

49th CIRP Conference on Manufacturing Systems (CIRP-CMS 2016)

## Advanced complexity management strategic recommendations of handling the “Industrie 4.0” complexity for small and medium enterprises

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### Abstract

The new chances and perspectives of “Industrie 4.0”, with cloud computing, cyber-physical systems and smart factory, lead to an increasing complexity and hence opacity, especially for small and medium enterprises.

The current Fraunhofer IPA empirical study “Industrie 4.0 - opportunities and prospects in the Metropolitan Region Rhine-Neckar”, on behalf of the Chambers of Commerce “IHK Rhein-Neckar”, “IHK Darmstadt Rhein Main Neckar” and “IHK Pfalz”, shows that enterprises expect an increase in future complexity in “Industrie 4.0”, but have not yet the knowhow for operational implementation.

The preparation of this study involved more than 200 companies in the Metropolitan Region Rhine-Neckar and neighbouring areas Westpfalz and Greater Darmstadt. 195 companies participated in the study survey, which was conducted in the form of 34 personal interviews and 161 online surveys. Furthermore, a workshop was organised with 25 enterprise participants. The participants of the survey and the workshop were mostly managing directors or production directors.

This paper presents the results of the study and sets out a developed approach, based on the aforementioned results, to the advanced management strategy for handling complexity with “Industrie 4.0”. This contains an enterprise-specific and stepwise approach, four principles for Industry 4.0 introduction, and specific recommendations for small and medium enterprises.

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Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems

**Keywords:** advanced Complexity Management; “Industrie 4.0”; small and medium-sized enterprises

### 1. Introduction

The production of the future will be characterised by shorter product life cycles, an increasing number of variants and short-term production program changes triggered by the customer. This leads to the rise of many new complex enterprise challenges [1-6]. Core competencies such as innovation capacity and fast implementation are crucial for the future, ensuring societal prosperity through sustainable and real value. An answer to this changed environment offers the fusion of information technologies with other technology fields such as mechanical engineering, automotive, etc. as defined by the German language term “Industrie 4.0”. Enterprises which refuse to address these new developments cannot remain competitive in the long term in the face of competitive pressures.

The metropolitan region Rhine-Neckar could especially benefit from the potential offered up by Industrie 4.0; on the one hand by the broad mix of industries and on the other by the strong economic power of the region. Many medium-sized companies in the metropolitan region Rhine-Neckar want a clear idea of the concept of Industrie 4.0 in terms of content and implementation. The reason for this is that the currently available literature either theoretically represents the theme or presented individual applications in the form of technologies [7]. It is therefore necessary, to structure the topic Industrie 4.0 practically and clearly. Similarly, the term needs to be sharpened in the enterprise awareness as well as that there is no generally accepted Industrie 4.0 solution. Industrie 4.0-applications must be chosen situation-specifically, depending on the business model or process.



how the relationship with the various customer segments is constructed. On the enterprise side, the internal manufacturing and provision of the product and service is the focus.

### 3.2. New benefits for customers by Industrie 4.0

The workshop participants were first introduced to the subject Industrie 4.0 and the business model issue by a keynote speech from Fraunhofer IPA. The main benefits of fields caused by Industrie 4.0 were presented as following [7]:

- Digital individualization: as additional benefit on product options and services that can be digitally generated and offered.
- Flexibility: e.g. faster response to demand fluctuations by easily adaptable production capacity.
- Demand orientation: e.g. products and services can be offered and produced according to scope of use, besides the desired quality of results will be explicitly taken into account.
- Sustainability: e.g. enabling cost and utilization optimised production program planning, especially in energy-intensive processes.
- Consistent process orientation: e.g. better connectivity to the relevant upstream and downstream business processes of the customer.
- Automated knowledge and learning: e.g., use of data for self-learning, continuous improvement in the product use.
- Collaboration skills: e.g. safer overcoming of interfaces between value creation partners.
- Productivity optimization: e.g. economic production and assembly of smallest batches with real-time conversion.

Each participant had then the opportunity to cast a vote and so give their opinion on the most important benefit field. The benefit fields with the most votes were used for the joint design of business models. The 25 enterprise participants of the workshop rated the benefit fields of productivity optimization, flexibility, process orientation and demand orientation as particularly important.

These topics were dealt with in a total of five groups of five workshop participants and an employee of Fraunhofer IPA in the role of facilitator.

The colorful mix of enterprise groups resulted in valuable discussions. The diverse composition of the groups led to new and creative ideas. Two groups focused on the workshop on the topic of productivity optimization and each one of the groups dealt with process orientation, flexibilisation and demand orientation.

## 4. Findings from the enterprise survey

In the related study [7] representatives of selected companies in the metropolitan region Rhine-Neckar and neighboring areas Westpfalz and Greater Darmstadt were asked for their assessment of Industrie 4.0. The aim of this structured survey was to determine the current state of implementation of Industrie 4.0 in the region.

### 4.1. Procedure of the business survey

The company survey includes the statements of participants from a total of 195 companies in the Rhine-Neckar and adjacent areas Westpfalz and Greater Darmstadt. The company survey was carried out between July and August 2015. The surveys were conducted in the form of 34 personal interviews and 161 online surveys on the internet. The interviews made possible a diverse and detailed investigation. Included among the selected companies were Industrie 4.0-providers and Industrie 4.0-users as well as Industrie 4.0-skeptics. The purpose of the online survey was the consideration and illustration of a broader basis of estimates and opinions on the subject of Industrie 4.0. This study is especially valuable in that it combines detailed analysis and broad opinion.

In both survey cases, the survey was divided into three survey blocks, each with four to eleven detailed questions.

#### *Self-assessment and technologies:*

- How do you assess the importance of Industrie 4.0 for your business today and in the future?
- How does your company already employ the technical Industrie 4.0 infrastructure?

#### *Industrie 4.0 as a challenge, an opportunity and risk:*

- In which areas do you see challenges, opportunities and risks in your enterprise?
- In which topics would you like external technical support?

#### *Demands on staff skills and regional infrastructure:*

- What skills do your employees need in operational and administrative areas?
- How satisfied are you with the knowledge of your trainees and graduates in relation to Industrie 4.0?
- How do you assess the regional Industrie 4.0-training opportunities for your staff and what support do you want from Chamber of Commerce?

The interviews were conducted in the form of open discussions. The survey blocks served as the interview guide.

The online survey was conducted with most questions in the form of multiple-choice selection. The participants were given several pre-formulated answers to choose from on a question.

### 4.2. Participants overview

The 161 participants in online survey were divided into 13 different industries. Industries with the most participants were "electrical engineering, electronics, IT and telecommunications equipment (PABX equipment)" and "consulting and services" (see Figure 2). In terms of size, small and medium-sized enterprises (SMEs), as well as larger companies, were represented. Among the respondents were joined by professionals and executives mainly CEO (61%).

In addition to the detailed analysis and the detection of a broad opinion image, diversity of branches represents another feature of the study.

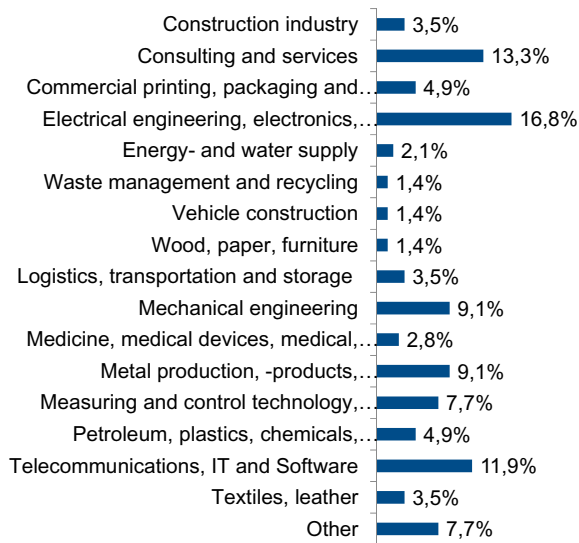


Fig. 2. Participants in the online survey by industry sector

34 enterprises from various branch sectors were visited as part of the interviews in the Rhine-Neckar and adjacent areas Westpfalz and Greater Darmstadt. The focus was on medium-sized businesses, but large companies were also interviewed. In the medium-sized companies, the discussions were held with CEO. In the large company CEO and Production Director were involved.

#### 4.3. Operative Industrie 4.0 implementation unclear

At the present time every fourth company already applies the topic Industrie 4.0 during strategic decisions. However, this is still expandable with almost as many companies. This applies in particular for operational implementation, because the majority of study participants had no clear idea about how Industrie 4.0 could be implemented operationally concretely within the company.

#### 4.4. Industrie 4.0 as complex challenge

The present study found that the costs arising from Industrie 4.0 challenges are considered to be more complex in the future than at present (results of the online survey see Figure 3). The companies surveyed confirmed for Industrie 4.0 a wide variety of possible technologies, which differ in a high diversity of its features and the possible solutions due to different providers. A high dynamics of development speed is added. For the companies surveyed, it is difficult to keep a complete overview, which leads to less transparency.

#### 4.5. Cloud computing and Big Data with great potential

There is great interest in regard to new Industrie 4.0 technologies. Especially the topic cloud computing with terms Internet of Things, apps, Big Data and real time data attracts attention of companies. The potential of cloud

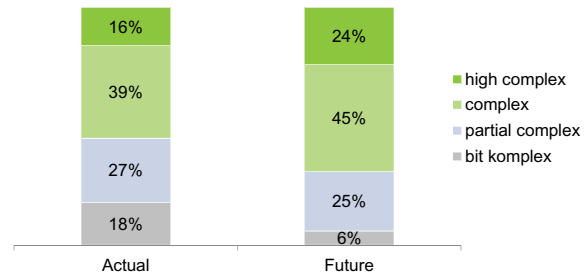


Fig. 3. Review the emerging challenges by Industrie 4.0 for the enterprise

computing and Big Data crystallised in bilateral exchange with the companies in detail out. Many companies from various sectors are able to get benefit from cloud computing, apps, Big Data and real-time data. In addition to the manufacturing industry this mainly includes the trade, logistics and the software industries. Hence the interest in cloud computing is very broad. Here, also, high potential can be assumed as to the benefits of these technologies.

#### 4.6. Challenges by Industrie 4.0

In the interviews, Industrie 4.0 challenges, risks and opportunities by Industrie 4.0 had a central and relevant meaning. The challenges of Industrie 4.0 are difficult to influence quantities by companies. However these challenges have a strong influence on the possible use of Industrie 4.0 [7].

In part, companies see challenges here again, which were already familiar in another context. In the new context of Industrie 4.0 they take on new meaning. A total of nine challenges are considered as relevant [7]. These challenges have strong mutual interactions (see Figure 4).

#### 4.7. Users and providers see different opportunities

The distinction between suppliers and users is particularly interesting in statements of the participants regarding opportunities from Industrie 4.0. Users see classic production targets, with increase of efficiency, effectiveness and flexibility as greatest potential. For providers, by far the biggest potential is in developing new business models.

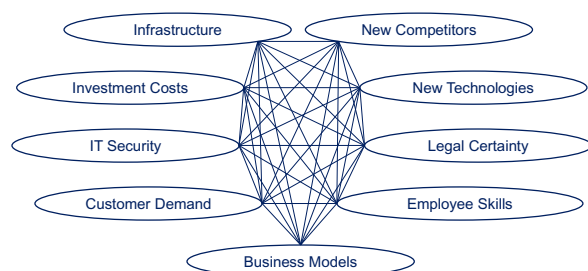


Fig. 4. Challenges by Industrie 4.0

#### 4.8. Risks by Industrie 4.0

In addition to increasing internal complexity most companies see the greatest risk from Industrie 4.0 in rising investment costs. The companies do not see the risk that their companies own products and services could get obsolete by Industrie 4.0.

Also the surveyed companies see dangers if control of Industrie 4.0-production could be temporarily lost. Especially for complicated systems risk of crash is very high. One of visited companies explained that, at worst, not one wrong product, but thousands of false products are manufactured. Another company points to the rising stress levels for employees, as a result of high-tech working environment.

In interviews insufficient IT security is identified as largest source of danger and therefore rated at highest risk.

### 5. Strategic Recommendations

When considering Industrie 4.0-technologies in discussions it became clear that there is not a generally accepted Industrie 4.0 solution for all businesses [7]. Successful suppliers and users of Industrie 4.0 can be emulated by others.

First, the company must define its own Industrie 4.0 goals. For this purpose the divisions are defined where significant changes are to be achieved by digitalisation. Interviewees surveyed also consider here business environment e.g. customer demand for individualization or development of competitors.

For structured implementation of strategic recommendations for action, the establishment of work packages to achieve objectives, planning of the timeline and definition of responsibilities should be based on definition of objectives.

#### 5.1. Objectives of users and providers

According to statements of company survey, following important objectives arise:

- High production efficiency (e.g. increase in performance and cost reduction).
- High production efficiency (e.g. quality and availability).
- High level of production flexibility (e.g. reaction time and reconfigurability).
- Least possible investment needs for means of production (e.g. use as a service performance).

Further guidance on development of an own goal give the exemplary objectives of discussions with interviewed companies.

##### *User goals of Industrie 4.0-related companies*

- Outsourcing of processes, hardware, software or infrastructure by increasing availability of machines and production equipment with improved monitoring and maintenance (everything as a service)
- Effective material supply through networking of production and logistics
- Smaller batch sizes as a result of greater flexibility

##### *Provider goals of Industrie 4.0-related companies*

- Development of new Industrie 4.0-business models in order to allow users to express their goal achievement and to generate them a high benefit value
- Corporate growth by opening up new markets and customer groups with Industrie 4.0 offerings
- Securing the own company position

#### 5.2. Principles for Industrie 4.0 Introduction

Another support in strategic planning gives four principles that have been discussed with interviewees. They apply to the design of industrial 4.0 technology systems:

##### *Modular architecture*

The implementation of Industrie 4.0 technologies is gradual. The starting point is the establishment of small and as independent as possible Industrie 4.0 technology systems. These systems are divided into more technology components. At best, these technology components are comparable, mutually similar and can replace each other. This leads to a higher robustness during turbulence and prevents total failure.

##### *Data Quality*

Elemental for digitalisation is quality of data and information. With the surveyed companies, in particular with companies that have already successfully begun implementing of Industrie 4.0, review criteria were discussed for data quality. The five characteristics of Big Data from recently published publications [7] are already being used by Industrie 4.0-related companies.

- Volume: Very large amounts of data
- Variety: Different data sources and formats
- Velocity: Seizures and analysing data in real time
- Veracity: Accuracy and reliability of data
- Value: Data must be usable

##### *Indirect cooperation machinery*

The indirect cooperation of machines in production is made possible by combination of intelligent production systems and intelligent transport systems. The machine should not be linked in a rigid production line, but add intelligent transport. As a result of a current order situation, the products are funneled differently through production depending on the situation.

##### *Adaptation by imitation*

Industrie 4.0-related companies indicate that many Industrie 4.0 solutions already exist in other fields of application and only adaptation of solutions from other industries has to be implemented. Industrie 4.0 progress of competitors on an equal footing, and the industry's leader should be observed, as well as the developments in inter-industry technology leaders. The involvements in clusters, associations and personal contact networks have a supportive effect.

## 6. Summary of the study results

The study results [7] show a top starting position for the companies in the metropolitan region Rhine-Neckar. The mix of Industrie 4.0-providers, -users and -researchers offers the best conditions for further development of the region.

Looking at the companies, the region includes a healthy mix of different industries. The region is characterised in particular by strength in the manufacturing sector and the information and communications technology. In these sectors, the region is significantly stronger position than other regions in Germany. By European standards, the region in the software industry even ranks among the top 3 locations. Industrie 4.0-providers and -users in the region are particularly well represented.

Many companies still approach Industrie 4.0-topic cautiously. With major investment decisions they show even more caution. The challenges in the field of modern technologies, processes, IT security, employee training and the development of new business models are judged by companies to be very complex and demanding. Medium-sized companies search for active support from the regional networks, from Chambers of Commerce, as well as partners in science.

Industrie 4.0 offers many new opportunities. Using these requires entrepreneurial courage and the will to innovate. Both can be seen clearly in the metropolitan region Rhine-Neckar. The use of information technology and the Internet will lead to the digitalisation of processes and the networking of means of production and thus revolutionizing the value. Industrie 4.0-users see enormous potential in improving their productivity, quality and flexibility. Industrie 4.0-providers particularly see potential in the development of new business models by Industrie 4.0.

For Industrie 4.0 the networking technologies are highly relevant. However, the networking of people in a personal contact network will be even more important for the successful implementation of complex Industrie 4.0 applications in the enterprises. The potential of Industrie 4.0 can be exploited only by an interdisciplinary collaboration across company boundaries. Joint inter-enterprise cooperation and mutual trust will be strengthened by regional proximity and greatly facilitated. The companies have already recognised this and cooperate in the metropolitan region Rhine-Neckar.

The metropolitan region Rhine-Neckar has an excellent scientific infrastructure with technology-oriented universities and institutions. In the immediate vicinity, the region is with Kaiserslautern, Darmstadt and Karlsruhe surrounded by three excellent science and higher-education institutions. There is still untapped potential through more intensive cooperation between medium-sized enterprises and scientific institutions

However, Industrie 4.0 not only affects the companies. Chambers of Commerce (CCI) will be even more in demand

in the future, especially in the fields of education and training of employees, particularly in the IT sector, as well as in the role of facilitator. The companies expect CCIs to facilitate exchange of best practice examples and aids in the legal field, as well as support for an even better access to regional universities and research institutions.

The policy in municipalities, county, state and federal governments can influence the location conditions for Industrie 4.0, the expansion of high-speed internet and mobile internet, positively. To compete in the future competition between locations, rural enterprises in particular need more support. Great opportunities arise through public funding programs to strengthen cooperation between industry and science.

## Acknowledgements

The authors would like to thank Mr David Görzig, Mr Dominik Paulus-Rohmer, Ms Heike Schaton, Ms Sina Baku, Mr Benjamin Krüger and Mr Markus Weskamp from Fraunhofer IPA for giving support in the documentation of the study as well as Mr Dr. Wolfgang Niopek, Ms Eva Maria-Lambertz, Mr Dr. Gerhard Gumbel, Mr Dr. Thilo Schenk, Mr Dr. Tibor Müller, Ms Christiane Huber, Mr Dr. Roland Lentz, Ms Dr. Clarisse Weischedel and many more from Chambers of Commerce to enable this study, organisation of interviews and giving advice and feedback. Very special thanks to Mrs Seanna Thum and Mrs Melanie Jäger for editorial support.

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