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Development of Digitalization in Production Industry – Impact on Productivity, Management and Human Work

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Abstract

Digitalization is a process that started already years ago and shows increasing dynamics. Since latest the year 2011 – when the vision of Industry 4.0 was presented – digitalization dynamics increase also in production industry. Simultaneously, manifold and partially far reaching expectations on the digitalization's impact on productivity and its management as well as on employees and work design came up. To gain information on the current state of digitalization as well as the related experiences and expectations three studies have been conducted by ifaa in the years 2015, 2017 and 2019 in the German metal and electrical industry. Now integrated analyses of these studies and especially of some replicated questions have been conducted to recognize development tendencies and gain further knowledge on the digitalization's development. In this way, several development tendencies were found, and assumptions were derived for explaining them. These include expectations on productivity gain, importance of digitalization for selected fields of application, the use of lean methods and holistic approaches as well as the impact on employees, their number, and their flexibility.

Keywords: digitalization; productivity management; human factors; development tendencies

1. Digitalization in production industry

Digitalization receives increased attention since the term "Industry 4.0" was introduced in the year 2011. The term describes the vision of a digitalized industry. Thus, it labels the aim of a development which started already years before very slightly and became more and more dynamic and present. Since digitalization in industry affects holistically processes, products as well as business models it is also labeled as digital transformation. In consequence,

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manifold expectations came up simultaneously with the term “Industry 4.0” and led to very different and partially far reaching visions of the further development of production industry and their resulting future. These contain for example huge expectations on productivity and flexibility gain, support by artificial intelligence, human-robot-collaboration, smart watches and data glasses, changed qualification requirements and completely new job profiles, but also automized production and potential job losses. Thus, the digitalization’s impact on industry became subject of the national and international scientific discourse. Also, standardization took digitalization closer into account, started several initiatives, adjusted existing activities, and developed for example the “German Standardization Roadmap Industry 4.0” (version 4 published in the year 2020 [1]). Furthermore, the “Reference Architecture Model Industry 4.0” [3] was developed as well as guidelines like “Digital Transformation of Companies” [12].

Since production industry and especially the metal and electrical industry is an important branch of the German economy, enterprises within this branch have been queried several times on their current implementation of digitalization and their further expectations. Due to the time and the continuous industrial development between these queries, it can be assumed that earlier expectations meanwhile have been proved by reality and that these experiences lead to a higher precision of subsequent queried expectations respectively an increased predictive power of current results.

For recognizing development tendencies, gaining further knowledge on the digitalization’s development and concretizing future expectations on Industry 4.0 selected studies will be analyzed. This helps companies to benchmark their own activities and expectations and contributes to the general scientific discourse on digitalization in industry. Furthermore, the analyses results can support the development of measures for supporting companies within their own digital transformation.

2. Methodology

The results of three surveys are the basis for analyzing development tendencies of digitalization and its implementation in industry. The analyses are focused on the impact of digitalization on productivity, management, and human work. The surveys were conducted online in the German metal and electrical industry by using the software tool SosciSurvey in the years 2015, 2017 and 2019. They contained several questions which were asked repeatedly in two respectively three of these studies. These replicated questions results are subject of detailed comparisons and analyses for deriving development tendencies. Since the surveys have been conducted independently some people might have participated multiple times – a longitudinal analysis of those is neither intended nor possible.

2.1. Participants and Samples

Participants of all three surveys were specialists and managers of the German metal and electrical industry. Invitations for survey participation were distributed electronically by the employers' associations of the German metal an electrical industry, by other associations and by using press releases.

2.1.1. Sample 2015

Between June and July 2015 (9 weeks) in total 498 participants from the German metal and electrical industry answered the questions. Most participants are working in enterprises with 250 and more employees (55 %). They are occupied mainly in corporate management (45 %), personnel department (26 %) and production management (22 %) [4], [6].

2.1.2. Sample 2017

Between January and June 2017 (20 weeks) in total 74 participants from the German metal and electrical industry answered the questions. Most participants are working at enterprise locations with 250 and more employees (69 %). They are occupied mainly in corporate management (33 %) as well as personnel department, production management and industrial engineering (about 15 % each) [8], [13].

2.1.3. Sample 2019

Between May and August 2019 (16 weeks) in total 112 participants from the German metal and electrical industry answered the questions. Most participants are working in enterprises with 250 and more employees (94 %). They are occupied mainly in production management (25 %), corporate management (19 %), personnel department (19 %) or industrial engineering (16 %) [9], [10].

2.2. Questionnaire

The replicated and analyzed questions were part of different questionnaires which always focused many different aspects of digitalization respectively Industry 4.0 in the production industry. They were partly accompanied by questions on business models, industrial engineering, productivity management, productivity strategies, leadership, corporate culture, and other topics. Even if both expressions – *digitalization and Industry 4.0* – have been used, the surveys are comparable since Industry 4.0 describes digitalization in industry and all surveys took place in industry.

Estimations on productivity were recorded as percentages which had to be entered freely. All other questions had to be answered on three- or four-leveled Likert-scales which partly included the option *do not know answering this question*.

2.3. Statistical analysis

Analyses were conducted descriptively using SPSS and Excel. Freely entered estimations from different surveys are integrated into a single diagram and sorted ascending according to the forecast horizon. Results on Likert-scales from different surveys are sorted in descending order (newer to older results) either in bar charts or in column charts. The sequence of different items within the same question was ordered as appropriate for each analysis.

2.4. Limitations

Compared to the distribution of the size of enterprises in the German metal and electrical industry, larger enterprises are overrepresented within all samples (definition of small and medium enterprises according to the European Commission [2]). Consequently, all results represent rather the situation and expectations of larger enterprises than of the whole branch.

Even though invitations for survey participation were distributed in the same way for all surveys, the sample sizes are very different. Especially within the smaller samples the overrepresentation of larger companies is stronger.

Since the replicated questions were asked in the context of different other questions, the other questions might have influenced the participants answers. This influence is assumed to be small since all questions were asked in the general context of digitalization.

3. Impact on productivity

3.1. General Productivity Gain

General estimations on productivity gain due to digitalization have been queried in the years 2017 and 2019. Each time the estimations for the next three and eight years had to be indicated. The results are illustrated in Fig. 1 and show a steady increasing tendency of the estimations from 22 percent for the year 2020 up to 38 percent for the year 2027. Additionally, as it can be expected, the standard deviations increase with the forecast horizon in both studies.

This leads to the assumption that early expectations have been confirmed by good experiences, showed new potential for digitalization, and thus led to higher expectations. This can be confirmed by a comparable study in which companies with an above-average degree of digitization showed by an average of 24 percentage points higher satisfaction values for numerous corporate key figures (e. g. sales, turnover, number of ideas, new customers) [11].

In the current pandemic situation these estimations underline the potential of digitalization and show its potential for renewing and strengthen productivity and economic prosperity. Nevertheless, it cannot be evaluated if these estimations are currently reachable or if participants would give the same estimations despite of the current pandemic.

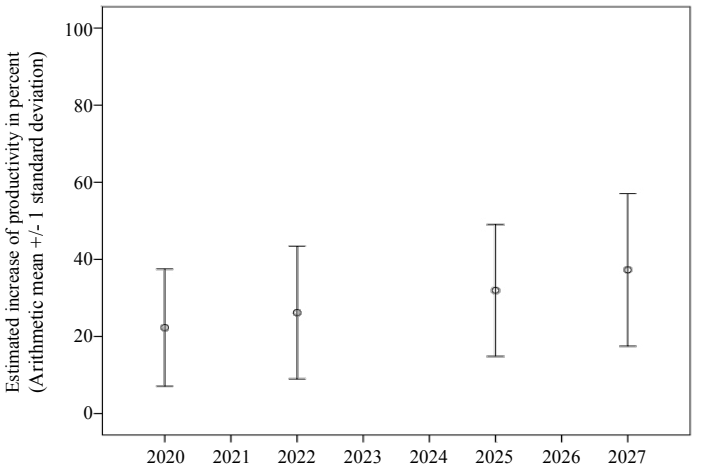

Fig. 1. How much productivity gain do you estimate due to digitization or the introduction of digital technologies in your company? (2017: n = 70-72 until the year 2020 respectively until 2025; 2019: n = 85-87 until the year 2022 respectively until 2027; [10]).

3.2. Importance by Field of Application

The importance of digitalization for selected fields of application in companies has been queried in the years 2015, 2017 and 2019. The results are illustrated in Fig. 2. Most of the respondents indicated a high or very high importance of digitalization for nearly all fields of application. Their percentage mostly increased with time. Combining *high* and v*ery high* as well as *low* and *very low* several developments become clear: For (a) *planning/controlling*, *supply chain management* and *quality management*, the importance increased steadily. For (b) *logistics*, *production area* and *storage* plateaus were reached. For (c) *development* and *administration*, the importance decreased from the year 2015 to the year 2017 and increased afterwards to a much higher level than originally. For (d) *assembly* and *maintenance/service*, the opposite was found: From the year 2015 to the year 2017 the importance increased and afterwards decreased but remained still on a higher level than originally.

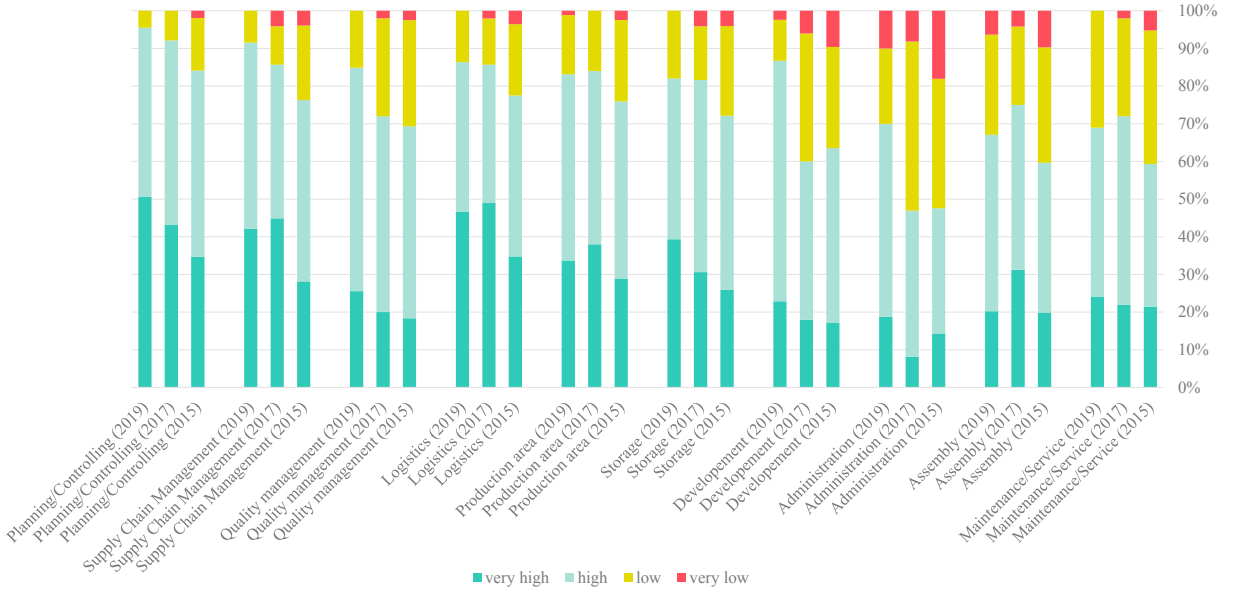

Fig. 2. How important do you estimate Industry 4.0/digitalization for different fields of application in your company? (2015: n = 349-370; 2017: n = 48-51; 2019: n = 79-89).

This leads to the following assumptions: For some fields of application (a) new opportunities have been found which probably are based on new technologies which require digitalization as their necessary basis (e. g. artificial intelligence). Furthermore, digitalization might be realizable easier or more successful in these fields than in others. In some fields of application (b) digitalization was introduced very early and most opportunities are/were already known und thus did not increase after reaching a plateau. In some fields of application (c) digitalization was introduced comparatively late and opportunities were also found later. This could also be explained by initial challenges which decreased expectations until the challenges were overcome. Finally, in some fields of application (d) the expectations were too high, or the opportunities are harder to reach than expected originally. This refers to fields of application with usually many manual tasks and manifold opportunities for supporting them digitally (e. g. described in Jeske and Lennings [5]) but also high requirements for work design.

4. Impact on management

4.1. Impact on Lean Methods

The impact of digitalization on management – especially on methods of lean management and lean production was queried in the years 2015 and 2019. The results are illustrated in Fig. 3. It is supposed that lean production and lean management describe comparable content when and since they are mentioned in the production industry. Combining *agree* and *strongly agree* as well as *disagree* and *strongly disagree* little changes become clear and show a uniform tendency. Already in the year 2015 the participants agreed with increasing percentages to the requirement of lean production for the introduction of digitalization as well as the current and future use of lean production. These percentages all have increased in the results of the year 2019 for lean management. The same strengthen tendency occurs for the rejection of the statement lean production/management would no longer be needed in digitalization.

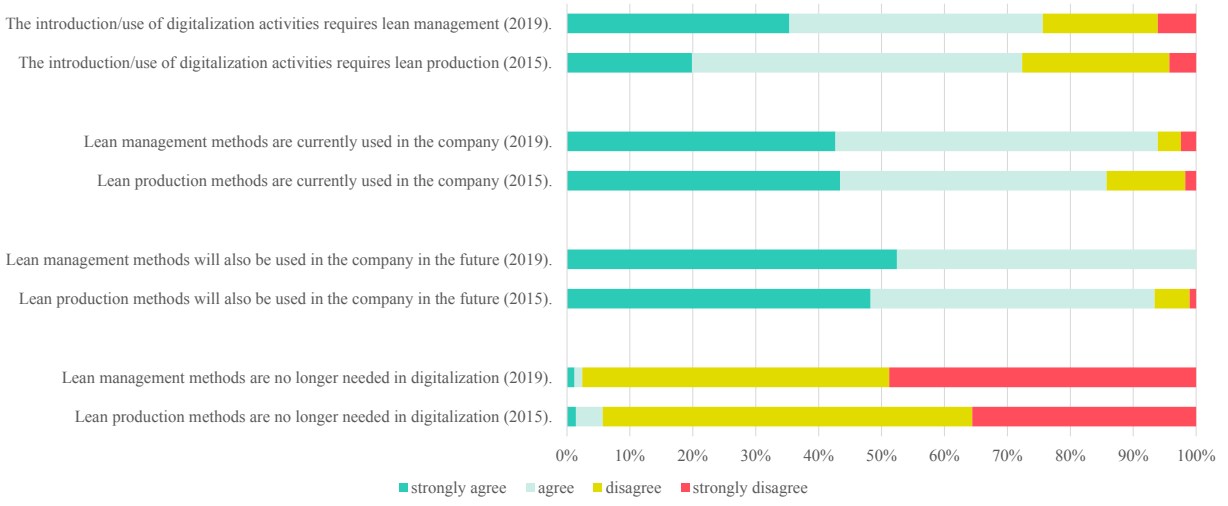

Fig. 3. How do you estimate the impact of Industry 4.0/digitalization on lean management/production methods? (2015: n = 273-288; 2019: n = 82).

It can be assumed that lean methods are well proven, their degree of usage will increase further, and they are indispensable for the digital transformation and future production respectively Industry 4.0.

Since larger enterprises use lean methods more frequently the increases may be influenced by the increased percentage of those enterprises between sample 2015 and sample 2019 – but that might affect the assumption only marginally.

4.2. Impact on Holistic Approaches

The impact of digitalization on holistic production/business systems was queried in the years 2015 and 2019. The results are illustrated in Fig. 4 – they are similar in both surveys. Combining *agree* and *strongly agree* as well as *disagree* and *strongly disagree* little changes become clear. The participants agreed a little more to introducing and using holistic production/business systems. Also, they rejected the statement those systems would no longer be needed in digitalization a little stronger.

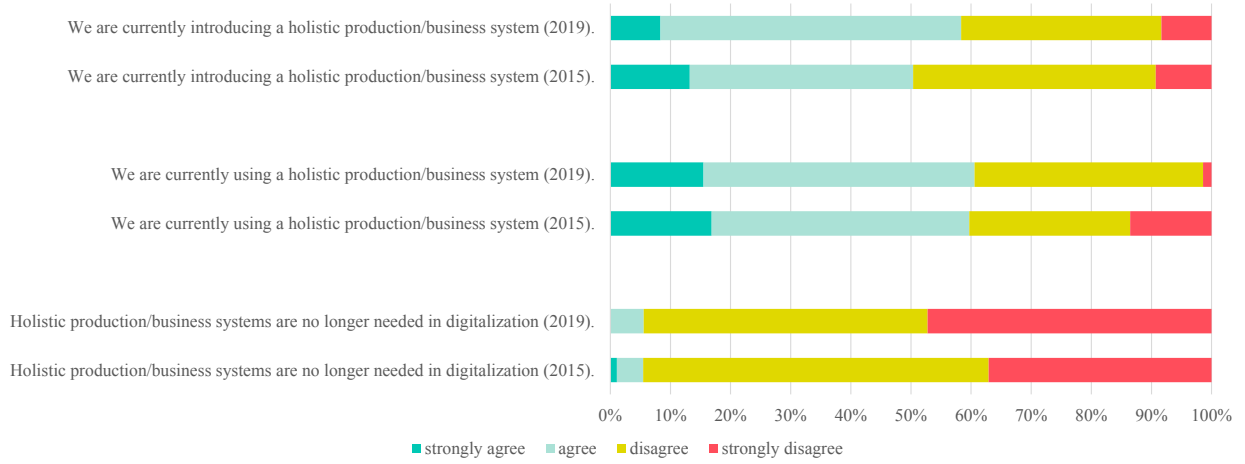

Fig. 4. How do you estimate the impact of Industry 4.0/digitalization on holistic production/business systems? (2015: n = 273-288; 2019: n = 71-72).

It can be assumed that production/business systems are well proven, their degree of usage will increase further, and they are indispensable for the digital transformation and future production respectively Industry 4.0. Further information on the application of digitalization for holistic approaches and especially for holistic productivity management can be found e.g. in Jeske, Weber, Lennings, and Stowasser [7].

Since larger enterprises use production/business systems more frequently the increases may be influenced by the increased percentage of larger enterprises between sample 2015 and sample 2019 – but that probably might not affect the assumption.

5. Impact on human work

5.1. Impact on Number of Employees

The impact of digitalization on the number of employees was queried in the years 2015 and 2019. The results are illustrated in Fig. 5. The percentages of the participants answering *do not know answering this question* decreased between both surveys for all items. The percentages of *unchanged* decreased for all items except of direct areas. For direct areas, the percentage of participants expecting an increasing number of employees nearly doubled while the percentage of those who expect a decreasing number nearly halved. For indirect areas, the expected increase was almost constant while the expected decrease increased. Across the company there was a polarization found: The percentages of expected increases and decreases increased both. This is also found for medium and upper pay grades. For lower pay grades, the expected increase tripled while the expected decrease became smaller. Nevertheless, the percentage of expected increase of lower pay grades is still less than half of the percentage of their expected decrease.

Probably the expected increases of the number of employees in direct areas can be explained taking up the assumptions to (a) and (d) in chapter 3.2: Increased experiences showed an increasing demand for employees in direct areas. For indirect areas, the assumptions of chapter 3.2 for (c) can be taken up: New opportunities might have been experienced – e.g. the potential of artificial intelligence for administration and knowledge work. Across the company

experiences seem to be gained for increases as well as decreases – this leads to the assumption that the number of employees required in industry will stay constant or – comparing the percentages of increase and decrease – could slightly decrease. The increased expectations on increasing numbers of employees for all pay grades allow the assumption that new tasks have been identified which have to be executed by new personal. At the same time also, tasks might have been identified which are no longer needed in future and explain expected decreases; even though, the expected decreases for lower pay grades have decreased.

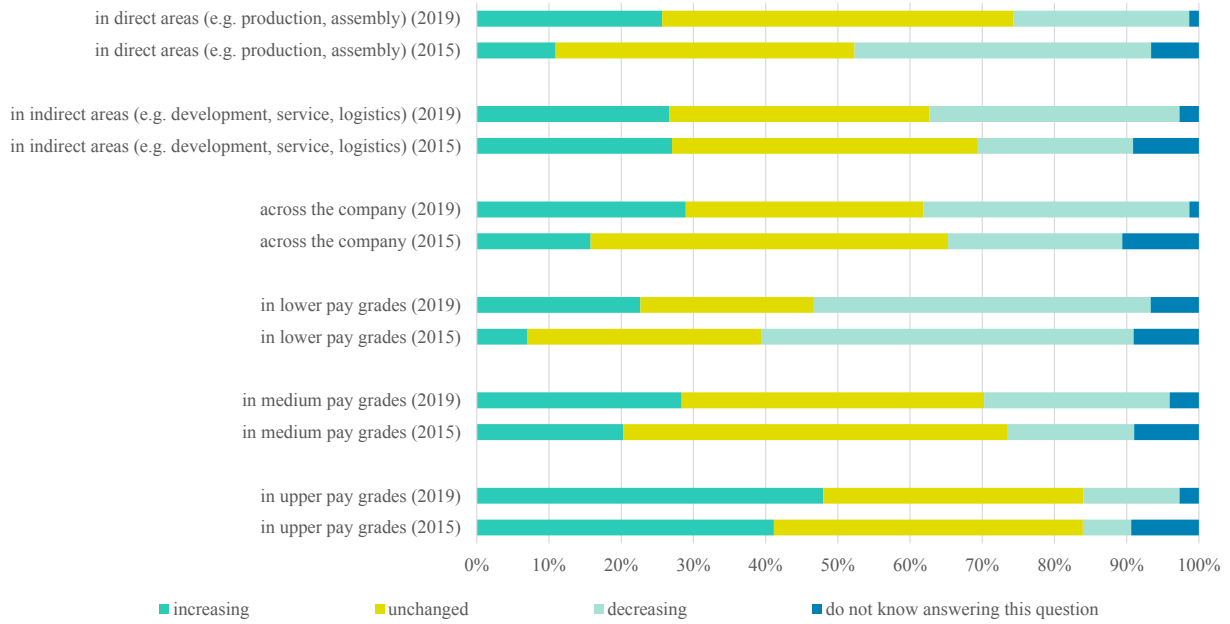

Fig. 5. How do you estimate the impact of Industry 4.0/digitalization on the number of employees in your company? (2015: n = 299-311; 2019: n = 74-76).

5.2. Impact on Employees

The impact of digitalization on employees was queried in the years 2015 and 2019. The results are illustrated in Fig. 6. The percentages of the participants answering *do not know answering this question* decreased for all items between both surveys. The expectations on qualification requirements for university graduates and skilled workers changed marginally. An increasing importance of humans as decision makers was indicated by 17 percentage points more often than before while the contrary was indicated 1 percentage point less. For physical load, the expectations on increase and decrease are constant while *unchanged* was indicated 6 percentage points more often. Thus, the percentage of expected decrease is still more than twice of the expected increase. For cognitive load, the percentage of expected increase as well as of the expected decrease increased both. Even though, the expected increase of cognitive load was still more than five times more often indicated by the participants than an expected decrease.

The high and constant percentages for increasing qualification requirements show a high degree of consensus of most participants of both samples/surveys. An increasing importance of humans as decisions makers seems to be proven by reality between both studies and is expressed by the strong growth of expected increase. The results on physical and cognitive load confirm the basic character of digitalization: The handling of information becomes more important and allows at the same time to support physical tasks by e. g. human-robot-collaboration (for example Jeske and Lennings [5]).

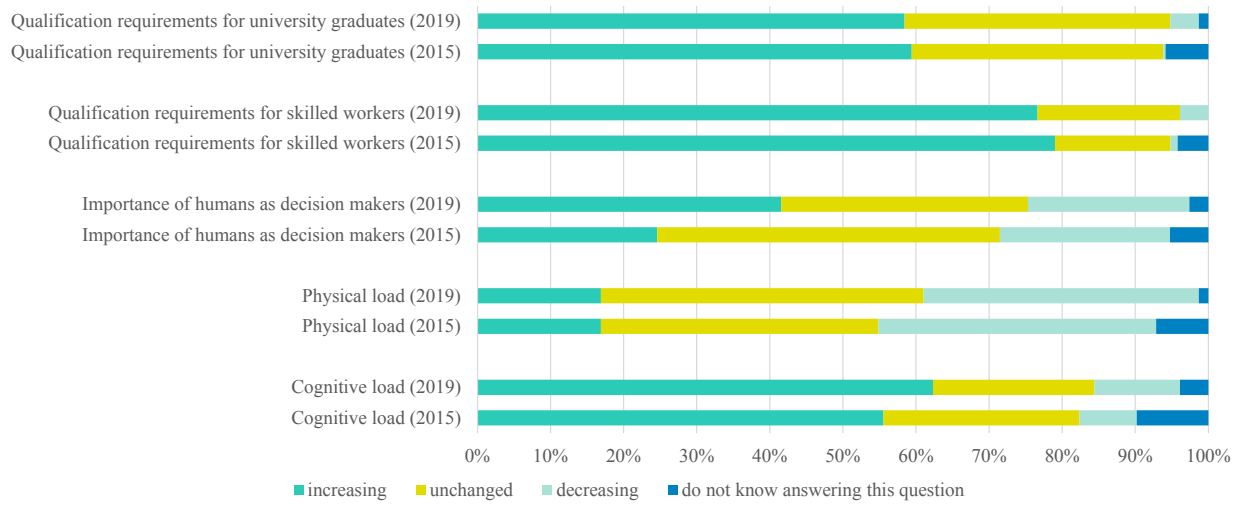

Fig. 6. How do you estimate the impact of Industry 4.0/digitalization on employees in your company? (2015: n = 305-310; 2019: n = 74-76).

5.3. Impact on Flexibility of Employees

The impact of digitalization on the flexibility of employees was queried in the years 2015 and 2019. The results are illustrated in Fig. 7. Combining *agree* and *strongly agree* as well as *disagree* and *strongly disagree*, the indicated consent for more opportunities for employees increased for all dimensions of flexibility while the indicated consent for more requirements for employees has decreased. The largest difference between consent to more opportunities and requirements occurs for spatial flexibility: Employees are expected to receive much more spatial flexibility than they have to provide. The smallest difference occurs for content flexibility: Employees are expected to receive the same content flexibility they have to provide. Temporal flexibility is in between. The largest consent in requirements for employees is indicated for content flexibility – the smallest for spatial flexibility. The largest consent in opportunities for employees is also expected for content flexibility – the smallest also for spatial flexibility.

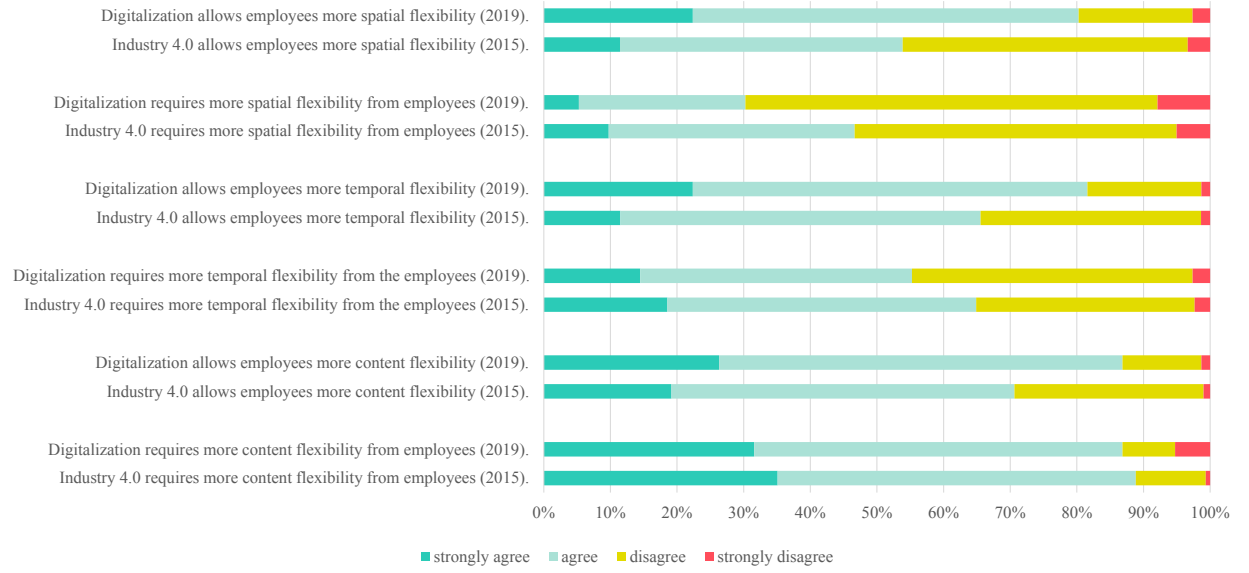

Fig. 7. How do you estimate the impact of Industry 4.0/digitalization the employees flexibility? (2015: n = 296-305; 2019: n = 76).

These results may be due to several aspects. (1) Even if spatial flexibility is facilitated strongly by digitalization, these opportunities are not available for all kinds of tasks and work. Especially production and assembly tasks usually depend on handling physical parts as well as on logistic support and thus have to be executed in factory halls or other defined places. This reduced number of affected employees might lead to the smallest expected requirements and opportunities for spatial flexibility. (2) Increasing requirements for content flexibility can be explained by an increasing variance of products due to individual customer needs which are more and more taken into account. Increasing opportunities for content flexibility might be due to improved production planning and steering mechanisms and support by algorithms which allow employees to influence the sequence of the tasks they execute. Since most employees are affected this leads to the highest expectations. (3) Expectations on temporal flexibility might be in between since not all employees are affected but more than regarding spatial aspects – even shift work is becoming more flexible.

6. Summary

Three surveys on the implementation of digitalization and its impact on productivity, management and human work have been integrated by analyzing replicated questions and deriving development tendencies. These surveys have been conducted in the years 2015, 2017, and 2019 in the German metal and electrical industry.

The development of expectations on productivity gain due to digitalization shows an increasing tendency. Until the year 2027 a productivity gain of 38 percent on average is expected. Thus, earlier expectations seem to be confirmed by good experiences and have led to further increasing expectations. For all queried fields of application in companies, most participants estimate digitalization to be important or very important.

Lean production and management are indicated to be required for introducing digitalization. Most participants are already using those methods and will do so in future. Similar applies for holistic approaches: Most participants are introducing or already using them. They will not be replaced by digitalization.

Uncertainty about the future number of employees has decreased and leads partially to a polarization between expectations on increasing and decreasing tendencies. Most participants expect increases in qualification requirements for university graduates and skilled workers as well as an increasing importance of humans as decision makers. Furthermore, the general opportunities of information handling by digitalization and consequently increasing cognitive load and decreasing physical load are still expected. Finally, the opportunities of employees for spatial, temporal, and content flexibility have increased while their requirements for these kinds of flexibility have decreased.

The results proof progress in implementing digitalization in production industry and still show manifold opportunities of digitalization for companies and employees.

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