

TOWARDS MEASURABILITY AND IDENTIFICATION OF KEY BENCHMARKS OF INDUSTRY 4.0

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Abstract: This study presents an analysis, comparison and evaluation of the Industry 4.0 Concept, with the focus on the measurement of its overall benefit. Based on a wide range of theoretical perspectives, outcomes of expert studies and analyzes of top consultancy firms, we infer that senior management currently has very indistinct ideas and exaggerated expectations of the content and benefits of the Industry 4.0 Concept. The result of this confusion is often either the rejection or questioning of the revolutionary aspect of Industry 4.0 and its overall benefits. Consecutively, executives are unable to effectively manage business processes towards gaining market benefits. The study identifies three major elements that are associated with management's unclear or exaggerated expectations about Industry 4.0 Concept. These factors are: the unclear theoretical basis; the broad practical focus of the concept itself and ultimately also the excessively misuse, exploitation and overly general application of the given term by marketers and consulting firms. Together with that Industry 4.0 faces an absence of generally accepted Key Benchmarks of Industry 4.0. The main impact of this is that there are currently very limited ways or criteria to differentiate the degree of companies' involvement in the Industry 4.0.

Keywords: industry 4.0; industrial internet of things; fourth industrial revolution; benchmark; qualitative research

JEL Classification: O14, O25, O31, O38, R58, L23

INTRODUCTION

Every author that wishes to comment on Industry 4.0 faces a difficult task right at the very beginning of its work. Whether for its own methodological purposes or reader's comprehensibility, this concept needs to be defined. As this study tries to show, the initial platonic question, 'what Industry 4.0 is', conceals in itself a number of controversies.

With respect to the origin of Industry 4.0 initiative, we will use the initial definition of German Plattform Industrie 4.0 (2017) that characterizes Industry 4.0 as a combination of production methods with state-of-the-art information and communication technology. It is changing the future of manufacturing and work in Germany: In the tradition of the steam engine, the production line, electronics and IT, smart factories are now determining the fourth industrial revolution.

What, however, originally started as a German initiative has soon become a global brand due to its high political pertinence, intensive marketing efforts and the global leadership of Germany in manufacturing. Industry 4.0 is also sometimes called 'smart industry', 'intelligent industry', 'smart factory' or 'smart manufacturing'. For the purposes of this study, Fourth Industrial Revolution will be equivalent to Industry 4.0. Furthermore, we consider the Internet of Things a key component of Industry 4.0, as it is the industrial use of the Internet of Things that makes the whole industry smart.

The contribution of this study builds primarily on the desk research approach based on a wide range of theoretical perspectives, academic research, outcomes of expert studies and analyzes of world leading consultancies and agencies.

1. INDUSTRIAL OR SOCIETAL REVOLUTION?

Currently, Industry 4.0, or the Fourth Industrial Revolution is a rather vast vision that stretches beyond merely technological aspects. Industry 4.0 is a digital transformation of the value chain of the industry, at

the beginning only focused on manufacturing, and nowadays on many other sectors beyond the industry. It is also a name for the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, artificial intelligence (AI), the Internet of Things (IoT), cloud computing and cognitive computing as their combinations create what has been called a 'smart factory' of the future (Mukerji, 2018).

While a similar description could have been comprehensive enough in previous years, we could see Industry 4.0 evolving beyond manufacturing and commerce. KPMG (2016, 6) suggests that 'companies need to adopt a holistic approach' and broaden their horizon beyond pure technology.

There are vivid examples of Industry 4.0 trends coming to life everywhere around us. Its effect could perhaps be best seen on the shivering job market. In 2016, Sood (2016) reported that a newly developed artificial intelligence wizard will free up company's 3 000 engineers from mundane software maintenance activities. It is not uncommon these days that the Fourth Industrial Revolution is associated with further complex changes in human society in its entirety. During 2017' Cebit (Europe's Business Festival for Innovation and Digitization) trade show, Japan went beyond smart factories and introduced a 'super-smart society', a new vision called Society 5.0. Japan's initiative, described in an ambitious statement 'Towards realization of the new economy and society' (2017), is built upon the key technological elements that are very well known in Industry 4.0 (IoT, cyber-physical systems, AI or Big Data), but beside these it focuses on the impact of their implementation on Japanese population.

We should keep in mind that Industrie 4.0 was first introduced in Germany as a publicly-backed and steered initiative. The majority of its policies 'aim at strengthening respective country's industrial competitiveness and modernization and better ensuring the sustainable growth of the manufacturing sector'. (European Commission, 2017)

Jao (2017) point out that Industry 4.0 is and never was 'just about the digitalization of manufacturing, but about digitalization across all levels', as governments seek to future-proof their economy in the face of the upcoming revolution. Similar initiatives which seek to further link technological evolution with other societal aspects follow elsewhere in the world. Czech Republic recently broadened its National Initiative Industry 4.0 into Society 4.0 that reacts on grand public challenges posed by the progress of Fourth Industrial Revolution (Alliance Society 4.0, 2017).

In the rest of the study, we wish to focus on the actual content of Industry 4.0 and as we will see later, it is important to remember that the subject matter of Industry 4.0 Concept is constantly evolving. In its complexity, the idea of Industry 4.0 presents a testament of modern time. In a contrast to Asimov's famous principles of robotics, this is not an ethical statement but the envisionment of a new era. The economic objectives of individual businesses are strongly linked with social and environmental ones, as governments play an all-important role in Industry 4.0 adaptation.

2. LITERATURE REVIEW

2.1 Facing a Lack of Understanding of the Content of Industry 4.0 Concept from the Perspective of Practice

If we do an extensive desk research of materials published about Industry 4.0, one thing stands out above the rest; an urgent need of all authors to answer the question: What is (and what is not) Industry 4.0? Even though most authors come with a particular Industry 4.0 characterization or a list of its essentials, definitions too often suffer from superficiality and therefore result in generalizations.

Besides that, many of these definitions are being phrased in language so indistinct that they slide over the surface and their predictions are remarkably cautious and all-encompassing as to be practically useless for business owners. On a same note, Georgieva's (2016) study shows 'the new industrial revolution faces the danger of ... lack of understanding. It is simply a problem of the concepts being too vaguely defined, and in parts too overarching, to be meaningful.' Many attempts to define Industry 4.0 resemble wild visions rather than specific conceptions suggesting concrete steps towards their real implementation.

An example of this inclination could be the definition of Industry 4.0 according to the European Parliament (2015, 2): 'Industry 4.0 is a term applied to a group of rapid transformations in the design, manufacture, operation and service of manufacturing systems and products. The 4.0 designation signifies that this is the world's fourth industrial revolution, the successor to three earlier industrial revolutions that caused quantum leaps in productivity and changed the lives of people throughout the world.'

As a result of this shallowness, businesses willing to implement some aspects of Industry 4.0 into their manufacturing process have few to none specific instructions as to what exactly they are supposed to be doing.

In addition to that, large consulting firms (McKinsey, Boston Consulting Group, Deloitte, KPMG etc.) unknowingly support this trend. Consider the study of the consulting company McKinsey (2015): 'Most manufacturing executives are likely confused about what it is. ... Yet a closer look at what's behind Industry 4.0 reveals some powerful emerging currents with strong potential ..., and executives should carefully monitor the coming changes and develop strategies to take advantage of the new opportunities.' While the quote acknowledges the uncertainty on the part of those who would apply this vision in practice, it immediately underlines the possible losses associated with this approach. Reports on Industry 4.0 that are being released to the public frame this new paradigm-changing revolution in terms so imprecise that more than a set of instructions they double as additional means of excitement for brighter tomorrows. Even though the reason for that is rather obvious – the income of these companies predominantly comes from hands-on consulting instead of providing free advices to everyone – such materials certainly do not bring the necessary level of exactness into the debate.

We fully understand the necessity of futuristic visions. They are a welcomed factor in motivating us towards Industry 4.0 adoption. However, the absence of specific definitions along with the lack of fixed 4.0 identifiers results in discussions concerning the real value of the Industry 4.0 strategy as a whole. Furthermore, it leads to questioning its overall meaning and genuine benefit.

2.2 Overhyped Expectations: The Controversy of Industry 4.0' Overall Benefit

It is showing to be extremely difficult to come up with a definition of Industry 4.0 that would cover all of its aspects and would not end in the above mentioned generalizations. In addition, Marijn ten Wolde of Bosch Siemens Home Appliances claims that 'Industry 4.0 has a different meaning for each company. Even within Bosch there isn't one definition of Industry 4.0. It's dependent on the strategy for each factory.' (Wray 2016) Despite this, we believe that through a combination of practical observations and theoretical analysis, it is possible to identify key points of a given concept.

There are extensive articles devoted to the sole research and analysis of Industry 4.0 definitions. One of the most comprehensive, dealing with the issue, is probably i-SCOOP's (2016) 'Guide to Industrie 4.0' that sums up all important definition attempts together with their brief characterization. In order not to get caught up in this problematic issue, let us perhaps first examine Industry 4.0 through the optics of its real value and advantage it carries for businesses.

Based on discussions with industry leaders, consulting group KPMG (2017, 5) claims that 'the real value of i4.0 comes not from the component technologies or capabilities but rather through the integration of automation, data, analytics, manufacturing and products in a way that delivers unique competitive advantages and unlocks new business and operating models'. As we can see, the cornerstone for business advancement and value-creation in Industry 4.0 is not based on technologies themselves but rather on their integration into the whole business model. That is why the transition from third to fourth industrial epoch relies on far more than on a purchase of specific 'smart' technologies. Similarly a manifesto or press release that acknowledges company's allegiance to 4.0 is far from sufficient. What should present only a start of successful transformation is for many also the finish line. A '2016 Global Industry 4.0 Survey' conducted by PwC (2016) suggests that many companies still hope that the 4.0 wave will effortlessly drag them towards the revolutionary current.

Similarly Drath and Horch (2014, 58) do not identify the Fourth Industrial Revolution with new technologies, but with novel combinations of the available technology. 'The revolution is not necessarily

the technical realization but the new horizon of business models, services, and individualized products.' The primary content of Industry 4.0 is formed by a combination of 'smart technology', its integration and innovative way of its usage. All this combined forms a smart factory of the future and unlocks the underlying value of Industry 4.0.

Since the first appearance of Industry 4.0 vision at Hannover Messe in 2011 (GTAI, 2011) there have been countless polemics debating whether we are really on the brink of the industrial revolution, or whether we are witnessing another technological bubble fuelled by inflated expectations of business forums and government initiatives. 'Part of the problem in today's world of highly active technology and social media is that it's sometimes hard to distinguish the hype from what's actually happening on the ground in manufacturing'. (Tate, 2015) We can see that the conferences surrounding Industry 4.0 are no longer unilaterally positive, and sceptical voices are beginning to emerge.

KPMG's (2017, 5) recent report points in a similar direction: 'Manufacturing executives hear that i4.0 will be revolutionary. And nobody wants to be left blind in the race to develop the factory of the future. Yet, our discussions suggest a growing gap between executive ambition and transformative action.' What we detect here is the difference between real application of disruptive ideas of Industry 4.0 and their mere declaration.

We believe that one of the causes of this phenomenon can be traced to an unfortunate exploitation of Industry 4.0 concept in marketing communications and to its excessive use in press releases. Nevertheless, marketers and public relations representatives are hardly the ones to be blamed as they are merely reflecting audience's (stock market investors; boards of directors) interest in a most recent technology buzzword. 'Every vendor marketing manager ... now seems eager to jump on the latest industry bandwagon in a desperate effort to position their company's offerings as 'ahead of the game'.' (Tate, 2015)

In a bright contrast to these debates we can hear the biggest consulting groups proclaiming that Industry 4.0 will flourish, attract billions in investment and exemplify the inevitable way for manufacturing enterprises that do not wish to perish. For instance Gartner (2017) suggests that IoT market will be worth almost US\$ 3.7 trillion by 2020.

The aforementioned overly hyped expectations could be viewed as a simple by-product associated with turbulent early years of all major revolutions. Nonetheless, our current research indicates one occurrence common to all previous discussions – the inability to identify what is and what is not Industry 4.0, and the associated helplessness in identifying its true value.

In conclusion, based on a wide range of theoretical perspectives, outcomes of expert studies and analyzes of top consultancy firms, we infer that senior management currently has very unclear ideas and exaggerated expectations of the content and benefits of the Industry 4.0 Concept.

3. IMPLICATIONS AND RESULTS

3.1 On the Road to Industry 4.0 Measurability

Despite the desire to adopt the Industry 4.0 Concept, executives are often unaware of what specific steps to take towards the 4.0 implementation. In order to manage business processes towards the successful implementation of Industry 4.0 principles, we must be able to measure the process of adaptation itself. In other words, to govern the adaptation process it is necessary to have more sophisticated instruments than the ones the concept already contains. In this part of the study we will present the necessary requirements for the future determination of these instruments.

Together with Gartner's earlier prediction we should also examine different materials, which this advisory group releases. While we can find that the key Industry 4.0 constituents (Intelligent Things, Digital Technology Platforms or Big Data) are recurrently appearing in their lists of 'Strategic Technology Trends' (Gartner, 2015, 2016, 2017), their other report 'Hype Cycle for Emerging Technologies' (Gartner, 2017) also places several technologies associated with Industry 4.0 near the 'peak of inflated expectations'. While these analyses suggest their future impact, they likewise tell us about the level of our expectations that we associate with new technologies.

Regular visitors to Hannover Messe start to note that they miss a major change from last year's, or even from 2013 presentations. What is omnipresent though is the 'widespread positive expectation amongst the Industry leaders, partially influenced by aggressive marketing of product/service vendors' (Krishna, 2016). It has been five years since the Industry 4.0 concept was introduced, but we can still see scholarly journals occupied with the same topic without the prospect of change. An aptly titled study 'Industry 4.0: Hope, hype or revolution?' (Bassi, 2017) deals with similar thoughts in relation to laser processing and its possible role in new industrial revolution.

In a recent article 'This Is Not the Fourth Industrial Revolution' E. Garbee (2016) casts doubt on the revolutionary potential of Industry 4.0. 'The [2016] World Economic Forum spent the entire summit doing its best to make the case that this coming revolution is somehow more new, more different, and more threatening than any we have previously experienced. But its justifications are the same as they have always been and in fact are simply characteristics of technological revolutions in general. ... In fact, the phrase the fourth Industrial Revolution has been around for more than 75 years.' We believe that not only our dialogue concerning Industry 4.0, but the concept itself lacks one crucial element that would put an end to similar speculations that tend to present Industry 4.0 as a meaningless phrase.

On the basis of mixed methods research, we claim that what is missing in Industry 4.0 discourse is a set of basic referential indicators, i.e. key benchmarks. By 'key benchmarks' we mean criteria and comparative indicators of Industry 4.0 Concept. Their role is to provide us with tools to assess the level of company's engagement in Industry 4.0 Concept as well as to measure companies' performance using a set of specific indicators. Ultimately, we are setting these key benchmarks to compare subjects of Industry 4.0 with one another through the means of given metric of performance.

Together with that, a set of benchmarks as such would allow us to monitor the degree of implementation of essential Industry 4.0 identifiers. To summarize, we do not need another Industry 4.0 definition, what is required is a set of Key Industry 4.0 Benchmarks.

3.2 Progressive Trend Towards Measurability of Industry 4.0

In a 2016 report 'From buzzword to value creation' consulting firm McKinsey & Company advocates an identical need. McKinsey (2016) stresses that it is creating value that is key – not focusing on the technologies themselves. While the report is not clear of profound statements as 'digital has the potential to profoundly reshape the way industrial companies interact with and serve their customers', we can see its shift of focus towards more practical questions such as 'what does digital bring in terms of performance jump across functions?' By the end of the report, authors admit that at the moment companies mostly focus on compelling opportunities that Industry 4.0 might bring to their businesses, rather than on a question whether they are ready for the upcoming revolution.

In response to this discrepancy McKinsey (2016) introduced their own 'MGI's Industry Digitisation Index that measures the extent of digitisation ... of the European economy'. While the extent of economy digitization does not equal to the level of Industry 4.0 implementation (or adoption), the quoted report anticipates a major turn in discussions regarding Industry 4.0. Similar inclination - the effort to bring distinctive features that would allow measurability and further exact analyses of the Industry 4.0 Concept - can be seen elsewhere.

In March 2017 ARC Advisory Group published an article 'Criteria for Industry 4.0 Products' (Wanke, 2017) that seeks to find constituents (general criteria) for identifying the Industry 4.0 products. Similar studies reflect an issue mentioned at the very beginning: the uncertainty how to precisely define or differentiate what is and what is not Industry 4.0. It is important to note that the terminological fuzziness and a non-existent generally accepted definition has implications that go far beyond academic sphere. Most notably, 'companies are struggling when it comes to identifying and implementing Industrie 4.0 scenarios.' (Hermann et al., 2016, 12)

During 2011-2015, we have mostly seen efforts to either popularize Industry 4.0, or to draw attention to its importance. However from 2016 onwards, we can observe a partial, albeit very slow shift of attention. We adjudge that 2018 will be a year of concretizing given Industry 4.0 vision into a form that offers

measurability of the degree of implementation. To conclude, we call this trend the Tendency towards Measurability and Identification of Key Benchmarks of Industry 4.0.

At the moment, there are no reports that would show the level of Industry 4.0 integration. Recent surveys are limited to responding on a question 'Is Industry 4.0 a topic of discussion at your company?' (Hannover Messe, 2015, 3) While its positive response might have brought something new to discussion in 2015, in a present time we need to ask different questions, which will provide us with exact answers about the actual use and benefits of Industry 4.0.

4. EVALUATIONS OF EXISTING INDICATORS, PRINCIPLES AND DRIVERS OF INDUSTRY 4.0 CONCEPT

To be able to ask these questions, we must first define what could be considered a practice of Industry 4.0. In order to do that, we need a set of reference indicators, i.e. determinants of companies' real involvement in Industry 4.0. Such knowledge will also enable us to differentiate between marketing fog and realistic expectations.

4.1 Industry 4.0 Performance Index

As an ideal way to assess the advantage that implementation of Industry 4.0 principles gives to individual businesses appears to be their fair market valuation, respectively stock market development of selected firms. An investment Swiss bank Vontobel (2017) recently introduced 'Industry 4.0 Performance Index', which 'tracks the performance of companies that generate significant revenues in Industry 4.0 segments: automation – robotics – sensors – software and data services– mechanical engineering'. It offers us to compare the development of this index over time with other, more general manufacturing indexes, e. g. The Purchasing Managers Index (PMI) that indicates the economic health of the manufacturing sector or The ISM Manufacturing Index (ISM) based on surveys of more than 300 manufacturing firms. This comparison, however, carries two major problems. The more general one depends on the fact that it is not possible to objectively determine whether it was the adoption of the principles of Industry 4.0 which has contributed to the better performance of the selected companies. The second one is associated with a particular way the index was constructed.

Rules for selection of index components are based on the following four criteria: high entry barriers – product appeal and market growth – internationality of business– quality of management. This method is not exact in a way that it uses professional estimation heuristics, as it is the 'index advisor picks the 20 most promising companies ... based on these criteria' (Vontobel, 2017). While this might be the ideal solution for investors who are not deeply concerned about Industry 4.0 determinants, these criteria cannot form a design of referential Industry 4.0 indicators as we have previously defined it – to be suitable to measure the degree of implementation.

We believe that a given performance index still presents a valuable guide, however, it is necessary to keep in mind the limitations that this assessment brings with it, concretely a partly-voluntary process of choosing its index members. The given index is one of the possible indicators, but it is necessary to count on the above mentioned reservations as its shortcomings.

4.2 Design Principles for Enterprises Based on Industry 4.0 Concept

Another attempt to come up with a comprehensive definition together with identifying key Industry 4.0 elements was conducted by Hermann, Pentek and Otto (2015). Based on a quantitative text analysis and a qualitative literature review they formulated four key components of Industry 4.0: Cyber-Physical Systems, Internet of Things, Smart Factory and Internet of Services.

Authors (Hermann, Pentek, Otto, 2015, 3932) of the mentioned study consecutively derived four design principles 'guiding practitioners and scientists on "how to do" Industrie 4.0: interconnection, information transparency, decentralized decisions and technical assistance'.

Despite the contribution these authors bring to identify the indicators of the Industry 4.0 Concept, the outcomes of their research – Industry 4.0 Design Principles – do not serve as the means for measurement

of either 1) the level of company's involvement in Industry 4.0 or of 2) the added benefits that the concept gives to its users.

4.3 Drivers and Challenges of Industry 4.0 Concept

Acatech (2016), the German Academy of Science and Engineering, also recognizes the need for realistic conception that would monitor the current performance of Industry 4.0. Its report 'Options for the Future and Recommendations for Manufacturing Research' firstly identified existing country-specific parameters, drivers and challenges in the context of international Industry 4.0 domain. 'Following the aggregation of these drivers and challenges into thematic areas, some areas in turn emerged as global drivers and global challenges to the implementation of Industrie 4.0.' (Acatech, 2016)

- Drivers: sustainability, user-friendliness, collaboration.
- Challenges: standards, migration and interoperability, business models, industry 4.0 brand.

The broad foundations of Industry 4.0 Concept together with its geographically changing focus are also reflected in the described drivers and challenges.

Even though the identified global drivers represent another viable set of Industry 4.0 indicators, we have the same reservations towards them as to the 'design principles' (Hermann, Pentek, Otto, 2015) mentioned above. First of all, we claim that the resulting indicators must be provided in a form that allows for their successful measurement. Secondly, they must be given in a set of benchmarks that are able to provide exact and accurate information of the above described factors (level of implementation, overall benefits).

The results presented in this subchapter are, however, beneficial as a study of key Industry 4.0 Indicators, on the basis of which any future benchmarks can be determined. In order to further develop Industry 4.0 Concept, it is not necessary to create additional indexes, neither to propose new principles nor to identify new drivers. Based on the evaluation of currently available indicators, we come to the conclusion that we should focus our future research on the design of the coherent system of key benchmarks that will demonstrate its usefulness for business executives by allowing them to measure the specific benefits, which Fourth Industrial Revolution brings to their field.

CONCLUSIONS

The study contributes to the ongoing discussion centring on Industry 4.0 within both academic and (more importantly) business' community. We have identified three major elements that are associated with management's unclear or exaggerated expectations about Industry 4.0 Concept. These factors are: 1) the unclear theoretical basis, 2) the broad practical focus of the concept itself and ultimately also 3) the excessively misuse, exploitation and overly general application of the given term by marketers and consulting firms.

We have showed that the 'hype or revolution' arguments present a continuous element in Industry 4.0 discussions. The result of this confusion is often either the rejection or questioning of the revolutionary aspect of Industry 4.0 and its overall benefits. The underlying cause of this situation is the inability to realistically measure the level of implementation of the Industry 4.0 principles and consequently to compare the individual subjects from both theoretical (academic) and practical (corporate) perspectives. Based on our research, we have discovered that one of the main reasons for that lies in indetermination of generally accepted Key Benchmarks of Industry 4.0. Because of that, there are currently limited ways or criteria to differentiate the degree of companies' involvement in the Industry 4.0. Consecutively, we struggle with monitoring whether the integration of Industry 4.0 principles brings a competitive advantage to its participants.

The secondary consequence of this disarrayed state, in which Industry 4.0 is currently found, is the inability to effectively manage business processes towards gaining market benefits, savings and, ultimately, increasing business profits.

It is only when we identify the main characteristics (relevant factors) of the Industry 4.0, when we can determine the extent of adaptation (adoption of 4.0 principles) of individual enterprises. In order to successfully manage business processes in the direction of implementation of 4.0 principles, executives

must be able to measure the process of adaptation itself. We believe that new standards are needed in order to take discussions surrounding Industry 4.0 to a more exact level. These relevant factors and standards will be called the Determinants of Industry 4.0 Adoption.

Based on this analysis, the primary objective which this study accomplished was to establish a theoretical basis for future design of Key Industry 4.0 Benchmarks. Such key referential indicators (benchmarks) will provide the management (but also the professional public) with the opportunity to monitor the implementation of the Industry 4.0 Concept and to measure its added benefits to businesses.

Acknowledgement: Studie vznikla za podpory grantového systému ZČU v rámci projektu SGS-2018-005 Vědecký rozum a lidské hodnoty: kritická reflexe.

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