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Enablers and inhibitors of Industry 4.0: results from a survey of industrial companies in Norway

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Abstract

Since 2011 when it was announced, Industry 4.0 has inspired a series of governmental and private programs worldwide. Nevertheless, it is an emerging research field and the academia calls for further explorative research, including on the enablers and inhibitors of Industry 4.0 implementation at national level. This paper addresses this topic based on a cross-sectional analysis of data collected through a two-step survey of 49 companies in Norway, 13 suppliers to the Oil and Gas industry and 36 from different manufacturing industries. The findings contribute primarily to the Training and Continuing Professional Development priority area in Kagermann et al. (2013).

Keywords: Industry 4.0; Operations management; Survey

1. Introduction

Industry 4.0 is Germany's reform program for a cutting-edge and highly competitive manufacturing industry [1] - a collaboration between industry, academia and government [2,3]. The program is highly ambitious, simultaneously pursuing goals, such as vast productivity and revenue gains, better quality, better customer service, and higher safety [4]. Industry 4.0 was announced at the Hannover Fair in 2011 [5] and it is metaphorically known as the '4th industrial revolution' [3]. While the first three 'revolutions' arose via mechanization by help of hydro- and steam-power, mass-production by help of electrical power, and automation by help of electronics and IT [5], Industry 4.0 is based on the integration of Internet of Things (IoT) and Cyber-Physical Systems (CPS) into the manufacturing environment [6]. The vision of Industry 4.0 is that industrial businesses will be connected in highly integrated global networks and their machinery, factories, and warehouses will form CPSs, which communicate with each other and humans in real time. Moreover, the machinery will be embedded with artificial intelligence, being capable to adapt to different circumstances [4].

Chronologically, Industry 4.0 was preceded by USA's program *Advanced Manufacturing Partnership* from 2011, and succeeded by France's *The New Industrial France* (2013), UK's *Future of Manufacturing* (2013), European Commission's *Factories of the Future* (2014), South Korea's *Innovation in Manufacturing 3.0* (2014), China's *Made in China 202*5 and *Internet Plus* (2015), Japan's *Super Smart Society* (2015), and by Singapore's *Research, Innovation and Enterprise 2020 Plan* (2016) [6]. The Norwegian government also announced a strategy for a 'greener, smarter and more innovative' industry in 2017, which is commonly known as 'Digitalization' and is mainly inspired by Industry 4.0 [7].

Even though the number of research publications related to Industry 4.0 appears to have grown exponentially in recent years, there are still many insufficiently explored avenues for future research. In line with Liao et al. two of these avenues are studies of Industry 4.0-inspired national programs and the enabling features of Industry 4.0 [6]. In 2017, Norway achieved the second highest Digital Economy and Society Index in Europe after Denmark, scoring very well with respect to

broadband connectivity, internet use, and digital public services [8]. However, does this mean that Norwegian industrial businesses are far ahead in terms of Industry 4.0 implementation? For instance, the percentage of Science, Technology, Engineering and Mathematics graduates is still below EU average [8]. To the authors' knowledge, since March 31th 2017 when Norway's Digitalization strategy was announced, only one survey was presented in journal/conference publications. Sannes and Andersen present the results of this survey that had the aim of revealing the `maturity` of large firms in Norway in terms of digitalization, compared to Sweden, the rest of Europe, North America and Asia [9]. Based on 372 answers from Chief Information officers (CIOs), this article claims that the digitalization maturity of firms in Norway and Sweden appears to be lower than that of the firms from the other regions. However, the data for this study was collected in 2015, when the domestic social debate about digitalization was very limited compared to the period after the Norwegian government announced the Digitalization strategy. Moreover, the study does not make any distinction between industrial firms and other type of firms. Thus, the authors regarded the possibility of studying the digitalization maturity of industrial firms in Norway, two years after Sannes and Andersen's study, as an extremely intriguing research opportunity. This article has a focus on the *Training and Continuing Professional Development (CPD)* action area in the Industry 4.0 Working Group's recommendations [1].

2. Literature study

Industry 4.0 might significantly transform worker's skill-profiles as a result of two trends [1]. First, manufacturing processes will require tasks that were traditionally carried out by other departments, e.g. decision-taking, coordination, control, and support service. Second, workers will have to manage the interactions between virtual and real machines, and production control systems. The *Training and CPD* is one of the 8 action areas in the Industry 4.0 Working Group's final report, 'Recommendations for implementing the strategic initiative Industrie 4.0' [1]. Furthermore, this area includes 6 recommended sub-actions. The 1st sub-action is the development of training and CPD strategies, including for promoting the mobility between vocational training, academic training and CPD courses, and for the acknowledgement of useful skills that employees possess outside their specific expertise area. The 2nd sub-action is the establishment of 'best practice networks' that should prepare case studies and support the knowledge transfer between the network actors. The 3rd sub-action is the development of new teaching methods for the workplace, such as e-learning techniques and systems, which are tailored to the individual worker. The 4th sub-action is the promotion of work organization approaches for Industry 4.0 that are based on research and the practical application of research e.g., (i) CPD for all ages that addresses the importance of health, physical activity and lifestyle in ensuring a lengthy working life, and (ii) the effectiveness of in-house versus out-of-house learning, and of general versus vocational education. Training partnerships between businesses and higher education institutions are expected to become highly important. The 5th sub-action is the promotion of system-thinking approaches and of increased cooperation between all disciplines (e.g. manufacturing engineering, automation engineering, IT and law). The last sub-action is the promotion of IT-based modelling of technological systems, including the modelling of the interaction between the real and digital worlds.

Furthermore, in 2015, Fraunhofer IPA Institute, part of the Industry 4.0-Working Group, conducted a survey of 195 German firms on the topic of Industry 4.0 opportunities and challenges [10]. For instance, the study shows that most of the survey companies regarded high investment costs, insufficient IT security, and the rising requirement for training of employees due to insufficient digitalization skills, as the biggest challenges when implementing Industry 4.0. Moreover, even though the networking technologies are highly relevant for Industry 4.0, the networking of people (as part of different types of professional networks) and the interdisciplinary collaboration across company boundaries appear to be increasingly important enablers of successful implementation of complex Industry 4.0 applications. There should be an intensive cooperation between companies and regional networks, scientific institutions, and business associations that should facilitate the exchange of best practice examples and provide legal aid. However, the study shows that for medium-sized companies there is still untapped potential in the cooperation with scientific institutions. Furthermore, the survey companies that had successfully begun implementing Industry 4.0, highlighted the importance of accurate and reliable data that should be collected and analyzed in real time and its value should be fully exploited, i.e. Big Data [10]. Nowadays, due to significantly higher storage and processing capacity, larger data types such as images, sounds and video files can be collected and used for the optimization of operations e.g. for predictive maintenance [11]. In a similar survey as Faunhoffer IPA`s study, the department of Business Information Systems at two German universities, demonstrated that a high utilization of idle data and a high level of automation (particularly in combination with computer integrated manufacturing) positively influences the use of Industry 4.0 [11]. However, the influence of a high level of automation is far less significant than a high utilization of idle data. These two surveys [10,11] together with Kagermann's Industry 4.0 recommendations are the starting point for the survey questions presented in Section 4. Further details are provided in (tow of) the authors' earlier paper [12].

3. Methodology

This paper addresses this topic based on a cross-sectional analysis of data collected through a two-step survey of 49 firms in Norway, 13 suppliers to the Oil and Gas industry (hereafter named *OG*) and 36 from different manufacturing industries (hereafter named *MI*). In addition, a workshop was conducted after each survey to discuss and triangulate the findings with the respondents [13]. The purpose of the survey was to identify how advanced the firms were with regards to Industry 4.0 implementation. The survey and workshops were carried out during 2017.

In the past 50 years, the Oil & Gas industry in Norway has benefited of generous profit margins, being known as a driving

force for applying novel technologies and business strategies [7]. Thus, this industry was considered a good choice for the first survey. The selected firms belonged to the largest cluster of suppliers to the Oil & Gas industry in Norway. However, the authors regarded the possibility of comparing the results from this first survey with other industries in Norway as an intriguing opportunity. Thus, the second survey was conducted and to this end, firms from Østfold county were selected, as it is one of the most industrialized in Norway [7]. Initially, the OG-survey was sent to 15 firms and the MI to 116 firms, and the response rate was 87% and 35%, respectively. The response rate for the latter survey was rather low, yet close to the average response rate (35.7%) for surveys sent to organizations by external researchers [14].

65% of OG-firms and 60% of MI-firms were large companies (over 50 employees, by Norwegian standard), while the rest were small and medium sized firms. The main activities of the OG-firms included technical consultancy, Research & Development, manufacturing of equipment, manufacturing of metals and metal products, service/repair/installation of equipment, IT/financial/media services, and transport & logistics. The MI-firms manufactured products such as electronic components, food & beverages, pharmaceutical & chemical products, clothes and other textiles, various types of plastic and other non-metallic products (e.g. to the construction industry), and various types of machines. There were used business codes from the Norwegian government's central register, Brønnøysund.

They survey was prepared in Questback and a link to this online platform was sent to each respondent group by e-mail. It was directed to managers (particularly CEOs) who should have the best knowledge about strategy development in their firms. Thus, 69% of the OG-respondents and 89% of the MIs were managers. The Likert scale was applied, with three alternatives: *'no or low importance/relevance'*, *'medium importance/relevance'* and *'high importance/relevance'*. The collected data was analyzed through frequency analyzes. Furthermore, the survey behind this study is part of a larger survey, which addresses several Industry 4.0 related topics. In line with the scope of this paper, only those questions that are relevant for training and CPD will be presented.

4. Enablers and inhibitors of Industry 4.0

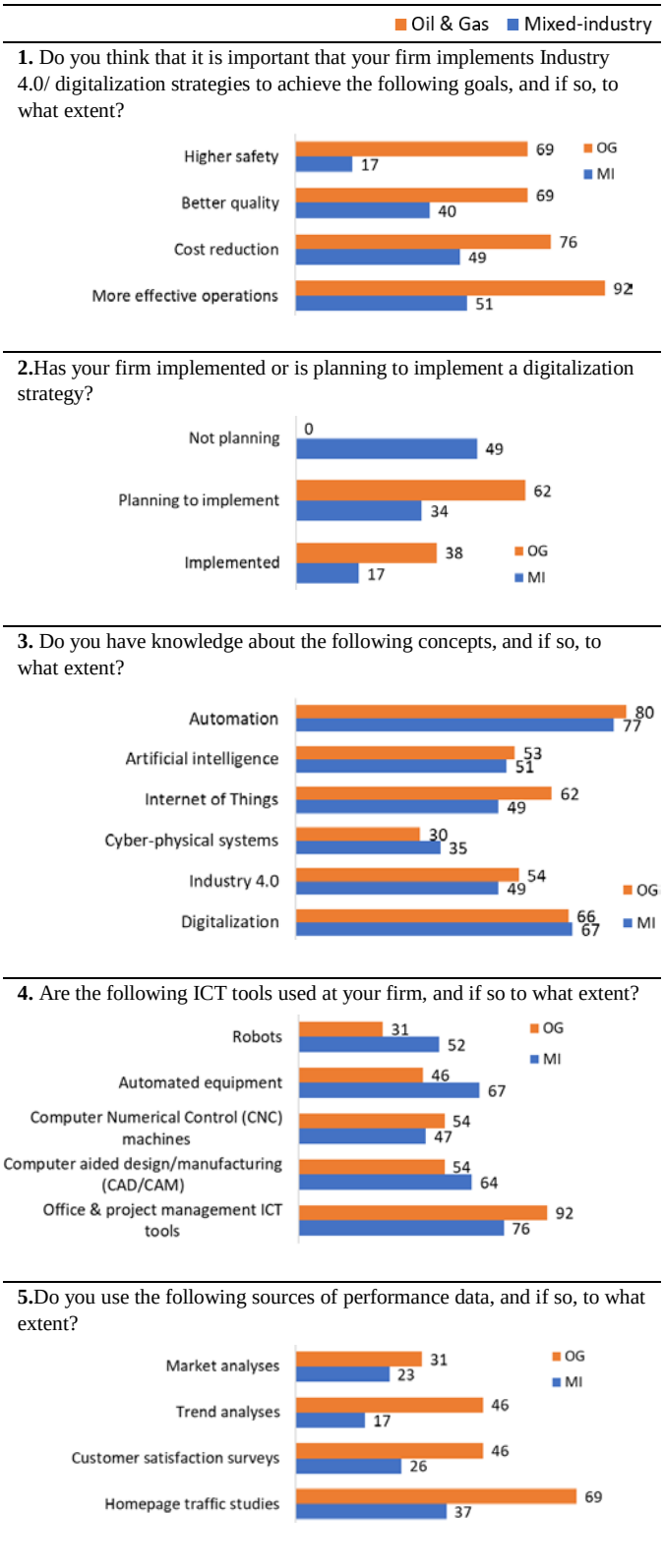
This section presents and discusses the results (Table 1 and Table 2) in the light of earlier research literature. The average numbers are used as a basis for a general discussion about the differences between the OG and MI group.

As Table 1 shows, most of the respondents in the OG-survey evaluated that by implementing Industry 4.0 and digitalization strategies, their firms can achieve on the 1st place, more effective operations (92%), on the 2nd, cost savings (76%), and on the 3rd, better quality (69%). During the post-survey workshop, OG-respondents explained that the possibility of significantly reducing costs through digitalization is increasingly appealing in a period of decreasing profit margins within the Norwegian Oil & Gas industry. The mixed-industry survey rendered similar results, yet with considerably lower scores. Furthermore, the OG-respondents answered that their firms had either implemented (and documented) a digitalization strategy (38%) or they were planning to do so (62%). In comparison, less than half (17%) of the MI-respondents revealed that their firms had implemented a digitalization strategy and about one out of three (34%) answered that their firms had not considered to do so. However, even though all the OG-respondents declared that their firms had implemented or were planning to implement digitalization strategies, a rather high proportion of them revealed that they had *little knowledge* of the concepts 'digitalization' (34%), 'Internet of Things' (38%), 'Industry 4.0' (46%), 'artificial intelligence' (47%), and CPS (70%). In comparison, slightly fewer MI-respondents revealed that they had little knowledge about 'digitalization' (33%) and CPS (65%), and slightly more that they had little knowledge about 'Internet of Things' (51%), 'Industry 4.0' (51%) and 'artificial intelligence' (49%). Conversely, significantly fewer had little knowledge about 'automation', an apparently more established concept. Moreover, it is worthwhile to mention that most of the OG- and MI-respondents have either Master`s (46% OGs and 31% MIs), Bachelor`s (31% OGs and 43% MIs), or PhD (8% OGs and 3% MIs) degrees.

In the light of Sannes and Andersen's survey from 2015 (see Section 1), where in average, the respondents answered that their firms' turnovers will be only to a small extent affected by digitalization (less than the respondents from other parts of the world), these results suggest that the attitude in Norwegian firms might be rapidly changing. The OG-firms had either implemented a digitalization strategy or they were planning to do so. If digitalization is perceived as a threat to the firm's economy, it will trigger relevant investments much more easily [15]. Sannes and Andresen's show that the most profitable firms in each sector in the survey considered digitalization as a significant threat to their firms' turnovers. Thus, for the OG firms, which have been experiencing decreasing profit margins in recent years, this survey's results might indicate that their managers have taken a significant step towards reversing the trend, and towards increasingly profitable operations in the future. Nevertheless, one third of the MI-firms have not considered implementing digitalization strategies and even though all the OG-respondents came from firms that had or were planning to implement digitalization strategies, and had higher education, their knowledge about what digitalization implies seems to be rather superficial.

Office & project management ICT tools are the top most used ICT tools by both the OG-respondents and the MIs. While, the MI-respondents also scored automated equipment and Computer aided design/manufacturing (CAD/CAM) tools and robots rather high, the OG-respondents scored the other ICT tool-examples relatively low. Furthermore, while the OG-group revealed that their firms exploit common sources of performance data relatively often (69% study their homepage traffic, 46% conduct customer satisfaction surveys, 46% trend analyses, and 31% market analyses), the MI-group might have an untapped potential in this area (37%, 26%, 17% and 23%, respectively). An increasing utilization of ICT tools is an unsurprising consequence of digitalization. Nonetheless, digitalization is not about collecting as much as possible technology; resulting data sets should be analyzed (whenever

Table 1. Survey questions and answers (% *highly important/relevant*)

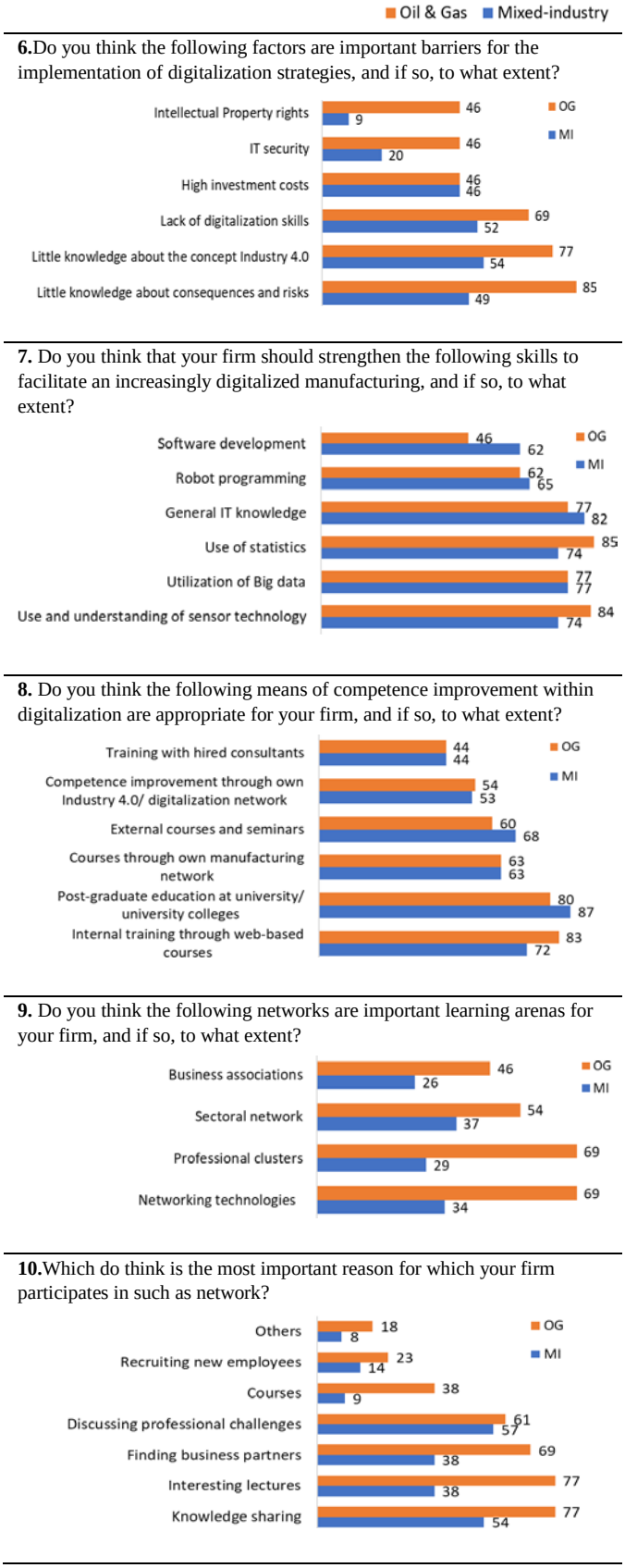


possible, in real-time by machines), to support decision making. However, the increasing accessibility of cloud storage, rental computing power, and ubiquitous network connectivity over the past years, has enabled data analyses that were previously impossible [4, 11]. Both OG and MI-firms seem to have an untapped potential either in terms of increased use of new ICT technology (especially OGs) or increased data utilization (especially MIs).

After the first set of relatively generic questions, the respondents were specifically asked about potential inhibitors of the implementation of digitalization strategies (see Table 2). The inhibitors that were ranked highest by both groups were: 'little knowledge about consequences and risks', 'little knowledge about the concept Industry 4.0', 'lack of digitalization skills' and 'high investment costs'. While a quite large proportion of the OG-group also evaluated "IT security" and "Intellectual Property rights" as important inhibitors (46% of the respondents for both), comparatively few MI-respondents regarded these issues as significant barriers (20% and 9%, respectively). Moreover, during the post-survey workshop, OG-respondents explained that in recent years, ca. 50000 people lost their jobs in the Oil & Gas sector in Norway; hence the industry was losing a high number of professionals, including with digitalization skills. As the profit margins were decreasing, their firms had a high focus on day-to-day operation and maintenance management, and the respondents felt that they were not sufficiently incentivized to dedicate themselves to digitalization. In comparison, the explanations provided by MI-respondents during the workshop were concentrated around personnel's competence, highlighting the lack of knowledge about Industry 4.0 and the lack of a good understanding of how to implement digitalization as central barriers. In addition, the MI-group pinpointed that their firms had little collaboration with education and research institutions and they were also lacking relevant industrial clusters where they could learn from others in the field. When asked what skills they considered that their firms should strengthen to facilitate a smoother digitalization, a significantly large part of both respondent groups rated high 'use and understanding of sensor technology', and 'utilization of Big data' (77% of both OGs and MIs). However, the OG-group rated highest 'use of statistics' (85%), whereas the MI-group rated highest 'general IT knowledge' (82%). 'Robot programming' and 'software development' got relatively lower scores.

The answers to the questions specifically related to digitalization inhibitors and the discussions during the workshops, basically confirmed the previous results of this survey. Both OG and MI respondents regarded the insufficient digitalization competency of the personnel as a central digitalization inhibitor for their firms and ranked high the necessity to strengthen both general IT skills and more complex data-analysis skills. Perhaps unsurprisingly, the respondents also raked the necessity of high investments as a significant inhibitor. The lack of appropriate skills, insufficient incentives from top management and the lack of resources have been already highlighted as common barriers to digital transformation in the existing literature (e.g. [9] and [4]). However, with respect to capital requirements, even though the necessary infrastructure for a smooth operation of several integrated systems (e.g. in the horizontal digital integration through value networks), may indeed require serious investments, most benefits can be achieved from less expensive solutions, such as the increasingly accessible RFID and NFC sensor systems for smart logistics. Thus, Industry 4.0 is

Table 2. Survey questions & answers (contin.) (% *highly important/relevant*)



considered as equally relevant for large and smaller firms [4].

The respondents were also asked about potential enablers of effective implementation of digitalization strategies at their firms (see Table 2). First, they were asked about optimal means of competence improvement within digitalization. While the OG-group scored 'internal training through web-based courses' highest and 'post-graduate education at university/ university colleges' second highest, the MI-group ranked the later mean on the 1st place and the first one on the second. Both groups also ranked high 'courses via own manufacturing network', 'external courses and seminars' and 'competence improvement through own digitalization network'; yet the MI-respondents scored external courses higher than the OGs. Both groups ranked lowest 'training with hired consultants', with the same scores. Furthermore, when asked about networks as learning arenas for their firms, a rather large part of the OG-group evaluated all the network examples as important learning arenas (69% of the OGs evaluated 'clusters' as important, 54% 'sectoral networks', and 46% 'business associations'). Conversely, the MI-group scored these networks significantly lower. Finally, when the OG-respondents were asked about reasons for being a member of the above-mentioned networks, a significant proportion of the OG-respondents ranked high 'knowledge sharing' (77%), 'interesting lectures' (77%), 'finding business partners' (69%) and 'discussing professional challenges' (61%). The MI-group only ranked high 'knowledge sharing' and 'discussing professional challenges', yet with lower scores than the OGs. 'Courses' and 'recruiting new employees' received low scores from both groups.

As mentioned in Section 2, the Industry 4.0 Working Group called for research on the effectiveness of in-house versus out-of-house learning and of general versus vocational education [1]. This survey's results suggest that the MI-firms in Norway might prefer the out-of-house academic education, whereas the OG-employees might find themselves more at ease with in-house web-based courses. E-learning techniques and systems that are tailored to the individual employee are namely among the Working Group's recommended potential facilitators of smooth Industry 4.0 implementation and are most certainly topics that merit further investigations. Furthermore, establishing 'best practice networks' is the 2nd training & CPD sub-action of the Working Group. While the OG-firms appear to be aligned with this prioritized sub-action, in average, significantly fewer MI-respondents regard being part of a network as a digitalization facilitator. However, interestingly, during the post-survey workshop, MI-respondents highlighted the lack of relevant industrial clusters where they could learn from others in the field, and an insufficient collaboration between their firms and academia as important digitalization inhibitors. Similar to other survey topics, this may suggest that the Norwegian firms are on an upward path in terms of their focus on digitalization, with businesses with traditionally more generous profit margins such as the Oil & Gas firms leading this trend.

5. Concluding remarks

In 2017, Norway achieved the second highest Digital Economy and Society Index in Europe after Denmark [8]. The authors regarded the opportunity of studying how advanced Norwegian industrial firms really are with respect to Industry 4.0 implementation as extremely intriguing. This paper addresses this topic based on a cross-sectional analysis of data

collected during 2017, through a two-step survey of 49 companies in Norway (13 suppliers to the Oil and Gas industry and 36 from different manufacturing industries). To the authors' knowledge, the survey presented in this paper is the first one on the topic of Industry 4.0 implementation maturity in industrial businesses in Norway, which has been presented in an academic publication, since March 31th 2017 when Norway's Industry 4.0-based strategy ('Digitalization') was announced.

In comparison with Sannes and Andersen's survey from 2015 [9], where the Norwegian firms evaluated that their firm's turnover will be only to a small extent affected by digitalization (while respondents from the most profitable firms from other parts of the world considered digital transformation as a significant threat), this survey indicates a rapid change of course. Norwegian firms appear to be on an upward path in terms of their focus on digitalization, with companies with traditionally more generous profit margins such as the Oil & Gas firms leading this trend. Nonetheless, even though all the OG-respondents came from firms that had or were planning to implement digitalization strategies, and had higher education, based on both the survey and post-survey workshop, their knowledge about what digitalization implies appears to be rather superficial. Both OG and MI-firms seem to have an untapped potential either in terms of increased use of new ICT technology or in terms of increased data utilization- an essential digitalization enabler [10, 11]. Both OG and MI respondents regarded the insufficient digitalization competency of the personnel as a central digitalization inhibitor for their firms and ranked high the necessity to strengthen both general IT skills and more complex data-analysis skills. Furthermore, as earlier described, the Industry 4.0 Working Group has called for research on the effectiveness of in-house versus out-of-house learning [1]. The survey-results in this study indicate that the MI-firms in Norway regard the out-of-house academic education as more effective than the in-house learning and as a central digitalization enabler, whereas the OG-employees prefer in-house e-courses. This is in line with the Industry 4.0 Working Group, which has namely singled out the e-learning techniques and systems that are tailored to the individual employee as potential enablers of smooth Industry 4.0 implementation and as innovation topics with a great potential. Finally, the OG-respondents also regarded participating in various types of business networks as important digitalization enablers for their firms. In comparison, the MI-respondents highlighted the lack of best practice networks for the digital transformation of their firms in Norway or nearby, as well as the need for closer collaboration between their firms and academia, as important digitalization inhibitors. Both respondent groups appeared to be aligned with the Working Group`s focus on 'best practice networks', which should prepare case studies and support the knowledge transfer between the network actors.

The authors claim that this study's findings contribute to the Training and Continuing Professional Development priority area in Kagermann et al. (2013). Moreover, this paper also addresses a call from the academia [6] for further explorative research on the enablers and inhibitors of Industry 4.0 implementation at national level. Furthermore, the findings should be particularly relevant for other industrial businesses in Norway that are not 'digital masters'. However, even though the findings were presented and discussed with the respondents during post-survey workshops, further methods should be applied to triangulate them. For instance, the survey could be repeated in order to study the progress made by the survey-firms.

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