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ORIGINAL RESEARCH



# Digitalisation and inter-organisational information exchange strategies of German companies—A survey with focus on small and medium sized enterprises

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## Abstract

The reliability of well-performing production processes not only depends on internal but also on external factors in the upstream supply chain. Therefore, companies require fast and reliable information exchange with cooperating organisations. Since existing researches usually put focus on reviewing intra-organisational solutions, the authors have conducted a survey to capture the current state and needs regarding the interorganisational information exchange between German companies. The main outcomes of the authors' survey are outlined. In a first step, the current status of digitalisation in the companies is analysed. The authors have found that the use and implementation of modern methods correlates positively with the company size. Taking a look on the current methods for inter-organisational information exchange in a second step, it is seen that only a few companies are completely satisfied with their current methods. Companies see the greatest potential for the improvement of information exchange in standardisation and the increase of required resources. This indicates that companies would be best supported by the development of solutions that can be implemented easily and help to form the heterogeneous landscape of data exchange strategies towards a structured, standardised way.

## KEYWORDS

computer integrated manufacturing, manufacturing industries

# 1 | INTRODUCTION

The manufacturing industry is subject to current trends and sustained tendencies in the market, such as increasing product variety, custom and individual fabrication, as well as reduction of production and delivery times [1, 2]. Due to these trends and the implied needs for innovation and differentiation, companies have started to review and adapt their internal processes and structures as well as enhance them by implementing Industry 4.0 technologies. This evolution within the companies can be seen in surveys, such as Ref. [3].

However, especially in the manufacturing industry, the success of business processes not only depends on companyinternal structures but also depends highly on external collaborations with partners along the supply chain. Such supply chain collaborations support companies to guard against risks, obtain complementary resources, reduce logistical costs, and enhance profit performance and gain a competitive advantage over time [4, 5].

Inter-organisational communication is the basic enabler for a tight supply chain collaboration [4] and it will, most probably, become more important in the near future [2]. Conventionally, inter-organisational communication is done via e-mail, fax and phone. Since these methods are usually based on high manual effort, they are often slow and error-prone and, therefore, not suitable for fast and comprehensive information exchange. To overcome these problems, companies can focus on the use of tools and systems that enable an automated information exchange between different organisations.

The importance and urgency to improve productionrelated information exchange are already recognised and discussed in many places. For example, in the past decade, several

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different concepts have been developed to realise and improve the company internal digital and automated information exchange (e.g. LISA [6], ProSense [5] and SmartFactory<sup>KL</sup> [7]). Some systems that are used for company internal information handling already imply basic approaches to share information with cooperating companies (e.g. via APIs or GUIs), while a few architectural approaches (such as IIRA [8], IMSA [9], IVRA [10] and RAMI4.0 [11]) and recent research (such as EPCIS [12], IDS [13] and GAIA-X [14]) already focus on this aspect.

Have companies already implemented modern technologies for the inter-organisational information exchange or is there still high potential of improvement? Several researches (see Section 2) have surveyed the implementation of digitalisation and Industry 4.0 aspects in the industry, but they did not address companies' strategies to perform information exchange with their cooperating partners across their companies' boarders. To support the research and industry in developing improved concepts for the inter-organisational information exchange, we decided to undertake additional research to capture the current state in the companies and to derive recommended actions from it.

In this article, we present the main outcomes of our survey regarding the current state of digitalisation and interorganisational communication strategies in German small and medium sized enterprises (SME) as an extended version of our publication "Current State of the Inter-Organizational Information Exchange Strategies of German SME - A Survey" [15]. After taking a look at the current state of art (see section 2), we give an insight into our motivation for the work in Section 3 and provide an overview of our survey's structure in Section 4. As explained in Section 5, we sent out the survey to more than 4500 companies based in Germany. Based on the 180 responses which we received (135 questionnaires from manufacturing companies plus 45 additional questionnaires from companies without manufacturing tasks)<sup>1</sup>, we provide the main outcomes of the survey in Section 6. After discussing the survey's outcomes in Section 7, as well as showing its limitations in Section 8, we finally state our conclusion in Section 9.

# 2 | STATE OF THE ART

Industrial evolution is an important topic for developed countries. This leads researchers to analyse companies' strategies and their implemented methods and tools in order to work on advanced solutions.

There exist several studies that focus on digitalisation in the industry and tried to document the improvement of processes and technologies in the industrial sector, such as the implementation of Industry 4.0 methods, for example, [3, 16–18]. Some researches especially put focus on the status of digitalisation within specific countries or regions, such as Refs. [19, 20] in Germany, whereas other researches exclusively focus on

selected groups of companies to define and support their specific needs, such as Refs. [21, 22], which focused on small and medium sized companies. However, the focus of these investigations is always on company-internal developments. The status of implemented cross-company strategies, such as communication with partner companies along supply chains, is not addressed in these studies.

Even if a well-functioning exchange of information between companies promises advantages (see Section 1), the current state of inter-organisational information exchange strategies in manufacturing industry sectors has not yet been well researched. Existing researches are either based on data that were collected some years ago [23, 24] or only casually deals with the topic [25], leading to rather general statements. Furthermore, some researches only address communication between companies and customers (B2C) or focus on customer-related industry sectors, such as service sector or food industry (restaurants, supermarkets) [26].

Pauer et al. [24] published data of a survey undertaken in 2017 which already give some insights in the current status of inter-organisational information exchange strategies at this moment. Apart from the fact that the situation could already have changed in the recent years, the Pauer et al. informed about the incidence of cross-company data sharing, but did not address the question how and in which data formats the information is exchanged. The study undertaken by Arnaut et al. [23] in 2018, especially, focuses on the exchange of data that are generated by machines and exchanged between companies (B2B data exchange). The study examined companies acting in the European Economic Area (EEA) and showed the general quantitative dimension of data sharing. However, with a total of 129 participating companies from the EEA, the study is not statistically representative. There is a lack of research that need to be filled in order to have explicit information about the information exchange strategies implemented in manufacturing companies, particularly when the focus is on SME.

# 3 | MOTIVATION

As described in Section 2, current research already examined the implementation of Industry 4.0 aspects in companies, whereas the current status of inter-organisational information exchange strategies has hardly been researched at the moment. To get more information and a more general overview of the digitalisation within companies and their behaviour regarding the inter-organisational information exchange, we decided to survey companies based in Germany on this topics. Since SME play a significant role in the economics of most countries [27], it is particularly important to support these companies in their development. Therefore, we decided to especially focus in our research on the status of digitalisation and inter-organisational information exchange strategies of SME. This research work explores the status quo in the companies as a first step to support research institutions and companies in developing new strategies that can be implemented in industry.

<sup>&</sup>lt;sup>1</sup>See Figure 1 in the results section (section 6).

TABLE 1 Structure of the survey.

Part	Objectives	Questions
Ι	General information	1-4
II	Digitalisation in general and in production	5–7
III	Inter-organizational information exchange	8–14
IV	Value and risks of digitalisation	15–16
V	Feedback	17–18

# 4 | STRUCTURE OF THE SURVEY

To reach as many companies as possible from all regions of the country, we decided to conduct an online survey. The survey was designed with a web-interface survey template and contained 18 questions. As displayed in Table 1, the questions asked in the survey can be grouped into five parts.

# 4.1 | Part I—General information

In part I, we asked for general information about the participants' company, such as size (number of employees), age of the company and industrial sector, with the latter being asked as an expandable multiple choice question. The general company information is relevant to group the responses in the analysis phase.<sup>2</sup>

# 4.2 | Part II—Digitalisation in general and in production

In part II, we wanted to get an overview of the companies' degree of digitalisation. We asked the participants to rate the degree of digitalisation in their company and to specify the use of different methods and tools within the company's production. For these questions we provided Likert scales to represent varying degrees of usage.<sup>3</sup>

# 4.3 | Part III—Inter-organisational information exchange

In part III, we asked for information regarding the handling of information exchange with external partners, such as customers or suppliers. Beside the evaluation of the current state of interorganisational information exchange, we also asked for the satisfaction of the current situation as well as possibilities to support the improvement. Here, the options for answers were also provided in the form of Likert scales.<sup>4</sup>

# 4.4 | Part IV—Value and risks of digitalisation

Part IV includes two open questions where the participants could give us feedback about their opinion regarding the value and the risks of digitalisation in general.<sup>5</sup>

## 4.5 | Part V—Feedback

In the last part, we offered two open questions to the participants by which they could leave us feedback to the questionnaire or further information regarding the topic of the survey.<sup>6</sup>

# 5 | METHOD

In this report, we present the statistical evaluation results on a survey that was carried out amongst companies, mainly settled within the manufacturing industry in Germany. Since the research is on companies in Germany, the questionnaire (see Section 4) was written in German.<sup>7</sup>

In order to reach a wide range of different companies we decided to distribute the questionnaires via networks and newsletters. We contacted more than 90 business associations and centres of excellence out of which 40 associations distributed our questionnaire to their members. Besides the distribution via newsletters and networks, we also sent out the questionnaires directly to the companies by e-mail. The companies contacted were selected based on their size (focus on SME) and the probability for executing manufacturing tasks (mainly in the aerospace, optics, electronics and automotive industries). For the direct messaging we predominantly became aware of the companies through the member lists of associations, networks and clusters as well as through Google searches.

The questionnaire was available online for one and a half month (middle of October until end of November 2021). Interested companies could follow the distributed link to participate at the survey. Due to the statistics of our online survey tool we could determine that the link to our survey was clicked more than 1000 times.

There are about 220,000 companies in the manufacturing sector in Germany [28]. From more than 4500 sent out questionnaires, we obtained 180 evaluable responses (response rate <4%), out of which 135 questionnaires were answered by employees of manufacturing companies. We are aware that the small number of answers may contain biases (also addressed in Section 7). Since we wanted to focus particularly on the development status of small and medium-sized manufacturing companies, and since more than three quarters of the

<sup>&</sup>lt;sup>2</sup>See all questions of part I in detail in the appendix.

<sup>&</sup>lt;sup>3</sup>See all questions of part II in detail in the appendix.

<sup>&</sup>lt;sup>4</sup>See all questions of part III in detail in the appendix.

<sup>&</sup>lt;sup>5</sup>See all questions of part IV in detail in the appendix.

<sup>&</sup>lt;sup>6</sup>See all questions of part V in detail in the appendix.

<sup>&</sup>lt;sup>7</sup>The original questions of the questionnaire in German and their translation to English are displayed in the appendix.

answers were given by companies with less than 250 employees, trends in this target group can be derived from the questionnaires.

# 6 | RESULTS

In this section, we present the results of our survey. Since not every question was answered by every participant, the evaluation of the questions is based on a range of 115–180 answers. In Section 6.1, we show some general information about the group of participants and the general state of digitalisation within their companies in Section 6.2. Section 6.3 comprises the outcomes regarding our questions about the interorganisational information exchange. Finally, we summarise the values and risks of digitalisation, which were stated by the participants, in Section 6.4.

# 6.1 | General information

As described in Section 4, we asked for general information about the participants company in Part I of the questionnaire. Since we wanted to put focus on companies that have manufacturing tasks we filtered the responses by this criteria.

Figure 1 shows the amount of participating companies distributed by the execution or non-execution of manufacturing tasks. Out of the 180 responses that we received, three quarters (135 questionnaires) were given by companies that execute manufacturing tasks, whereas one quarter (45 questionnaires) was given by companies without manufacturing tasks. Even though our focus in this study is on manufacturing companies, we partially used the answers from the non-manufacturing companies to provide comparative values to our group of interest.

Considering the age of the participating companies, it turns out that most of the participating companies (87%) do exist for more than 10 years, whereas only 13% are younger companies (see Figure 2). The percentage of start-ups (companies that were founded maximum 3 years ago) in our survey is 4%.



Figure 3 displays the distribution of the manufacturing companies by their size. As shown in the figure, 78% of the obtained responses we received were from members of medium or smaller sized companies.

To get an overview of the companies' field of activity, we, furthermore, asked the participants to indicate in which business areas their company operates. Participating companies not only operate in the industry sectors of electronics (52%), Automotive (38%), Space (30%) and Aircraft (26%) but also in other industry sectors, such as manufacturing systems engineering, medical technology and optics (see Figure 4).

## 6.2 | State of digitalisation

Since we wanted to get a general overview about the current state of digitalisation in the companies (part II of our survey), we asked the participants to rate their company-internal level of digitalisation. As displayed in Figure 5, two-thirds of the participants rank the level of digitalisation of their company to 60% or higher. Compared to the responses of all participating



**FIGURE 2** Age of the companies (180 companies) Results of question 10.2 (see appendix).



**FIGURE 3** Distribution by company size top: manufacturing companies (135 companies) bottom right: answers of all participants (180 companies) Results of question 10.1 (see appendix).



FIGURE 4 Results for 'Which industry sectors belong to your company's business area?' (multiple choice, 180 companies) Results of question 10.3 (see appendix).



**FIGURE 5** Results for '*How extensively has digitisation been implemented in your company?*' (Likert scaling, 180 companies) Results of question 11.1 (see appendix).

companies, it can be observed that manufacturing companies consider themselves to be less digitised in comparison to the general level of digitalisation in German companies.

As we asked for the use of modern methods within the manufacturing area, we could recognise that methods to physically support production such as autonomous driving systems, drones, and exoskeletons, as well as methods of augmented reality and virtual reality (VR) are used rarely (see Figure 6). In contrast, manufacturing management supporting systems, such as enterprise resource planning (ERP) and manufacturing execution systems (MES), as well as the record and usage of manufacturing data are already implemented in many companies (see Figure 7). It can be seen that the progress on implementing the aforementioned systems and methods correlates with the company size. Less plans on such integration can be found amongst small- and microsized companies. An example is shown in Figure 8, it displays the current state of integration of manufacturing management supporting systems, such as ERP and MES, in the companies.

The results displayed in Figure 7 show, that besides the use of manufacturing planning software, the collection and automatic analysis of manufacturing data are the most popular methods. It can be observed that the collection of manufacturing data, as a previous step to the automatic treatment of the data, is the further developed method of these two.

# 6.3 | Inter-organisational information exchange

In part III of your survey (see Section 4), we asked for information exchange methods with external partners. The results of our survey show that the majority of the companies (>70%) only rarely make use of methods such as fax and letters. As displayed in Figure 9, the results furthermore show that the main methods for inter-organisational information exchange are still the common methods, such as phone and e-mail. Besides that, several companies apply additional methods (see Figure 10). 66% of the companies stated to, at least sometimes, use FTP/ FTPS-Servers for the information exchange with external partners. Furthermore, the information exchange via APIs, GUIs and digital platforms is used from time to time, but regularly only used by less than 30% of the companies.

Information is mostly exchanged as human readable documents, followed by tabular data and (de-facto<sup>8</sup>) standardised data formats. Proprietary and non-standardised data formats are less in use (see Figure 11).

At the end of part III of our questionnaire (see Section 4), we asked the participants to define their degree of satisfaction with the current state of the inter-organisational information exchange (see Figure 12) and to name potential measures that could help to improve the inter-organisational information exchange in the future (see Figure 13).

The results show that three quarters of the companies are in general more satisfied than being unsatisfied about the current situation. Only 3% of the participating manufacturing companies stated to be absolutely satisfied with the current exchange of information. Compared to the responses of all participating companies, it can be observed that manufacturing companies seem to be less satisfied with the exchange of information than German companies in general.

As displayed in Figure 13, companies indicated that more standardisation, more resources and a higher degree of company-internal digitalisation would provide best support for the development and improvement of the interorganisational information exchange. Currently, only a few companies (<10%) directly work on improvements of the

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<sup>8</sup>De-facto standardized data formats: for example, CAD- or PCB-files.
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5 of 12



FIGURE 6 Results for 'Which of the following technologies are used or planned to use in your company?" (Likert scaling, 133 manufacturing companies) Results of question 11.3 (see appendix).



FIGURE 7 Results for 'Which approaches of digitalisation and interconnectivity have been implemented in your company so fars' (Likert scaling, 134 manufacturing companies) Results of question 11.2 (see appendix).



**FIGURE 8** Results for 'To what extent is planning software (e.g. Enterprise resource planning and manufacturing execution systems) used in your company?' (Likert scaling, 134 manufacturing companies) Results of question 11.2 (see appendix).

inter-organisational information exchange. Most of the companies focus on the improvements of company-internal digitalisation strategies.<sup>9</sup>

# 6.4 | Benefits and risks of digitalisation

In Part IV of our survey (see Section 4), we asked the participants to tell us what benefits and risks they generally see in

Use of traditional methods for the inter-organizational information exchange



**FIGURE 9** Results for 'Which tools and methods do you use to exchange information with corporate partners?' (1/2) (Likert scaling, 135 manufacturing companies) Results of question 12.1 (see appendix).

digitalisation. Among the 113 responses, the benefit of digitalisation was mostly seen in the increase in efficiency (e.g. time reduction, quality improvement and cost reduction). Security concerns, undesired dependencies and dehumanisation of the corporate culture were identified as the main risks of digitalisation. In general, we could observe that the opinions on digitalisation's benefits and risks vary strongly among the participants.<sup>10</sup>

<sup>&</sup>lt;sup>9</sup>This information was collected via an open question in our survey. We asked the participants which developments and improvements are currently aspired in their company. The answers were evaluated but will not be published verbatim.

<sup>&</sup>lt;sup>10</sup>As described in section 4 these questions were asked as an open question format. The answers were evaluated but will not be published verbatim.



FIGURE 10 Results for 'Which tools and methods do you use to exchange information with corporate partners?" (2/2) (Likert scaling, 135 manufacturing companies) Results of question 12.1 (see appendix).

Use of formats for the inter-organizational information exchange



**FIGURE 11** Results for 'Which data formats do you use for interorganisational information exchange?' (Likert scaling, 135 manufacturing companies) Results of question 12.2 (see appendix).



**FIGURE 12** Results for 'How satisfied are you with the current exchange of information with cooperating companies?' (Likert scaling, 178 companies) Results of question 12.3 (see appendix).

# 7 | DISCUSSION

As stated in Section 5, we received an adequate number of responses to obtain results with statistical relevance. Due to the high number of participating SME (more than 60% of all participants), we could detect the status and needs of this relevant group of companies of the German economy system. Since we also received a number of questionnaires from large companies (>250 employees), we were able to form a reference group to identify differences in strategy between smaller and larger companies.

As written in Section 6.1, two-thirds of the companies rank the current level of digitalisation in their company to 60% or higher (see Figure 5). This outcome conforms to the results from other studies, such as Refs. [3, 20]. However, the number still needs to be regarded critically since there could be a bias in such case that members of companies, which are not interested in digitalisation, would probably rather not participate at a survey that is concerned to this topic. Since we distributed our survey digitally via e-mails and newsletters, it is also possible that we did not reach less digitized companies, or that they did not dare to take part in our survey. Even if most of the companies rate their level of digitalisation at 60%-80%, there are only a few companies that rate their current status as 100% digitised (only 5% of the manufacturing companies). This numbers show, that most companies still see potential to further improve their level of digitalisation. Whether this last improvement from 80% to 100% digitisation would also lead to economic added value cannot be answered at this point.

We could observe that the progress of the implementation of modern methods and technologies in the manufacturing plant correlate with the size of the company: the larger the company is, the further developed is the progress of implementation (see Section 6.2). This could be caused by the restricted resources of smaller companies. In addition, the expected benefit of implementing a new method increases further, if more executed orders will be effected and improved by this change. This could be also a reason why larger companies rather tended to invest in such methods than smaller companies with a smaller amount of orders. This theory is supported by the fact that small companies in particular do not even strive to use planning software in the production plant (see results in Figure 8).

The results are surprising when it comes to the question of which modern technologies are used in the manufacturing plant. As the results show (see Figure 6, only visual inspection seems to be a technology that companies generally consider as useful to implement (70% of the participants indicated that they use visual inspection in some form or plan to use it in the future; 50% stated to used visual inspection at least partially in the production). Other technologies only seem to be interesting for some companies. These results suggest that companies see most fields of application or the greatest potential in visual inspection. Another interpretation of these results is that companies see the lowest barriers to entry when implementing visual inspection (e.g. low investment costs for hardware; possibility of implementation without having to change existing processes or systems).

7 of 12

Potential actions to improve the inter-organizational information exchange



FIGURE 13 Results for 'Which measures would help to improve the current situation with regard to the exchange of information with cooperating companies?" (Likert scaling, 115 manufacturing companies) Results of question 12.4 (see appendix).

Due to the responses we got in part III of our survey (see Section 6.3), we were able to show that old methods for interorganisational information exchange, such as fax and letter, are almost completely replaced by the information exchange via phone and e-mail. It is furthermore observable that newer methods, which would support automated or pull-based information exchange, are not very popular to use. Nevertheless, as displayed in Figure 12, only 3% of the participants of manufacturing companies (6% of all companies) stated to be absolutely satisfied with the current state of interorganisational information exchange. This shows very clearly that there is still potential for improvement in most companies. However, inter-organisational information exchange currently does not seem to be the focus for most of the companies. As we could recognise, when we asked the participants for their current developments, it becomes obvious that companyinternal improvements regarding the digitalisation and the improvement of information exchange seem to be more urgent. This fact leads to the assumption that many companies did not already reach an internal level of digitalisation that is required to build an automated inter-organisational information exchange upon it.

# 8 | LIMITATIONS OF THE STUDY

As displayed in this paper, our survey could show some tendencies of the current state of digitalisation and the interorganisational communication strategies of German companies. However, our work is subject to some limitations. Those are mainly related to its limited time frame and the short duration of our survey period. A longer duration might have helped to attract more companies to participate in our work, resulting in mote responses and a greater statistical relevance of the work.

Furthermore, our survey was conducted anonymously. We checked for plausibility, but we cannot completely rule out that the answers of the participants are not correct. In addition, although we have reviewed our questions several times and sought feedback from experts, we cannot exclude the possibility of misunderstandings and misinterpretations about certain terms in our questionnaire.

Finally, our survey did not capture respondents' position within their organisation, meaning it was not possible to map variations in responses that may be related to an individual's position within their organisation. Including the respondents' profile details, such as position in the company, in the survey might be an approach for future work.

# 9 | CONCLUSION

Since small and medium-sized companies play a significant role in most supply chains [29], it is particularly important to support their development and consider their needs in the implementation of methods and systems for inter-organisational information exchange. Compared to large enterprises, SME face even bigger obstacles by the development and implementation of new technologies, due to their limited resources in personnel, funds, and knowledge [18]. As our survey shows, the degree of digitalisation and the implementation of process and production supporting systems and methods differ between the companies. We could show that the implementation of modern methods correlates positively with the company size. Smaller companies are mostly at the beginning of such implementations or even do not plan to implement the methods and technologies at all. However, there is still a high potential for improvement in most German SME.

Whereas most existing research only focus on the current state of digitalisation within companies, we also focus on analysing the implemented methods for inter-organisational information exchange. Information exchange methods that require a lot of manual work, such as e-mail and phone, are often slow and error prone. Hence, they should be replaced by automated solutions which help to improve the information exchange between cooperating companies and help to react faster on occurring events that come up in the supply chain. With our survey we are able to show that the development towards the use of fast and automatic information exchange systems is in most cases not very advanced. While traditional methods for inter-organizational information exchange, such as fax and letter were almost completely replaced by telephone and email, modern methods, such as data exchange via APIs or digital platforms, are not extensively used so far.

Even if companies generally rate their current state of interorganisational information exchange rather positively, the results of our survey show that there is still potential for improvement. Companies stated that more standardisation, more resources and a higher degree of company-internal digitalisation would

8 of 12

provide best support for the development and improvement of the inter-organizational information exchange.

In order to support SME in improving their communication strategies, it is necessary to develop and provide solutions for the inter-organisational information exchange that can be easily implemented and connected to existing systems of the companies. Furthermore, companies need to invest in company-internal digitalisation in order to create a digital basis in the company on which modern methods and processes for a smooth inter-organisational information exchange with cooperating companies can be built.

## AUTHOR CONTRIBUTIONS

Laura Sophie Thiele: Formal analysis; visualization; writing original draft. Diana Peters: Funding acquisition; supervision; writing—review and editing.

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## **CONFLICT OF INTEREST STATEMENT** None.

## DATA AVAILABILITY STATEMENT

This article is based on data that we collected through an online survey. Due to data protection reasons we are not able to publish the raw data that we collected. Processed data is published in 'Current State of the Inter Organizational Information Exchange Strategies of German SME - A Survey' and will be published in this article too.

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# APPENDIX A

## **Questionnaire Part I**

#### Size of the company

Question: "Wie groß ist Ihr Unternehmen?"

What size is your company?

- Possible answers (single choice):
- "Kleinstunternehmen (<10 Mitarbeiter/innen)"
- micro-enterprise (<10 employees) • "Kleines Unternehmen (10-49 Mitarbeiter/innen)" small sized company (10-49 employees)
- "Mittelständisches Unternehmen (50-249 Mitarbeiter/innen)"
- medium sized company (50-249 employees) "Großes Unternehmen (>250 Mitarbeiter/innen)" large company (>250 employees)
  - Age of the company
- Question: "Seit wann gibt es Ihr Unternehmen?" How long has your company existed?

Possible answers (single choice):

• "<3 Jahre"	<3 year
• "3-10 Jahre"	3-10 year
• ">10 Jahre"	>10 year

#### Business sectors of the company

Question: "In welcher/n Branche(n) ist Ihr Unternehmen tätig?" Which industry sectors belong to your company's business area?

Possible answers (multiple choice):

• "Raumfahrt"	space industr
• "Luftfahrt"	aviation industr
"Automobilindustrie"	automotive industr
• "Elektronik"	electronic
• "IT-Branche"	IT secto
<ul> <li>"Dienstleisungen"</li> </ul>	service

"Sonstige" other (with possibility to enter a further option)

## Selection of manufacturing companies

Question: "Ist Ihr Unternehmen ein produzierendes Unternehmen?" Is your company a manufacturing company?

Possible answers (single choice):

• "Ja" / "Nein" yes / no

#### Questionnaire Part II

## State of digitalization in the company

Question: "Wie umfassend ist Digitalisierung in Ihrem Unternehmen umgesetzt?"

How extensively has digitization been implemented in your company? Description: "Bitte schätzen Sie den Stand der Digitalisierung in

Ihrem Unternehmen ein. 0% -> Das Unternehmen arbeitet ohne digitale Hilfsmittel. 100% -> Das Unternehmen wird, soweit möglich und sinnvoll,

durch digitale Prozesse/Technologien unterstützt." Please, assess the status of digitalization in your company

0% -> The company works without digital tools

100% -> As far as possible and reasonable,

## the company is supported by digital processes/technologies.

## Possible answers (Likert Scale with 6 options):

• "0%", "20%", "40%", "60%", "80%", and "100%"

0%, 20%, 40%, 60%, 80%, and 100%

### Implementation of approaches for digitalization

Question: "Welche Ansätze zur Digitalisierung und Vernetzung wurden in Ihrem Unternehmen bisher umgesetzt?

Which approaches of digitalization and interconnectivity have been implemented in your company so far?

### Topics to assess:

## "Nutzung von Planungssoftware (z.B. ERP, MES, etc)"

- use of planning software (e.g. ERP, MES, etc) "Papierlose Fertigung" • paperless production
- "Automatisierung der Fertigung" automation of manufacturing
- "Erfassung und Speicherung von Produktionsdaten
- (Maschinendaten, Prozessdaten, Qualitätssicherung, etc)"
  - collection and storage of production data (machine data, process data, quality assurance data, etc)
- "Automatische Auswertung von Produktionsdaten (Maschinendaten, Prozessdaten, Qualitätssicherung, etc)"
  - automatic analysis of production data
- (machine data, process data, quality assurance data, etc) • "Sonstige" other (with possibility to enter another option)

#### Possible answers (Likert Scale with 6 options and a fallback option):

"kein Einsatz geplant" no use planned in planning phase "in Planung "in Testphase" in test phase "teilweise umgesetzt" partially implemented "weitgehend umgesetzt" largely implemented "komplett umgesetzt" fully implemented "kenne ich nicht' I don't know (fallback option)

#### Use of technologies

Question: "Welche der folgenden Technologien werden in Ihrem Unternehmen eingesetzt bzw sind in der Planung oder Einführung?' Which of the following technologies are used or planned to use in your company?

#### Topics to assess:

•	"Kooperierende Roboter"	cooperating robots
٠	"Exoskelette"	exoskeletons
•	"Drohnen"	drones
•	• "Autonome Logistikfahrsysteme	
	autonomous drivin	ng systems for logistics
٠	Visuelle Inspektion (z.B. zur Qualitätssiche	rung)"
	visual inspection (e.g. to sup	port quality assurance)
•	• "Augmented Reality / Virtual Reality"	

- augmented reality / virtual reality "Intelligente Werkzeugsysteme"
- intelligent tool systems "Pick by Light" pick by light
- other (with possibility to enter another option) "Sonstige'

### Possible answers (Likert Scale with 6 options and a fallback option):

<ul> <li>"kein Einsatz geplant"</li> </ul>	no use planned
<ul> <li>"in Planung"</li> </ul>	in planning phase
<ul> <li>"in Testphase"</li> </ul>	in test phase
<ul> <li>"teilweise umgesetzt"</li> </ul>	partially implemented
<ul> <li>"weitgehend umgesetzt"</li> </ul>	largely implemented
<ul> <li>"komplett umgesetzt"</li> </ul>	fully implemented
<ul> <li>"kenne ich nicht"</li> </ul>	I don't know (fallback option)

## Questionnaire Part III

### Methods and tools for information exchange

Question: "Welche Tools und Methoden nutzen Sie, um Informationen mit Partnerunternehmen (z.B. Kunden, Zulieferern) auszutauschen?" Which tools and methods do you use to exchange information with corporate partners (e.g. customers, suppliers)?

Topics to assess:

•	"Brief"	letter
•	"E-Mail"	email
•	"Telefon"	fone

- "Fax" fax "FTP/FTPS - Server" FTP/FTPS - server
- "Informationsübermittlung über Eingabemasken (GUIs)"
- information exchange via graphical user interfaces (GUI) "Automatischer Datenaustausch über Schnittstellen (APIs)"
- automatic data exchange via programming interfaces (API) • "Nutzung interner Software mit Informations-Zugriff für
- Partnerunternehmen" use of in-house software with information access for cooperating companies
- "Datenübermittlung an spezifische Software von Partnerunternehmen' data transmission
- to specific software from cooperating companies • "Datenaustausch über digitale Plattformen / Data Spaces"
- data exchange via digital platforms / data spaces
- "Sonstige" other (with possibility to enter another option)

Possible answers (Likert Scale with 6 options and a fallback option):

• "gar nicht"	not at all
• "selten"	rarely
<ul> <li>"gelegentlich"</li> </ul>	occasionally
<ul> <li>"regelmäßig"</li> </ul>	regularly
<ul> <li>"häufig"</li> </ul>	often
• "immer"	always
<ul> <li>"kenne ich nicht"</li> </ul>	I don't know

#### Data formats for information exchange

"Welche Datenformate nutzen Ouestion: Sie für den überbetrieblichen Informationsaustausch?" Which data formats do you use for inter-organisational information exchange?

Topics to assess:

- "Menschenlesbare Dokumente z.B. PDF"
- human readable documents, e.g. PDF-files
- "Tabellarische Daten z.B. Excel, CSV" tabular data e.g. Excel, CSV
- "Dem Inhalt entsprechende, (de-facto-) standardisierte Formate z.B. CAD- oder PCB-Files" (de facto) standardized data formats corresponding to the content e.g. CAD or PCB files
- "Proprietäre, nicht-standardisierte Formate (z.B. vom Kunden vorgegeben)" proprietary, non-standard formats (e.g. specified by the customer)
- "Sonstige" other (with possibility to enter another option)

#### Possible answers (Likert Scale with 6 options and a fallback option):

• "gar nicht"	not at all
• "selten"	rarely
<ul> <li>"gelegentlich"</li> </ul>	occasionally
<ul> <li>"regelmäβig"</li> </ul>	regularly
• "häufig"	often
• "immer"	always
<ul> <li>"kenne ich nicht"</li> </ul>	I don't know (fallback option)

#### Satisfaction with the current data exchange

Question: "Wie zufrieden sind Sie mit dem derzeitigen Informationsaustausch mit Partnerunternehmen?" How satisfied are you with the current exchange of information with cooperating companies?

Possible answers (Likert Scale with 6 options):

- "Sehr unzufrieden" "Sehr zufrieden"
  - very dissatisfied very satisfied

#### Measures for improvement

Question: "Welche Maßnahmen würden die aktuelle Situation im Hinblick auf den Informationsaustausch mit Partnerunternehmen verbessern?"

Which measures would help to improve the current situation with regard to the exchange of information with cooperating companies?

#### Topics to assess:

- "Erweiterung des unternehmensinternen Wissensstands über Möglichkeiten zur Verbesserung des Informationsaustauschs'
  - expansion of the company's internal knowledge about

ways to improve the exchange of information "Automatisierter Informationsaustausch mit Partnerunternehmen"

- automated inform. exchange with corporate partners
- "Mehr Digitalisierung bzw. verbesserter automatisierter Informationsaustausch im eigenen Unternehmen" higher degree of digitization or improved automated information
  - exchange in your own company
- "Mehr Ressourcen (Mitarbeiter/innen, Finanzierung) für die Umsetzung von Optimierungslösungen im eigenen Unternehmen" More resources (employees, financing) for the implementation

of optimization solutions in your own company

• "Mehr Support von der Geschäftsleitung und/oder anderen Entscheidungsträgern" more support from senior management and/or other decision makers)

- "Mehr Digitalisierung bei den Unternehmenspartnern"
- "Mehr Standardisierung"
- "Sonstige"
- other (with possibility to enter another measure)

Possible answers (Likert Scale with 6 options and a fallback option):

"würde zu keiner Verbesserung führen" -"würde zu einer sehr großen Verbesserung führen" would lead to no improvement -

would lead to a very large improvement

"bereits ausreichend vorhanden bzw. implementiert" already sufficiently available or implemented (fallback option)

#### Probability of taking action

Question: "Wie wahrscheinlich ist die Umsetzung der folgenden Maßnahmen in Ihrem Unternehmen?" How likely is the implementation of the following measures in your company?

#### Topics to assess:

• "Erweiterung des unternehmensinternen Wissensstands über Möglichkeiten zur Verbesserung des Informationsaustauschs" expansion of the company's internal knowledge

about ways to improve the exchange of information

• "Umsetzung eines automatisierten Informationsaustauschs mit Partnerunternehmen" implementation of

automated information exchange with corporate partners • "Ausbau der Digitalisierung bzw. verbesserter automatisierter Informationsaustausch im eigenen Unternehmen'

expansion of digitization or improvement

of automated information exchange in your own company

• "Erhöhung der Ressourcen (Mitarbeiter/innen, Finanzierung) für die Umsetzung von Optimierungslösungen im eigenen Unternehmen" Increasing the resources (employees, financing) for the implementation

of optimization solutions in your own company • "Mehr Support von der Geschäftsleitung und/oder anderen Entscheidungsträgern"

- more support from senior management and/or other decision makers)
- "Mehr Standardisierung"
   more standardization
- "Sonstige" other (with possibility to enter another measure)

Possible answers (Likert Scale with 6 options and a fallback option):

- "Umsetzung sehr unwahrscheinlich" -"Umsetzung sehr wahrscheinlich" implementation very unlikely implementation very likely
- "Maßnahme bereits umgesetzt" measure already implemented (fallback option)

## Current Implementation of measures I

Question: "Sind in Ihrem Unternehmen bereits Maßnahmen zur Verbesserung des Informationsaustauschs in der Planung oder Umsetzung?" Are measures for the improvement of information exchange currently planned or in implementation in your company?

Possible answers (single choice):

• "Ja" / "Nein" yes / no

### Current Implementation of measures II

Question: "Um welche Maßnahme(n), bzw. um welche Veränderung(en) handelt es sich?"

Which measure(s) or which change(s) are involved?

Open answer (free text).

#### Questionnaire Part IV

Value of digitalization

Question: "Welchen Mehrwert sehen Sie in der Digitalisierung?" What added value do you see in digitization?

Open answer (free text).

Risks of digitalization

Question: "Welche Risiken sehen Sie in der Digitalisierung?" What risks do you see in digitization?

Open answer (free text).

## **Questionnaire Part IV**

#### Closing Questions - Additions to the Content

Question: "Haben Sie Ergänzungen zu den Inhalten des Fragebogens?" Do you have any additions to the contents of the questionnaire?

Open answer (free text).

#### Closing Questions - Suggestions to the Survey

Question: "Haben Sie Hinweise zum Aufbau des Fragebogens / der Art der Befragung?" Do you have any suggestions on the structure of the questionnaire / the type of survey?

Open answer (free text).