Industry 4.0 in Industrial Plant Manufacturing
Revolution or Evolution?

Results of a joint study by maexpartners and the VDMA Large Industrial Plant Manufacturers’ Group (AGAB) – November 2015
# Industry 4.0 in Industrial Plant Manufacturing

**Revolution or Evolution?**

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Initial situation and issues</td>
<td>4</td>
</tr>
<tr>
<td>2 Most important points at a glance</td>
<td>7</td>
</tr>
<tr>
<td>3 Study design: Survey feedback and structure</td>
<td>10</td>
</tr>
<tr>
<td>4 Global battle for market share – Current situation in large industrial plant manufacturing</td>
<td>11</td>
</tr>
<tr>
<td>5 Impact of Industry 4.0 on business models in large scale industrial plant manufacturing</td>
<td>16</td>
</tr>
<tr>
<td>6 Challenges for industrial plant manufacturing</td>
<td>26</td>
</tr>
<tr>
<td>7 The potentials for industrial plant manufacturing afforded by Industry 4.0</td>
<td>38</td>
</tr>
<tr>
<td>8 Outlook</td>
<td>46</td>
</tr>
<tr>
<td>9 Profile and contacts</td>
<td>49</td>
</tr>
</tbody>
</table>
1 Initial situation and issues

Across all sectors “Industry 4.0” appears to promise new business models, higher productivity and better working conditions. While current discussion primarily concentrates on manufacturing in the intelligent factory and the associated logistics processes, the effects on upstream phases in the value chain – production of raw materials and the requisite plants – are not really being considered, let alone mentioned with any sufficient clarity.

The present study offers an introduction to this topic. Numerous aspects relevant for plant manufacturing are explained in detail, and the question is discussed as to how the sector can benefit from Industry 4.0. Plant manufacturers in the sense of this study are companies that build bespoke industrial plants once or several times a year based on comprehensive knowledge of process technology. The large-scale industrial plant manufacturers defined as such by the VDMA are for example the builders of power plants, chemical plants, steel works and rolling mills, cement plants, pulp and paper mills as well as suppliers of plants for the electrical industry, for the wood processing industry and installations for the extraction of raw materials. Overall, the sector supplies plants to more than twenty different industrial sectors. This is characterized by a collaborative and global provision of services, which last but not least is reflected in an export quota of around 80 per cent.

The opportunities and forms of intensified connections between suppliers and customers are viewed as characteristic for Industry 4.0. Therefore, the present study also takes the view of plant operators and equipment suppliers into account. At the same time, the focus is on plant manufacturing in 2020 and the changes the industry anticipates over the next five years.
Industry 4.0 is essentially applying the Internet of Things and Services in the industrial process. In the process, the core element is comprehensive access to near real-time information in high resolution. That means that parts and components are extensively digitized, and intelligence for proactive control and regulation is ubiquitous, making it possible to optimize processes in near real-time and to react quickly to changes. Integrated networks of value creation, connected production and IT systems as well as the digital consistency of engineering have such comprehensive access to information beyond the lifecycle of the plant and the value chains.

In concrete terms this means, e.g. that components and parts will carry knowledge, i.e. know their history, their current status, their route and destination and communicate with their environment. This produces a transparency of building stages which places plant manufacturers and operators in a position e.g. to master surprises on the construction site more efficiently and to optimize transports. In plant operation, intelligent plant equipment in a similar fashion optimizes production and makes it possible to compensate for downtime faster and to adjust capacity better to modified marginal conditions.
In turn, end-to-end digitization dissolves barriers between plant manufacturers, operators, and equipment suppliers, but also within one’s own organization. To this end, homogeneous structures have to be created for this and new types of collaboration must be defined.

Industry 4.0 thus creates the technical requirements that enable plant manufacturers to respond to future market requirements by networking resources (employees, systems, production resources, etc.). For the most part, it is still unclear how these new technologies can be used in plant manufacturing, which aspects of Industry 4.0 will be especially relevant for plant manufacturing and what expectations are associated with them.

Therefore, for plant manufacturing, it is important on the one hand to identify where it can profit, for instance, in engineering, in logistics, in managing the construction site or in its collaboration with customers and suppliers. On the other hand, areas of application in plant operation must be identified and the effects on plant design must be examined.

Jointly prepared by VDMA Large Industrial Plant Manufacturers’ Group and the management consulting company maexpartners, the current study delivers answers to these questions and also points to other fields of action.
The current study shows that plant manufacturing does not anticipate Industry 4.0 to revolutionize its industry. In fact, the sector assumes that current business models will continue to endure. It does, however, expect major challenges in the wake of Industry 4.0’s implementation. At the same time, study participants attest to the considerable potential of Industry 4.0 for process optimization.

The risk of a disruption of existing business models should not be underestimated in plant manufacturing

Plant manufacturing does not expect Industry 4.0 to have any disruptive potential over the medium term. Although those surveyed see an opportunity to increase sales through new products and services, growth, however, will remain rather small. Therefore, existing products will not lose their relevance. Those surveyed are also not anticipating that companies outside the industry will considerably change the market. The majority see such companies outside the industry at most as operating as additional suppliers in the market. The likely scenario, as they see it, is of IT companies now providing plant manufacturers and operators with the services they already offer in other markets.

Study participants are of the opinion that new products and services will complement the core business of plant manufacturers, but not replace it. However, the sector does anticipate that these new products and services will only function in new plants. Hence an initial conclusion can be drawn from the assessments: The plant manufacturing industry does not expect Industry 4.0 to bring about an ad-hoc change to industry logic. Nevertheless, this leaves one question unanswered: In a period longer than the five-year forecast period selected for this study, to what extent will the changes implemented by Industry 4.0 reshape the plant manufacturing industry, its customers, suppliers, and service providers?

In fact, there is the risk that companies involved in plant manufacturing will not recognize the opportunities for the new areas of business Industry 4.0 creates, or will recognize them too late. Also the risk of new competitors from other branches of industry gaining influence in plant manufacturing should not be underestimated: to those who have been outsiders until now, the increasing importance of data-driven services can thus definitely offer opportunities for leveraging industry-relevant know-how and channelling off a portion of the value-adding from classic plant manufacturing.
Industry 4.0 poses major challenges to plant manufacturers

The plant manufacturing industry generally does not feel particularly well prepared for Industry 4.0. This finding is not all that surprising: It coincides with the findings of the VDMA Readiness Study which found that only one in five mechanical engineering companies has taken a closer look at Industry 4.0. Plant manufacturers have also implemented very few Industry 4.0 solutions. Training and continuing education are considered the best way to change this situation. Study participants see IT security as the greatest risk to the actual introduction of Industry 4.0.

The plant manufacturers surveyed continue to expect the mode of operation to change immensely, specifically in engineering. Engineering lays the foundation for a plant’s digital lifecycle. To meet the requirements of this digital lifecycle, engineering must evolve and become a multi-disciplinary systems engineering. In this scenario, IT-based business process management and Big Data will have a greater impact on work in engineering.

Cooperation with customers and suppliers will also undergo perceptibly significant changes and be increasingly characterized by digital integration. For example, the majority of those surveyed assume that operator requirements for the digital scope of service will increase. It is conceivable that plant manufacturers in future will provide the digital platform used to operate the plant. Digital integration is still in its infancy when it comes to the cooperation between plant manufacturing and its suppliers. According to the study participants, suppliers are not expected to be sufficiently qualified for digital cooperation in the medium term. Consequently, equipment suppliers from industrialized countries should capitalize on their technological advantages in order to be better prepared than their competitors from newly industrializing countries for meeting the anticipated demands of plant manufacturers and operations in the long term.

The improvement potential inherent in plant manufacturing processes is great

Efficiency in engineering is expected to improve with Industry 4.0. Engineering will focus more closely on the plant’s lifecycle and thereby evolve into multi-disciplinary systems engineering that will be faster and more affordable overall. However, the percentage of external services will grow. Demand for these services and the requisite level of qualification for engineering service providers will rise, which will drive the costs for external engineering.

Logistics processes will also become more efficient, primarily due to two developments. First, the majority of those surveyed assumes that parts will be able to identify themselves, meaning that they will carry information. Any intelligence per se beyond that is not expected to be available within the next five years. Second, digital logistics planning will pave the way for smart logistics, in other words opening the door to the use of data-driven services in logistics, which will make important contributions towards optimizing transports, leveraging efficiency, and improving tracking and quality control.
As those surveyed see it, the construction site also stands to benefit considerably from Industry 4.0. Parts of site management will be automated, for example, and delivery reliability on site will improve. Industry 4.0 renders the state of construction more transparent, and in the end the quality of as-built documentation will also markedly improve.

Improvements in these processes will also have a direct impact on project management and sales. In turn, both functions stand to profit from greater overall transparency. However, sales in particular must develop a feeling for which services actually offer operators added value and then offer these specifically. At the same time, sales is also faced with the challenge of using the Internet to tap into new markets for plant manufacturing. For example, configurations for important system components give the potential customer an idea of the plant’s possibilities and, perhaps, also of their investment volume and operational expenditure.

Today’s processes and structures in plant manufacturing have evolved over decades of conventional business and are deeply rooted within the companies. This is also why study participants see the potential of Industry 4.0 for optimizing these processes and structures, which today only partly meet the requirements established by Industry 4.0 – and these findings extend beyond the study’s five-year perspective. It may be that sticking with the familiar and ignoring the opportunities presented by Industry 4.0 will put plant manufacturers at a disadvantage when compared to new competitors, if the latter are smaller and more responsive and closer to new technologies.

**Important action areas are identified**

The survey revealed two major findings:

- Plant manufacturers still need to take action to recognize and fully exploit the potential of Industry 4.0.
- The potential for change inherent in Industry 4.0 for the business models in plant manufacturing as well as the opportunities presented to new competitors must not be underestimated.

The study also shows how important it will be for operators and plant manufacturers to communicate intensively with regard to the use of data taken from plant operations. Concepts must also be developed as to how companies and universities can ensure the availability of qualified employees. And, those new business models must be developed that are enabled by Industry 4.0 in the first place – before someone else does it first.

Enabling plant manufacturing companies to profit from and survive in Industry 4.0 should generally follow a clear target and proceed in small value-adding steps. It will accomplish definite changes in the processes and structures of plant manufacturers and thus become a corporate-wide project of change.
3 Study design: Survey feedback and structure

The online survey for the present study was conducted from July through September 2015 and addressed three groups: manufacturers of (large-scale) industrial plants, operators of large-scale industrial plants as well as selected suppliers. A total of 43 evaluable responses were received from 33 different companies (Figure 1). It appears that the good feedback is due to the high level of interest and importance of the topic Industry 4.0. Most of the feedback (81 per cent) came from the plant manufacturing sector.

The results can be considered representative for German large-scale industrial plant manufacturing. In addition to the high number of responses, this is also due to the feedback structure: The random sampling includes both medium-sized companies with fewer than 500 employees and turnover under € 100m as well as international groups with more than 10,000 employees and turnover in the billions.

All important branches of plant manufacturing are represented. In addition to manufacturers of chemical plants, power plants as well as steel works and rolling mills, which account for 60 per cent of the feedback, those surveyed include plant manufacturers for the construction materials, paper, electronics, and food industries.

Most of the companies that participated in the study provide turnkey industrial plants. This means that they can develop technologies and are also in a position to plan entire plants, purchase or manufacture the necessary deliveries and services as well as provide subsequent assembly. Hence those surveyed are capable of making qualified statements about the potential of Industry 4.0 in all important areas of competence associated with large-scale industrial plant manufacturing.
Since around 2010 the market structure in large-scale industrial plant manufacturing has been characterized by a marked increase in the number of suppliers despite a trend toward constant, but in some segments even declining project volumes. Next to classic plant manufacturers from Europe and North America, the new competitors are primarily often locally operating Engineering Procurement Construction (EPC) contractors from Asia which are not specialized in a specific technology. This development is most evident in chemical and power plant construction.

Consequently, the balance of power between large-scale industrial plant suppliers and their customers has permanently shifted. The competitive pressure in plant manufacturing has increased significantly and, according to the study’s findings, will continue to grow sharply over the next three years: Whereas 85 per cent of the last survey’s participants in spring 2014 assumed that competitive pressure would tangibly increase or rise sharply in the medium term, in the fall of 2015 more than 90 per cent of managers anticipate a significant increase (Figure 2).
Providers from industrial countries are global leaders

The global market for large industrial plants is still dominated by established providers from Western Europe, North America, and Japan; in 2015 they achieved a joint market share of approximately 66 per cent. The U.S. is still the largest plant building nation with a 20 per cent share of the global market. However, companies from the United States suffer from the relative strength of the US dollar on foreign bids. Their capacities also continue to be well utilized by projects on their domestic market. The augmented activities of many German suppliers in the wake of the shale gas boom in the USA is probably the main reason why they increasingly perceive U.S. plant manufacturers as competitors, more again than they did in the past. Some U.S. plant manufacturers are also expanding their activities specifically to Europe, e.g. through long-term engineering partnerships with plant operators or through financial holdings in plant manufacturing companies.

In 2012 and 2014, only 17 per cent of those surveyed reported increased competitive pressure from the United States. In the meantime, this number has climbed to 40 per cent, and over the next three years, over half of those surveyed expect keen competition from the U.S. (Figure 3).

In the recent past, the Japanese plant manufacturing industry was able to recover lost ground and strengthen its market position through cooperation and corporate acquisitions in Europe. This observation is clearly reflected in the expectations held by the study participants. According to them, probably no other country will improve its relative competitive position in plant manufacturing as much as Japan by 2018. Successful changes in direction in business, the favourable exchange rate development and a national economic policy that views plant manufacturing as a strategic industry and supports it accordingly, play an important role in this assessment.

<table>
<thead>
<tr>
<th>Increasing competitive pressure by country</th>
<th>Origins of the most important non-European competitors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>China</strong></td>
<td><strong>China</strong></td>
</tr>
<tr>
<td><strong>Western Europe</strong></td>
<td><strong>South Korea</strong></td>
</tr>
<tr>
<td><strong>USA</strong></td>
<td><strong>USA</strong></td>
</tr>
<tr>
<td><strong>South Korea</strong></td>
<td><strong>Japan</strong></td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td><strong>Another Country</strong></td>
</tr>
<tr>
<td>0% 50% 100%</td>
<td>0% 50% 100%</td>
</tr>
<tr>
<td>94% 92% 91%</td>
<td>18% 10%</td>
</tr>
<tr>
<td>62% 90% 91%</td>
<td>21%</td>
</tr>
<tr>
<td>71% 74% 78%</td>
<td>10%</td>
</tr>
<tr>
<td>49% 66%</td>
<td>3%</td>
</tr>
<tr>
<td>41% 53%</td>
<td>1%</td>
</tr>
<tr>
<td>30% 50%</td>
<td>1%</td>
</tr>
<tr>
<td>18% 22%</td>
<td>0%</td>
</tr>
<tr>
<td>17% 17%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Figure 3
Among Western European suppliers, German large-scale plant manufacturers continue to lead the market. Noteworthy European competitors come from France, Italy, and Scandinavia. It is also remarkable that Spanish plant manufacturers were able to succeed on the market with a very selective approach even on major EPC projects. Despite the continuing strong market position, it is apparent that those surveyed attest that only the European plant manufacturing industry is losing its competitive edge (Figure 3). This makes it all the more important to improve the current position by implementing specific measures to improve competitiveness. A current survey of German industrial plant manufacturers prior to the 4th Engineering Summit states the steps required to achieve this. In addition to consistent internationalization, the expansion of the service business and lowering procurement costs, this also involves investing in Industry 4.0 technologies.

**Chinese large-scale industrial plant manufacturing on the upswing thanks to state support**

Yet over the long term, the lead enjoyed by industrial nations is diminishing. As in other industries, the number of market players from emerging economies is steadily increasing, even in plant manufacturing. Particularly companies from China have significantly expanded their market position in the past few years. At the same time, they have received direct support from their country’s political leaders. Furthermore, the saturation of the domestic market has caused the Chinese plant manufacturing industry to rely ever more heavily on export. The combination of low prices and attractive financing conditions proves to be the central competitive advantage Chinese offers provide when tapping into the market. Accordingly, 82 per cent of those surveyed state that the pressure of competition from China has increased significantly over the past three years, and for the near future, even 94 per cent of the study participants see growing pressure from China, more than from any other country (Figure 3).

Should this assessment prove true, based on incoming orders China will probably be counted among the most important plant manufacturing nations over the medium term.

**Competitors from South Korea step up risk management**

In the past, competitors from South Korea stood out due to their extreme level of risk tolerance and price aggressiveness. From 2007 to 2012 they acquired numerous projects in the Arab Gulf states and in North Africa with this strategy. In the meantime, however, it has been shown that the calculations at the time were in part too optimistic and resulted in financial setbacks. Initial restructuring processes that are supposed to help tap into potential for improving efficiency and optimize processes in project and risk management are therefore already in place. However, it would certainly be a mistake to conclude from this that the competitive pressure from Korea will continue to wane over the long term. In fact, the responsible parties in the German plant manufacturing industry are expecting the opposite: the share of those surveyed that are feeling the strong to very strong competitive pressure from South Korea is currently at 47 per cent and increases to 53 per cent when looking at the next three years (Figure 3).
Industry 4.0 in Industrial Plant Manufacturing – Revolution or Evolution?

Global battle for market share – Current situation in large industrial plant manufacturing

Figure 4

Hit rate – Study 2014

Average hit rate* (orders/offers)

Figure 5

Hit rate – Study 2015

Average hit rate* (orders/offers)

Figure 4

Bidding costs – Study 2014

Average bidding costs* (as % of order value)

Figure 5

Bidding costs – Study 2015

Average bidding costs* (as % of order value)

*Arithmetic mean
Hit rate drops significantly – bidding costs rise

The hit rate in plant manufacturing reflects the ratio of orders received to orders issued. In the past year and a half, this indicator has deteriorated. While the studies for 2012 and 2014 still show values in the range of 30 per cent, since then the hit rate has fallen to 26 per cent (Figure 4). The increase in pressure from competition in the industry described earlier is clearly manifested here. In light of an increasing number of suppliers accompanied by falling demand, the companies surveyed have been unable to maintain a constant hit rate. All the same, the industry expects that it will be able to raise this indicator back to 28 per cent by 2020.

Behind this expectation is, one the one hand, the hope of an improved economic climate, especially in emerging economies, combined with a significant increase in the number of projects ready to be awarded. On the other hand, companies are anticipating that they will be required to spend significantly more money to prepare the tender: the survey indicates that the average costs for a tender, which were still at 1.2 per cent of the order value in 2012, have risen to 1.4 per cent in the meantime and are expected to continue to rise to more than 1.5 per cent by 2020 (Figure 5).
5 Impact of Industry 4.0 on business models in large-scale industrial plant manufacturing

The impact of Industry 4.0 on a business model can be either disruptive or evolutionary. If the impact is disruptive, the previous industry logic and thus the previous business models will become obsolete in plant manufacturing. In this case, companies from outside the industry will enter the market; new products and services will displace the importance of the old. On the other hand, if the impact of Industry 4.0 is “only” evolutionary, industry logic will remain as it is, as will the main customer and supplier relationships as well as the previous products and services. Though new services expand the existing portfolio, they will not replace it. In this case, Industry 4.0 is primarily a leveraging tool for improving existing business.

Study participants do not see any disruptive potential in plant manufacturing

First of all, those surveyed do not see any potential for disruptive changes by applying Industry 4.0 in the plant manufacturing industry. Measured on the lifecycle of a plant, the time horizon of five years, which is what the study asked about, is selected so that only truly revolutionary changes would have this potential. Such a radical upheaval cannot be derived from the study result.

Although the majority of respondents see the opportunity in Industry 4.0 to increase sales using new products (Figure 6), the expectations in such sales growth based on a new or expanded business model, however, remain negligible (Figure 7). Obviously a majority of those surveyed do not perceive any new business model.

A disruption must always be seen in the context of that industry in which it takes place. As a rule, the speed of change in plant manufacturing is slower than in other industries, for example in communications and information technology. Against this backdrop, the study participants’ assessment that a revolution of business models in plant manufacturing is unlikely in the timeframe of five years, which is relatively short for this industry, is understandable. However, the risk is also all the greater that plant manufacturing companies will not recognize the opportunities for new business segments as presented by Industry 4.0 until it is too late.
What opportunities does Industry 4.0 offer to the plant manufacturing industry?

![Figure 6: Percentage of mentions “very relevant”](image)

What turnover will be generated additionally in the year 2020 based on new business models?

![Figure 7](image)
The impact of companies from outside the industry must not be underestimated

The majority of those surveyed expect that in the next five years companies from outside the industry will appear on the market as additional service providers (Figure 8). They will not be perceived as serious contenders in the actual core business of plant manufacturing (Figure 9), but at the same time, opportunities for new, digital business models – based on data-driven services and “smart” products – are primarily intended for other service providers (Figure 10).

Plant manufacturing is about providing bespoke solutions for customer-specific plants. This business model differs greatly from that of operators and equipment suppliers, in which series and mass production prevail. Therefore, digital business models are obviously harder to envision in plant manufacturing over the medium term, based as they are on a certain degree of standardization and scalability. Nevertheless, the assessments are not consistent: at least a third of those surveyed – plant manufacturers and equipment suppliers or operators alike – believe it is entirely possible for companies from outside the industry to gain a foothold in plant manufacturing.

The responses do not provide any conclusions as to which companies from outside the industry could be meant as potential new competitors in this context. More than likely, it will tend to be companies whose businesses are similar to that of the plant manufacturer that will enter into their market. For example, this would be construction companies that plan and implement major infrastructure projects. However, whether it will be these companies that become new competitors facilitated by Industry 4.0 appears to be at least questionable.

Companies that to date have been operating in other industries as service providers for data-driven services will also initially make an appearance as such in plant manufacturing. For these companies the market is new, the step into the industry is ambitious. IT companies offering business analytics in the B2C sector and now providing similar products for evaluating data from plant operations are just one example. Those surveyed rate this scenario as likely. However, study participants do not believe the next step is realistic over the medium term in which these companies, for example, get in on plant operations or even in plant manufacturing.

Still, the risk that new competitors from other industries may gain influence in plant manufacturing should not...
be underestimated. In the past, the distinctiveness of project business in plant manufacturing and the attendant high market entry barriers have usually saved plant manufacturers from having to react quickly to market changes. Nonetheless, potentially new competitors will be coming from industries that are subject to a completely different dynamic and in this way have permanently altered other branches of industry in a short period of time. Especially the increasing importance of data-driven services and the platform concept for data exchange offers these companies the opportunity to leverage know-how and to divert a portion of the value-adding away from classic plant manufacturing. Even on the part of equipment suppliers, Industry 4.0 holds a risk for plant manufacturers, namely the latter for their part will increasingly contact operators directly to offer their new technologies.

**How do you rate the chances of new, digital business models?**

For plant operators 20 %
For plant equipment suppliers 23 %
For other service providers 42 %

Percentage of mentions „very high“
New products and services will complement core business

The new products and services those surveyed are expecting will complement core business; they will not replace it, and the sector logic will remain in place.

The majority of responses are based on the assumption that plant operators will more and more request new, digital services or they will increasingly be offered these services (Figure 11). As a rule this will involve data-driven services that will be imposed upon the virtual representation of the plant, or services that use data from the operation of one or several plants (smart data). In the course of implementing Industry 4.0, digital security, for example, will permeate the entire lifecycle of a plant. The sale of such services gives plant manufacturers opportunities to profit from plant operations as well, which extend beyond the pure construction. This could give rise to other segments for new services such that the planning documentation is no longer just input for building the plant but also for maintenance, modernization, asset management as well as for turnaround planning.

An important reason for the merely restrained optimism with respect to new products and services is the expectation of those surveyed that such innovations will only be considered for new plants.

The plants that exist today, however, cannot use the new products and services (Figure 12). The reason being the high expense required for either the subsequent digitization and installation of business intelligence or for retrofitting existing plants, if one wishes to render them capable of using the new products and services. Most plants in Germany were built before Industry 4.0 technologies were conceivable. As a general rule, no major investment in subsequent digitization will be made for these plants. At the same time, the plants are constantly being modernized without necessarily updating the digital documentation of the entire plant.

Nevertheless, the technology for retrofitting intelligent systems into existing plants is available. This makes it possible to produce a digital representation of the plant in which all relevant data is digitally available and up to date. In turn, this is the basis for risk-based inspection and maintenance and ultimately results in greater plant availability.

Aside from increasing sales through new products, study participants are anticipating improvements in the existing business model in the form of reducing costs, shortening the time to market, and increasing sales. Specifically, they are hoping for greater system stability and a reduction of operating costs.

Are digital services beyond the building of the plant offered or requested?

<table>
<thead>
<tr>
<th>Service</th>
<th>Very Relevant</th>
<th>Relevant</th>
</tr>
</thead>
<tbody>
<tr>
<td>For maintenance</td>
<td>51 %</td>
<td>41 %</td>
</tr>
<tr>
<td>For plant optimization</td>
<td>49 %</td>
<td>46 %</td>
</tr>
<tr>
<td>For plant monitoring</td>
<td>63 %</td>
<td>34 %</td>
</tr>
</tbody>
</table>

Figure 11
In which plants do new business models work?

- In existing plants: 2%
- In retrofitted plants: 12%
- In existing plants with intelligently digitized models: 12%
- In new plants: 71%

Percentage of mentions „very relevant“
The piping chain

One example of digital consistency already in use in plant manufacturing is the digital piping chain from planning of the plant and installations to its assembly:

Engineering plans the pipelines. For every conduit these plans are automatically exported in a format the bending machine is able to read. Based on this data the pipeline buildability is reviewed and, as applicable, the pipeline geometry or splitting is adjusted in the model. This is an iterative process which, consequently, should already be carried out and completed during the planning stage and no longer, as is frequently the case, between plant design and manufacture. This corresponds to the trend to multi-disciplinary systems engineering. In the next step, the data is transferred to manufacturing in a machine-readable format; there are thus no media discontinuities and no effort is needed to produce isometric drawings by hand. Compared to the conventional process this considerably reduces cycle times and the likelihood of errors.

Communication along the entire value-adding chain uses a central database in which all changes in the following process in manufacturing, logistics, and assembly of the pipeline are managed. If the plant design is changed during the course of the project, the status of every single pipe is thus known: whether it has already been manufactured, whether it is in transit, or even already installed. Planners are therefore provided with a good indication of the impact of any and all changes. Consequently, changes can be implemented more affordably. The level of transparency created thus results in much lower change-related costs.

By using user-friendly (mobile) systems at the construction site, changes made during installation can also be added to the database. In this way, the actual status is automatically included in the as-built documentation.
Today, only a small portion of a plant’s data is actually taken into consideration when making decisions. The reason being that data analysis is process-driven, meaning that it is based on detailed knowledge of the process. Dedicated data are requested, retrieved, and processed. The analytical models used rely on causalities being known. Data analysis thus currently assumes that the plant is known and can thus be modeled.

Big Data uses a different approach; the major difference being that no process know-how is needed. Evaluating all data available about a plant (mass data evaluation) makes it possible to search for and find patterns in the data. The findings obtained in this case are thus not based on causality but rather on correlation. The plant is measured, not modeled. Since this does not require any significant specific knowledge, even new competitors from other industries can afford doing it and enter the market.

The next step is to recognize causalities instead of modeling them. Auto-adaptive systems can be trained by using selected process know-how. They increasingly no longer simply recognize just correlations in the vast amounts of data, but also causal relationships. In this way, new competitors can rapidly acquire the competence specific to plant manufacturing.

Auto-adaptive systems acquire their knowledge all the faster the larger the main unit of data is. To fully exploit the advantages of these systems, plants must be networked even across the boundaries between operators. In the end, all those involved will profit from these systems; any attempt to seal oneself off is thus pointless. What is important is to act fast in order to be one of the first to profit from them and to keep a competitive advantage for as long as possible. Examples from other industries indicate that this advantage will vanish at some point. And of course, the danger also grows: This extensive networking will give new competitors the opportunity to develop large parts of the industry in one fell swoop.
Augmented Reality at the building site

The networking of devices capable of using the Internet, mobile terminals such as smart phones, tablets, or data goggles or the Cloud also makes it possible to use Augmented Reality on the building site. Using data goggles, for example, can help avoid errors and provide a level of transparency in construction site controlling.

Data goggles display the respective employee’s work plan in accordance with qualification, language, and experience. This information is constantly updated from the ongoing activities and considering in planning the personal worklist. In assembly, information about the employee’s surroundings are projected in the employee’s field of view. If an existing plant is expanded this would be, for example, container content, pressure and temperature in fittings, the date of the last repair or the next replacement. In this case, the information is communicated by the corresponding equipment on its own.

Even more important for installation is displaying the point and position of installation. This information is sent by the part to be installed. Information from the 3D model is now superimposed onto the real image of the plant in the employee’s field of view. In the next step, the individual installation steps are displayed. Accentuating the steps in the data goggles, for example, ensures that the correct sequence is adhered to for screw connections. By using intelligent tools, the right torque is automatically set and the progress of installation is also automatically reported.

This system can also be expanded: e.g. to include the monitoring of an employee’s vital functions in hazardous plant areas or to simply ensure that break times are complied with. It can also monitor and ensure whether the right tools are being used and whether safety instructions were read.
Industry 4.0 presents major challenges for plant manufacturing. Engineering and cooperation with operators and equipment suppliers in particular will undergo permanent changes. Until now the plant manufacturing industry has been ill equipped to meet these challenges.

Plant manufacturers do not consider the industry particularly well prepared for Industry 4.0

The study clearly shows that only a small portion of those surveyed consider the plant manufacturing industry as prepared for Industry 4.0 (Figure 13). On the other hand, plant operators and equipment suppliers are perceived as being better prepared, whereby significantly greater diversification is seen among equipment suppliers than among operators. This result is not surprising because equipment suppliers are positioned very differently with regard to their size, complexity of their products and thus also their technological know-how.

It is striking how different the fitness of one’s own company for Industry 4.0 and that of the plant manufacturing industry in total are rated overall: about 40 per cent of the study participants estimate their company as fairly well equipped for Industry 4.0. Plant manufacturing overall, however, is perceived as significantly much less well prepared. This discrepancy could be explained by the fact that still too few implemented Industry 4.0 solutions are known in plant manufacturing.
How well is the industry prepared for Industry 4.0?

**Own company**
- Well: 39%
- Not at all: 17%
- Less well: 44%

**Plant manufacturing total**
- Well: 10%
- Not at all: 7%
- Less well: 83%

**Plant operators total**
- Well: 23%
- Less well: 78%

**Plant equipment suppliers total**
- Well: 28%
- Not at all: 5%
- Less well: 67%

Figure 13
The assessment that the plant manufacturing industry is so far only ill equipped for Industry 4.0 suggests that training and further education are of the utmost importance. And for the most part the companies that responded do in fact see this area of action as the most important requirement for implementing Industry 4.0 (Figure 14). By contrast, the corresponding risk of not having enough qualified employees available was assessed to be significantly lower. In principle, this requirement is viewed as one that can be met. Nevertheless, the question remains as to how the plant manufacturing industry can manage to keep loyal employees familiar with the dynamics of other sectors, in particular communications and information technology. It may be necessary to take an entirely new approach and pull qualified employees together into a line of business that enjoys great freedom from the classic plant manufacturing business. For instance, opportunities for applying networked product and data-driven services in plant manufacturing could be explored in a “Connected Solutions” segment and tested in conjunction with research institutions and startups. Further models are also conceivable in which the plant manufacturer e.g. serves directly as the incubator for industry-related startups. In this way, manufacturers could lock in promising technologies and employees without establishing them directly in plant manufacturing. Once this is commercially viable, plant manufacturers can then decide whether these companies are to be integrated further to strengthen their own core business or whether they will offer these developed products and services independently on the market.

Unlike the issue of the availability of qualified employees, those surveyed took the IT security risks very seriously (Figure 15). In any case, the danger of cyber attacks rises with the advancing networking of all plant parts and their connection to the Internet. The likelihood of security problems caused by internal error or negligence also continues to grow because industrial plants are no longer data technology islands protected against the risks inherent in the Internet. Therefore, comprehensive protection concepts must be developed, also taking into account the fact that an industrial plant cannot be restarted on regular basis to install security updates. In addition to the security of internal data, of business and trade secrets against unauthorized access as well as the protection of personal data, Industry 4.0 also focuses on issues that result specifically in connection with sharing data and using common
digital platforms. Against this backdrop the issues of ownership and relevant rights of use to existing and newly generated data must be clarified among all persons involved in plant manufacturing projects and, if necessary, regulated in individual contracts. Other points to be settled include new liability scenarios for specific automated actions, related accountability issues, and correspondingly appropriate insurance coverage. Therefore, it makes sense to include the respective legal department and external legal counsel in the digitization strategy early on to be in a position to regulate the legal questions raised in accordance with standard practice.

With all requisite attention for data security and the relevant legal framework conditions, this topic should not serve as a pretext for generally refusing to apply Industry 4.0 technologies. Rather more crucial is how data can be exchanged without disclosing process know-how.

Unlike the security issues, those surveyed do not see the area of action “Operational and Organizational Structure” as an important requirement for Industry 4.0 nor as a noteworthy risk. This coincides with the assessment that changes in industry logic are not expected over the medium term. However, both points only apply as long as processes and structures match any modified collaboration with customers and suppliers. For instance, end-to-end Systems Engineering also requires consistent planning structures, which in turn must be supported by a corresponding operational and organizational structure. So are the existing structures already suited to meet changing requirements arising from Industry 4.0, or has perhaps the awareness of the difficulties in plant manufacturing not yet sufficiently developed? Satisfaction with the current situation is surprising in any case insofar as Industry 4.0 has a very high level of impact on operational and organizational structures. The technical solutions for Industry 4.0 are basically already available. Yet, major restructuring projects are necessary in order to exploit these opportunities, projects that may deeply affect internal operations and inter-company structures.

Where are the risks of Industry 4.0?

<table>
<thead>
<tr>
<th>Risk Area</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure of new business models</td>
<td>10%</td>
</tr>
<tr>
<td>Required investment is unclear</td>
<td>10%</td>
</tr>
<tr>
<td>Operational and organizational structure don’t fit</td>
<td>16%</td>
</tr>
<tr>
<td>Legal framework conditions / data protection</td>
<td>25%</td>
</tr>
<tr>
<td>Availability of qualified employees</td>
<td>31%</td>
</tr>
<tr>
<td>No standards</td>
<td>37%</td>
</tr>
<tr>
<td>Security risks (e.g. IT security)</td>
<td>51%</td>
</tr>
</tbody>
</table>

Figure 15
Percentage of mentions „very relevant“
Industry 4.0 will change how engineering work is done

A main component in the implementation of Industry 4.0 in plant manufacturing is the plant’s virtual representation. This produces a lifecycle that extends beyond the plant’s physical one: the digital lifecycle. It starts by saving the first data of the plant and does not end before all its data has been deleted. Engineering lays the foundations for this digital lifecycle, which extends far beyond the planning and building of the plant. Therefore, working practices are expected to undergo far-reaching changes.

In the course of all this, engineering will evolve to be a multi-disciplinary Systems Engineering, which focuses on the plant’s entire lifecycle and covers the totality of all engineering activities. Systems Engineering is characterized by five elements, which according to those surveyed, will all gain in importance: early testing and validation, digital availability of data and processes everywhere, feedback loops from operations, integrative development of products, processes and production systems as well as a modularization and reutilization of plant and systems concepts (Figure 16). The ensuing engineering chain includes preparing and using the systems for engineering, simulation, and operation of the plant and embedding them in an IT-based process management. These systems will be planned together from the outset and continually developed over the plant’s entire digital lifecycle. In detail this means that engineering applications are linked via a real central database. This makes it increasingly possible to synchronize planning activities since changes in the database are recorded directly in all systems.

How will the way of working in engineering change?

![How will the way of working in engineering change?](image_url)

Figure 16
Only Systems Engineering as described will keep the increasingly complex Industry 4.0 plants at all manageable. Challenges along the way include, among other things, the coordination of methods, tools, and engineering environments. This makes integrated planning structures a main requirement. Media discontinuities must also be avoided not only internally, but also in the exchange with suppliers and customers. A very significant media break is the document delivery of equipment suppliers, which the purchasing department usually orders as an unchangeable drawing (as a rule as a PDF document). More and more this simple digital paper must be replaced by intelligent, i.e. digital formats that can be processed, which for instance are networked via relational databases. In this way, for example, any changes in piping and instrumentation diagrams can be incorporated directly in 3D models.

Systems Engineering is supported by IT-based Business Process Management, which in addition to Big Data will become increasingly more important in engineering (Figure 17). The majority of business processes in engineering and beyond along the Engineering Procurement Construction (EPC) chain will be automated by business process management systems.

Executing these processes in a cloud-based infrastructure allows for flexibility in adjusting to changed framework conditions and makes it possible to integrate external resources rapidly.

These systems will be able
- to integrate internal and external employees and systems involved in a business process;
- to simulate processes in order to define the optimum process;
- to monitor, control, and improve business processes in real time.

This will make it possible to optimize engineering processes and better integrate suppliers. Ultimately, the entire process can be more flexible in responding to modified requirements arising from downstream processes. On the other hand, engineering must create the foundation for embedding the plant itself in IT-based process management.
In contrast, “Big Data” for a start is a catchphrase that stands for the analysis of large amounts of data. Basically this is about the lifecycle of collecting data until information for creating value from it is obtained. Hence Big Data includes all IT topics that deal with handling this lifecycle. In this context, Industry 4.0 is promising innovations in IT architecture that make it possible to integrate data from various sources and that optimize the execution of data-intensive workflows for analysing the data. Examples of this are auto-adaptive algorithms, used to significantly increase the data mining performance, i.e. the search for valuable information in large amounts of data.

The great potential of Big Data is the value that the data has (and primarily the information obtained from it). To profit most from any data, a data-driven business model is needed that recognizes the value of the data and can exploit it efficiently. Within the framework of operations intelligence, current discussions are focusing primarily on examples from plant operations, such as collecting and analysing operating data from plant components (e.g. pumps, fittings). If their operating condition is approaching a critical value, corresponding measures can be introduced, such as changing the operating conditions or installing a replacement at the next turnaround. This is also where connections to IT-based process management come in. A critical operating condition is generally only recognized as such if it has already led to a malfunction. Auto-adaptive algorithms consequently recognize this condition as critical at an early stage and try to avoid it. If an operator networks several plants, even those plants in which this has not yet led to a malfunction will recognize the critical conditions. Plants do not really become smart until the network extends significantly beyond the boundaries between operators and they learn from the mistakes of other plants (Figure 18).
Big Data is thus a central topic for engineering because it is the plant manufacturer as integrator that must enable the plant to exchange data with other systems and analyse it at the same time. However, the road to such an intelligent plant is long, considering that only a fraction of the plant’s data is currently being consulted for the decision making process, and this data is virtually never exchanged beyond the confines of the plant. The impact of Big Data is insofar greater than only on engineering since the question must still be answered as to who is ultimately responsible for data mining. Will all the data from existing plants be given to external services providers, who will analyse it and send back relevant information? Or will this competence be found elsewhere: with the operator, the equipment supplier, or the plant manufacturer?

Cooperation with operators and suppliers will change significantly
According to study participants, the exchange of data between plant manufacturers and operators will intensify significantly. In principle, the plant manufacturer has no interest today in disclosing data. The added value must also be clear to the customer, the plant operator; but then the operator will certainly request the data. In the past, digitization has frequently been blocked by contractual framework conditions and transfer agreements because an expanded scope of supply increases the investment sum. Accordingly, the plant’s operating costs must fall for the operator to benefit from digital integration. Maintaining a digital model in operations is also expensive; the ensuing added value must be correspondingly higher.
Most of those surveyed are in any case expecting that operators’ requirements for the digital scope of supply will increase (Figure 19). Study participants are therefore assuming that plant operators will recognize the value of the data and in the course of doing so will also drive the digital integration with plant manufacturing forward (Figure 20). While today the digital supply usually only consists of a digital paper, intelligent database-supported formats will be delivered in the course of digital integration.

Industry 4.0 also results in the fact that providers of technical systems also operate them. Basically such operator models are nothing new; but it was not until now that the technical requirements for it exist, for instance remote monitoring and control based on a comprehensive networking of components. Also new technologies can measure variables, which until now could not be recorded or only at a great effort and expense.

This opens up new possibilities for order accounting, which can provide the basis for new operator models. Examples in this regard are taken from mechanical engineering, where compressor manufacturers sell pressurized air by cubic meter or manufacturers of track vehicles sell mileage and reliability.

In all likelihood for industrial plant manufacturing this does not necessarily mean that in the age of Industry 4.0 plant builders will also operate them. However, it does mean that plant manufacturing will be providing the digital platform that the operator uses for risk-based inspection, maintenance, and operation of the plant. In the end, no one is in a better position to deliver the data this requires than those who designed and built the plant.
What demands does the operator make on the digital scope of delivery?

- Centralized register for parts descriptions (tags): 28% very relevant, 51% relevant
- Management of change: 27% very relevant, 56% relevant
- Standards for parts and document naming: 29% very relevant, 56% relevant
- Review of received documents for compliance with standards: 30% very relevant, 55% relevant
- Centrally structured data storage: 37% very relevant, 51% relevant

Figure 19

Will a large-scale digital integration be required in the future?

- Data will be generated in jointly used systems: 32% very relevant, 44% relevant
- A common database will be used: 34% very relevant, 44% relevant
- Data will be transmitted digitally: 38% very relevant, 48% relevant
- Models will be used jointly: 39% very relevant, 51% relevant
- Data will be transmitted in intelligent formats: 57% very relevant, 36% relevant

Figure 20
So while the plant operator on the one hand has to demand digital integration with plant manufacturing, on the other hand the plant builder’s digital cooperation with suppliers is also not yet very far advanced. In the long term, this is the route that will be taken. Although digital communication is already far advanced, digital integration is still in the beginning stage (Figure 21). In addition to the use of intelligent data formats, shared digital workspaces with common workflows and centralized data storage are also important in this context. Global access for all parties involved, scalability and reliability can be guaranteed if data storage is cloud-based.

From the perspective of study participants, most suppliers will still not qualify for this type of digital cooperation by 2020 (Figure 22). In any case, those surveyed are not expecting that any significant number of equipment suppliers will close ranks in the next five years with those that are today already well prepared for Industry 4.0 (Figure 13).

Against this backdrop Industry 4.0 could offer a competitive advantage for equipment suppliers from industrial countries since they are possibly better prepared for the changes associated with Industry 4.0 than suppliers from emerging economies. Over the medium term this situation could even result in today’s prevailing best-cost country sourcing being replaced in some areas by a leading-technology country sourcing. Otherwise, in emerging markets suppliers will have to work very hard and plant manufacturers will be required to offer comprehensive supplier development programmes in order to close the technology gap.
How many of your plant equipment suppliers will be qualified for digital cooperation by 2020?

69% of those surveyed view the majority of suppliers as not qualified.
Industry 4.0 in Industrial Plant Manufacturing – Revolution or Evolution?

Study participants acknowledge that Industry 4.0 has a great deal of potential to improve the value chain in plant manufacturing. In fact, improvements are expected in all value-creating processes with impact on the existing business model. Engineering, logistics, and the construction site will especially benefit from the introduction of Industry 4.0 technologies.

**Engineering efficiency will improve**

As presented in section 6, through Industry 4.0 engineering will undergo crucial changes that will also increase its efficiency. The question is whether the new working methods in engineering will primarily result in improvements in downstream processes, which may possibly not appear until the plant is in operation, or whether engineering itself will benefit.

The result of the study is not fully clear on this point. Most of the responses assume that the costs for a company’s own engineering work will decrease (Figure 23). Yet at the same time, costs for external engineering services are also not expected to fall (Figure 24); 39 percent of those surveyed even expect them to increase. The majority, however, are anticipating turnaround times in engineering to be shorter in future (Figure 25). Thus the basic message is that engineering overall will become faster and less expensive, and the share of external services will increase.

The sufficient availability of qualified employees is viewed as a possible bottleneck, which will especially be reflected in engineering and will have to be bridged with external service providers. These services may potentially be quite different in nature than the majority of previous engineering services. The requirements and the accompanying qualification level will rise, which would explain the expected increase in costs.

### How will efficiency in engineering change in regard to cost?

<table>
<thead>
<tr>
<th>Option</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>much better</td>
<td>6%</td>
</tr>
<tr>
<td>worse</td>
<td>17%</td>
</tr>
<tr>
<td>unchanged</td>
<td>17%</td>
</tr>
<tr>
<td>better</td>
<td>60%</td>
</tr>
</tbody>
</table>

The majority of those surveyed anticipate reduced engineering costs

Figure 23
How will the costs of engineering services change?

![Costs of Engineering Services Change Diagram]

The majority of those surveyed do not anticipate any reduction in the cost of engineering services.

Figure 24

How will the efficiency of engineering change in regard to cycle times?

![Efficiency of Engineering Change Diagram]

The majority of those surveyed expected shorter cycle times in engineering.

Figure 25
Logistics processes will become more efficient
In the application of Industry 4.0 in other sectors of industry, logistics will play a pioneering role. Specifically, allotted distribution to the end customer provides examples of smart commodities or intelligent parts, which consequently improve efficiency and flexibility.

In general, smart commodities are described as a combination of physical and virtual representations of a part. This part has a unique identification, can communicate with its environment, store data about itself and share data as well as help to make decisions about its onward transportation route. This basically creates five development phases of smart commodities (Figure 26), with the minimum requirement being that parts identify themselves. The majority of those surveyed see this requirement as being met by 2020 (Figure 27), but are hardly expecting advanced intelligence to arrive over the medium term.
Five development stages of smart commodities

1. Identify
   - Identification by barcode or RFID should not just be used to check incoming goods!
   - Parts have at least one unique ID.
   - In the simplest case, it can be a barcode or RFID

2. Localize
   - Parts identify their locations themselves.
   - They know e.g. where they are on a transport route.

3. Monitor
   - Parts have sensors which they use to monitor themselves and their environment.
   - Application e.g. for tracking and quality assurance

4. Process
   - The part processes sensor information itself.
   - The part knows, e.g. that it is damaged or at the wrong location.

5. Communicate
   - The next logical step is "Act", this makes the part an actuator.
   - The part communicates the information proactively.
   - This triggers an activity at another location.

What demands does the plant manufacturer make for the intelligence of parts within logistics?

- Parts communicate: 13%
- Parts identify their location themselves: 18%
- Parts have sensors: 25%
- Parts are intelligent: 30%
- Parts carry information: 55%

The most important piece of information is always the part’s identification.

Figure 26

Figure 27
However, according to the study participants, consistently equipping parts with the minimum level of intelligence is definitely enough to noticeably increase the efficiency of logistics processes in conjunction with digital logistics planning (Figure 28). Tracking and quality control as well as the quality of transport will likewise benefit (Figure 29). Especially for quality control, smart commodities in the future will offer the advantage that every part will be able to monitor on its own its transport route and influencing factors crucial to quality and to report back on these.

Of course smart commodities alone will not be enough to give logistics a decisive boost in efficiency. The full potential of smart commodities will not be realized until they have been integrated into relevant IT-supported processes. Therefore digital logistics planning, which without media discontinuities builds on engineering and construction site planning, constitutes another important aspect in improving logistics.

Logistics makes it particularly clear how important it is to have digital consistency throughout all phases in the value chain: hence, construction and delivery sections, for example, are planned in 3D models, but are processed in an ERP system. If these systems are intelligently connected, changes in engineering are automatically adopted in the planning of downstream processes. It is this form of networking that makes it possible to simulate when which part can be transported. Shipments planned and optimized in this way can then be controlled autonomously with software agents and intelligent parts.

Logistics processes are not essentially specifically related to plant manufacture. New technologies that improve efficiency in logistics are therefore not expected to be developed in or explicitly for plant manufacturing. It is more likely that companies outside of the sector will be offering new products, methods, and tools with applications across the industry.
How will the efficiency of logistics change?

91% of those surveyed expect the efficiency in logistics to improve.

Better: 81%
Much better: 10%
Unchanged: 10%

To what extent is an optimization of transports to be expected?

Better: 65%
Much better: 20%
Unchanged: 15%

What is the influence on tracking and quality control to be expected?

Better: 64%
Much better: 21%
Unchanged: 14%

No mentions “worse”
The construction site will definitely profit from Industry 4.0
According to those surveyed, in addition to logistics, the construction site also stands to profit significantly from Industry 4.0. The obvious advantages will be in construction site management with the ensuing adherence to delivery dates and documentation of the actual status.

Management of the construction site will be automated in parts (Figure 30). Study participants see the automation of the status check and visualization of construction progress as the major advantages. Similar to digital logistics planning, this also requires construction planning to be linked to engineering without media discontinuities, hence basically a link to the 3D model. The challenge of transferring a functional engineering structure to a site-specific construction site BOM is thus resolved in the model. It is here that construction stages can be identified; the requisite BOM information is consequently generated automatically. At the same time, it is crucial that the engineering systems and the ERP system communicate with one another.

Construction site planning will be automatable because in the engineering phase it is already possible to simulate when which building component can be installed. Changes in engineering would be automatically adopted in the construction site planning, and thus construction site planning would always be up to date.

This planning provides the basis for an automated progress check and the visualization of site progress based on this check. Since each step on the construction site has its counterpart in the 3D model, a corresponding visualization is provided when a construction site activity is logged off. User-friendly solutions with mobile terminals are also conceivable for logging off activities. For construction it is also conceivable that thanks to position and touch sensors intelligent building components know when they have arrived at their construction site and are installed – and consequently independently report complete installation.

These days the construction site often does not get data until it is too late. Therefore, reactions to problems are delayed. With a status report close to real time, the reaction to incidents on site can also be immediate, ideally they can even be avoided entirely. According to study participants, the measures described can in any case contribute towards significantly improving delivery reliability on the construction site (Figure 31).

<table>
<thead>
<tr>
<th>What is the impact on management of the building site and determination of the progress of construction to be expected?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-automatic optimization of the construction site</td>
</tr>
<tr>
<td>Automatic status determination</td>
</tr>
<tr>
<td>Visualization of the progress of construction in virtual real time</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage of mentions</th>
</tr>
</thead>
<tbody>
<tr>
<td>very relevant</td>
</tr>
<tr>
<td>12 %</td>
</tr>
<tr>
<td>27 %</td>
</tr>
<tr>
<td>27 %</td>
</tr>
</tbody>
</table>

Figure 30
Changes in construction compared to the planning are currently generally documented on paper; the actual plant is currently not congruent with the digital plant. The described transparency of the construction status and the networking of the construction site that can be achieved with Industry 4.0 technologies will ultimately also significantly improve the quality of as-built documentation (Figure 32), and the digital plant will correspond to the actual plant.

**What is the impact on the delivery reliability for the construction site to be expected?**

86% of those surveyed expect delivery reliability on the construction site to improve.

**How is the quality of as-built documentation expected to be affected?**

88% of those surveyed expect the quality of the as-built documentation to improve.
8 Outlook

According to the results of this study, the plant manufacturing industry is aware that implementing Industry 4.0 will require a great deal of effort. At the same time, the importance of new business models and value chains as well as the danger of new competitors appearing on the market must not be underestimated. Plant manufacturers must also keep an eye on the fact that Industry 4.0 will affect existing processes and structures developed for today’s business models.

The main business endeavour beyond the period reviewed by the study is the development of new business models. Today plant manufacturers often still do not have what it takes to be able to develop and offer new, data-driven products and services. This is precisely where Industry 4.0 may be a great opportunity for plant design and planning, to provide smart services and to benefit from the entire digital lifecycle of the plant. These services deliver and use plant operations data; these services are not developed around the plant but rather are an integral part of it.

The most important requirement mentioned by study participants for implementing Industry 4.0 in large-scale industrial plant manufacturing is training and further education. Together, companies and universities must develop concepts in order to be in a position to guarantee not only that the existing workforce receives continuing training but also that new employees are trained. This urgently calls for (study) programmes adapted to the company’s needs or brand-new programmes. It will be just as important to find ways to win over qualified employees for jobs in plant manufacturing. To do so, models must be developed that can keep pace with the dynamics of other industries. Examples of this are venture capital concepts or establishing separate sectors in which suitable qualified employees are pooled and that enjoy far-reaching freedoms from classic plant manufacturing business.

The study has furthermore revealed that in particular an intense exchange will be important between operators and plant manufacturers on the use of plant operations data. Until now this data is only rarely disclosed. It is here that considerable potential for optimization in further plant development has been allowed to lie fallow. It is all the more important to develop and define binding norms and standards for the automated exchange of data and for the communication with intelligent systems and equipment.

Most of the new services made possible by Industry 4.0 are aimed at preventing production downtimes and losses. Basically these services are intended to make use of the increasing flows of information in and between plants. Therefore, the first in line are control services or pure information services such as data analytics. For example, plant manufacturing could provide the digital platform that plant operators use for risk-based inspections, maintenance and operation of the plant, and charge for the use of the platform for new or expanded services.

Furthermore, the plant manufacturing industry must also keep an eye on tasks such as the opening of new distribution channels by applying Internet technologies and the development of new intelligent operator models.

The technologies for Industry 4.0 are largely already available. Combining these technologies to create a functioning and profitable entity is the challenge that large-scale industrial plant manufacturing industry has to master. Industry 4.0 is currently a topic primarily being driven by suppliers. Therefore, the question must always be asked as to what advantages the individual Industry 4.0 application can actually offer in the value-adding process of plant manufacturing. Each and every company is called upon to find out for itself how it can benefit from the new opportunities being offered by Industry 4.0.
Industry 4.0 will not be implemented in the plant manufacturing industry in one fell swoop. Companies need to have a clear picture of their intended final outcome and an implementation strategy. It should be introduced in small steps that contribute toward creating value in a short period of time (time to value). Moreover, if successfully implemented, Industry 4.0 will not only require but also result in significant changes in the processes and structures of plant manufacturing. Industry 4.0 in the large-scale industrial plant manufacturing industry thus resembles more of a company-wide project of change than the mere introduction of additional IT systems.
maexpartners is a management consultancy with a focus on industry and high technology. Our team has profound knowledge of technology, in-depth business expertise as well as vast experience. Our service offerings are holistic, extending from innovative strategy to the pragmatic implementation of developed solutions on site. We purposely push the limits of traditional consultancy services and assume operational co-responsibility.

The foundation and compass of our consultancy services is based on a trilogy of consistent targets that allow us to improve client competitiveness for the long term:

**Creating Value:** Intelligently engineering product value  
**Boosting Operations:** Holistically optimizing processes and structures  
**Sustaining Growth:** Ensuring long-term growth

More at www.maex-partners.com

maexpartners GmbH  
Grafenberger Allee 277–287  
40237 Düsseldorf, Germany  
Tel.: +49 211 598396-83

Thorsten Helmich  
Tel.: +49 173 2794050  
thorsten.helmich@maex-partners.com

Marc Artmeyer  
Tel.: +49 172 5814772  
marc.artmeyer@maex-partners.com

Dr. Sven Haverkamp  
Tel.: +49 174 9447054  
sven.haverkamp@maex-partners.com

VDMA Large Industrial Plant Manufacturers’ Group (AGAB) represents the interests of its members and is the largest German network of companies in the industry. Member companies have an annual order intake in excess of € 20bn, and they employ more than 60,000 in Germany as well as 100,000 at international locations. With a global market share of 16% and an 80% export quota, the companies provide considerable stimulus for the domestic and international supply industry.

In addition to representing its members’ interests and providing a neutral platform on which to exchange experiences, the group also offers its members a wealth of knowledge on relevant management issues surrounding large-scale industrial plant manufacture.

More at http://agab.vdma.org

VDMA  
Large Industrial Plant Manufacturers’ Group  
Lyoner Straße 18  
60528 Frankfurt/Main, Germany  
Tel.: +49 69 6603-1858

Thomas Waldmann – Managing Director  
Tel.: +49 69 6603-1271  
thomas.waldmann@vdma.org

Klaus Gottwald – Specialist Advisor  
Tel.: +49 69 6603-1264  
klaus.gottwald@vdma.org

Olaf Stecken – Specialist Advisor  
Tel.: +49 69 6603-1625  
olaf.stecken@vdma.org
The content of this publication is based on surveys and assessments conducted and prepared by the VDMA Large Industrial Plant Manufacturers’ Group and by maexpartners. The facts, opinions, and recommendations submitted here are only intended to serve as a guide; the presentation does not claim to be complete. Furthermore, the specifics of each industry sector and the products of plant manufacturing must be taken into account. Therefore, there are many more conceivable configurations beyond the one underlying this study and its recommended courses of action that may also result in the drawing of different conclusions.

Picture credits:
ThyssenKrupp Industrial Solutions AG (p. 4, p. 15, p. 21, p. 26, p. 37, p. 48)
The Linde Group (p. 6, p. 7, p. 11, p. 22, p. 26)
Siemens AG (p. 5, p. 6, p. 32, p. 37, p. 40)
Primetals Technologies Limited (p. 8, p. 9)
Voith GmbH (p. 34)
Outotec GmbH & Co. KG (p. 47)
ABB Group (p. 42)
Gerard Koudenburg / Shutterstock (cover picture)