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Suitability of Industry 4.0 Concepts for Small and Medium Sized Enterprises: Comparison between an Expert Survey and a User Survey

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Abstract

The introduction of Industry 4.0 is currently mainly taking place in large companies. In order to introduce the concepts and technologies of Industry 4.0 into small and medium-sized enterprises as well, however, there is a need for organizational tools, which show which Industry 4.0 concepts are best suited to the respective size of enterprise. At present, there is no scientifically founded knowledge on this subject. Therefore, based on a company survey and an expert survey, this paper examines and discusses the suitability of industry 4.0 concepts in different company sizes. The aim is to find out which Industry 4.0 concepts are considered promising by users (enterprises) and experts. On this basis, a final list of suitable Industry 4.0 concepts per company size will be provided.

Keywords
industry 4.0, small and medium-sized enterprises, assessment model, maturity model, industry 4.0 roadmap

1. Introduction

The vision of Industry 4.0 pictures a radical transformation of the manufacturing industry, fundamentally characterized by new forms of organization enabled by the latest developments in technology. Industry 4.0 embodies the evolution of the three former industrial revolutions, whereas this approach is grounded on technological approaches of the smart factory, and computer-integrated production. The concept aims at highly flexible, autonomous networking of production and components of various kinds through software and data networks. Furthermore, data accrued are specifically recorded and evaluated (Hompel et al., 2016). This opens up new potential for autonomous control and organization of sustainable production processes or even entire value chains (Dallasega et al., 2015). In addition, this creates highly promising opportunities for novel products (Rauch et al., 2015; Rauch et al., 2016a) as well as cloud based and disruptive business models (Rauch et al., 2016b).
As good and promising as this may sound, the whole digital transformation process is not as straightforward and represents considerable challenges for companies and especially for small and medium sized enterprises (SME). Companies are seeking to exploit the potential of Industry 4.0 in order to make their production more effective and efficient and to be more competitive in the global environment (Merz, 2016). In most cases, however, the digital revolution causes them considerable problems and challenges and therefore cannot be realized simply as theoretically specified in literature. In practice, this shift not only requires large financial resources, which is a major challenge for SME in particular, but companies also encounter difficulties from a strategic perspective. As the term Industry 4.0 is debated almost everywhere, there is a lot of confusion pervading and consequently companies are struggling to filter out ways to benefit from this novel approach. Additionally, many find it challenging to derive strategic fields of action for their specific enterprise (Schumacher et al., 2016). As a result, digital change is slowing dramatically (IBM, 2105). In response to these problems, some ideas have emerged to propose approaches that support enterprises in overcoming the uncertainty surrounding Industry 4.0. So-called Industry 4.0 roadmaps are intended to provide guidance in the planning and implementation of modern digital organization models (Ghobakhloo, 2018). According to these, a strategic approach should be pursued in order to establish Industry 4.0 successfully in enterprises, bringing together

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the most important components within the framework of an Industry 4.0 implementation strategy. These roadmap approaches give companies guidance in this often-foreign territory, no concrete, practical, effortless and applicable recommendations for action are provided to enterprises. In particular, the question of which Industry 4.0 concepts could be suitable for the most diverse types of companies according to their different sizes remains unanswered up to the present.
Thus, this paper aims to provide first findings regarding the suitability of Industry 4.0 concepts in enterprises of different sizes. In order to analyze this, a self-assessment model is developed in a first step, with which companies (users) can evaluate themselves in relation to their implementation of defined industry 4.0 concepts. In addition, the companies have to indicate what potential or suitability they see in the use of the respective Industry 4.0 concept. This survey is compared with the results of an expert survey sent to an international group of specialists in the field of Industry 4.0. The aim is to identify those concepts, which both experts and users regard as suitable for a certain size of company. The overall ambition is accordingly to develop rough directions and guidelines for the roll-out of suitable Industry 4.0 concepts based on organization size. This is meant to enable companies, based on their size, to easily identify, introduce and then to subsequently implement promising concepts.
To achieve this goal the paper is structured as follows: in this first Section an introduction into the topic is given to the reader. Section 2 describes the background of this research explaining the Industry 4.0 self-assessment tool developed by the research team. Section 3 illustrates how the survey for the experts as well as for the users (enterprises) is designed and structured. In Section 4 the results of this surveys are analyzed in order to identify similarities but also differences within the user responses as well as between the expert meanings and the meanings of enterprises (user). This comparison leads than to a final list of suitable Industry 4.0 concepts for SME (Section 5). Section 6 summarizes the main findings of this research and gives an outlook for further need for research.

2. Background: developed Industry 4.0 self-assessment model

The initial step laying the cornerstone for the realization of an Industry 4.0 self-assessment tool is respectively represented by the conduction of a systematic literature review based on the methodological principle described in the scientific work of Liao et al. (2017). In this work, the authors propose a five-phases review approach that passes over to the deployment of pre-defined exclusion or inclusion criteria, whose application ends with the determination of a significant record collection.
Factually, one research question and two affiliated sub-questions centered on fourth industrial revolution concepts have been specified as follows by the research team in (Matt et al., 2018):

1. Which are the concepts of Industry 4.0?
   1.1. How can concepts be classified by their typology?
   1.2. How can concepts be thematically clustered?

The directive query formulation allows at this point to put into action the database search, whose main objective consists in the identification of a rough record collection. In respect thereof, by courtesy of SCOPUS a substantial amount of 733 scientific works has been determined. At this stage, for the first time the established criteria, epitomized by the exclusion parameter, move into the limelight. A total of six exclusion criteria, respectively represented by Source Type (ST), Cover Period (CP), Document Type (DT), Language (L), Subject Area (SA) as well as Source Type Completeness (STC) were applied. Concretely, only scientific elaborations classified as subject-related, complete and English journal papers, whose publication year lies not behind the 2011, are taken further into consideration. The 133 scientific works crystalized after the accomplishment of the third phase, undergo a bipartite scrutinization, whose uppermost objective consists in the categorization of the record collection into non-pertinent (NP), moderately-pertinent (MP) as well as firmly-pertinent (FP) works. Grounded on the objective review strategy, the classification is accepted only in case of accordance between two commissioned researchers. If that is not the case, a third researcher assumes the role of the decision maker. Finally, it has to be emphasized that the execution of the systematic literature review has enabled the determination of 75 moderately-pertinent as well as 27 firmly-pertinent papers, which encompass relevant Industry 4.0 concepts.
Subsequently, a content analysis facilitates the establishment of 75 general Industry 4.0 elements, which are structured in a first dimension into i) Operation, ii) Organization, iii) Socio-culture and iv) Technologies. In a second level there were defined further thematic groups like Agile Manufacturing, Additive Manufacturing and more. This elements were then transformed into so-called Industry 4.0 concepts forming the fundament for the industrial self-assessment tool. The described procedure has facilitated the definition of a total of 42 Industry 4.0 concepts, used as a basis for the definition of the self-assessment tool. Pursuant to each Industry 4.0 concepts, five maturity levels comprising the

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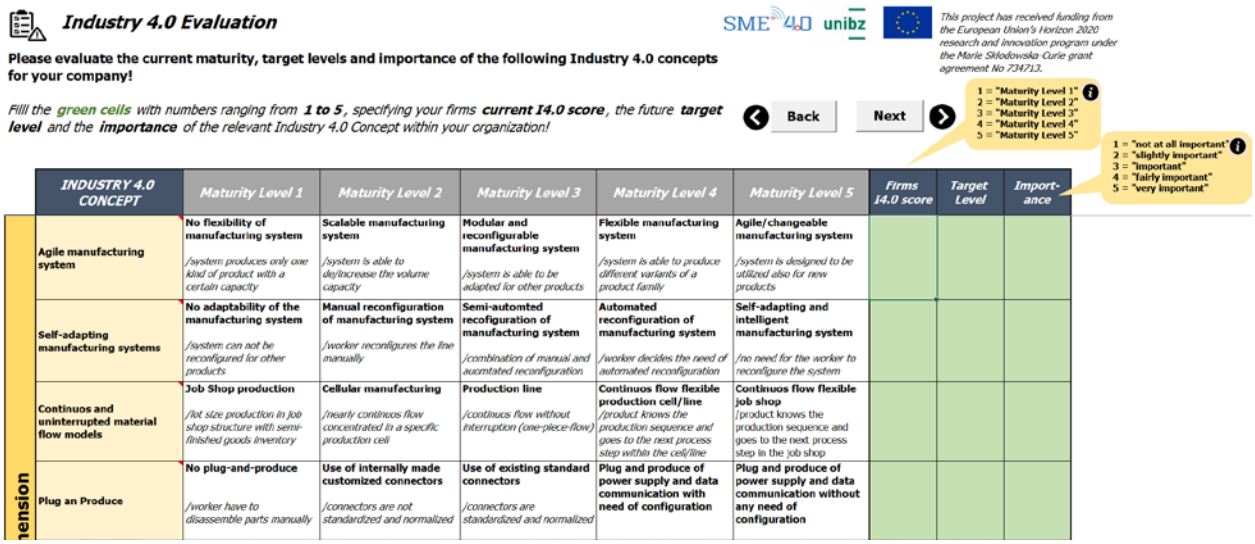
terminology as well as a succinct instance have been defined. At this point the quantitative assessment approach consists mainly of three components, namely the firms industry 4.0 score, the target level as well as the importance. By means of the firms industry 4.0 score, the maturity level of the enterprise with respect to the considered concept is defined. The target level stands for the aspired maturity level, which is ought to be reached in foreseeable and realistic time frame. Conclusively, the importance offers the companies the possibility to attribute a significance to the examined Industry 4.0 concept. For this study we focus primarily on the importance level in order to get a common understanding of how users, but also experts, evaluate the suitability of different Industry 4.0 concepts for small, medium sized and large companies.
Figure 1 shows an excerpt of the in Microsoft Excel developed self-assessment tool in order to show the structure as well as the main fields, where user have to insert their self-evaluation.



Industry 4.0 Evaluation

SME 4.0 unibz

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Please evaluate the current maturity, target levels and importance of the following Industry 4.0 concepts for your company!

*Fill the green cells with numbers ranging from **1 to 5**, specifying your firms **current I4.0 score**, the future **target level** and the **importance** of the relevant Industry 4.0 Concept within your organization!*

Back Next

1 = "Maturity Level 1"
2 = "Maturity Level 2"
3 = "Maturity Level 3"
4 = "Maturity Level 4"
5 = "Maturity Level 5"

1 = "not at all important"
2 = "slightly important"
3 = "important"
4 = "fairly important"
5 = "very important"

	INDUSTRY 4.0 CONCEPT	Maturity Level 1	Maturity Level 2	Maturity Level 3	Maturity Level 4	Maturity Level 5	Firms I4.0 score	Target Level	Import-ance
nension	Agile manufacturing system	**No flexibility of manufacturing system** */system produces only one kind of product with a certain capacity*	**Scalable manufacturing system** */system is able to de/increase the volume capacity*	**Modular and reconfigurable manufacturing system** */system is able to be adapted for other products*	**Flexible manufacturing system** */system is able to produce different variants of a product family*	**Agile/changeable manufacturing system** */system is designed to be utilized also for new products*			
	Self-adapting manufacturing systems	**No adaptability of the manufacturing system** */system can not be reconfigured for other products*	**Manual reconfiguration of manufacturing system** */worker reconfigures the line manually*	**Semi-automted recofiguration of manufacturing system** */combination of manual and auomtated reconfiguration*	**Automated reconfiguration of manufacturing system** */worker decides the need of automated reconfiguration*	**Self-adapting and intelligent manufacturing system** */no need for the worker to reconfigure the system*			
	Continuos and uninterrupted material flow models	**Job Shop production** */lot size production in job shop structure with semi-finished goods inventory*	**Cellular manufacturing** */nearly continuos flow concentrated in a specific production cell*	**Production line** */continuos flow without interruption (one-piece-flow)*	**Continuos flow flexible production cell/line** */product knows the production sequence and goes to the next process step within the cell/line*	**Continuos flow flexible job shop** */product knows the production sequence and goes to the next process step in the job shop*			
	Plug an Produce	**No plug-and-produce** */worker have to disassemble parts manually*	**Use of internally made customized connectors** */connectors are not standardized and normalized*	**Use of existing standard connectors** */connectors are standardized and normalized*	**Plug and produce of power supply and data communication with need of configuration**	**Plug and produce of power supply and data communication without any need of configuration**			

Figure 1. Maturity model based self-assessment of 42 Industry 4.0 concepts identified in scientific literature.

3. Methodology: survey design for collecting expert and user opinions

3.1. Classification of enterprises

According to the European Commission enterprises can be classified into different categories according to their size. For the classification, various criteria can be used, the most commonly employed however usually being the number of persons employed (see also Figure 2). As the graphic below illustrates, two further criteria can be applied for the classification, namely the annual values of turnover and balance sheet total of an enterprise.
The most common form of segmenting enterprise sizes is the division into four different categories, based on the number of persons employed. Industry 4.0 technologies are already in phase of introduction in large enterprises. According to the research team this development will have to be extended also to small and medium sized enterprises, while it wouldn't make many sense (at least in a very first step) to invest time and effort also in investigating the potential in smallest enterprises (micro-enterprises). Thus, in this work we will concentrate our survey and the study on the small and medium sized enterprises compared to the attractiveness and importance in large enterprises.

eurostat
Statistics

	Description	Abbre-viation	Number of employees	Turnover	Balance Sheet Total
SMEs	***Micro** enterprises*	*XS*	less than 10	≤ € 2 million	≤ € 2 million
	***Small** enterprises*	*S*	from 10 to 49	≤ € 10 million	≤ € 10 million
	***Medium** -sized enterprises*	*M*	from 50 to 249	≤ € 50 million	≤ €43 million
	***Large** enterprises*	*L*	250 or more	> € 50 million	> € 43 million

Figure 2. Classification of company sizes (European Commission, 2018).

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3.2. Design of the user survey

In a first moment, company information is requested to allow the categorization into the sizes. These information are number of persons employed, turnover, balance sheet total and operating sector. Selection fields are activated to request this information, allowing the respondent to choose from several options or intervals respectively.
Afterwards follows the evaluation of maturity and target levels (from 1 to 5) of the in Section 2 introduced 42 Industry 4.0 concepts in relation to the enterprise. Additionally, it should be specified how important the concepts are to the company (again from 1 to 5).
It is particularly vital to create added value for companies and to encourage the respondents to completely participate in the survey. One way of doing so, is to provide visual graphics that show the Industry 4.0 readiness and target levels in relation to the concepts already during the process of filling out the self-assessment. By integration of the immediate visualization of the current status report in the form of spider web diagrams (which compares the current value of each Industry 4.0 concept with its target value) participants have an incentive to complete the assessment. Besides this, the participants is shown a ranking list of Industry 4.0 concepts, which offer the highest potential for their company based on the information regarding their importance. Therefore, a list with the top potential concepts is shown in a printable Excel spreadsheet. In addition, the companies are also informed that the result of the entire work will be handed over to them and thus they will get a general recommendation for assessing their situation related to the average of their company size. Figure 3 shows an overview of the main steps for the survey design of the enterprises.

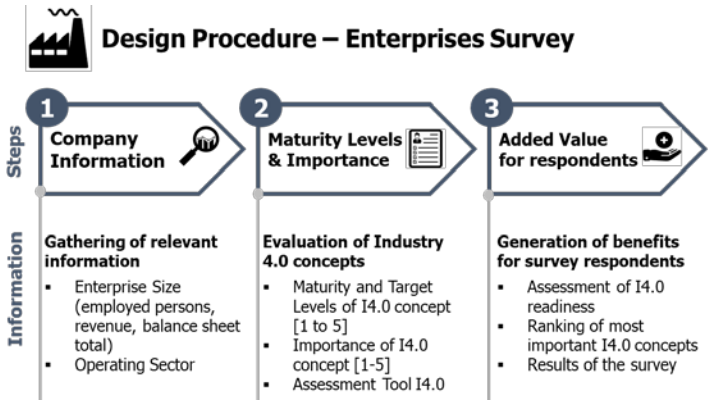

Figure 3. Overview over the design of the enterprise (user) survey.

3.3. Design of the expert survey

This section is intended to give an overview of the structure of the expert survey. With regard to the procedure for the expert survey, in the first step the participants are explained what the survey is about, how it is structured and how they should proceed. In the next moment, various general information is retrieved, ranging from name to e-mail over research focus. Once this basic information has been gathered, the next step relates to the core of the evaluation. Here the experts evaluate the suitability of Industry 4.0 concepts within all size combinations for manufacturing firms. For this purpose, they evaluate the suitability of the corresponding Industry 4.0 concepts for micro, small, medium and large enterprises in a separate Excel sheet. The importance of the various concepts is evaluated from 1 to 5, where 1 reflects the lowest and 5 the highest importance of a given concept (same as in the user survey).
In addition, a supplemental response option "no answer" is implemented in order to give the respondent the possibility of not evaluating a concept for whatsoever reason (e.g. missing expertise on a certain topic).
The last major step in the survey design is to give experts encouragement to complete the survey and make it more interesting for them. To achieve this, respondents will receive the results of the study. The researchers are themselves concerned with the subject and are also interested in the scientific progress in this regard even better, if they can contribute to it. By assuring them the results of the study, it can be expected to significantly increase the encouragement to completely fill out the survey.
Figure 4 graphically shows the discussed three main steps and the associated information of the survey design for the expert's form.

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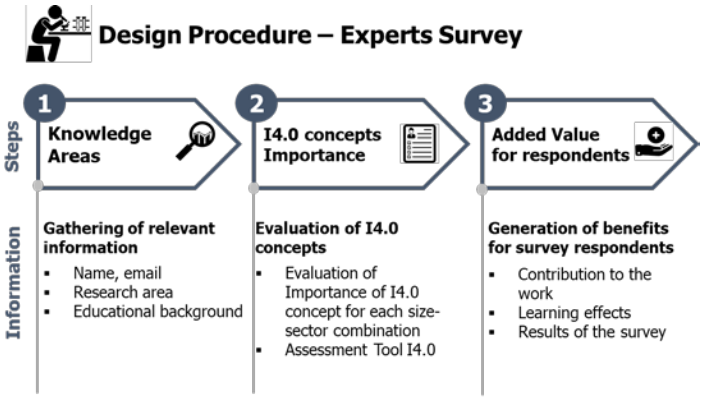

Figure 4. Overview over the design of the expert survey.

4. Evaluation of survey results

After showing how expert and user survey were created and structured, it is now a matter of evaluating and analyzing the results. For this purpose, the user survey, which is based on the opinions of enterprises is examined at first. Subsequently, the evaluations from science within the expert survey in which various researchers and scholars were surveyed will be discussed. The aim of this evaluation is to identify possible patterns of importance and applicability of different Industry 4.0 concepts related to enterprise size. To do this, two different perspectives are examined, in this case one more practical (user survey) and one more theoretical (expert survey) comparing their results.

4.1. Data processing of survey results

A number of 28 companies of various sizes (8 small, 9 medium and 11 large enterprises) and fields of activity from USA, Italy, Austria and Slovakia participated in the user survey. The participating companies were animated to evaluate how important each Industry 4.0 concept is for their business on a scale from one to five.
The expert survey was addressed to professors and researchers working on Industry 4.0 for SMEs involving different universities, research institutions and other experts worldwide. A total of 12 experts from the field completed the survey.
All assessed the suitability and importance of the respective Industry 4.0 concepts for the relevant company sizes (small, medium and large). The grading scale ranged from 1 to 5, where 1 stands for a concept that is not at all important and 5 for a concept that is rated as very relevant. In general, the assessed importance of a single Industry 4.0 concept is characterized by the average value ($\bar{X}$), the respective standard deviation (σ), the coefficient of variation (C_v) as a measure of relative variability of the answers as well as the number of answers (n).

$$(1) \quad \bar{X} = \frac{\sum Importance\ Values}{Number\ of\ answers - "No\ answer"}$$

$$(2) \quad \sigma = \sqrt{\frac{\sum_{n=1}^{i}(x_i - \mu)^2}{n}}$$

$$(3) \quad C_v = \frac{\sigma}{\bar{X}}$$

These values are processed for every Industry 4.0 concept in the expert and user survey and for every size of enterprise. In the following tables (Table 1, 2 and 3) we show the results categorized by the size of enterprise and prioritized by the average value of the user responses comparing the results of the expert meanings.

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Table 1. Results of user and expert survey for large enterprises

LARGE (L)	**Enterprise / User**				**Expert**			
Industry 4.0 Concept	*n*	$\bar{X}$	σ	*Cv*	*n*	$\bar{X}$	σ	*Cv*
Cyber Security	11	4,82	0,39	8%	12	4,50	0,76	17%
ERP/MES	11	4,73	0,45	9%	12	4,25	0,83	20%
Industry 4.0 Roadmap	10	4,60	0,49	11%	12	4,25	0,83	20%
Digital Real-Time Monitoring Systems	11	4,36	0,88	20%	12	4,75	0,43	9%
Cultural Transformation	11	4,36	0,64	15%	11	4,18	0,83	20%
Big Data Analytics	11	4,27	0,45	10%	12	4,25	1,01	24%
Agile Manufacturing Systems	10	4,10	1,22	30%	12	4,08	0,76	19%
Digital and connected workstations	10	4,10	0,94	23%	11	4,09	0,79	19%
Role of the Operator	11	4,00	0,95	24%	11	3,82	1,03	27%
E-Kanban	9	4,00	0,94	24%	10	4,20	0,75	18%
Automated Transport Systems	10	4,00	0,89	22%	12	4,25	0,83	20%
Cloud Computing	11	3,91	0,90	23%	12	4,00	1,00	25%
Automated Manufacturing/ Assembly	11	3,91	1,24	32%	12	4,33	0,75	17%
Collaborative Robotics	10	3,90	1,04	27%	12	4,17	0,99	24%
Training 4.0	11	3,82	0,94	25%	12	4,58	0,64	14%
Automated Storage Systems	11	3,82	0,94	25%	12	4,25	0,72	17%
Remote Monitoring of Products	10	3,80	1,66	44%	12	4,50	0,65	14%
IoT and CPS	10	3,80	1,25	33%	12	4,08	0,64	16%
Predictive Maintenance	10	3,80	1,17	31%	12	4,67	0,47	10%
Identificat. and Tracking Technology	11	3,73	0,96	26%	12	4,50	0,50	11%
Decision Support Systems	11	3,64	0,98	27%	12	4,33	0,75	17%
Digital Product-Service Systems	10	3,60	1,36	38%	11	3,91	1,24	32%
Collaboration Network Models	10	3,60	0,80	22%	12	3,83	0,90	23%
PDM and PLM	10	3,60	0,92	25%	11	4,36	0,77	18%
CPS Standards	10	3,60	0,80	22%	11	4,18	0,72	17%
Self-adapting manufacturing systems	10	3,50	0,81	23%	12	3,83	0,99	26%
Tele-Maintenance	10	3,50	1,12	32%	12	3,92	0,95	24%
Simulation	10	3,50	0,92	26%	12	4,42	0,64	14%
Digital Point of Sales	9	3,44	1,42	41%	12	3,67	1,03	28%
Open Innovation	10	3,40	1,11	33%	11	3,27	1,14	35%
Smart Assistance Systems	10	3,40	0,80	24%	11	3,91	0,90	23%
Continuous material flow models	11	3,36	0,98	29%	12	4,58	0,76	17%
Sustainable Supply Chain Design	11	3,27	0,86	26%	12	4,17	0,90	22%
Artificial Intelligence	11	3,27	1,14	35%	11	4,45	0,78	22%
Plug and Produce	9	3,00	0,67	22%	12	3,58	0,86	18%
VR and AR	10	3,00	0,63	21%	12	4,00	1,00	24%
Servitization/Sharing Economy	9	2,89	1,52	53%	8	3,25	1,20	25%
Additive Manufacturing (3D-Print)	11	2,82	1,19	42%	11	3,45	0,78	37%
Object Self Service	9	2,78	1,55	56%	9	3,78	1,13	23%
Digital Lock-In	10	2,70	0,90	33%	8	3,38	0,99	30%
Freemium	10	2,70	1,35	50%	11	3,00	1,04	29%
Digital Add-on or Upgrade	10	2,60	1,36	52%	9	3,44	0,96	35%

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Table 2. Results of user and expert survey for medium enterprises

MEDIUM (M)	**Enterprise / User**				**Expert**			
Industry 4.0 Concept	*n*	$\bar{X}$	σ	*Cv*	*n*	$\bar{X}$	σ	*Cv*
Digital Real-Time Monitoring Systems	9	4,11	0,99	24%	12	3,92	0,86	22%
ERP/MES	9	4,11	0,99	24%	12	4,00	0,91	23%
Industry 4.0 Roadmap	9	4,11	0,74	18%	12	4,33	0,75	17%
Digital and connected workstations	9	4,11	0,74	18%	11	3,91	0,67	17%
Cloud Computing	9	3,78	0,63	17%	12	3,42	1,04	30%
Cyber Security	9	3,78	0,79	21%	12	4,25	0,92	22%
Agile Manufacturing Systems	9	3,67	1,05	29%	12	3,92	0,76	19%
Collaboration Network Models	9	3,67	0,67	18%	12	3,67	0,75	20%
Cultural Transformation	9	3,67	1,15	31%	12	4,08	0,86	21%
Training 4.0	9	3,56	0,68	19%	12	4,42	0,64	14%
Automated Storage Systems	9	3,56	0,68	19%	11	3,55	0,89	25%
Big Data Analytics	9	3,44	1,07	31%	12	3,67	1,43	39%
Identificat. and Tracking Technology	9	3,44	0,83	24%	12	4,33	0,47	11%
Predictive Maintenance	9	3,33	1,15	35%	12	4,33	0,47	11%
Continuous material flow models	9	3,22	1,13	35%	12	4,17	0,80	19%
Role of the Operator	9	3,22	1,13	35%	11	3,82	0,83	22%
PDM and PLM	9	3,22	1,13	35%	11	3,73	0,75	20%
Object Self Service	9	3,22	1,40	43%	9	3,22	1,13	35%
Decision Support Systems	9	3,11	0,74	24%	12	3,92	0,76	19%
IoT and CPS	9	3,11	0,87	28%	12	3,67	0,62	17%
Tele-Maintenance	9	3,11	1,20	38%	12	3,75	0,92	25%
Self-adapting manufacturing systems	9	3,00	0,82	27%	12	3,83	1,14	30%
Open Innovation	8	3,00	1,22	41%	11	3,18	1,11	35%
Smart Assistance Systems	9	3,00	0,82	27%	11	3,64	0,98	27%
Automated Transport Systems	9	2,89	0,87	30%	11	3,45	0,89	26%
Automated Manufacturing/ Assembly	9	2,89	1,10	38%	12	4,00	0,91	23%
Remote Monitoring of Products	9	2,78	1,23	44%	12	3,83	0,80	21%
Digital Point of Sales	9	2,78	1,03	37%	12	3,25	0,83	26%
Collaborative Robotics	9	2,78	1,03	37%	12	4,00	0,82	20%
VR and AR	9	2,78	0,92	33%	12	3,33	0,85	25%
Simulation	9	2,78	1,31	47%	12	3,92	0,49	13%
Digital Product-Service Systems	9	2,67	1,56	59%	11	3,64	1,07	29%
CPS Standards	9	2,67	1,15	43%	11	3,82	0,83	22%
Servitization/Sharing Economy	9	2,56	1,64	64%	8	3,13	0,93	22%
E-Kanban	9	2,56	1,26	49%	10	3,70	0,78	30%
Sustainable Supply Chain Design	9	2,44	1,07	44%	12	3,83	0,90	21%
Artificial Intelligence	9	2,44	0,83	34%	11	3,73	0,96	23%
Freemium	9	2,22	1,47	66%	11	3,00	0,74	26%
Plug and Produce	9	2,11	0,74	35%	12	3,42	0,64	25%
Digital Add-on or Upgrade	9	2,00	1,05	53%	9	2,89	0,74	19%
Additive Manufacturing (3D-Print)	9	1,78	1,03	58%	11	3,18	0,72	26%
Digital Lock-In	9	1,44	0,50	34%	8	3,25	0,97	22%

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Table 3. Results of user and expert survey for small enterprises

SMALL (S)	**Enterprise / User**				**Expert**			
Industry 4.0 Concept	*n*	$\bar{X}$	σ	*Cv*	*n*	$\bar{X}$	σ	*Cv*
Agile Manufacturing Systems	8	4,75	0,66	14%	12	3,58	0,86	24%
Cultural Transformation	7	4,14	0,83	20%	12	3,92	1,26	32%
Continuous material flow models	7	4,00	1,31	33%	12	3,58	1,11	31%
Digital and connected workstations	7	4,00	1,31	33%	11	3,18	0,83	26%
Digital Real-Time Monitoring Systems	8	3,88	0,78	20%	12	2,67	1,31	49%
Role of the Operator	7	3,86	1,36	35%	11	4,00	0,95	24%
Self-adapting manufacturing systems	7	3,71	1,03	28%	12	3,08	1,11	36%
Big Data Analytics	7	3,71	1,39	37%	12	2,50	1,04	42%
ERP/MES	8	3,63	0,99	27%	12	3,25	1,09	34%
Cyber Security	8	3,63	0,99	27%	12	3,75	1,09	29%
Decision Support Systems	7	3,57	0,90	25%	12	3,00	1,00	33%
Industry 4.0 Roadmap	7	3,57	1,18	33%	12	3,75	1,01	27%
Training 4.0	7	3,57	0,73	20%	12	3,67	0,85	23%
PDM and PLM	7	3,43	0,73	21%	11	3,09	1,00	32%
Sustainable Supply Chain Design	8	3,38	0,99	29%	12	3,00	1,00	33%
Digital Product-Service Systems	8	3,25	1,20	37%	11	3,09	1,00	32%
Collaboration Network Models	8	3,25	0,66	20%	12	3,58	0,86	24%
Tele-Maintenance	7	3,14	1,12	36%	12	3,17	1,40	44%
Additive Manufacturing (3D-Print)	8	3,13	1,05	34%	11	2,91	0,67	23%
Open Innovation	8	3,00	0,87	29%	11	3,55	1,37	39%
Cloud Computing	8	3,00	1,12	37%	12	3,17	1,14	36%
E-Kanban	8	3,00	1,32	44%	10	2,90	1,04	36%
IoT and CPS	7	3,00	1,20	40%	12	2,83	1,14	40%
Predictive Maintenance	7	3,00	1,07	36%	12	3,58	1,04	29%
Automated Manufacturing/ Assembly	7	2,86	1,55	54%	12	2,92	1,04	36%
Collaborative Robotics	7	2,86	1,64	57%	12	3,25	1,16	36%
Simulation	7	2,86	0,99	35%	12	3,17	0,90	28%
Object Self Service	7	2,71	0,88	32%	9	2,44	1,17	48%
Plug and Produce	7	2,57	0,73	28%	12	3,00	1,41	47%
Identificat. and Tracking Technology	7	2,57	1,18	46%	12	3,42	1,11	33%
Automated Storage Systems	7	2,57	0,90	35%	11	2,55	0,89	35%
Smart Assistance Systems	7	2,57	1,40	54%	11	3,18	1,27	40%
Freemium	7	2,29	1,28	56%	11	2,64	0,77	29%
Remote Monitoring of Products	8	2,25	0,97	43%	12	2,42	0,49	20%
Automated Transport Systems	7	2,14	0,64	30%	11	2,27	0,86	38%
VR and AR	7	2,14	1,25	58%	12	2,75	0,83	30%
CPS Standards	7	2,14	1,36	63%	11	3,09	1,24	40%
Digital Point of Sales	8	2,13	1,27	60%	12	3,00	0,91	30%
Servitization/Sharing Economy	8	2,00	1,00	50%	8	3,38	1,11	33%
Digital Add-on or Upgrade	8	2,00	1,22	61%	9	2,00	0,47	24%
Artificial Intelligence	7	1,71	1,03	60%	12	2,83	1,14	40%
Digital Lock-In	8	1,25	0,43	35%	8	2,63	1,22	46%

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4.2. Discussion of results

First of all, it is noticeable that Industry 4.0 seems to be an important topic especially for large companies in industry. They see 11 Industry 4.0 concepts as fairly important to very important (average value greater than 4), while each, small and medium-sized enterprises, consider only 4 Industry 4.0 concepts as important. The coefficient of variation shows that the opinion seems to be quite uniform here. With an equally low variability, experts are convinced that only 1 Industry 4.0 concept for small enterprises, but 10 for medium-sized enterprises, have a value greater than or equal to 4. It is especially impressive that for large enterprises the experts see 27 Industry 4.0 concepts with a value of at least 4. In summary, these results can be interpreted that Industry 4.0 concepts are particularly important for medium-sized and large companies. A further hypothesis from the results is that the experts see the significance of Industry 4.0 in the future for these two groups much higher than the companies themselves are currently aware of.
The homogeneity of the responses for all results was also investigated. This clearly shows that experts have a much more uniform and consistent opinion on the significance of the various Industry 4.0 concepts than is the case with companies. This is interpreted by the fact that they have a better level of knowledge about Industry 4.0, which in turn requires that companies must be informed much more in this direction in order to increase their knowledge of Industry 4.0 and the qualification of their management and employees.
In some cases experts and enterprises have a very different meaning. E.g. enterprises evaluate concepts like 'Agile Manufacturing Systems', 'Digital and connected workstations', 'Digital Real-Time Monitoring Systems' and 'Big Data Analytics' much more important than experts do this for small enterprises. At the other side 'Predictive Maintenance', 'Open Innovation', 'Identification and Tracking Technology' as well as 'Servitization/Sharing Economy' are seen much more important by experts.
In the case of medium sized enterprises the expert group is in general much more emphasized about the benefits of Industry 4.0 concepts than the companies are (especially for 'Training 4.0', 'Identification and Tracking Technology', 'Predictive Maintenance' and 'Continuous material flow models').
For large enterprises the meaning of experts and companies is more homogeneous as for the other two enterprise sizes.

5. Most suitable Industry 4.0 concepts for different sizes of enterprises

Based on the results of the two surveys, Table 4 and Table 5 provide an overview of the most suitable and significant Industry 4.0 concepts according to companies and experts (according to a ranking of the average value for the importance of the Industry 4.0 concept). The Industry 4.0 concepts in bold are those that appear in the ranking of enterprises as well as in the ranking of experts and thus, they seem to be even more relevant as the other ones.

Table 4. Most promising Industry 4.0 concepts for different enterprise sizes according to enterprise survey results

Rank	Small (S)	Medium (M)	Large (L)
1	Digital Real-Time Monitoring Systems	Agile Manufacturing Systems	**Cyber Security**
2	ERP/MES	**Cultural Transformation**	ERP/MES
3	**Industry 4.0 Roadmap**	**Continuous material flow models**	Industry 4.0 Roadmap
4	Digital and connected workstations	Digital and connected workstations	**Digital Real-Time Monitoring Systems**
5	Cloud Computing	Digital Real-Time Monitoring Systems	Cultural Transformation
6	**Cyber Security**	Role of the Operator	Big Data Analytics
7	**Agile Manufacturing Systems**	Self-adapting manufacturing systems	Agile Manufacturing Systems
8	**Collaboration Network Models**	Big Data Analytics	Digital and connected workstations
9	**Cultural Transformation**	**ERP/MES**	Role of the Operator
10	**Training 4.0**	**Cyber Security**	E-Kanban

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Table 5. Most promising Industry 4.0 concepts for different enterprise sizes according to expert survey results

Rank	Small (S)	Medium (M)	Large (L)
1	Role of the Operator	Training 4.0	**Digital Real-Time Monitoring Systems**
2	**Cultural Transformation**	Industry 4.0 Roadmap	Predictive Maintenance
3	**Cyber Security**	Identification and Tracking Technology	Training 4.0
4	**Industry 4.0 Roadmap**	Predictive Maintenance	Continuous material flow models
5	**Training 4.0**	**Cyber Security**	**Cyber Security**
6	**Agile Manufacturing Systems**	**Continuous material flow models**	Remote Monitoring of Products
7	Continuous material flow models	**Cultural Transformation**	Identification and Tracking Technology
8	**Collaboration Network Models**	**ERP/MES**	Artificial Intelligence
9	Predictive Maintenance	Automated Manufacturing/ Assembly	Simulation
10	Open Innovation	Collaborative Robotics	PDM and PLM

For small enterprises, experts and companies have similar meanings and propose concepts for preparing the organization as well as people for Industry 4.0. In addition, concepts for agile manufacturing and collaboration are needed. For medium sized enterprises concepts for realizing a continuous material flow as well as ERP/MES systems play an important role. For large enterprises real-time monitoring seems to be a highly requested concept. In all three companies sizes the topic cyber security is high ranked and therefore of general interest.
Both tables give an important statement for practitioners who are currently working on the introduction of Industry 4.0. On the one hand, Table 4 shows which methods, according to companies, offer the most practical benefits and whose feasibility is also perceived as realistic. On the other hand, Table 5 summarizes the opinions of experts and scientists, which also include concepts whose importance the companies are not yet aware of or which they simply do not (sufficiently) know, since they, for example, will only be transferred from research to industry in the near future. Therefore, practitioners should consider both tables for the definition of initiatives and the selection of Industry 4.0 concepts to be introduced in the company.

6. Conclusion and outlook

The introduction of Industry 4.0 in industrial companies poses a particular challenge for small and medium-sized enterprises. While large enterprises can afford their own personnel resources for the introduction and research of Industry 4.0 topics, this is usually not the case with SMEs. Therefore, the aim of this work was to identify the most promising Industry 4.0 concepts for different sizes of enterprises (small, medium, large) on the basis of an existing Industry 4.0 self-assessment tool as well as a survey conducted among enterprises and experts. The study showed that the potential of Industry 4.0 concepts is assumed to be much higher by medium-sized and large enterprises than by small enterprises. Experts in particular see a great opportunity in the introduction and transfer of Industry 4.0 in medium-sized enterprises. While large enterprises show a uniform and homogeneous picture of meanings between enterprises and experts, this is not the case for small and medium-sized enterprises. This shows that there are still major discrepancies between research and industrial practice and that there is therefore a need for further research and knowledge transfer to bring Industry 4.0 into this kind of companies.
Further research is therefore needed for the future to investigate why Industry 4.0 concepts have not yet been adopted in some cases. Especially for small enterprises a more detailed investigation should be carried out in the future to understand why Industry 4.0 is considered to have a lower potential.

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