few differences among definitions can actually be explained by the label used to describe the phenomenon. (Culot et al., 2020, p. 9)

The diversity with which we are faced with today thus stems from: 1. translations of the original German label into ones native language and a more international applicable, or English, label; 2. a countries desire to create their own label or brand to denote, the countries specific approach regarding, the phenomenon that arose in Germany, and; 3. creations by companies, General Electric for instance promotes the term Industrial Internet (Evans & Annunziata, 2012). These origins are also what make the movement towards the use of a single label complicated. Countries and companies cannot simply change a promotional label which they have heavily invested in. And as long as countries and companies use their labels, so will, in all probability, the academics and consultants embedded within those countries/companies. As Habraken (2020) pointed out, the use of a single label among scholars will therefore only be established if this topic is discussed. An achievement which, given the broadness of the phenomenon (i.e. scholars from a wide range of disciplines are involved), is a challenge in and of itself. As a result, a question that arises is whether the obtainment of one label is of enough importance that it justifies tackling this huge challenge? Or, can we work with the current unnecessary diversity while at the same time reduce expected issues as much as possible, such as a lesser awareness of scholars conducting research in this domain leading to reinventions of the wheel.

Though I am in favour of the establishment of a single label, it might be better to work with the situation that has emerged. Not just because of the complexity of the challenge, but also since striving for full awareness of all domain-specific knowledge is in general – thus probably also with a single label – a difficult task to achieve given today's knowledge generation and dissemination age. It, however, does not imply that we should abandon all attempts to improve awareness and integration. To assist this, existing developments like the presence of duplicate key words (i.e. the inclusion of several of the aforementioned labels as distinct key words) could be embraced and used to our advantage. For example, we could agree on counting a certain set of words as a single key word (e.g. to see inclusions like Industry 4.0, Smart Industry and Advanced Manufacturing as one entry). This would allow the retaining of multiple interchangeable labels while facilitating knowledge transfer across diverse labels, without interfering with the limitations, often placed on the available amount of key words.

UNDERSTANDING OF MEANING

As with the number of labels, diversity is also apparent regarding the description of the phenomenon in question. But the presence of various descriptions cannot be attributed solely to the existence of a multitude of labels. First, there are multiple definitions in existence, offered by both scholars and practitioners, with respect to one label. Take for instance the prevalent label Industry 4.0. In the paper by Culot et al. (2020), it is mentioned that 42 definitions of Industry 4.0 were found in the included academic sources and six definitions in the non-academic sources assessed. Bringing the number of descriptions for the label Industry 4.0 already to 48 based only on papers included in the systematic literature review by Culot et al. (2020). Second, Habraken (2020) showed that the label Smart Industry in the Netherlands has been described differently over time, by one source. Observations that in part are due to new insights, that is, descriptions changed with new knowledge. But another reason lies in the different facets, each containing various elements, that encompass the phenomenon. It, in other words, facilitates the emergence of variations. This presence of multiple facets also explains why the phenomenon is often coined as being 'broad' and 'overarching'.

In the next part, I will briefly elaborate on the different facets, using results from the systematic literature review by Culot et al. (2020) and the qualitative study pertaining to Smart Industry by Habraken and Bondarouk (2019). The inclusion of the latter paper stems from its analyses of the term Smart Industry which, despite the vast list of selected terms, was not considered by Culot et al. (2020). I am aware that this incites the question, what about all other related terms that were not incorporated? My intention with the addition was not to cover all existing labels, but rather arose from the use of the term Smart Industry in the title of this book. As a result, it was found to be a relevant inclusion to make.

Multiple Facets

In the paper by Culot et al. (2020), the notion of the multiple facets becomes evident by the fact that four coding categories were created, or needed, to refer to the constituting elements of the phenomenon: key enabling technologies, other enablers, distinctive characteristics, and possible outcomes. With *key enabling technologies*, the authors imply the main technological innovations supporting the change, or the technological drivers. Specifically the following 13 elements (not counting the unspecified element) – stated in order of popularity, with the number of observed occurrences indicated in brackets:

Internet of Things (84), cloud computing (81), machine learning and artificial intelligence (64), cyber-physical systems (63), simulation and modelling (63), big data analytics (63), interoperability and cybersecurity solutions (62), 3D printing (51), visualization technologies (47), advanced robotics (39), new materials (17), energy management solutions (16), and blockchain technology (11).

It is a category that is, in and of itself, broad since the phenomenon does not stem from a development in one domain but rather various fields. In other words, it is 'not about a single breakthrough invention but comprises several "tech ingredients"…' (Culot et al., 2020, p. 5). The category *other enablers* consists of the elements organizational enablers and business model innovation. Regarding the first, the following points are implied: organizational design should pursue higher inter- and intra-organization linkages, organizational structures should flatten out to accommodate distributed decision-making, and digital and strategic capabilities will be needed at all levels (Culot et al., 2020). These factors tie in with aspects that Habraken and Bondarouk (2019) classified under the heading preconditions (e.g. supporting infrastructure, people's ability to adapt and maintain value-adding capability, legislation-related issues). The element business model innovation, in contrast, was stated to be related to the increasing spread of smart products (i.e. products with integrated data-driven services or data-driven services that replace traditional product sales) and new forms of production such as 'home manufacturing' due to 3D printing, and offering activities via digital platforms (Culot et al., 2020). Based on this explanation, the element business model innovation appears to fit better under the category distinctive characteristics. The category *distinctive characteristics* is explained as containing descriptions of 'how to do Industry 4.0'. Its elements in a sense represent the transitions or developments generated by the key technologies. Examples are process integration, predictability, real-time information transparency, virtual representation of the real world, and autonomy (i.e. self-thinking and/or reacting systems). The distinctive characteristics are portrayed in a more abstract manner by Habraken and Bondarouk (2019), via their three technology-based developmental streams that each contains the notion of digitalization – the establishment of connections, the ability to make more use of the value of information and the availability of contemporary physical and non-physical

assets. The category *possible outcomes* consists of possible impacts of the phenomenon. It overlaps with an extensive set of impacts found by Habraken and Bondarouk (2019). Finally, the results from Habraken and Bondarouk (2019) included the presence of intended rationales. It addresses the intention behind the phenomenon, which was retaining industries competitiveness and alerting industry of emerging opportunities.

The fact that multiple facets encompass the phenomenon is visually represented in Fig. 1. With 1A and 1B depicting the frameworks as developed by respectively Culot et al. (2020) and Habraken and Bondarouk (2019). Fig. 1C represents a model that combines insights from both frameworks.

Having addressed the different facets of the phenomenon, I will now turn to the topic of workability.

A Workable Phenomenon

The model presented in Fig. 1C cannot be considered a workable description. In other words, something cannot be part of a concept and at the same time facilitate, hinder or result from that concept. In that sense it is more reminiscent of a research field, depicting various directions of interest, than a concept. Removing the presumed interfering categories (rationales, conditions and outcomes), however, still leaves two potential categories. This raises the question of whether a workable construction of the phenomenon is to be understood as the key technologies or the distinctive developments? While there is no definitive answer to this question, I will present my view by taking inspiration from the manner in which the first, second and third industrial revolution are commonly understood. An assessment of the abundant, online industrial revolution diagrams and the mention of these revolutions in the papers by Davies (2015) and Drath and Horch (2014) shows that the main wordings are machination, mass production and automation, accompanied by the notion that these are driven by respectively steam and water power, electrification and the conveyor belt, and electronics and information technologies. Both categories thus also coexist in descriptions of these three industrial revolutions, but the brief reflection shows that emphasis is generally placed on the direction of the transitions

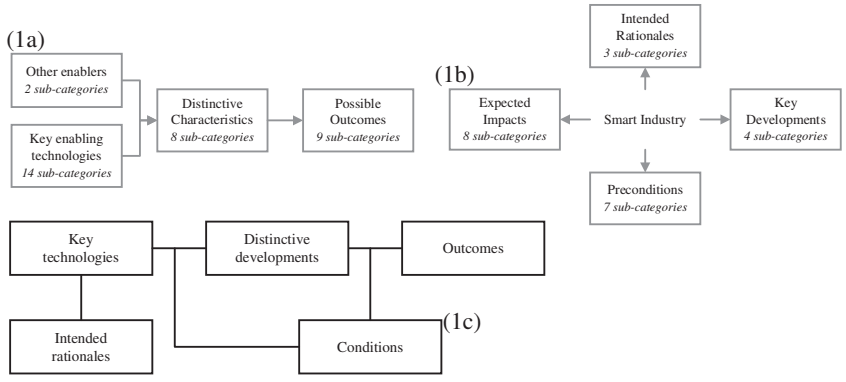

Fig. 1. Representing the Multiple Facets. 1A, is the framework inspired by Culot et al. (2020); 1B, is the framework by Habraken and Bondarouk (2019); and 1C, is the model developed based on the frameworks presented in 1A and 1B.

or the developments, rather than the underlying technological advancements. Following this line of reasoning, current phenomenon can then be understood as the distinctive developments. Therefore this category will be addressed in more detail below. However, with the phenomenon still unfolding, its content may not be limited to these elements. It thus covers the prominent transitions that can, to date, be attributed to the prior stated key technologies. As a result, especially the key technology 'energy management solutions' appears not to be represented. Though, it could be questioned whether this is an issue of time and more insights, or setting boundaries with respect to the key technologies tied to the phenomenon. 'Energy management solutions' addresses the sustainability theme, making it potentially more relevant for it to be positioned under the general topic of sustainability. The elements of the phenomenon in question covered here are:

Servitization

The notion of offering services in itself is not new, but what is visible is an increasing usage of services as a means of building revenue; whether it be in addition to, or as replacement of the original product/value proposition. In their article entitled 'What is servitization of manufacturing? A quick introduction', Emerald Publishing Limited (2020) presents five examples, and the following quotes offer two more, respectively from a manufacturer of adapted bicycles, and of winter maintenance vehicles.

> We developed a business model in which we will develop services as well as products. We are currently working on an app for reading relevant data from the e-bikes; with that information we can organise the service towards the customer in a smarter – preventive – way. (Financial/HRM director at manufacturer of adapted bicycles; in Link Magazine, 2016)

> From a hardware supplier we become a caretaker with integrated solutions. In doing so, we respond to the megatrends: solutions instead of products, availability instead of ownership. (Director at manufacturer of winter maintenance vehicles; in Link Magazine, 2017)

Platform Economy

As with servitization, the platform economy is not new. What makes it a noteworthy development is the fact that they are 'bigger, more virtual, more dynamic, and more intelligent than "platforms" of the past' (co-author of the book 'Platform Revolution'; in Manville, 2016). Recent innovations, thus, have led to a growth in and increased attention for the platform economy. The statement more intelligent, in the prior quote, indicates a connection with the next element (data usage), as explained with the following quotes:

> Platforms win, not just by facilitating such new interactions [e.g. joining more producers and customers], but also by aggregating and analysing the data of it all (Manville, 2016) and The explosion of data, and its use by platform businesses to keep learning is perhaps most significant. Uber, for example, is not just matching rides to travelers, but increasingly predicting and even structuring demand by algorithms that rebalance supply of available cars. (Co-author of the book 'Platform Revolution'; in Manville, 2016)

Data Usage

Combine the vast and varied amount of (real-time) data that can now be collected and the different (new) ways in which data can be processed, with the notion that done purposefully there is value to be gained from data and the core of this element becomes clear – data can and are used more frequently for various reasons. From monitoring, understanding

and decision-making (take for instance the Covid-19 situation) to prediction, as shown via the following examples:

> A smart factory with machines that are packed with sensors that measure productivity. They keep track of everything: process values, alarms, vision control images, temperature, humidity, energy consumption, failure, malfunctions, logs, checklists, etc. … The ultramodern injection molding factory that K. is now building has been developed entirely according to the Industry 4.0 concept. A factory that constantly monitors the condition of the machines, predicts maintenance and generates the big data with which it can produce more efficiently. (Verpakkingsmanagement, 2017)

> The robotic system provides a flow of data as well as milk, [this data flow is used] to keep track of the best producers and the cows that may eventually have to be culled. 'We've got seven cows out of 113 that we're looking at', Jim Austin said, as he pointed to the red bars lighting up an office computer screen. (Boyle, 2016)

Another reason is traceability, for instance, to offer customers details about the path taken by products like food. A chapter in the book entitled 'Blockchain chicken farm: And other stories of tech in China's countryside' (Wang, 2020) presents a relevant case example. The improvement of services, for instance in the healthcare and tourism sector (Benjelloun, Lahcen, & Belfkih, 2015), is an additional reason that can be observed. The link between utilizing data and services is also evident in the above element of servitization since the manufacturer of winter maintenance vehicles is able to focus on availability instead of ownership by gaining insights into the deployment of their vehicles; 'the firm has equipped their grit and salt spreaders with a controller that offers up-to-date information, accessible through a web application, on performance aspects, such as spreading quantities, and on service aspects such as usage in hours or kilometres driven' (Habraken & Bondarouk, 2020, p. 7). Finally, a link with the next element can be made as 'autonomous' systems utilize data to function. To illustrate, autonomous mobile vehicles (AMV) are not restricted to fixed routes but navigate dynamically due to a blueprint of a location and live input of their surrounding (Fetch Robotics, 2018). To conclude, the element data usage can be seen as a standalone element leading to an increased focus on predicting, monitoring, assisted decision-making, etc. In addition, it ties to several of the other elements.

'Autonomous' Systems

A fourth development is the presence of 'independent' systems. The brackets around the word independent are included to highlight that systems are more autonomic than before, but often still require human involvement, for instance, to assist it with dealing with changes in the environment or human-made errors in the systems input. In other words, full autonomy is not really the case yet. Autonomous systems can range from being interpreted as autonomous devices like the above AMV and the milking robot from an earlier example (Boyle, 2016). But it can also be understood as people-light processes. An example is given with the quote from a supplier of sheet metal:

> To do this [people-light process from order to production], you must be able to recognise a customer's drawing, convert it into a quotation using software, then automatically have the right materials removed from the warehouse, have it processed, packaged, etc. (Van Ede, 2015)

The example highlights an autonomous process from customers to production. Firms could, however, extended it towards suppliers (e.g. autonomous ordering of parts) as well as decide to introduce a smaller scaled autonomous system.

Human-Robot Interaction

As Bartneck et al. (2020, p. 6) point out, 'the notion of human interaction with robots has been around as long as the notion of robots themselves'. What makes this development important now is that robots have moved beyond merely being a tool, to being an interaction partner in numerous ways. The AMV can be considered an example here as it interacts with people in order to not run into them. More examples of human-robot interaction applications are addressed by Bartneck et al. (2020, Chapter 2), with some of the discussed types being: service robots (e.g. tour guides, receptionist, delivery or security robots); robots for entertainment; robots in healthcare and therapy (e.g. for senior citizens or rehabilitation); collaborative robot (co-bot) arms; and remotely operated robots. An example of a remotely operated robot are drones, when interpreted in terms of moving sensors (i.e. scanning or mapping a terrain or conducting inspection work). But drones can also be classified as delivery robots as shown by the following headline from a news article by Palmer (2020) – 'Amazon wins FAA approval for Prime Air drone delivery fleet'.

Reconfiguration

As the word reconfiguration implies, this development is focused on the ability to rearrange settings, or the ease with which diverse outputs can be created. A well-known approach is additive manufacturing or 3D printing. This approach is featured in the quotes below from the manufacturer of adapted bicycles and a concrete factory:

> We see a great future for this [3D printing] because we are a producer with small series. We want to 3D print more and more products. We are also looking at collaborative robots. We have already done studies to see where we can deploy them. (Technical director at manufacturer of adapted bicycles; in Provincie Gelderland, 2019)

> 3D printing of concrete offers the new generation of architects a world of new possibilities. You can play with shapes, colours and structures and you are no longer bound to serial production of large volumes of the same product. A robot does not care whether it has to produce 10 or 100 different designs in a row. The construction world was primarily a mechanized industry, thanks to Smart Industry it is becoming a digital industry with many new possibilities. (Innovation manager of a concrete factory; in Boost, 2017)

What makes 3D printing relevant now, despite its origin in 1986, is the emergence of new applications both in method and in materials to print with (Ngo, Kashania, Imbalzanoa, Nguyen, & Hui, 2018). Besides a 3D printer, the prior mentioned co-bot arms also enable reconfiguration since they are 'able to change from one process to another with ease, making it possible to use one co-bot for multiple tasks…' (Shepherd, 2019); a statement evident in the above quote from the manufacturer of adapted bicycle. Finally, reconfiguration is reflected in the general quote from the supplier of sheet metal:

> In recent years machines have been introduced that can not only perform the operations automatically, but where you can also adjust an operation at the touch of a button. The changeover time is then zero. (Van Ede, 2015)

Separation

One interpretation of this element are developments related to reality. That is, the usage of digital currency, digital models, augmented reality (AR) and virtual reality (VR). Regarding digital currency and AR, the quote below offers an example from a clothing store. In addition, other AR and VR applications can, for instance, be found in respectively FDM (2020) and Mekni and Lemieux (2014).

> When you place a piece of clothing on the wooden box next to the mirror, 360-degree photos automatically appear on the mirror. By moving your finger over the photo, you can virtually rotate the article and view it from all sides. And the store also accepts payments in DigiByte. (Editorial Smart Industry, 2020)

Digital models entails the grown possibility of constructing virtual representations or digital models; better known as digital twins. This growth is due to the 'explosion of machine learning, wireless communication and cloud computing' (Lu, Liu, Wang, Huang, & Xu, 2020, p. 2). It is connected to the data usage element as digital twins rely on real-time data to depict what is currently happening (i.e. create a digital replica of a real-world 'thing'). In addition, according to Lu et al. (2020, p. 2) 'a digital twin can be used for monitoring, control, diagnostics, and prediction'. Separation in terms of reality is also visible in the creation of deep fakes. Linked to the data usage development, recent advancement have led to the creation of materials that are difficult to distinguish from reality. In the words of Kietzmann, Lee, McCarthy, and Kietzmann (2020, p. 135) 'Powered by the latest technological advances in artificial intelligence and machine learning, deep fakes offer automated procedures to create fake content that is harder and harder for human observers to detect. The possibilities to deceive are endless – including manipulated pictures, videos, and audio'. A second interpretation of this element is the introduction of assets which enable tasks to be performed away from their traditional location. To help explain what I mean, there is the following quote showcasing the presence of tablets on the shopfloor:

> In the old situation, the operators could see how the production was going on large screens. The machines were also equipped with all kinds of hmi-screens. In the new factory, most screens have disappeared and are replaced by tablets. With the help of those tablets, the operators can control everything and receive information about the status of the line. The processes and important functions can be found via icons on the tablet. If the compressed air icon turns red, the operator knows that something is wrong with the compressed air installation. If he inspects the machine and sees, for example, that there is an oil leak, he can take a picture with the tablet. The log is recorded instead of typed in and the service engineer immediately receives an SMS message and sees what the problem is. (Engineering consultant; in Verpakkingsmanagement, 2017)

Another example is the current piloting of smart grocery carts which brings the cash registration of groceries inside the store, as you can pay directly from the smart carts card reader, in contrast to a traditional, fixed cash registration point – see video by CityNews Toronto (2019) for a case example.

Though still being multifaceted, the distinctive developments present a more focused understanding of the phenomenon compared to Fig. 1C. It is viewed as expressing visible developments, from a business perspective, as a result of recent technological advancements. This understanding, however, does not take away from the complexity of working with the phenomenon. As shown in Fig. 2, the phenomenon comprises of elements that are being addressed and implemented independently. In other words, scholars may concentrate on one specific element (e.g. platform economy or human-robot interaction) and firms may just focus, for instance, on reconfiguration. But a combined view is of importance as well, since there are firms that have introduced aspects from various elements. Take for example the manufacturer of adapted bicycles, who focused on reconfiguration, offering services besides producing, and using data for prevention, or the farmer with an autonomous milking robot that simultaneously makes use of the data which this robot can generate, a step that is not strictly necessary when adopting a milking robot.

The above discussion will be used as input for the next, concluding heading.

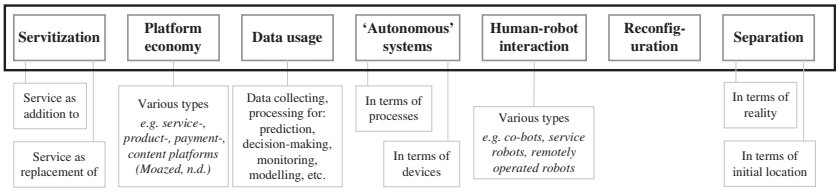

Fig. 2. Representing the Complexity. The bold line represents the phenomenon, the top row represents the seven developments that encompass the phenomenon, and the bottom row highlights the variety within a certain element.

CONCLUSIONS: MANAGEMENT IN THE ERA OF THIS PHENOMENON

With management defined as 'the act or art of managing: the conducting or supervising of something' ('Management', n.d., definition 1), it has a wide focus, covering aspects such as the management of people and work, external relations, data and the devices as well as systems themselves. Given the complexity depicted in Fig. 2, the effects of the phenomenon for each specific management direction will be heavily dependent on the particular context that is examined. Put differently, the phenomenon is tied to a number of technological breakthroughs or advancements, which have led to several (sub-) developments that can either be considered on their own or in various combinations; a fact that results in a set of multiple, unique expressions of the phenomenon in practice. Such unique expressions are unlikely to be captured by a single reflection of management in the current era, for each specific management direction. It is thus of importance to be aware of and clear about the particular expression of the phenomenon one deals with when assessing management-related questions, a notion facilitated by case-based research, where a single or several organizations take centre stage with respect to the raised question(s) of interest. In other words, the benefit of case studies is that it enables gaining insights into the expressions that exist, while assessing questions pertaining to the effect of a certain expression on various management directions and vice versa (i.e. expressions may effect management but it should also be kept in mind that existing management may influence the way in which the phenomenon is expressed in that context). A brief assessment of the use of case studies in existing literature on the phenomenon reveals that despite their relevance, case studies are not widely applied yet. That is, a literature enquiry using the most frequently used label 'Industry 4.0' for the period 2011 till present yielded, on 3 March 2021, 13,938 results in Scopus and 7,904 result in Web of Science. While a search for the keywords "Industry 4.0" AND "case study" for the same period and date provided 1,292 results in Scopus and 649 results in Web of Science, which is respectively 9.3% and 8.2% of the prior results. Both are a relatively low percentage, especially given that they stem from a generic search (i.e. it was not assessed if a case study was in fact conducted or, for instance, only proposed as a future research direction and the inclusion of a link with the topic management was not assessed). This low outcome could be due to a limited amount of empirical research towards the phenomenon in general. Nevertheless it leads me to recommend the use of case studies in future research on management in the era of this phenomenon. Over time, such research, supplemented by relevant existing case studies, will yield a better, more complete overview of the phenomenon in practice and a more comprehensive understanding of management in the era of this phenomenon.

I am aware that this is an abstract, future-dependent answer. However, we have to realise that we are dealing with a relatively new phenomenon, though coined in 2011, it did not take off till about five years ago (Habraken, 2020), that comprises of (at least) seven independent and interconnected developments which can be broken down into sub-components. This combination of novelty and diversity makes how management will look like in the era of this phenomenon, a topic that requires time and, importantly, well-documented efforts. Without the latter, it will be challenging to connect and collectively assess the conducted work in a few years' time. Fig. 2 and the earlier proposition related to the variety in labels (i.e. to count a specific set of labels as a single key word) are expected to assist with the establishment of well-documented papers by: facilitating the linking of papers with various but interchangeable labels for this phenomenon; creating a clearer understanding of the fact that there is no single expression of this phenomenon in practice; and helping with the establishment of unity in the manner in which the unique expressions of the phenomenon are documented in research articles.

NOTES

1. Members of the KvK entrepreneur panel who represent a diverse group with respect to gender, age, sector, and whether they are an independent entrepreneur or part of an SME.
2. Retrieved, Dec. 2020 from: https://www.nist.gov/mep/advanced-manufacturing-technology-servicesindustry-40.

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