Study on Interoperability in Mechanical and Plant Engineering

The Global Production Language as a basis for Industrie 4.0

in cooperation with

FKM
Forschung im VDMA

VDMA

Editorial

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Interoperability as a strategic key

Industrie 4.0 necessitates changes at all hierarchical levels in companies and throughout the entire value chain. Plattform Industrie 4.0 addresses the three areas of interoperability, autonomy and sustainability in its new vision. Interoperability is the key strategic component and must be guaranteed in order to realize an autonomous and sustainable value creation network.

We often talk about digital ecosystems, which form the basis for Industrie 4.0. However, there can be no doubt that smart and connected production requires more than just an online connection. Of course, the characteristics of Industrie 4.0 differ from one company to the next. For smaller and medium-sized enterprises in particular, connected production is a decisive aspect. The question of efficiency is increasingly taking the spotlight, and with it, the subject of interoperability. Industrie 4.0 has heralded a new way of thinking when it comes to organizing processes. For companies, it is ultimately the added value that counts: Interoperable production enables these firms to enjoy the benefits of new digital structures and business models. And interoperable interfaces also simplify integration into value creation networks in existing and new production landscapes.

This study illustrates how companies assess the relevance of interoperable interfaces and the associated standards, such as OPC UA. The companies have recognized the demand for a standardized data model and are taking advantage of the opportunity to play an active role in shaping the standard and build up additional knowledge in OPC UA. VDMA has already been prioritizing the activities relating to OPC UA for several years and will continue to provide companies with important orientation on the subject in the future, too. In doing so, VDMA sees itself at the heart of efforts to standardize OPC UA interfaces and is developing the Global Production Language in collaboration with numerous companies. Together with its international partners, VDMA is also working on cross-domain harmonization. The Federal Ministry for Economic Affairs and Energy (BMWi) has recognized how important this is and is funding the "Interoperable Interfaces for Intelligent Production" project (II4IP).

We hope it makes for inspiring reading.

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Executive summary

The mechanical and plant engineering industry primarily associates Industrie 4.0 and digitalization with connected production and therefore new business models, a high degree of automation and a multitude of possible applications. This requires interoperability between a wide variety of machines, components and systems and the provision of all the relevant data.

In the mechanical and plant engineering industry, the OPC UA technology is used as a universal interface. VDMA is developing the Global Production Language in cooperation with the OPC Foundation by means of interface standardization. Under the auspices of VDMA, experts from around 600 companies are working in more than 35 working groups to develop these interface standards, which are known as OPC UA Companion Specifications. This clearly illustrates the relevance of an interoperable interface and the corresponding standards.

VDMA recognized early that interoperability is essential for Industrie 4.0.

In order to find out more about the strategic importance of interoperable interfaces, the objectives associated with these and the requirements companies place on such an interface, VDMA conducted this study.

VDMA has been developing Companion Specifications for more than six years, and the number of working groups is continuously increasing. This also begs the question as to whether OPC UA interfaces and the first specifications are already being implemented in products, or whether this is a purely future-oriented issue.

The study is made up of two parts: First, 14 interviews were conducted with experts from various industries, followed by an online survey with a total of 602 participants.

The results show that the overall cross-domain objective for the use of interoperable interfaces is to cover production systems in their entirety. This means that Industrie 4.0 should be characterized by the effortless communication of all participants in the communication network. Accordingly, an interoperable interface is important or very important for more than half of participating companies that require interoperability. Of these, 90 percent indicate that they have already implemented OPC UA as an interface or plan to do so in the future. From a strategic perspective, the companies are clearly focusing on replacing proprietary interfaces in order to enable "plug and produce" and similar visions. In addition, it allows the companies to benefit from advantages including the ability to offer more attractive products and save costs on both the customer and supplier side by reducing the amount of work required for integration and development.

From the companies' point of view, a suitable communication standard must above all be technically durable and widely accepted in order to guarantee security of investment.

In the future, the use of interoperable interfaces is to enable **production monitoring**, the structured provision of data and process information as well as **condition monitoring**, alongside other benefits. Although the complete implementation of these use cases in all of their facets is currently still a topic for the future, necessary aspects of the mentioned use cases are already covered in Companion Specifications, e.g., machine identification or the description of the machine state.

Another relevant factor for more than half of the companies is a form of **production control**, which is currently a challenge as the real-time mechanisms required in some cases are still in development.

It will take some time until all production systems can be covered in full and all participants in a production network are able to communicate with one another without any problems. Despite this, it is no longer purely an issue for the future – indeed, the vision is already being turned into reality in parts. The results of the study show that just under 70 percent of surveyed companies are currently implementing an OPC UA interface in their products and/or that the implementation is part of current development projects. Some 62 percent of participants indicate that they use existing Companion Specifications, an in-house information model or a mixed model for this.

The direction of travel has thus already been defined; the mechanical and plant engineering industry and the companies within it will tread this path together. In VDMA, new working groups – and therefore also new Companion Specifications – will continue to be created in the years to come, gradually turning the vision into reality. The companies that are working on these together with VDMA have recognized the demand for a standardized data model and are now taking advantage of the opportunity to play an active role in shaping the standard and build up additional knowledge in OPC UA. In turn, the global marketing through **umati – universal machine technology interface –** is facilitating the implementation of a Global Production Language.

1. Introduction and objective

The vast significance of Industrie 4.0 and digitalization for companies is widely known. But what exactly is behind these terms? What does Industrie 4.0 look like in reality? Digitalization and Industrie 4.0 are often and primarily associated with new business models, a high degree of automation and a multitude of possible applications. The basic prerequisite for this was the provision of the required data. If possible, this data should be of the same type – for instance, in order to monitor production without a great deal of integration effort. In addition, the communication partners must be able to understand the interface contents. As such, connecting production in an interoperable manner is a key task of the mechanical and plant engineering industry.

The aim is to create a Global Production Language.

The challenge here is to achieve interoperability between a wide variety of machines, components and systems. Firstly, a standardized interface is required for this. In this connection, the OPC UA technology has established itself as the preferred standard for the mechanical and plant engineering industry. OPC UA can be viewed as a universal interface and, alongside the secure transmission of data from the shop floor to the cloud, provides a kind of grammar for the Global Production Language. In a subsequent step, machinery and systems must be given the ability to understand the interface contents. This takes place by developing what are known as OPC UA Companion Specifications (CS), which define the **vocabulary** of this language. Under the auspices of VDMA and in cooperation of the OPC Foundation, experts from around 600 companies are working in more than 35 working groups to develop domain-specific OPC UA Companion Specifications for their specialist fields.

The number of VDMA working groups speaks for itself and also underlines how relevant an interoperable interface and corresponding standards are for the companies. The relevance of interoperability for the mechanical and plant engineering industry as a whole and companies' motivations when handling this topic are to be identified. To this end, VDMA has been conducting a study over the last few months with the objective of investigating the strategic importance of an interoperable interface such as OPC UA in the various companies. To do so, the following overarching questions were defined:

- What is the strategic importance of an interoperable interface such as OPC UA for the companies?

- Which criteria does a communication stand need to meet?

- Which use cases should be realized using an interoperable interface such as OPC UA (in the future)?

- Which communication channels should be covered by the Companion Specifications?

- To what extent have interoperable interfaces such as OPC UA already been implemented in the products?

- What is the motivation of companies that are actively participating in the creation of Companion Specifications?

The study design chosen to answer these questions is described in chapter 2.

2. Study design and sample

The chosen study design combines the methods of qualitative and quantitative research.

At the beginning of the study, a series of expert interviews was conducted. This personal interaction with the study participants allowed individual answers to be scrutinized while also enabling certain aspects to be discussed or complicated matters explained in greater depth. In this context, the term "experts" refers to people who possess clear and accessible knowledge relating to the object of the study. The interviews themselves were based on a set of interview guidelines and were conducted in a structured manner, i.e., all participants were asked the same questions in the same order. In a first step, the interviews were then evaluated: The interview texts were compared with the objective of working out principles shared by all interviewees in order to formulate hypotheses, and were analyzed on an individual basis in order to limit the solution space for the subsequent quantitative online survey. To ensure that the entire scope of the mechanical and plant engineering industry was covered, experts were selected for the interviews in line with the following criteria:

- Different sectors

- Different company size

- Different positions in the supply chain (both customers and suppliers)

All experts had a lot of experience with the topic of OPC UA.

The objective of this study is to determine the extent of a characteristic and its interrelationships regarding the questions defined above. This was performed through quantification using a representative survey conducted in the form of an online questionnaire. Unlike the expert interviews, the survey was geared towards the entire mechanical and plant engineering industry, regardless of the respective level of experience and implementation.
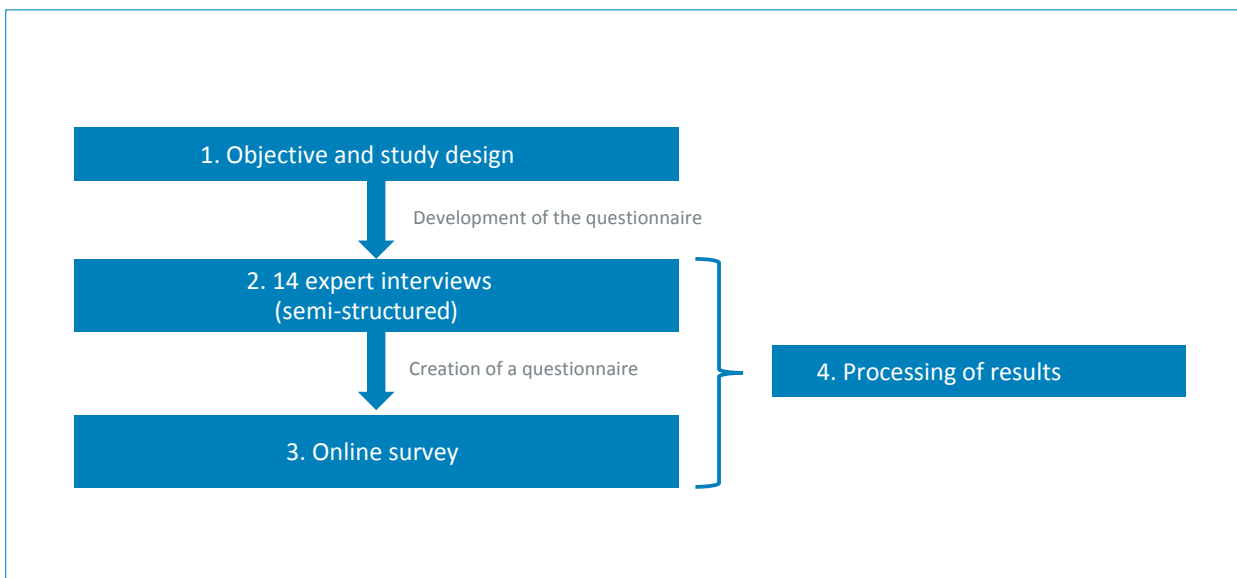

Figure 1: Design of OPC UA study

As a result, the questionnaire was sent to people who have not yet had any direct experience with OPC UA, as well as being distributed via the existing OPC UA groups. A total of 602 participants completed the questionnaire, of which 91 percent (n = 549) specified that they have a requirement for interoperable interfaces. Only those companies that require interoperable interfaces are taken into account in the overall analysis.

The companies were most divided in terms of current activity in committees:

- 55 percent (n = 294) of companies are already involved in committees relating to OPC UA

- 45 percent (n = 238) of companies are not involved in committees relating to OPC UA

In terms of company size, the sample is composed as follows:

The majority of study participants work in large companies with more than 500 employees, while small and microenterprises make up the smallest group.

The study participants hold the following positions in their company:

Figure 3 shows that many participants work in and around IT, which is due to the questions asked and was also to be expected. Despite this, there are enough responses from other positions for us to conclude that the results do not predominantly reflect the IT perspective.

The survey was aimed at the mechanical and plant engineering industry, which can be subdivided into another 30 different sectors. Companies from all sectors took part in the survey. The composition will not be discussed in detail here, as the results will not be analyzed in a segment-specific manner.

The data is evaluated by taking both the online survey and the results from the expert interviews into account. The evaluation of the online survey is based on the generalizations and through statistical analyses. It is supplemented by an interpretative analysis of the results from the interviews to describe the situation. These are complemented by an interpretive analysis of the results from the interviews in order to describe the situation.
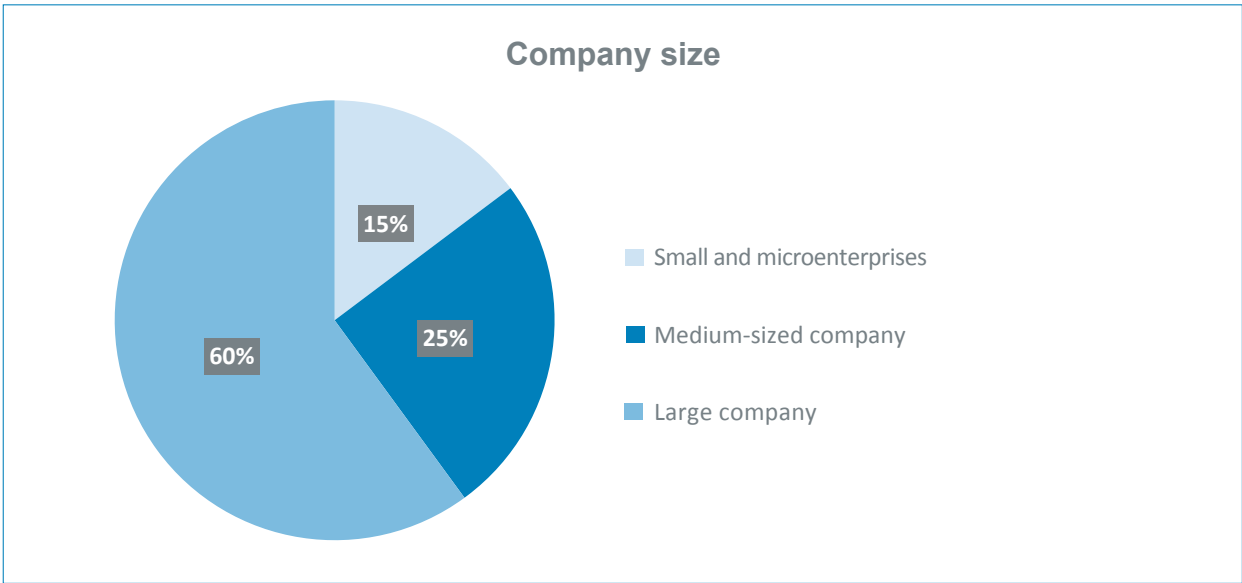
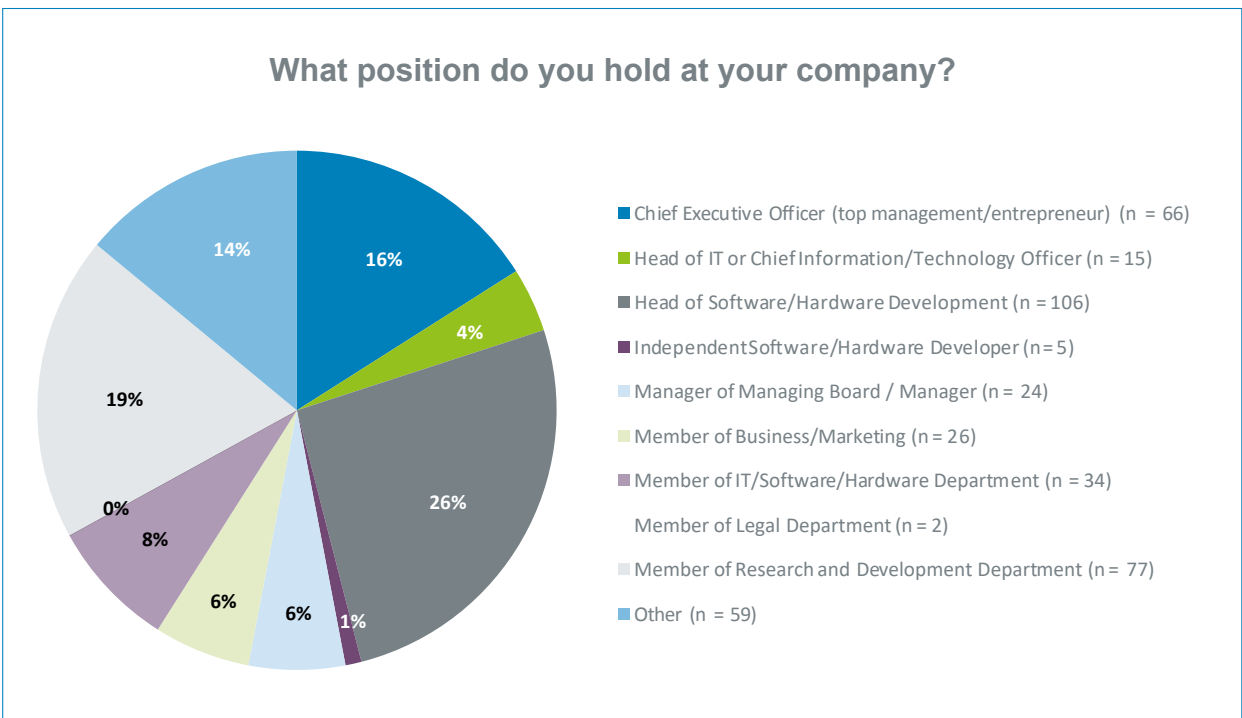Figure 2: Distribution of the sample for the online survey by company size

Figure 3: Distribution of the sample for the online survey by position in company

3. Results

The results from the online survey and the expert interviews were taken into account when analyzing the data. In doing so, the online survey was analyzed on the basis of generalizations and statistical analyses. This is complemented by an interpretive analysis of the results from the interviews in order to describe the situation.

The following chapter is for describing the results and is based on the questions asked at the beginning of the study. Chapter 3.1 focuses on the importance of interoperable interfaces from the perspective of companies, followed by an evaluation of criteria for selecting a communication standard in chapter 3.2. Chapter 3.3 summarizes and discusses possible use cases for an interoperable interface, while the communication channels to be realized to this end are described in chapter 3.4. Because OPC UA is a relatively new topic, chapter 3.5 is dedicated to the extent to which OPC UA is already being

implemented by the companies. Finally, chapter 3.6 illustrates why companies are deciding to play an active role in standardization with regard to OPC UA.

3.1 The importance of an interoperable interface for the companies

Interoperability is repeatedly highlighted as a key strategic component for Industrie 4.0. Its characteristic feature is that all involved communication partners understand the contents of the interface – that is the basic prerequisite for many new digital business models.

But how do the companies assess how important an interoperable interface is for them?

To answer this question, the companies were asked to rate the relevance of an interoperable interface on a scale from 0 (not relevant) to 5 (very high relevance); see Figure 4.

The importance of OPC UA for the companies

General assessment (n = 446)   Ø = 3.5

0	1	2	3	4	5
No relevance					Very high relevance

Companies active in committees (n = 254)   Ø = 3.8

0	1	2	3	4	5
No relevance					Very high relevance

Companies not active in committees (n = 192)   Ø = 3.1

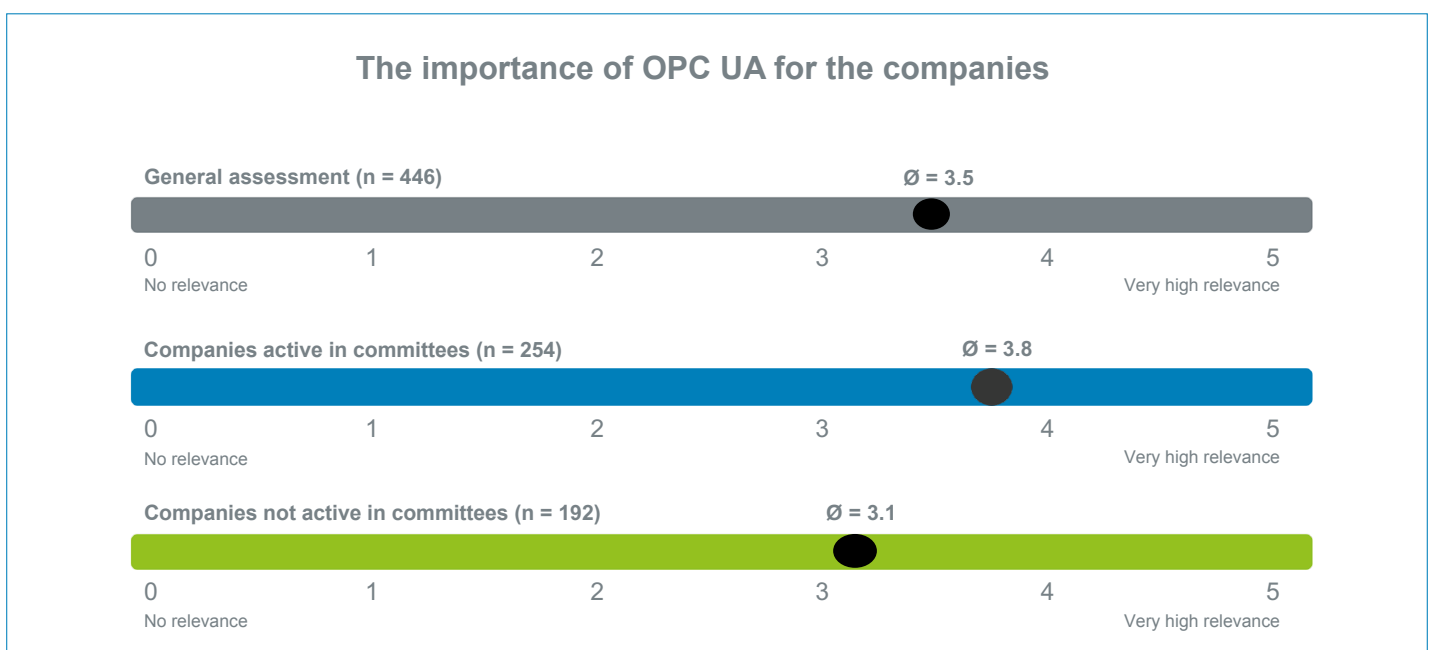| 0	1	2	3	4	5
No relevance					Very high relevance

Figure 4: The relevance of interoperable interfaces from the companies' perspective

In total, 56 percent of companies assign a high to very high relevance to an interoperable interface from a corporate perspective.

When splitting the response to this question into companies that are active in standardization committees and those that are not, we receive a more differentiated picture (see middle and bottom diagrams in Figure 4). It is evident that companies that are actively involved in standardization committees give the relevance of an interoperable interface a significantly higher rating than companies that are not involved in such committees:

- 69 percent of "active" companies assign a high to very high relevance to an interoperable interface from a corporate perspective

- 38 percent of "inactive" companies assign a high to very high relevance to an interoperable interface from a corporate perspective

Alongside the general importance of an interoperable interface, the question arises as to what strategic importance the companies ascribe to such an interface. During the interviews, the participating companies were asked an open-ended question regarding the strategic importance of an interoperable interface for them. The answers were clustered into 11 strategic aspects. As part of the subsequent online survey, the companies were asked to select all aspects relevant to them; the result of this can be seen in Figure 5.

Strategic importance of OPC UA for the companies (n = 472)

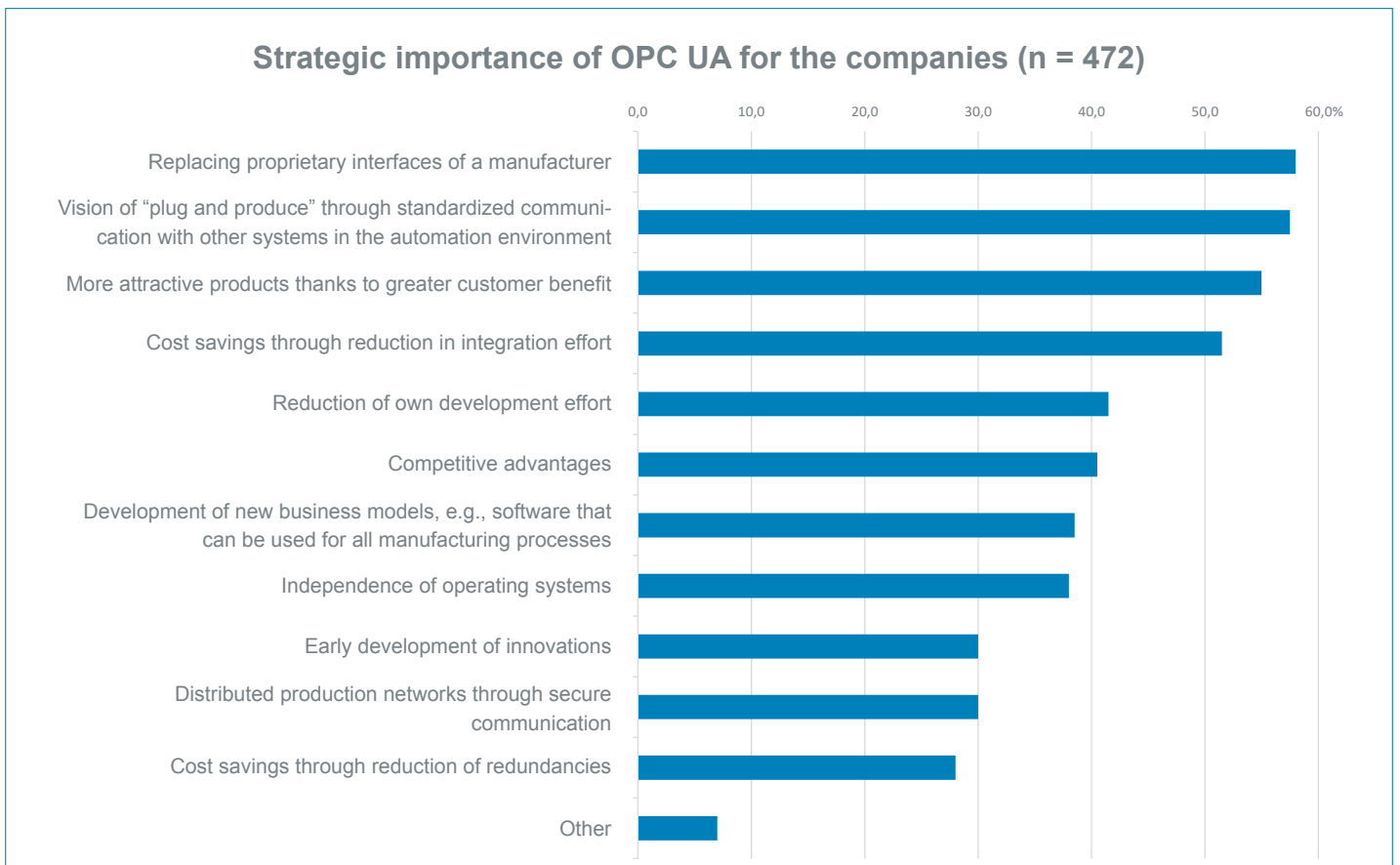|	0,0	10,0	20,0	30,0	40,0	50,0	60,0%
Replacing proprietary interfaces of a manufacturer							
Vision of "plug and produce" through standardized communication with other systems in the automation environment							
More attractive products thanks to greater customer benefit							
Cost savings through reduction in integration effort							
Reduction of own development effort							
Competitive advantages							
Development of new business models, e.g., software that can be used for all manufacturing processes							
Independence of operating systems							
Early development of innovations							
Distributed production networks through secure communication							
Cost savings through reduction of redundancies							
Other							

Figure 5: The strategic importance of an interoperable interface from the companies' perspective

The aspect of **replacing proprietary interfaces** was judged to have the greatest strategic importance for the companies. At the same time, this is also a basic prerequisite for further aspects, such as the vision of a "plug and produce" offering. An interface can be viewed as the point at which two systems or machines transfer data to each other. Proprietary, manufacturer-specific interfaces that are specially tailored to a small number of systems are offered in many cases today. Replacing these proprietary interfaces allows communication that in turn enables platform-independent data exchange. At the same time, these open standards make scenarios such as "plug and produce" possible. This principle is already well known from our everyday lives – for instance, printers no longer have to be installed using various drivers. Because the execution of their basic functions has been standardized, a pre-installed driver is sufficient and printers merely have to be connected. The mechanical and plant engineering industry wishes to pursue this example of the **"plug and produce" vision through standardized communication** and is attempting to enable the integration of plants, machinery or components just as easily. Through this, the amount of commissioning effort required on both the customer and supplier side can be lowered considerably and **cost savings can be realized as a result of the reduction in integration effort**.

Like all innovations that come with Industrie 4.0, interoperability between machines also enables **the development of new business models, and thus also new business areas**. For example, the ability to trace data and design processes in a transparent way gives rise to wholly new use cases, which can be served by new business models. **Developing innovations at an early stage** can also be a decisive competitive advantage here. The interviews reveal that some companies will also (in the future) offer software solutions alongside plant and machinery. However, they believe that such a business model is only sensible if machines from different manufacturers can be integrated with little effort – and replacing proprietary interfaces is a basic prerequisite for this. This applies in two directions: Firstly, standardized interfaces allow third-party systems to be integrated into a company's own software solutions

without a great deal of modification effort, and secondly, this opens up the market for third-party applications, i.e., a company does not have to offer everything itself. This effect is amplified when standardized data models are transferred. By doing so, these data models can be analyzed and utilized in the same way everywhere, thus reducing the need for individual solutions. This allows manufacturers to offer **more attractive products thanks to a greater customer benefit**, which, like many other factors, can develop into a **competitive advantage** with a global impact.

In a globalized world characterized by the vision of Industrie 4.0, **distributed production networks** are also growing in importance. In particular, global enterprises such as original equipment manufacturers (OEMs) are pursuing the goal of having harmonized standards in production, as data is to be exchanged securely all over the world. From the customer's perspective, standardization of interfaces beyond their own sector is important as they then have to invest less expertise in specifying interfaces themselves.

Therefore, selecting an open, cross-industry preferred standard also offers a multitude of possibilities for their own company. Manufacturers can use this to **accelerate the reduction of their own development effort**, as not as many proprietary interfaces would need to be operated. If the interfaces are proprietary and not standardized, suppliers are forced to implement individually defined interfaces, in turn leading to a large number of different variants used by companies. The **independence of operating systems**, e.g., as offered by OPC UA, amplifies this aspect. The interviews reveal that the costs arising from the additional development effort for customer-specific interface solutions are often not completely covered in the jobs. This high development effort is also accompanied by maintenance and administration effort, which results in a cost burden for the company. As a consequence, introducing a standardized interface brings about **cost savings by reducing redundancies** (multiple interfaces with the same function).

3.2 Criteria for selecting a communication standard

During the interviews, the companies were asked which requirements they place on an interoperable interface. The specified requirements were grouped and, during the online survey, were rated on a scale from 0 (not relevant) to 5 (very relevant) by the companies.

Figure 6 shows the results of the analysis. The average rating is shown in each case.

One important criterion is the **technical durability** of the interface. Companies pay particular attention to factors such as the standard's ability to adapt to developments in the field of IT. Because products from the mechanical and plant engineering sector are often used for several decades, the communication standard they use must not change frequently or at all. Instead, it needs to develop along with the changing needs of users by means of a versioning model. In addition, such a model is important because it is also necessary to ensure that older machines with older versions can also be integrated. For the companies, technical durability not only means that a system works perfectly, but also guarantees that an analysis of possible errors and vulnerabilities is simple.

For interoperable communication in particular, **widespread acceptance of the standard** is required for a durable interface. This allows manufacturers to give their customers security of investment. In the context of Industrie 4.0, this must take place across industries and borders.

From a technical point of view, the standard must primarily be **platform-independent**. This is especially important in the context of interoperable communication, as various systems are involved in communication from the field device, through the machine and up to the corporate management level. **Secure data transmission** is another important criterion. With Industrie 4.0 scenarios such as distributed production networks, data security is continuously growing in importance. Indeed, some interviewees believe that the topic of security and secure data trans-

mission will be among the most important aspects in the future. However, this is not currently the top priority for many companies, as production networks are generally isolated systems.

Scenarios like "plug and produce" do require **standardized data models**. Plants, machinery or components are given semantic descriptions, with which they can provide information regardless of the manufacturer. This offers significant added value for the operator. For manufacturers, too, implementing the interface without a suitable standardization is a challenge that is primarily reflected in time expenditure and coordination effort. Standardized data models can be adapted much quicker than conventional interfaces. One interviewed person was of the opinion that it is not even possible for one standard to cover all the needs of a company – rather, it is important that a functioning communication channel, a functioning server and a suitable information model are available. If 90 percent of use cases are covered and the standard can also be adapted for individual users, the interviewee believes there is no reason to establish individual bypass systems. As a consequence, the **reduction of integration effort** is another important criterion that is essentially dependent on platform independence and the standardization of data models. Alongside the benefits it offers to manufacturers, it above all makes the technology more accessible for customer industries.

A **simple implementation** is also important and is to be provided to manufacturers through a wide range of tools (software development kits (SDKs), software/hardware solutions). This also includes simple connection using Ethernet. At the same time, the interoperable interface must offer **a wide range of functions**. It is important to the companies that such an interface is not solely intended for data transmission, but can also, for example, facilitate the production workflow. As such, it must be possible to ingrate the information model in all processes that take place in a machine. To this end, the companies feel that functional mechanisms such as state machines, method calls, events and statuses are necessary.

Criteria for selecting a communication standard

Technical durability of the interface (e.g., versioning of data models, ability to adapt to developments in IT) — Ø = 4.1

Platform independence — Ø = 4.1

Widespread acceptance of the standard (security of investment) – across sectors and internationally — Ø = 4

Secure data transmission — Ø = 4

Standardized data models — Ø = 4

Reduction of integration effort — Ø = 4

Can be implemented easily (e.g., via control system, wide range of development stacks) — Ø = 3.6

Open standard (open source) — Ø = 3.6

Fast data transmission — Ø = 3.2

Integration into the Industrie 4.0 environment (RAMI 4.0, IDTA) — Ø = 3.2

Scalability (data width, performance) — Ø = 3.1

Range of functions (method calls, alarms and events) — Ø = 3.1

Integration of components, modules, individual or special-purpose machines in production lines (continuous production) — Ø = 3.1

Real-time capability — Ø = 2.9

The previous version is already used in the company (e.g., OPC DA) — Ø = 2.1

Figure 6: Reasons for selecting a communication standard

To prevent individual solutions from having to be created, the mechanisms should be defined in advance as methods and structures.

Open standards in the form of "open source" technologies are also popular. Projects and developments that are publicly available allow every participant to access the technology easily.

The companies assign medium importance to technical criteria such as **fast data transmission, real-time capability** or **scalability**. Scalability mainly refers to the ability to adjust the data width and performance in line with needs.

The **integration into the Industrie 4.0 environment** is also of medium importance. The type of organization in which the standard is developed and its position in the Reference Architecture Model Industrie 4.0 (RAMI 4.0), for example, is less important.

In the view of the survey participants, the fact that the company is **already using a previous version of the standard** is rather unimportant as a criterion when choosing a communication standard.

The integration of components, modules, individual or special-purpose machines in production lines (continuous production) is also assessed as being unimportant, as communication at this level is currently realized using fieldbus systems in most cases. System integrators in particular do not see the benefit in switching these to OPC UA at this point in time, as the cost/benefit ratio is not favorable at present.

If the assessment of the criteria for selecting a communication standard is split according to the companies' activity in committees, the ratings in Figure 7 result.

These figures show that the average assessment of the criteria differs significantly for the following items:

	Committees	No committees
Standardized data models	4.351	3.965
Technical durability of the interface (e.g. versioning of data models, ability to adapt to developments in IT)	4.218	4.175
Widespread acceptance of the standard (security of investment) – across sectors and internationally	4.113	4.058
Fast data transmission	3.097	3.287
Secure data transmission	4.073	3.982
Platform independence	4.012	4.158
Reduction of integration effort	4.089	3.953
Integration of components, modules, individual or special-purpose machines in production lines (continuous production)	3.242	3.105
Scalability (data width, performance)	3.222	3.175
Range of functions (method calls, alarms and events)	3.423	3.175
Real-time capability	2.770	2.895
Can be implemented easily (e.g., via control system, wide range of development stacks)	3.548	3.684
Integration into the Industrie 4.0 environment (RAMI 4.0, IDTA)	3.282	3.287
Open standard (open source)	3.548	3.684
The previous version is already used in the company (e.g., OPC DA)	1.500	1.170

Figure 7: Ratings of the reasons for selecting a communication standard, divided by committee activity

- **Standardized data models:** Companies that are active in committees rate this aspect as being considerably more important, although the absolute difference is only 0.35 points. The objective of working in committees is to develop standardized data models, as these are the basic prerequisite for a large number of use cases. As a result, the relevance and importance of such models are also known to companies that do not (yet) actively participate in committees.

- **Wide range of functions:** It should be possible to integrate an information model in all processes that run in a machine. The more functional mechanisms that are defined in the technology, the fewer individual solutions are created and the easier it is to integrate certain functions into the standard. This is especially important for companies that work in committees, as the developed standard should be applied as widely as possible; at the same time, the companies wish to refer to other Companion Specifications with a similar structure.

- **Fast data transmission:** The aspect of fast data transmission is rated as being significantly more important by companies that are not actively involved in committees. One of the main criticisms of OPC UA as a technology is the data transmission speed and the lack of real-time capability. This is one possible reason why companies consciously decide against OPC UA and instead opt for another technology. The topic is also discussed in the working groups. Therefore, there is awareness of it. However, in the interviews some experts indicated that real-time capability and fast data transmission are not relevant for them, because the processes do not require them. Accordingly, the criterion is currently not very important to them. Others are using OPC UA and MQTT alongside one another until OPC UA works in combination with TSN.

3.3 Use cases

The results of the study illustrate that an interoperable interface is of great strategic importance for the companies. This in turn begs the question as to which use cases the companies wish to realize with an interoperable interface. Based on the results from the interviews, nine possible answers were derived that are described in more detail below.

Among other things, **production monitoring** includes transmitting the current machine state, error messages and the current utilization of a machine, as well as calculating the efficiency of a machine.

This is closely related to the second use case, **providing process data**.
Here, for example, sensor readings such as temperatures are made available.

Another use case is **condition monitoring**, which is becoming increasingly important in the context of Industrie 4.0. In this case, a wide range of machine data is used to derive an assessment regarding maintenance and machine wear. Another important use case is **asset management**, which can comprise the identification of machines and components so that they can be replaced during the product life cycle.

One important aspect is that the control of production is kept separate of the direct control of a machine. While **production control** merely comprises the forwarding, starting and management of jobs and formulas, **direct control of a machine** entails directly influencing an axis and moving it to a certain position, for example. A special use case in this context is **safety-related control**, which sets high requirements regarding machine safety and thus also data transmission.

Other use cases of an interface are **remote maintenance** or **virtual commissioning**.

The results of the survey (see Figure 8) reveal that **production monitoring** is the most frequently mentioned use case. This use case opens up many new possibilities that can, for example, be embedded in new business models. However, the prerequisite for this is that all machines in production are equipped with a standardized interface or are connected in such a way that all relevant data is transmitted.

This enables applications including the following:

• Through the targeted collection and evaluation of data, the whole of production can be optimized and new insights can be gained

• Dashboards can display the efficiency of the machine park

• The utilization of the individual machines can be displayed through targeted **machine monitoring**

• The whole of production can be integrated and transparency assured if information is transferred directly from the machine to a superordinate program. By doing so, users can see which machine is processing which job in which quality at any time. As a result, anomalies can be highlighted immediately and quality issues reported without delay

Use cases to be realized through the deployment of an interoperable interface
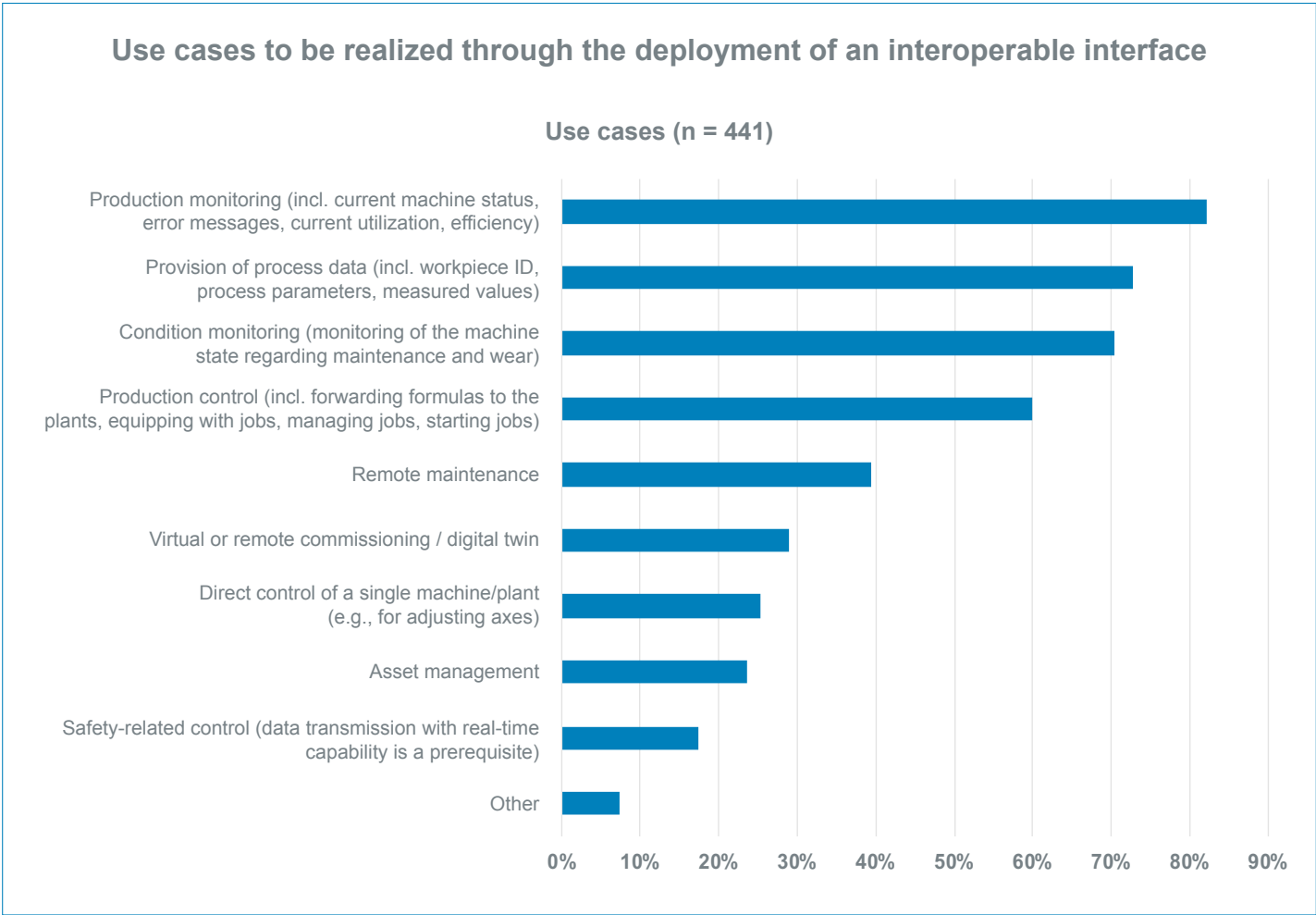
Use cases (n = 441)

Figure 8: Use cases to be realized through the deployment of an interoperable interface

The implementation of this use case with all of its facets is currently still a topic for the future, as the composition of machine parks and the interfaces used by customers are still highly heterogeneous. As a result, making the data available is a challenge.

The second most important use case with a score of 72 percent is **providing process data**. This also concerns storing data in a standardized format. Some companies report that more and more customers want to access the data today and in the future; accordingly, the provision of data is becoming ever more important.

The data is processed further when required. Like the replacement of proprietary interfaces, the **provision of process data** is a basic prerequisite for enabling further use cases. Today, data is generally provided to a superordinate system, e.g., an MES. However, this use case also aims to transfer manufacturer-independent data to a cloud using open gateways so that this data can also be used in new business models.

Some 70 percent of the companies would like to realize the **condition monitoring** use case. A number of interviewees already offer condition monitoring of their most important components including a life cycle analysis and prediction; until now, however, these services have been fully based on proprietary solutions and are only available for individual components.

The provision of data is becoming ever more important.

The fourth item is **production control**, which is to be realized using OPC UA in the future. Up to now, some manufacturers have realized such remote control for their own machines using highly complex proprietary interfaces. Direct machine control is also a matter for the future, as the standardization and implementation of machine reporting (e.g., the forwarding of the machine or job status) is a basic prerequisite for this.

Another important aspect for 40 percent of the companies is **remote maintenance**. Here, the focus is on supporting customers in machine optimization and service deployments. For instance, if the data is stored in the cloud in a standardized manner, the supplier can support the customer through service or solve an acute problem without having to visit the customer's premises.

In this connection, the question arises as to whether companies that are active in committees have priorities to those that are not involved in committees. Figure 9 shows how the two groups rate the various use cases.

The results show that the "active" companies generally have a greater tendency to rate the individual use cases as relevant. In working groups, companies exchange experiences on various topics and also discuss the different use cases. Therefore, it can be assumed that these active discussions also increase awareness of further use cases.

The only use case that was given almost the same rating by both groups is **remote maintenance** – a use case with an effect that extends beyond the system boundary of the production facility. Companies are reliant on secure communication here, which is an inherent property of OPC UA. The topic of secure data exchange is also being grappled with by companies not involved in standardization (see Figure 7). By contrast, the "active" group rated **asset management** as being relevant significantly more often than the other group.

The result in Figure 9 is compared to the use cases dealt with by OPC UA working groups in Figure 10.
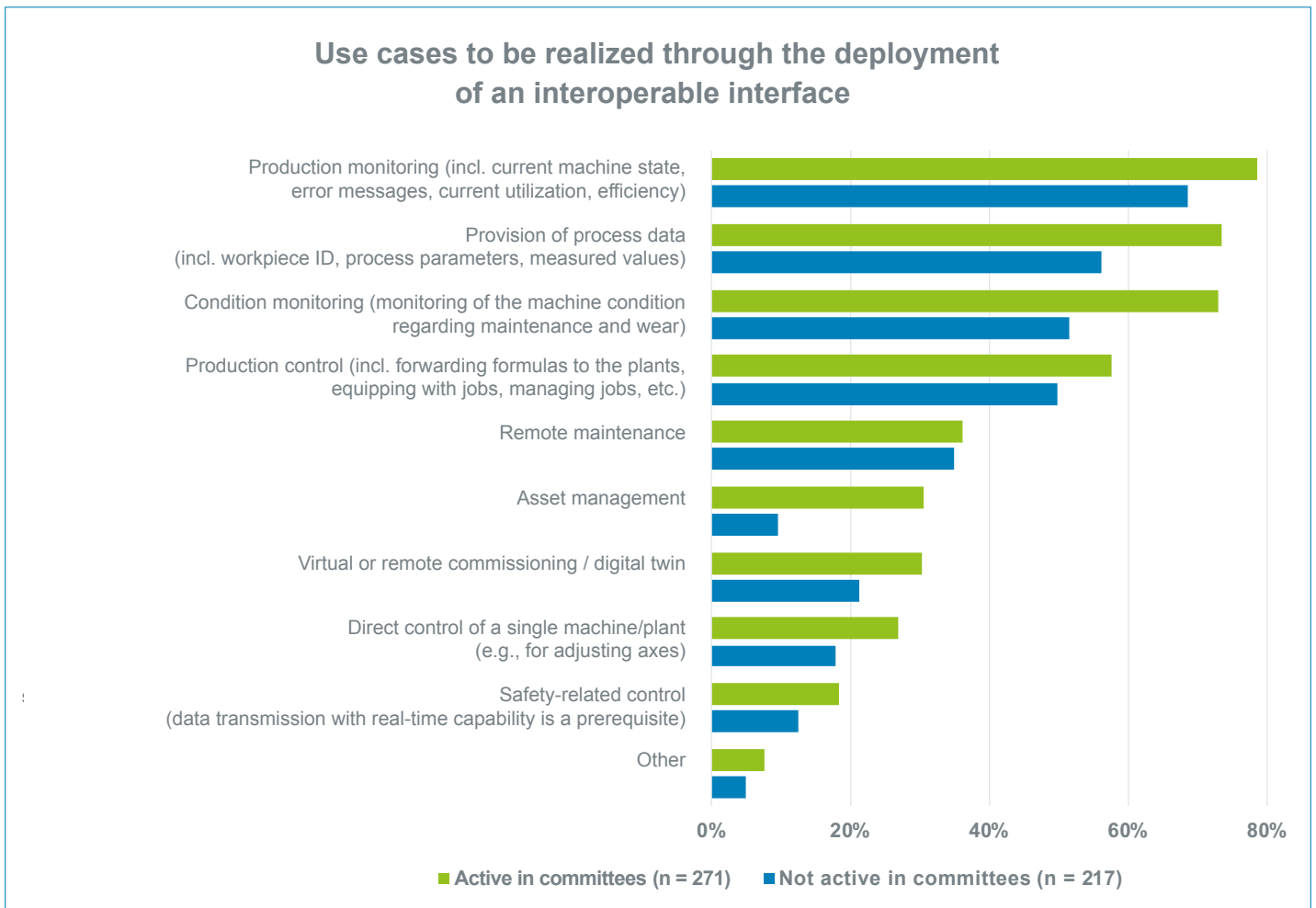
Use cases to be realized through the deployment of an interoperable interface

Figure 9: Use cases to be realized through the deployment of an interoperable interface, divided into "active" and "inactive" companies

The overview in Figure 10 reveals that the use cases rated as being most important are already the subject of working groups. However, this does not mean that the entire use case is already covered by the corresponding Companion Specification: The exact characteristics of the respective use case are to be defined individually. Mutual dependencies between the use cases must also be taken into account. For instance, a **production control** solution is only possible if certain process data is made available. In addition, this data is inherently highly complex, which means that it needs to be concretized ever further over a longer period of time in multiple cycles. However, the Companion Specifications already offer important components of this, e.g., mapping the machine status.

It is striking that many working groups deal with the topic of **asset management**, even though this does not have a particularly high rating (see Figure 9). This is because issues such as the identification of machines and components are already covered in the OPC UA Companion Specification "OPC UA for Machinery," which covers the entire mechanical and plant engineering industry. Sector-specific groups refer to this overarching standard and use the models – or "building blocks – within.

3.4 Communication channels

When discussing strategic importance and possible use cases, the communication channel must also be taken into account, e.g., the analysis of which systems are to communicate with each other. To realize the "production monitoring" use case, for example, communication must at least take place between the machine and a superordinate system.

This communication channel can be horizontal or vertical. Within the scope of this study, these are defined as follows:

• Horizontal communication: machine to machine (M2M) and field device to machine (FD2M)

• Vertical communication: machine to MES (M2MES), machine to ERP (M2ERP) and machine to cloud (M2C)

An OEM sums it up as follows:
"The way we see it, OPC UA should be the communication interface both on the shop floor and to superordinate systems – that's why we see both horizontal and vertical communication." Generally, companies believe it is relevant to use OPC UA for both types of communication.

The objective is to cover production systems in their entirety, i.e., Industrie 4.0 should be characterized by seamless communication between every participant in the communication network.

The objective is to depict production systems in their entirety.

However, a number of working groups have decided to describe and implement vertical communication first, with horizontal communication following in a second step. In this connection, Figure 11 shows the communication channels that are currently covered in published Companion Specifications by industry sector.

Use case	Example	P&R	IJT	EoAT	MV	Rob	Met	MT	ED	F&P	Sur
Production monitoring	Current machine state, error messages, current utilization, efficiency	x	x	x	x		(x)	x	(x)	x	(x)
Provision of process data	Workpiece ID, process parameters, measured values	x	x	x			(x)	(x)		x	(x)
Condition Monitoring	Monitoring of the machine condition regarding maintenance and wear	x	x	x	(x)	x	(x)	(x)			(x)
Production control	Forwarding formulas to the plants, equipping with jobs, starting jobs	x		(x)	x	(x)	(x)	(x)			
Remote maintenance	Remote access to the machine		(x)								
Virtual commissioning / digital twin	Simulation of machine and plant processes		(x)	(x)			(x)				
Direct control of a single machine/plant	Adjusting the axes	(x)					(x)				
Asset management	Documenting replacement of components	x		(x)			(x)	x	(x)		(x)
Safety-related control	Transmission of safety-relevant data with real-time capability									(x)	(x)

x = part of a specification (x) = in development

Figure 10: Use cases dealt with in selected committees

Today, the perception is that standardization is required for vertical communication in particular, as the need is greatest here. Companies report that customers are directly affected by this – for example, they need to perform OEE calculations, forward jobs to machines and obtain feedback on the machine/job state. Accordingly, the current focus is clearly on communication between machine and MES. However, the interviewees believe that the communication channels will change in the future. In vertical communication, the focus will no longer lie on communication between machine and MES, which represents the old status of the automation pyramid. Instead, the companies want the machine or production plant to communicate directly to the cloud in years to come. In addition to defining the interfaces and describing the use cases, the surveyed companies see a number of other challenges that have to be overcome before cross-domain communication to the cloud can actually be realized:

• Specifying a structure that meets the requirement for data integrity

• Access and ownership rights of data

• Secure data transmission

In the view of the companies, and the system integrators in particular, the horizontal level is more of an internal topic. Today, communication generally takes place via field buses. As the amount of effort required to perform this in OPC UA is deemed to be high and due to the lack of real-time capability, not all players currently see the added value compared to the existing solutions. Despite this, horizontal communication via OPC UA is a topic that will become relevant as soon as the entire shop floor enters the focus.

In contrast, machines that work in a manufacturer-independent manner, want to provide all necessary machine data at the point at which it is used, without specifying whether horizontal or vertical communication is to be used.

Because use cases such as **asset management** or **condition monitoring** should not merely be realized for a single machine or sector, both vertical and horizontal communication are to take place on both a manufacturer-independent and a cross-domain basis. VDMA is especially active in this area. Since 2019, a cross-domain working group has been drawing up the "OPC UA for Machinery" specification. This deals with cross-domain use cases and develops universal information models for them.

Communication channel	Horizontal	Vertical
Machinery	x	x
Machine Tools		x
Robotics		x
Machine Vision	x	x
Plastics and Rubber Machinery	x	x
Weighing Technology		x
Food Processing and Packaging Machinery		x
Woodworking Machinery		x
Pumps and Vacuum Pumps		x
Compressors		x

Figure 11: Communication channels in published Companion Specifications

The role of OPC UA in product development

An OPC UA interface is already being implemented or is planned (n = 424)

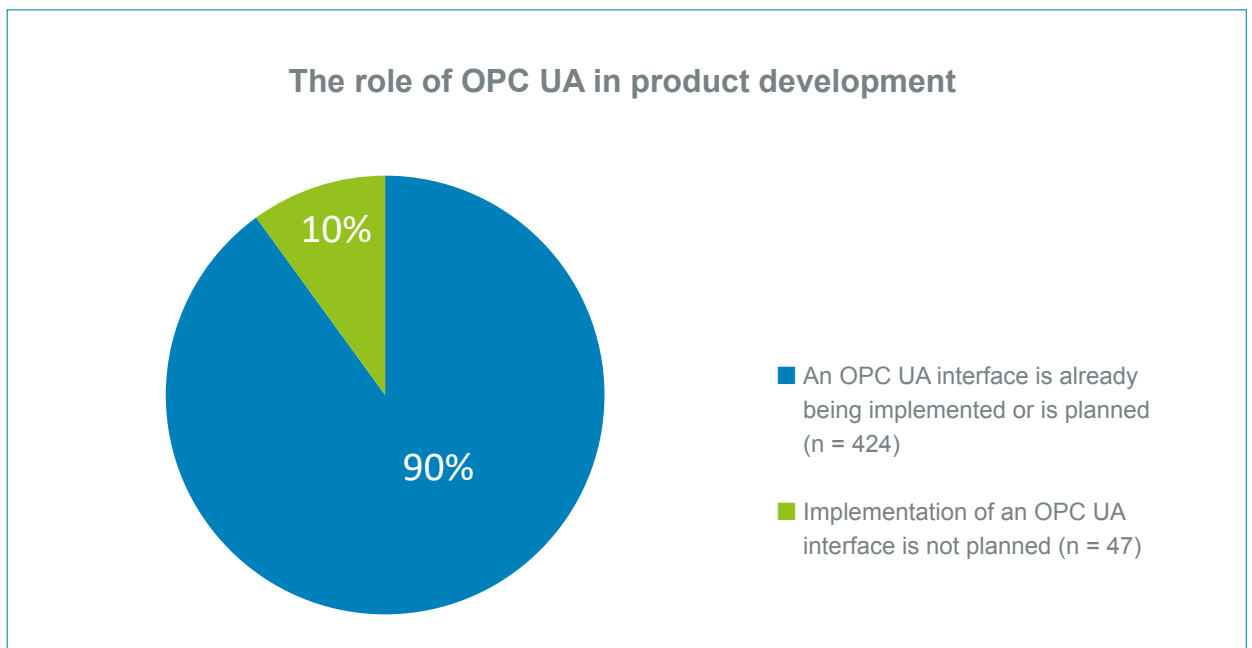**Implementation of an OPC UA interface is not planned (n = 47)**

Figure 12: (Planned) integration of OPC UA

3.5 The role of OPC UA in product development

The survey results indicate that companies assign a high level of relevance to OPC UA for different reasons. This in turn begs the question as to how widely used the OPC UA technology already is in the companies. Some 90 percent of the surveyed companies have already implemented OPC UA as an interface or plan to do so in the future; see Figure 12. Only 10 percent state that they currently have no plans to implement the technology.

From a product development perspective, the implementation of an OPC UA interface can be in three different phases:

1. An OPC UA interface has already been integrated in the products and is thus available in the market.

2. The implementation is part of ongoing development projects and will enter the market with a future product generation or a new product.

3. The implementation of an interface is planned for the future, i.e., it is a strategic development objective or a predevelopment project.

90 percent of the companies have already implemented OPC UA as an interface or plan to do so in the future.

Because the various phases cannot be separated from one another in a fixed manner, it is possible that multiple phases are present at the same time: Products can be at the transition of two phases, the depth of use of OPC UA can vary over two product generations or different products from the same company can be at a different stage of development in relation to a communication standard. Figure 13 shows the current status at the surveyed companies.

When combining categories A, B and AB (see Figure 13), it is evident that a total of 69 percent of the companies have already implemented an OPC UA interface in their products and/or that the implementation is part of current development projects.
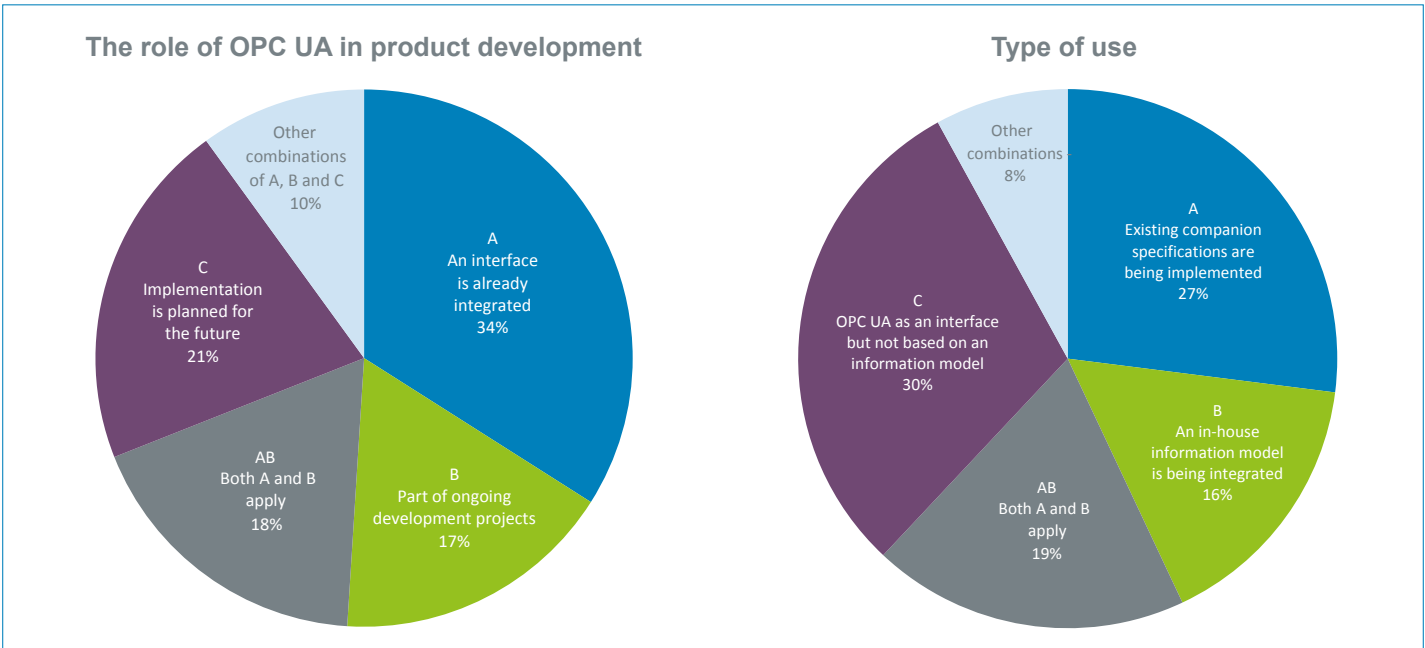
The role of OPC UA in product development

Figure 13: Level of implementation of OPC UA in products

Type of use

Figure 14: How OPC UA is used in products

Only 21 percent (category C in Figure 13) of the companies only plan to implement an interface in the future. This clearly shows that OPC UA is established at the companies as a communication standard.

However, this does not mean that the goal of interoperability has already been achieved – this is only possible if the participating communication partners also understand the interface contents. A standardized information model is required to this end, which is defined and described in the Companion Specifications. The implementation of these specifications is being supported by **umati**.

69 percent of the companies have already implemented an OPC UA interface in their products and/or the implementation is part of current development projects.

As a general rule, an OPC UA interface can be implemented in three different variants:

1. The interface refers to predefined Companion Specifications

2. An in-house, company-specific information model is developed and used

3. Data is transmitted via OPC UA without a defined information model

OPC UA is established at the companies as a communication standard.

Combinations of these variants are also possible. Figure 14 shows how the companies use or plan to use the interface.

This reveals that 62 percent of companies (A, B and AB in Figure 14) are implementing an existing Companion Specification, their own information model or a combination of the two.

Almost a third of the companies implement existing Companion Specifications in their products. The standard does not necessarily have to be implemented in full here: Some companies only use partial models with the functions needed for the respective product.

In a number of sectors, the use of existing Companion Specifications is still limited by the restricted level of availability. Many specifications are still in development and no standard is yet available. Furthermore, there is not yet a working group for many machine types and sectors. In such cases, many companies instead use their own standardized company specifications, which can be expanded on a customer-specific basis if required. From the interviews, we know that companies often directly or indirectly contribute their preparatory work to the committees as soon as a working group is established. The reasons for this include keeping company-specific modification efforts to a minimum when Companion Specifications are released, safeguarding their own investment or ensuring that their own requirements are adequately taken into account in a publicly accessible standard.

A fifth of companies indicated that they use existing specifications as well as implementing their own information models. There are a variety of reasons for this, for example:

- Companion Specifications are not available for all products offered by the company

- OPC UA has been used in various products for a long time and the implementation of existing Companion Specifications is part of the development of a future product generation, in which proprietary protocols may be replaced completely

- Existing Companion Specifications do not completely cover the requirements profile of the customer and are supplemented by internal specifications for this purpose

- Very general Companion Specifications such as OPC UA for Devices (DI) are used, which are complemented by the company's own specifications

By contrast, a third of companies use OPC UA as an interface for the provision of data without utilizing a defined information model. The interface can be developed to meet the needs of specific customers by having specialists from the supplier and the customer work together to define the respective product interface.

One very common practice in this group is purchasing OPC UA modules available in the market, which in most cases convert the data to OPC UA in an unstructured form. This data often cannot be analyzed without a corresponding document for explaining the parameters.

In order to provide a statement as to how widespread the various uses of information models are in the various implementation phases, the results shown in Figures 13 and 14 have been correlated. The result can be seen in Figure 15.

A high percentage of the companies plan to use existing Companion Specifications during the implementation. Because many new working groups have been established in various industry sectors over recent months, the number and scope of available Companion Specifications will increase significantly in the near future. This, in turn, means that the development of the Companion Specifications in the working groups and implementation at the companies will take place in parallel to a certain extent.

umati
(universal machine technology interface) is a community made up of the mechanical and plant engineering industry and its customers, which has set itself the objective of promoting and implementing the OPC UA Companion Specifications.

umati facilitates communication between machines and plants or their integration into customer- and user-specific IT ecosystems – easily, seamlessly and securely.

As such, the initiative aims to unlock new potential for the production of the future – worldwide.

umati.org

In spite of the large number of working groups, a third of the companies plan to offer OPC UA as an interface standard without a defined information model in the future, too. There are many reasons for this. For example, these may concern special mechanical engineering products that cannot be covered by a standardized interface.

It is also striking that a third of companies that already integrate an OPC UA interface and are pursuing implementation as part of ongoing development projects use both existing Companion Specifications and their own information models (category AB in groups 1 and 2 in Figure 15).

Some of these companies use both approaches in parallel, for instance in order to cover a broader range of functionalities. The interviews also revealed that some companies have already been offering their own information models based on OPC UA in various products for some time; in the next product generation, these will be replaced by Companion Specifications that were released in the interim.

The question also arises as to what influence a company's activity in standardization committees has on how OPC UA is used in its own products. Figure 16 shows this interrelationship.

Accordingly, companies that play an active role in committees use existing Companion Specifications slightly more often than the other group. In-house information models tend to be implemented by companies that are not active in standardization.
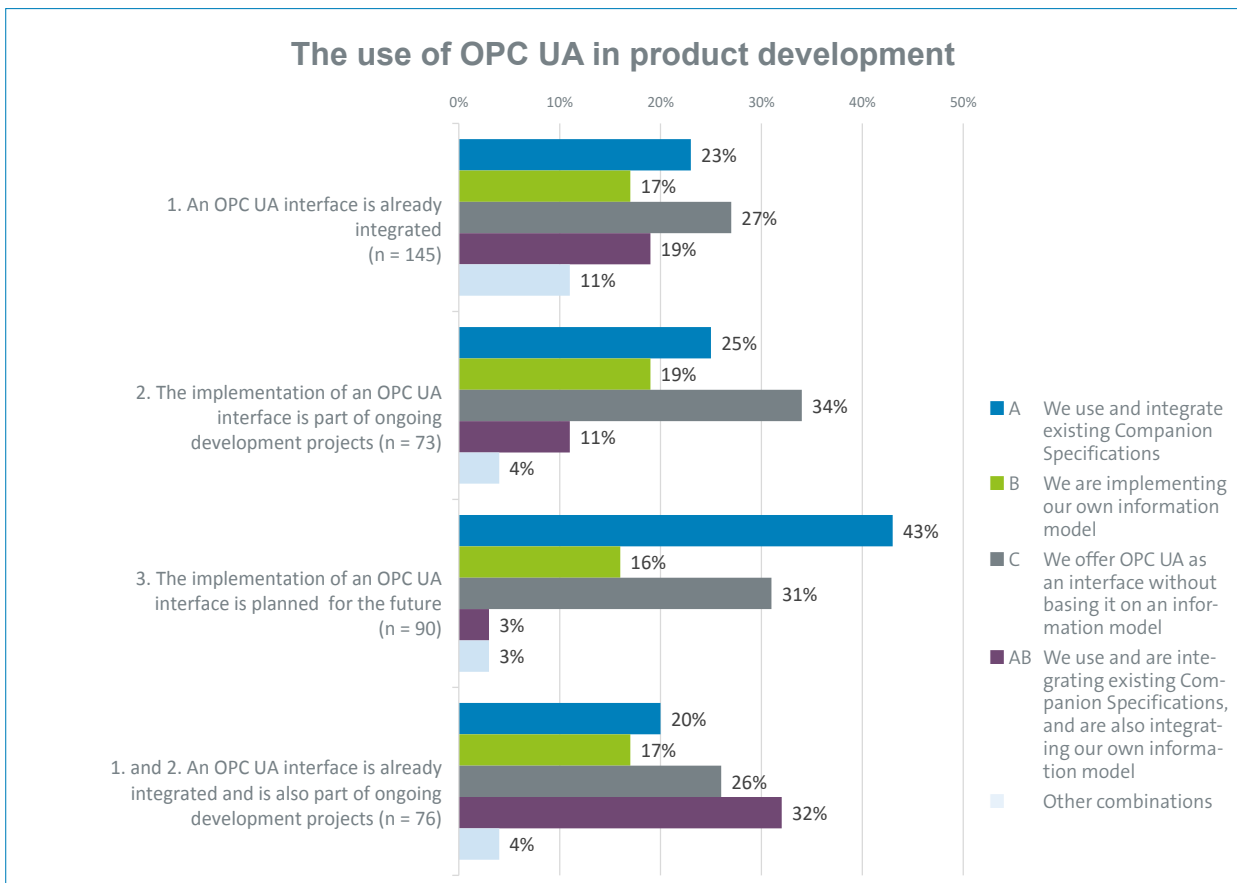
The use of OPC UA in product development

Figure 15: Correlation between degree of implementation and type of use of OPC UA
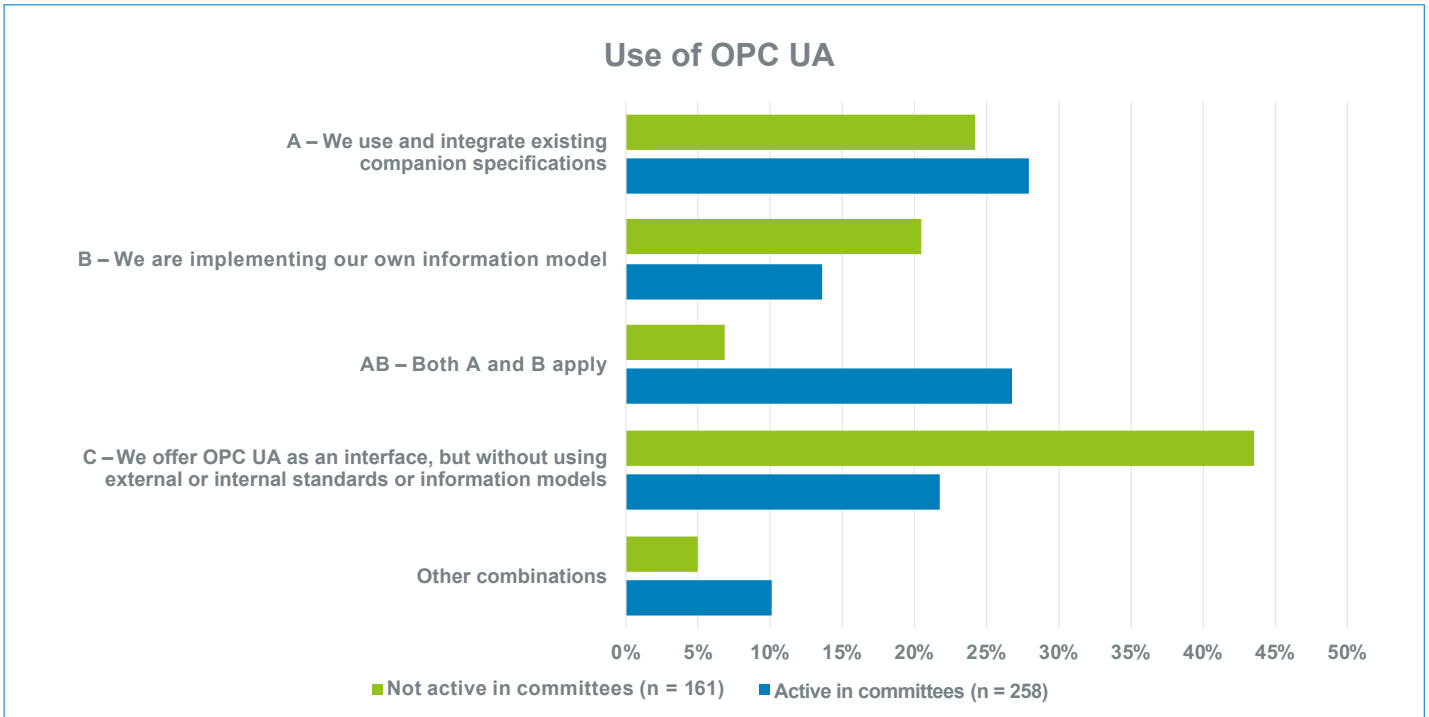
Use of OPC UA

Figure 16: Use of OPC UA by committee activity

It is noticeable that a combination of the two approaches (A and B in parallel) is pursued by "active" companies far more frequently. In this group, 27 percent of companies implement both forms, while the equivalent figure for the "inactive" companies is only around 7 percent. One possible reason for this is that "inactive" companies do not know all the specifications available in the market and thus have a greater tendency to develop their own information model or use OPC UA as an interface without basing it on an information model. In working groups, it repeatedly becomes apparent that companies have a great need for information in this area, as not all businesses have sufficient capacities to keep abreast of general developments.

Furthermore, 43 percent of the "inactive" companies implement OPC UA as an interface without using external or internal standards or information models. Among the "active" companies, this figure is just 22 percent. Because no further information is available regarding the degree of use in the respective products, it is not possible to make any statement regarding to the extent to which OPC UA is actually utilized. As mentioned previously, the scope can range from customer-specific interface design to using OPC UA modules available in the market.

3.6 Collaboration in committees

Today, there are 35 working groups dedicated to creating OPC UA Companion Specifications in VDMA alone. Here, company representatives from a wide range of sectors get together to define information models for their industry. The number of these working groups continues to grow. Therefore, the question arises as to what motivates companies to get actively involved in standardization committees and provide capacities to this end. Here, too, the interviewees were first asked what motivated them to work in these committees. In the next step, the participants in the online survey were requested to rate the reasons for this from their own perspective on a scale of 0 (not relevant at all) to 5 (very relevant). Figure 17 shows the average values of this assessment.

In some cases, large companies or companies with a large market share in their sector believe they have an obligation to lead the way in this area and play an active role in working groups. The same applies for companies that want to be seen as innovators in their sector. An important factor here is the **opportunity to help shape the standard**. The companies have a chance to point the way forward and contribute their own requirements to the development of the standard. Being involved in the working group also prevents them from having to implement things that do not meet their own standards. In the interviews, a large end customer explained that it did not merely want to use standards provided to it by the industry; instead, it wanted to directly influence the contents of standards in order to ensure that its requirements were also implemented. Otherwise, it may have had to continue using proprietary solutions, as the information model described in the standard was not compatible with its own requirements of the interface.

As such, the companies have an **information advantage** over competitors that are not involved in such bodies. In addition, the companies find out at an early stage in which direction things are heading and which ideas are being discussed, thereby allowing them to incorporate the new developments in product planning earlier on.

The finished Companion Specification contains a consolidated solution that brings together the best features of various approaches. Companies that grappled with the topic earlier on and developed internal data models in particular are happy to **contribute their preparatory work to the standard**. In doing so, they safeguard their own preparatory work and keep the need for adaptation low.

The **demand for a uniform data model in the sector** is a major motivation for many businesses. OPC UA is the technology, and not the model and semantics behind it. However, uniformity is essential in order to make visions like "plug and produce" a reality. It forms the basis for a large number of use cases (see chapter 3.3), and thus many business models. Moreover, the companies hope that a common standard will **protect their own investments**. If an entire industry sector focuses on a certain issue and develops standards in this regard, it points the way ahead, even for the company in question. In addition, companies' work in committees also constitutes public relations work, thereby compensating for some of the effort invested.

> **"We have really learned a lot and also pass this knowledge on to the rest of the company. For me, this was a key motivation behind getting involved. We have tackled issues that we didn't address in the past and have gathered information about how we could and should do things differently."**

Working in committees inherently entails **knowledge transfer** between the experts involved in the discussions.
One company representative described his experience as follows:

"We have really learned a lot and also pass this knowledge on to the rest of the company. For me, this was a key motivation behind getting involved.

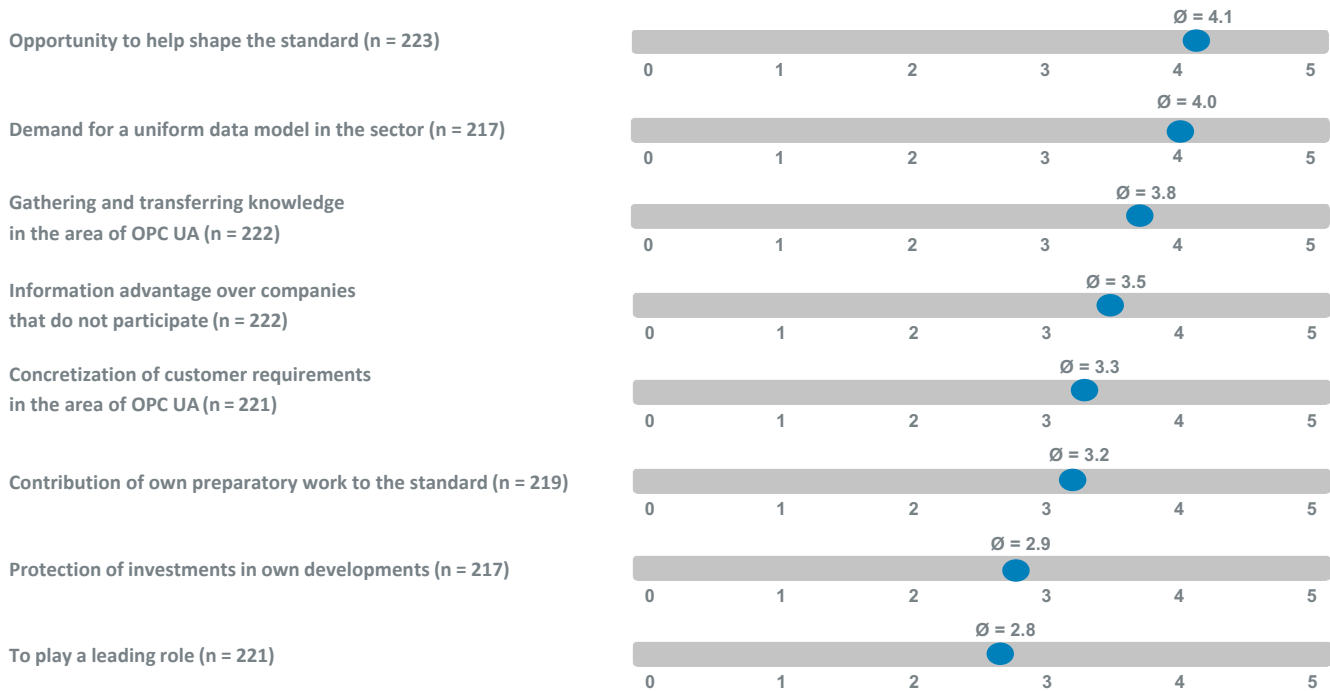## Reasons for participating in a working group

Opportunity to help shape the standard (n = 223)
Ø = 4.1
0   1   2   3   4   5

Demand for a uniform data model in the sector (n = 217)
Ø = 4.0
0   1   2   3   4   5

Gathering and transferring knowledge
in the area of OPC UA (n = 222)
Ø = 3.8
0   1   2   3   4   5

Information advantage over companies
that do not participate (n = 222)
Ø = 3.5
0   1   2   3   4   5

Concretization of customer requirements
in the area of OPC UA (n = 221)
Ø = 3.3
0   1   2   3   4   5

Contribution of own preparatory work to the standard (n = 219)
Ø = 3.2
0   1   2   3   4   5

Protection of investments in own developments (n = 217)
Ø = 2.9
0   1   2   3   4   5

To play a leading role (n = 221)
Ø = 2.8
0   1   2   3   4   5

Figure 17: Reasons given by companies for participating in committees

We have tackled issues that we didn't address in the past and have gathered information about how we could and should do things differently."

Some end customers involved in the development of standards play a more passive role: They forward their requirements to the working groups and leave it to the plant or component experts to implement them accordingly. They do not wish to use standards that are handed to them by the industry. Under certain circumstance they may then have to continue creating proprietary solutions, because more or different information is required. In turn, the collaboration of customers helps manufacturers **concretize customer requirements regarding OPC UA** and align their own development with these. According to one interviewee, the joint development of a model helps to prevent problems later in the development process. Chapter 3.5 illustrates that a number of companies use existing Companion Specifications while simultaneously developing their own informa-

tion models, which can, for example, complement one another. Participating in working groups helps these companies further concretize their own specific information model on the basis of customer requirements and the Companion Specifications to be developed.

4. Summary and conclusion

VDMA conducted the study in order to find out more about the relevance of interoperable interfaces from the point of view of the individual companies. The objective was to investigate the strategic importance of an interoperable interface such as OPC UA in the various companies.

To this end, a series of questions were defined, which were then examined using an approach combining qualitative and quantitative empirical research measures:

1. What is the strategic importance of an interoperable interface such as OPC UA for the companies?

More than 56 percent of the surveyed companies (n = 549) assign a high to very high level of importance to an interoperable interface from a corporate perspective. Among the companies that are active in standardization committees, this figure is almost 70 percent.

From a strategic perspective, the companies are clearly focusing on replacing proprietary interfaces – this is the prerequisite for realizing platform-independent data exchange. Only by doing this does it become possible to realize the "plug and produce" vision, which is of strategic relevance for more than half of the surveyed companies. Alongside the possibility of offering more attractive products, both customers and suppliers benefit from a reduction in integration effort, which in turn leads to cost savings on both sides.

For around 40 percent of the surveyed companies, an interoperable interface means cost savings thanks to a reduction in development effort and enables them to offer new business models, e.g., software solutions alongside plant and machinery.

2. Which criteria does a communication stand need to meet?

The technical durability of the interface takes top priority for the companies, i.e., the communication standard needs to develop along with the changing needs of users by means of a versioning model. At the same time, this ensures that older machines with older versions can also be integrated. In the view of the companies, durability is almost equally as important as widespread acceptance of the standard in order to guarantee investment security. Further aspects that are assigned high relevance by the companies are platform independence, the reduction of integration effort, secure data transmission and standardized data models.

3. Which use cases should be realized using an interoperable interface such as OPC UA (in the future)?

Production monitoring is of particular value as a use case, with more than 80 percent of the surveyed companies regarding it as relevant. This is followed by the **provision of process data** and **condition monitoring** with over 70 percent each. The full implementation of these use cases with all of their facets is currently still a topic for the future. However, a random analysis of the current focus topics in the working groups relating to OPC UA shows that necessary aspects of the implementation of the use cases mentioned above are already covered in Companion Specifications, e.g., machine identification or state.

More than half of the companies also name **production control** as a relevant factor. Today, this is still something of a challenge. The real-time mechanisms needed for this are still in development and this undertaking also requires the aforementioned use cases as a basis.

4. Which communication channels should be covered by the Companion Specifications?

Another key part of the discussion of possible use cases is the communication channel, e.g., the analysis of which systems are to communicate with each other. To ensure that the entirety of production systems can be represented, the companies generally believe it is relevant that both horizontal and vertical communication take place via OPC UA. However, the working groups are currently focusing on a description of vertical communication. Although the focus still lies on communication between machine and MES here, in the future the companies want to enable communication directly from the machine or production plant and into the cloud. Horizontal communication will only follow in a second step.

5. To what extent have interoperable interfaces such as OPC UA already been implemented in the products?

In the survey, it is clearly evident that interoperable interfaces are highly relevant to the participating companies. Some 90 percent of the companies that deem interoperable interfaces relevant indicate that they have already implemented OPC UA as an interface or plan to do so in the future. 69 percent of these companies already implement an OPC UA interface in their products and/or focus on implementation as a part of ongoing development projects. Here, 62 percent of participants use existing Companion Specifications, an in-house information model or a mixed model combining the two.

6. What is the motivation of companies that are actively participating in the creation of Companion Specifications?

The three most important aspects behind the companies' decision to participate in the drafting of Companion Specifications are the possibility to play an active role in shaping the standard, the need for a harmonized data model in the sector and the opportunity to gather and transfer knowledge in the area of OPC UA.

What do the individual results mean in general for the strategic importance of OPC UA and thus the future course of action?

The survey indicates that the overall cross-domain objective is to cover production systems in their entirety. As such, the ability of every participant in the communication network to communicate seamlessly should be a distinguishing feature of Industrie 4.0. The results of the study show that the use of interoperable interfaces is to enable **production monitoring, condition monitoring** and **production control** in years to come. The structured provision of data and process information is an essential basis for the realization of these use cases. This means that the second most frequently mentioned use case is especially important, as it provides the foundation for everything else. Another prerequisite for covering the whole of production systems is the cross-domain replacement of proprietary interfaces in order to enable platform-independent data exchange. This does not simply mean specifying a uniform technology in the same manner as OPC UA has been chosen as a preferred standard; rather, it entails the joint development of standardized data models. Only when such cross-domain data models are available can use cases such as the **monitoring** and **control of production** be realized to their full extent.

Companies are aware of the demand for standardized data models, which is reflected in the fact that this is one of the main motivating factors behind some companies' decision to get involved in committees. The actual implementation of the most important use case, **production monitoring**, is based on the machines making all necessary information and data available, especially to superordinate systems. This also explains the decision of the working groups to initially incorporate vertical communication in the Companion Specifications.

While **production monitoring** can also take place in a closed production network, a functioning **condition monitoring** concept is reliant on an external connection to the manufacturer, for example via a cloud. As a consequence, communication between machine and cloud will grow in importance over coming years.

It will take some time until all production systems are covered in full and all participants in a production network are able to communicate with one another without any problems. However, the large number of working groups that already exist in VDMA and the constant establishment of new groups shows that the direction of travel has been set; the mechanical and plant engineering industry will travel down this road together and develop the standardized data models required for this along the way. This common desire is also reflected in the harmonization activities in "OPC UA for Machinery" and the foundation of the umati initiative, which concentrates on much more than the pure standardization of interfaces.

umati stands for **universal machine technology interface** and is a brand and community consisting of manufacturers and customers; it pursues the goal of promoting the worldwide distribution and introduction of OPC UA interfaces in practical applications and allowing potential adopters to experience the technology through demonstrators and marketing.

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Design and layout
VDMA Verlag GmbH

Publishing House
VDMA Verlag GmbH
Lyoner Str. 18
60528 Frankfurt am Main
Germany
Internet   www.vdma-verlag.com

Print
Druck- und Verlagshaus
Zarbock GmbH & Co. KG

Year of publication
2021

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VDMA

List of images
Cover image: Shutterstock
Page 1:   VDMA

Graphics
VDMA

vdma.org/opcua