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The current and future use of simulation in discrete and process industries

Results of a global online survey September 2020

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1. Preface

Nowadays, everyone is talking about the Digital Twin and it's benefits along various fields of application. Simulation models are an essential part of the Digital Twin, as they make the Digital Twin alive. They are like the "ghost in the shell" or the brain and nervous system, if we use the human analogy. Simulations are used in various engineering domains for many years, resulting in many highly specialized tools for different fields of application. As time changes, we are eager to understand how the world of simulation is changing and how simulation is used today and what the anticipation is for the future. We conducted an online survey about the use of simulation in 2014 for the process industry. In the beginning of 2020, we decided to initiate a second in-depth online survey to get comprehensive market feedback.

The 2020 survey broadens the focus group to the discrete industry and thus focusses on the application of simulation along the value chain of all industries. With this survey we wanted to get answers for the following three questions:

- How is simulation currently used in discrete and process industries and did this change for the process industry compared to 2014?
- What is the updated vision about the future use of simulation?
- To which extend has the vision of 2014 been realized and what long term-oriented conclusions about the perception of simulation within industries can be drawn?
- Does the extended scope of the survey significantly change the results of the study?

The survey was online from May to July 2020 and was completed by 239 participants. At this point, we want to thank all the participants who made this possible by sharing their knowledge, vision and time.

We also would like to thank Mrs. Sabine Rass and Mr. Ondrej Vilnius who supported us during the survey design and data analysis.

The Siemens AG generously provided the IT infrastructure for deploying and hosting the survey professionally. A special thank you goes to Mr. Guido Fey regarding this work.

Thanks also to Prof. Dr. Jens Jäkel from HTWK Leipzig and Chairman of VDI/VDE GMA Working Group 6.11 for his dedicated support in reviewing and supporting the survey.

We are pleased to provide the insights we gained conducting this survey within this report.

Linus Bruckner, Dr. Mathias Oppelt, Prof. Dr. Leon Urbas, Prof. Dr. Mike Barth

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2. Executive Summary

In May 2020 we rolled out a global online survey to gain insights about the use of simulation in process and discrete industries. Until mid of July, 239 people completed the questionnaire (217 from companies, 22 from universities/research institutions), providing a valuable statistical basis for analysis and future research. The group of survey participants from companies mainly works for larger companies with over 1000 employees (70%), the rest is employed at companies with 101-1000 employees (12%) and in small companies with up to 100 employees (16%). The companies the participants work for are system integrators/solution providers (39%), equipment manufacturers/machine builders (30%) and owner or operators of production facilities (30%) and others (multiple answers are possible). 28% of the participants work in the Chemical industry, 20% in Energy, 18% in Oil, Gas and Petro Chemicals, 17% in Electronics, 14% in Pharma and Biotechnology, 12% in Machine Tools and Production Machines industry, 12% in Water and Wastewater and 13% in Automotive and Robotics (multiple answers possible). Most of the participants work as Engineers (64%), followed by 26% in Research and Development, 23% in Management and 6% in Production (multiple answers possible). Most participants are based in Germany (47%), followed by participants from Europe (excluding Germany) 22%, then comes North America (14%), India (8%) and the other participants are split all over the globe.
Based on the data collected and its analysis, we derived the following statements on the current use of simulation:

- S1. Safety and quality are the most important drivers within process and discrete industries.
- S2. The Digital Twin is a virtual replica of a planned or already existing physical entity, this replica can be a simulation model.
- S3. The majority of decisions made across the life cycle are still based on (1) individual experience and (2) on standards. Analyzing historical data is most often used within the operations phase.
- S4. Simulation has grown acceptance over the past years, for all use cases.
- S5. Simulation is currently used a lot during the product design, process and plant design/production planning, engineering and commissioning/product engineering and during operation/production execution including service/maintenance.
- S6. Simulation is used for a wider range of tasks compared to 2014 (e.g. increasing quality, supporting decisions, visualization and presentation).
- S7. Participants who do not use simulation often state that it is too expensive, too much effort or they don’t see the added value for their applications.
- S8. Simulation is mostly used for milestone checks during engineering and commissioning.
- S9. It is still not very common to use standards for model creation or exchange, but the importance of standards even decreased since 2014.
- S10. The tool handling concept is the most important criteria when choosing a simulation tool.
- S11. Proprietary tools developed by end users lost importance on the market since 2014.
- S12. Engineering and Management decide which simulation tools should be used.
- S13. Price and licensing are not so important in Germany compared to other countries. They are especially important in India.
- S14. Price sensitive customers prefer a usage-based pricing model or a one-time payment instead of reoccurring payments.
- S15. Customers prefer to download new or updated simulation tools rather than using a DVD or other physical storage.
- S16. Many users would share their content with other users and would also use the content developed by others.

The following hypotheses about the future and vision on simulation have been retrieved from the survey data:

- H1. The continuous use of simulation will be supported by a modular, open and flexible tool landscape.
- H2. Ensuring quality and cost as well as time pressure are the most important challenges for industry in future.
- H3. Users who consider the environment as important are also increasingly concerned about safety, even though safety, environmental protection and limited resources lost relevance since 2014.
- H4. Cloud solutions have gained much relevance since 2014. The same is true for data driven solutions. Cloud solutions are especially important in India.
- H5. Simulation, cloud solutions and integrated engineering are the most relevant technological trends.
- H6. The importance of simulation driven solutions and products increased since 2014, even though it was already rated as very important at that time.
- H7. Simulation will gain even more importance in the future.
- H8. The prospects of simulation are especially good for the operation phase.
- H9. The future plant/machine/product engineering is to a high degree integrated/interdisciplinary and simulation is an important basis to cope with complexity.
- H10. The expectation that simulation models will accompany the life cycle of the product/production site as part of the digital twin has increased significantly since 2014.

Simulation will become more important in order to support the decision-making process along the whole life cycle in the future. Thus, simulation is definitely one of the core components of the digital twin, as it brings the digital twin to life.
Every company should reflect how and where the use of simulation is practical, efficient and helpful and if there is room for optimization of the company's current way of using simulation, as there are many different ways of how to use simulation efficiently. In addition, it is even more important to ensure that use cases are linked (see also chapter 4.2, page 8), and models can be reused. We hope that companies take this report as a tool to evaluate and benchmark their position. We are also available to consult on an individual level, if required.

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4. Introduction

4.1 Research Motivation

Market dynamics are rapidly changing and requiring highest flexibility to cope with the challenges of volatility in demand and resource availability. In the context of Industry 4.0 the lot size of one is heavily discussed [1], which requires to rethink the design and operations of the factories and plants of the future. Further the speed of change induced by digitalization is seen by everyone, with a clear tendency to increase even further.

In general, there is a demand for highly flexible, efficient and safe production sites, no matter of the industry. Complexity is steadily increasing and thus the demand on engineering and operations of such production sites. This complexity will massively complicate the engineering and operational decision-making process, because multi variable optimization problems occur, which can no longer be answered by experience alone. To optimize a production site over the life cycle with regards to its impact on multiple dimensions such as planet, people and profit can hardly be done without any supporting methodology and technology. One possible technology to support the decision-making process is simulation, which can be used to answer engineering and operational questions earlier and with lower risks [2] [3]. Further, simulation will be one key element of a successful digitalization strategy, because it enables the virtual representation of a production plant or product within a digitalized supply chain. To be more specific, a digital twin [4] is more than for instance a 3D model including all dimensions. An interactive digital twin needs to imitate also the behavior, which will be taken care of by an executable simulation model. Further experts' prediction on simulation and digital twin you can find in a technology outlook report recently published by Siemens AG as well [5].

Simulation is already used today in many industries for various applications and it is expected that it will gain further importance across all industries and many applications. To investigate the use of simulation and the aspirations of its future use, a team of researchers has already performed a global online survey focusing the process industries in 2014 [2].

Now in 2020, with an extended team, we wanted to find more answers, broaden the scope beyond the process industries and compare the results with the insights gained in 2014 to conclude long term trends. Thus, we did it again and conducted a global online survey in order to gain further insights.

4.2 The role of simulation in the life cycle of discrete and process industries

Figure 1 shows the typical life cycle in discrete and process industries for production sites and plants. When speaking about life cycle, we do refer to the following definition for both discrete and process industries.

In both the discrete and process industries, the life cycle begins with product design (phase 1, Figure 1), though the products in both industries differ from each other. In the discrete industry the second step is production planning (phase 2), followed by production engineering (phase 3) and finally production execution (phase 4). In the process industry the second phase is the process and plant design. The third phase can be defined as engineering and commissioning. After the commissioning the final phase is the operations phase (phase 4). [6] [7] [8] [9]

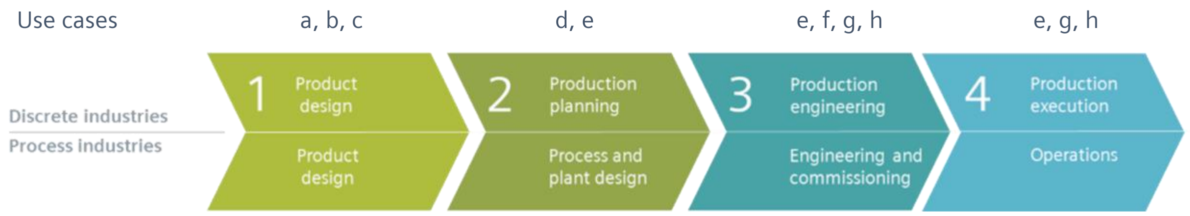

Figure 1 life cycle in discrete and process industries

Simulation is already being used in all the phases in both discrete and process industries, but with different goals. The following use cases have been derived from both interviews and literature.

a. **Early design of processes, plants, machines or products** (part of phase 1, Figure 1) [10] [11] [12] [13]:
The production process, plant, machine or product is being designed using simulation in an early stage.
b. **Product design optimization** (phase 1):
The product design is optimized based on the results of simulation to either reduce costs and / or improve the product quality.
c. **Product design validation** (phase 1):
The product design is validated before production. The validation is based on the results of simulation. With the use of simulation, problems in the product design are getting eliminated before production.
d. **Design of experiment** [14]:
Experiments are designed and the user can change multiple variables together in one step instead of just one at a time. This step is part of the product / process development and improvement process.
e. **Simulation-driven engineering/development** (phase 2) [15]:
The engineering process is supported by simulation. Questions occurring during this process can be answered faster. New ideas and approaches can be tested using the simulation model. During the engineering also the automation system functions are being implemented.
f. **Operator training** (phases 3 and 4) [16] [17] [18] [19] [20] [21] [22]
The goal of operator training is to familiarize the plant or production site operator with the automation system and the process control system. Normal production situations are getting simulated as well as emergency situations. The operators are also getting trained on plants and production sites which are still under construction, so the operators can directly operate the site after its completion.
g. **Virtual commissioning** (phase 3): [2] [10] [11] [23] [24] [25] [26] [27] [28] [29]
Simulation can support the automation system validation by providing a model and the signals the controller expects from the real plant devices. Therefore, a real controller can be used (hardware-in-the-loop) or an emulated controller is replacing the real controller (software-in-the-loop) [15] [30]. Commissioning can be simulated virtually and problems during this step can be detected.
h. **Offline operations analysis and optimization** (phases 3 and 4):
With the use of simulation, operators can validate, optimize and test possible actions in the virtual plant or production site before deploying those actions to the real plant. In the offline operations mode, the simulation model is not connected to the actual plant and required changes in operations must be entered manually by the operator after the offline analysis is done.
i. **Online operations analysis and optimization** (phases 3 and 4):
The online operations analysis and optimization differs from the offline version only in the connection to the actual plant. The simulation model in this case could be used in

closed loop operations and apply optimization results to the real production directly (if configured like this).

j. **Support in service and maintenance**:
This use case includes service and maintenance tasks like maintenance planning, calculation of the remaining service life and prediction of wear.

4.3 The Survey Design

The survey aimed to answer three major questions. With this goal in mind, we designed the survey.

1. How is simulation currently used in discrete and process industries?
2. What is the vision for simulation and how will it be used in the future?
3. How has the view on simulation changed since 2014?

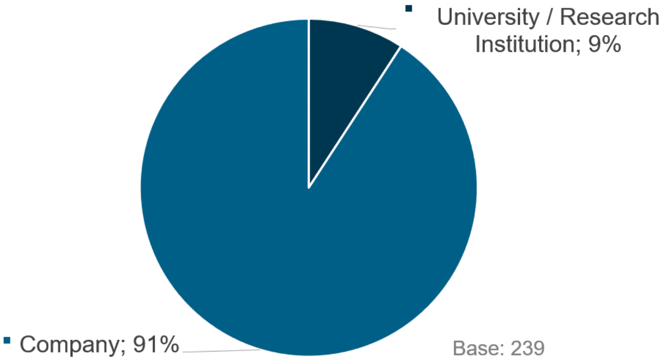

Figure 2: Class of participants

After developing a first set of questions, these were reviewed and optimized together with experts from the Siemens Global Shared Marketing Services, who also implemented and hosted the online survey.

To ensure global participation, the survey was offered in English and German language. On the 6th of May the survey went online and was available until the 15th of July.
The atp edition and Automation.com both published notes about the survey to spread the word towards an international audience. The survey has also been shared in various social media networks (LinkedIn, Xing, Twitter) by supporters and the Siemens Industry social media account. We used a customized link to gain more attention and create more interest.

In the questions which are referring to the future of simulation, we defined future as a timespan "within the next six to eight years", as this timeframe is out of the next budget cycle, but not too far in the future in order to still be tangible for the individual. Some of the questions have already been

Survey Structure

Trends, Challenges and Drivers
Drivers today
Drivers tomorrow
Technology trends affecting tomorrow

Current use of Simulation
The digital twin
Decision making support
Use cases
Kinds of simulation and tools
Standards and milestone checks

Business models
Decision makers
Licensing models
Distribution models
Content exchange between individual customers

Expectations and vision for Simulation
Future relevance of Simulation
Scenarios describing tomorrow

Color Code
Simulation today
Simulation in the future

included in the 2014 survey to guarantee a sound basis for a statistical valid comparison of both surveys.

After analyzing and evaluating the survey results, we have discussed them with various experts to validate them.

4.4 The survey participants

The questionnaire was completed by 239 participants. 217 of the participants work for companies whilst 22 are employed at a research institution or university (Figure 2).

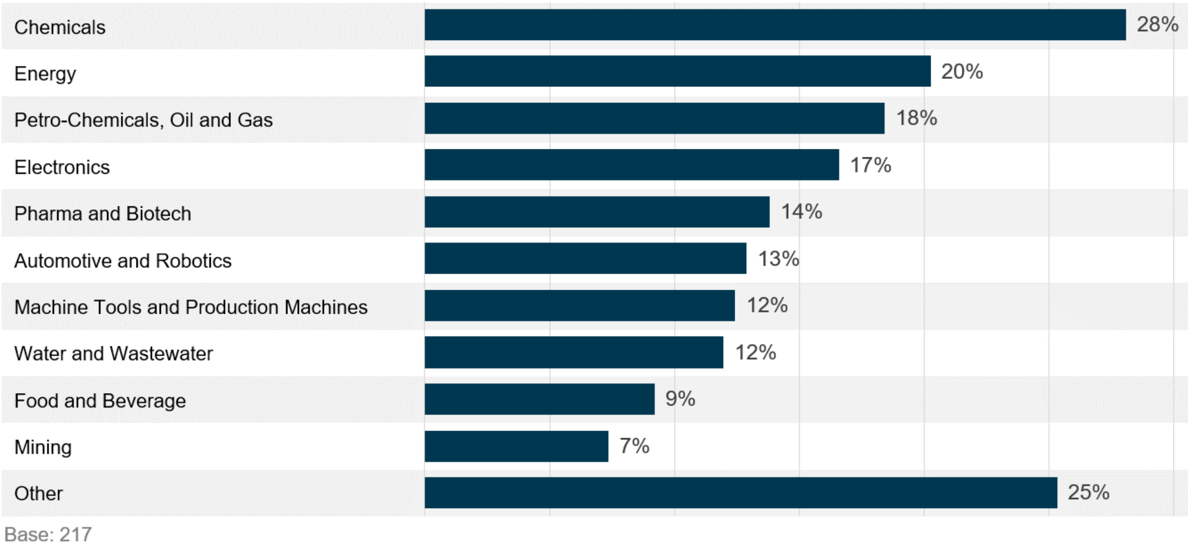

Figure 3 Industries – companies (multiple answers possible)

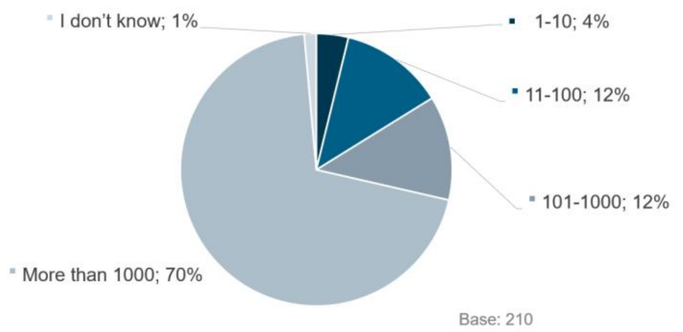

Figure 4 Company size

Within the group of participants working for companies, 28% work in the chemical industry, 20% in energy, power plants and renewables, 18% in the petrochemistry including oil and gas, 17% in electronics, 14% in pharmaceutical and biotechnology, 13% in automotive and robotics, 12% in machine tools and production machines industry, 12% in water and wastewater and the rest is divided as seen in Figure 3. Multiple answers to this question were allowed, so the sum of percentages adds up to more than 100%.

Within the group of participants 70% are working in large companies with more than 1000 employees, whereas 12% are working in companies with 101 to 1000 employees and 16% are working for smaller companies with a maximum of 100 employees (see Figure 4).

Most of the survey participants from research institutions and universities are working in the area of automation engineering (68%) followed by electrical engineering (18%), chemical engineering (14%) and others (Figure 5).

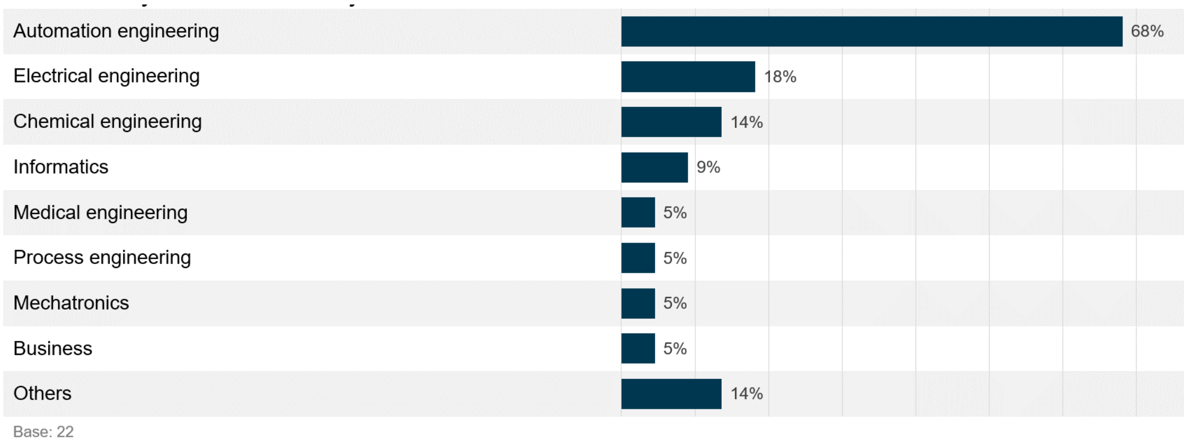

Figure 5 Research and subject matter field – universities (multiple answers possible)

In the group of participants from universities and research institutions, 41% are head of institute or professors, 36% are research assistants or PhD candidates, 14% are teachers, 9% students, whilst 5% are senior engineers (Figure 7). Also, for this question multiple answers were allowed. On the company side 64% are working as engineers, 26% are working in research and development, 23 % in management, 6% in production, 3% in quality management and 3% in the IT department (Figure 6).

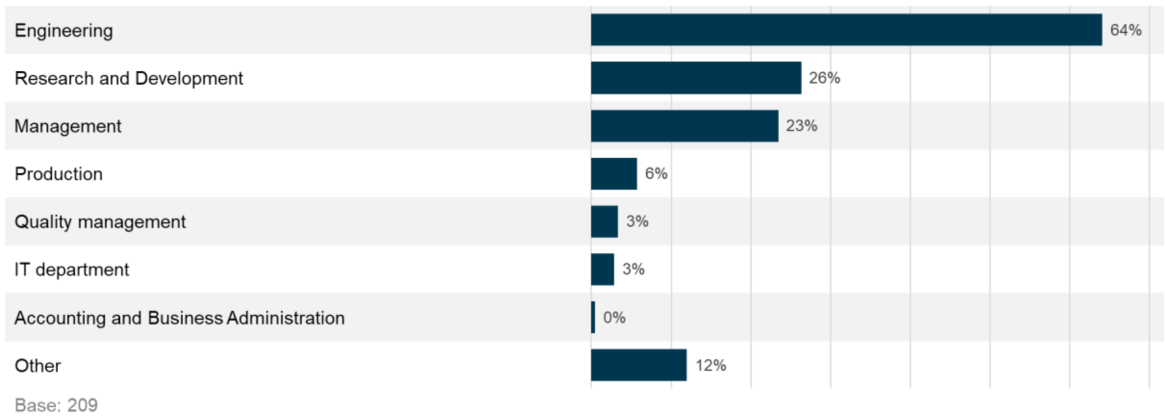

Figure 6: Role in the company (multiple answers possible)

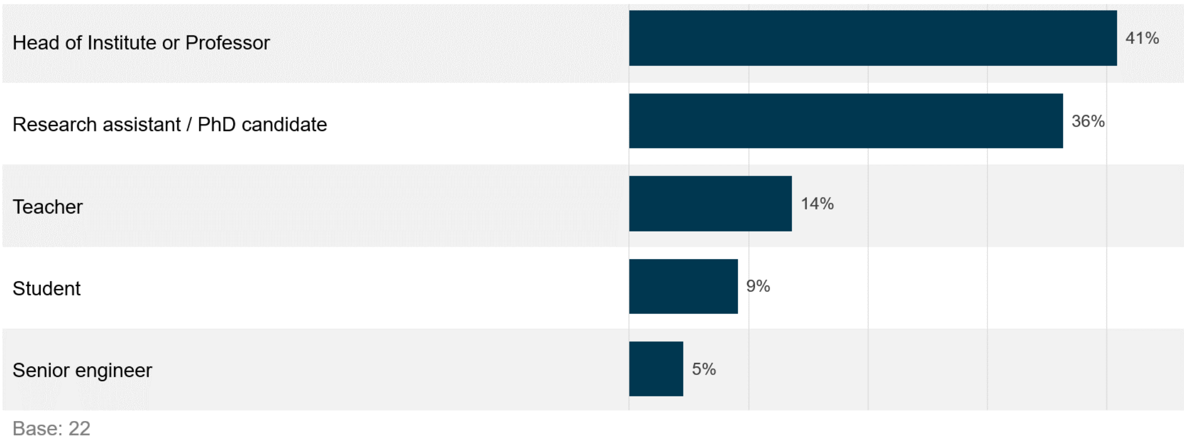

Figure 7: Role in the university (multiple answers possible)

39% of the participants employed at companies are working for a system integrator, 30% for an equipment manufacturer and 30% for an owner/operator (multiple answers possible, Figure 8).

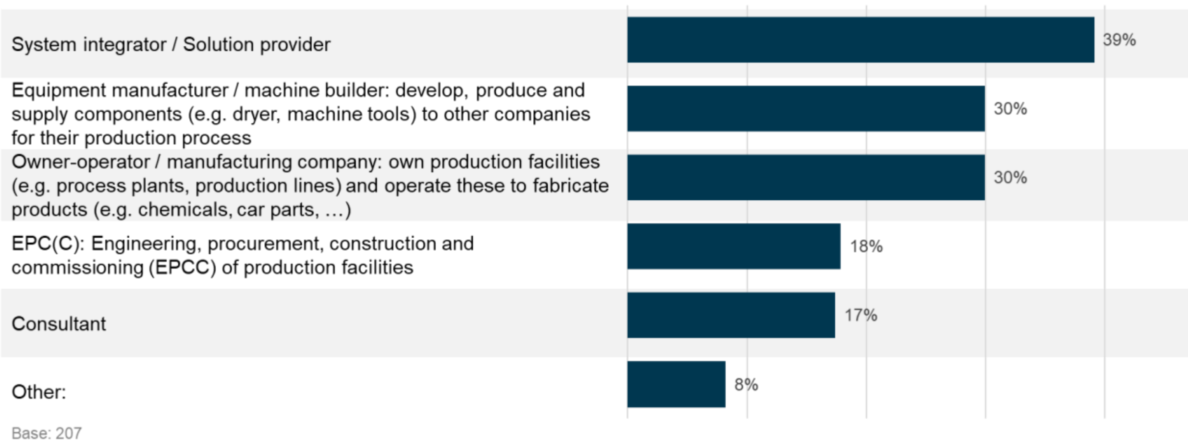

Figure 8 Company type

The main part of participants are based in Germany (47%), followed by the Europe excluding Germany (22%), then comes North America (14%), India (8%) and the rest is split all over the globe (10%) (Figure 9).
29% of all participants are between 50-60 years old, while 22% are between 40 and 50 years old, 25 % are 30-40 years old, 11% are 20-30 and 13% are older than 60 years (Figure 10).

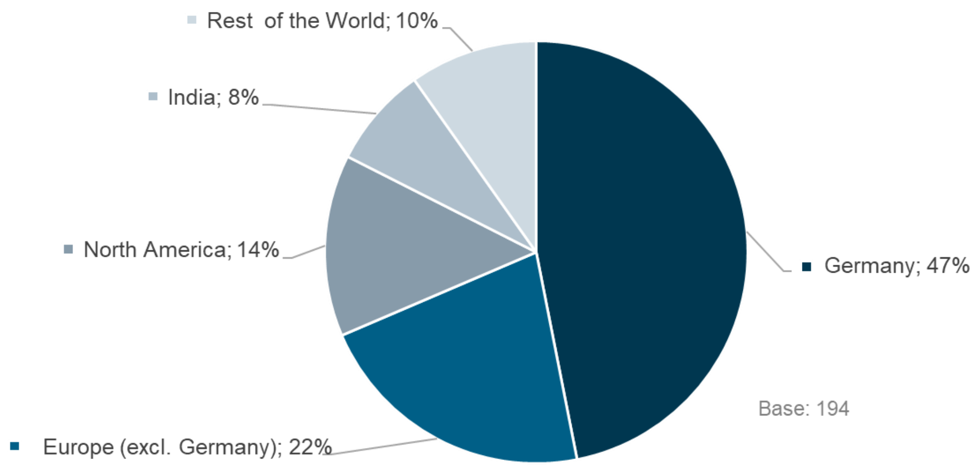

Figure 9 Region/Country

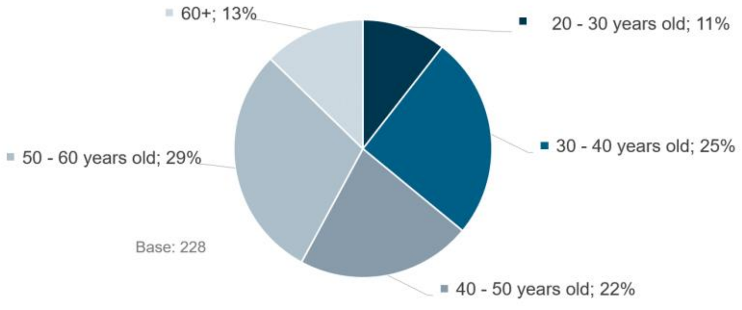

Figure 10 Age structure

Tests that compare the answers of individual subgroups (e.g. regions or industries) are based on asymptotic tests for proportion of means with a confidence level of 5% (e.g. in Figure 19). For example the value for a subgroup (e.g. Production in Figure 19) is compared against the weighted average of the values of all other subgroups (here: of all other industries).
Zero correlation tests are used to find out whether a correlation coefficient for the results of the different years is significantly different from zero or not. Significant differences are marked with a dot in the charts (see Figure 43). Asymptotic tests for zero correlation with 5% confidence level are used.

In the upcoming chapters, significant differences between results in the individual life cycle phases (see Chapter 4.2, page 8) are investigated, based on an asymptotic test for proportion and mean with a confidence level of 5%. Significant differences are then marked with a green or red arrow in the tables and charts.
When comparing the results of the two surveys (2014 and 2020), asymptotic tests for proportion and mean are used with a confidence level of 5%. In order to compare the two surveys on a statistical sound basis, we have created a subset of the 2020 results, which only includes the answers of participants from the process industry (as in the 2014 survey only members from process industries were addressed).
Significant differences are marked with a green or red up- or downwards arrow, depending on the direction of the change. Increasing percentages are marked with a green upwards arrow and decreasing percentages are marked with a red downwards arrow (see Figure 14). Increasing numbers are marked with a red upwards arrow and decreasing numbers are marked with a green downwards arrow (see Figure 12).

5. The current use of simulation

Safety and quality are the most important drivers within process and discrete industries.

In the beginning of the survey the current drivers of participants daily work have been identified (Figure 11). For the participants, the most relevant drivers are quality and safety in both discrete and process industries, with no significant difference between both industries. Directly followed by productivity and costs.

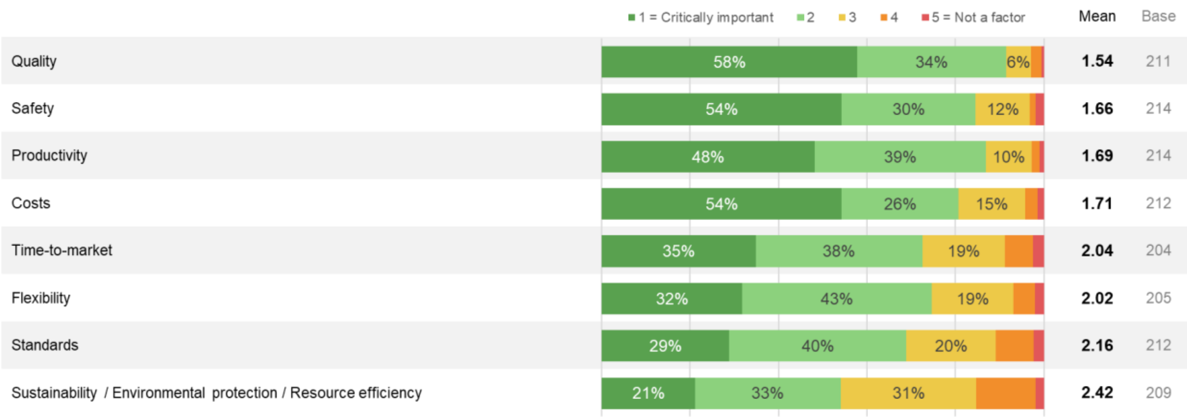

Figure 11 How much is your daily work driven by one of the following points?

The importance of safety and quality has not changed since 2014 as they are remaining the most important drivers (Figure 12)*. Compared to 2014 time to market has become more important (statistically significant), while sustainability has become less important. The importance of safety has slightly decreased but is remaining on a high level.

	2014	2020 Process	2020 Total
Base	189	176	214
Quality	1.49	1.54	1.54
Safety	↓ 1.44	↑ 1.68	1.66
Productivity	1.61	1.69	1.69
Costs	1.81	1.74	1.71
Flexibility	.	2.02	2.02
Time-to-market	↑ 2.42	↓ 2.04	2.04
Standards	2.13	2.17	2.16
Sustainability / Environmental protection / Resource efficiency	↓ 2.04	↑ 2.39	2.42

Figure 12 Comparison with 2014 - How much is your daily work driven by one of the following points?

The Digital Twin is a virtual replica of a planned or already existing physical entity, this replica can be a simulation model.

* Significant differences between the survey results of the different years are marked with a green or red arrow

Next, the participants were asked what they think is a suitable definition for the digital twin (Figure 13, multiple answers possible). 59% of the participants think that the Digital Twin is a virtual replica of a planned or already existing physical entity. One in two participants would define the digital twin as a simulation model of the plant/product.

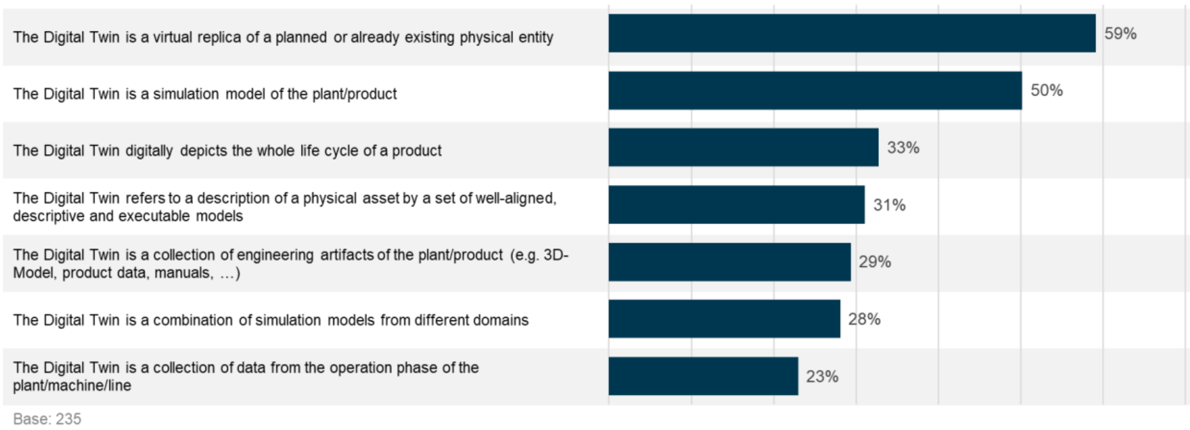

Figure 13 From your point of view: What is suitable definition for the Digital Twin?

The majority of decisions made across the life cycle are still based on (1) individual experience and (2) on standards. Analyzing historical data is most often used within the operations phase.

Looking at the decision-making process, standards are more important for supporting the decision-making process during process planning (Figure 14)*. Analyzing historical data is significantly more important for the decision-making process in the operation phase. Otherwise the use of norms for supporting the decision process is not as important during operations, then it is during the other phases. The most important factor in all the phases is still the experience of individual users.

	Product design	Process and plant design / production planning	Engineering and commissioning / production engineering	Operation / production execution including service / maintenance
Base	210	212	213	210
Experience of individual persons	64%	60%	67%	69%
Use of norms and standards	63%	↑ 66%	63%	↓ 47%
Analysis of historical data	47%	51%	↓ 31%	↑ 57%
Use of simulation	50%	↑ 52%	50%	↓ 26%
Use of security factors	↓ 34%	43%	46%	39%
I don't know	10%	8%	7%	5%

Figure 14 How is the decision process supported today?

* Significant differences between the answers in the individual phases are marked with a green or red arrow.

Simulation has grown acceptance over the past years, for all use cases.

Investigating the tasks for which participants would use simulation reveals that simulation is mostly used for test, validation and checkout, followed by supporting decisions, gaining know-how and understanding and finally minimizing risks (Figure 16, multiple answers possible). Not many of the participants would use simulation for supporting their communications. Since 2014 the top three did not change, but now more users see simulation as a valuable tool to increase the quality of their products. For all the tasks the ratings are higher in the current survey, what shows a growing acceptance of simulation within the last years. (Figure 15).

	2014	2020 Process	2020 Total
Base	204	196	234
Test: validation and check-out	1.63	1.57	1.56
Support decisions	1.72	1.58	1.58
Gain know-how and understanding	1.64	1.60	1.59
Minimize risks	1.68	1.63	1.59
Visualization und presentation	1.78	1.69	1.71
Problem identification	1.76	1.75	1.73
Increase quality	↑ 2.01	↓ 1.79	1.79
Decrease time to market	1.86	1.81	1.80
Support communications	2.39	2.47	2.43

Figure 15 Comparison with 2014 - Would you use simulation for one of the following tasks? (multiple answers possible)

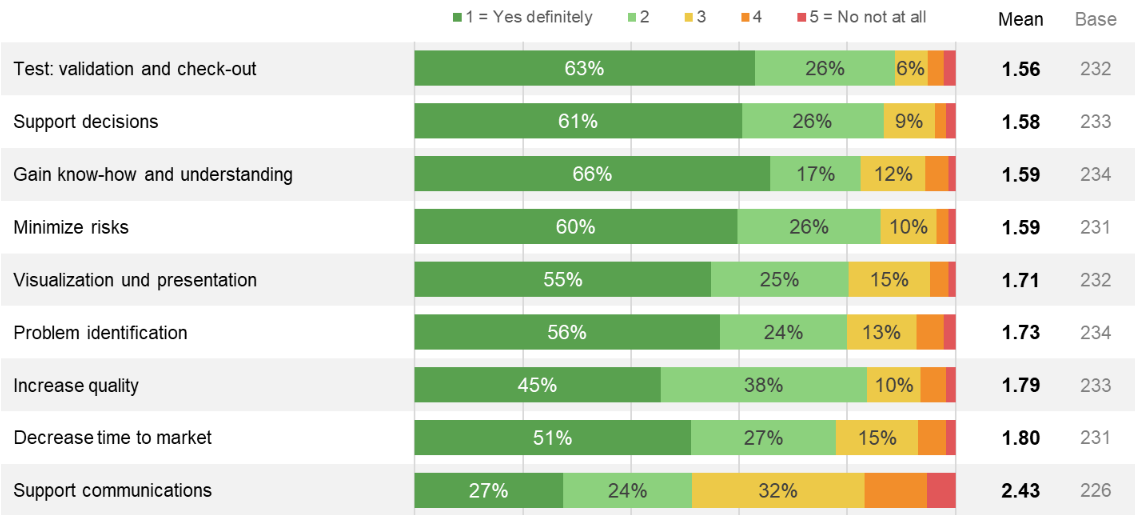

Figure 16 Would you use simulation for one of the following tasks? (multiple answers possible)

The following question identifies use cases which are important for the participants (Figure 17). Product design optimization, simulation driven engineering and virtual commissioning are most important use cases of simulation. Simulation is seen as important to be used within design and engineering, followed by operations. The use cases were explained in detail in chapter 4.2 on page 8.

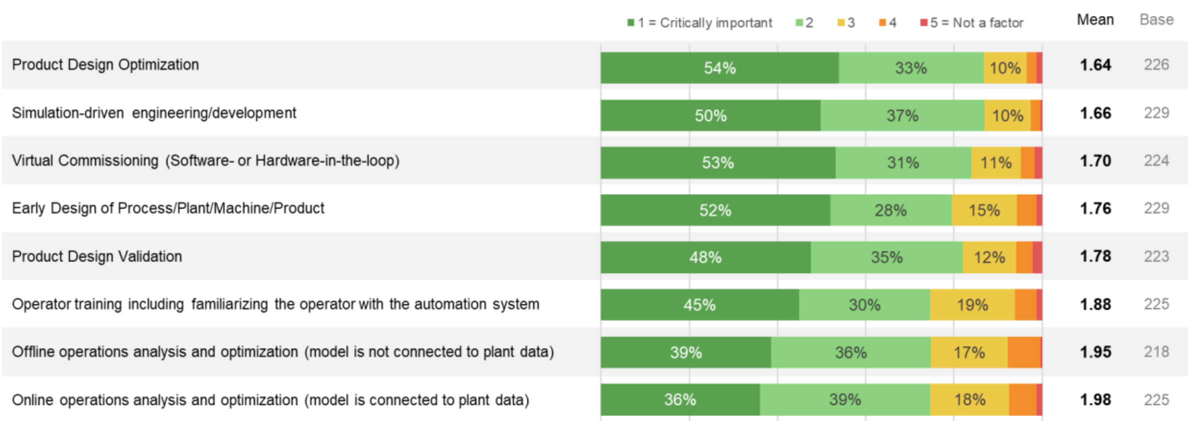

Figure 17 From your perspective: What are the most important use cases of simulation?

The next question revealed that simulation is currently widely used in all phases. But the percentage of participants not using simulation at all or just every now and then is significantly higher in the operation phase compared to the other phases (Figure 18). This tendency does not shift for employees which are working in production (Figure 19). The same applies for companies which are owning, or operating plants or production sites (Figure 21). So even the participants who are directly involved in the operation phase do use simulation a bit less during the operation phase, what undermines the reasoning that just not many participants know about the potential of simulation during the operation phase. The thesis is supported by the fact that the participants assess the potentials of simulation better during engineering compared to the potentials during operation (Figure 20). No significant changes can be identified since 2014 (Figure 22).

Simulation is currently used a lot during the product design, process and plant design/production planning, engineering and commissioning/product engineering and during Operation/production execution including service/maintenance.

Simulation is used for a wider range of tasks compared to 2014 (e.g. increasing quality, supporting decisions, visualization and presentation).

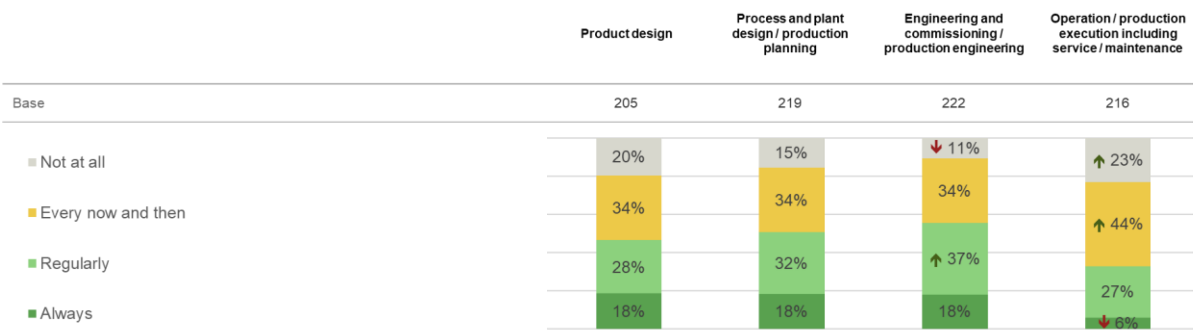

Figure 18 How often is simulation currently used in your organization within each phase?

Phase	Frequency	Total	Engineering	Management	Production	Research and Development	Other
Product design	Always	18%	16%	16%		↑ 29%	7%
	Regularly	28%	26%	28%	25%	↑ 40%	24%
	Every now and then	34%	34%	35%	50%	23%	45%
	Not at all	20%	↑ 24%	21%	25%	↓ 8%	24%
Process and plant design / production planning	Always	18%	18%	18%	8%	20%	6%
	Regularly	32%	29%	31%	42%	43%	45%
	Every now and then	34%	36%	38%	25%	33%	29%
	Not at all	15%	17%	13%	25%	↓ 4%	19%
Engineering and commissioning / production engineering	Always	18%	18%	16%	10%	↑ 31%	22%
	Regularly	37%	33%	40%	50%	37%	44%
	Every now and then	34%	35%	36%	30%	29%	↓ 19%
	Not at all	11%	14%	9%	10%	4%	16%
Operation / production execution including service /maintenance	Always	6%	6%	7%	10%	2%	7%
	Regularly	27%	24%	23%	10%	↑ 43%	28%
	Every now and then	44%	43%	↑ 59%	60%	47%	41%
	Not at all	23%	↑ 28%	11%	20%	↓ 9%	24%

Figure 19 How often is simulation currently used in your organization within each phase? - Role

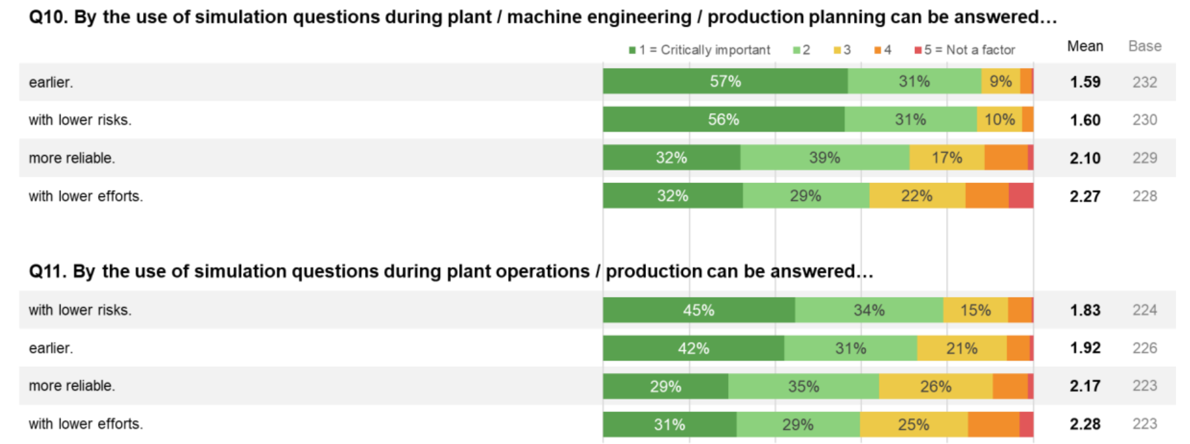

Figure 20 By the use of simulation...

Phase	Frequency	Total	Consultant	EPCC	Equipment manufacturer	Owner - operator	System integrator	Other
Product design	Always	18%	20%	21%	28%	10%	14%	21%
	Regularly	28%	23%	17%	↑ 42%	31%	31%	29%
	Every now and then	34%	33%	38%	↓ 22%	31%	33%	29%
	Not at all	20%	23%	24%	↓ 8%	27%	21%	21%
Process and plant design / production planning	Always	18%	24%	26%	21%	17%	18%	7%
	Regularly	32%	29%	41%	↑ 45%	33%	36%	36%
	Every now and then	34%	29%	24%	26%	36%	27%	43%
	Not at all	15%	18%	9%	8%	14%	19%	14%
Engineering and commissioning / production engineering	Always	18%	23%	24%	24%	13%	↑ 27%	
	Regularly	37%	43%	26%	38%	40%	37%	40%
	Every now and then	34%	26%	41%	31%	36%	27%	33%
	Not at all	11%	9%	9%	7%	11%	8%	27%
Operation / production execution including service /maintenance	Always	6%	10%	7%	2%	7%	6%	8%
	Regularly	27%	21%	21%	37%	28%	26%	8%
	Every now and then	44%	48%	48%	46%	38%	45%	62%
	Not at all	23%	21%	24%	15%	28%	23%	23%

Figure 21 How often is simulation currently used in your organization within each phase? - Company type

Q10. By the use of simulation questions during plant / machine engineering / production planning can be answered…

(1 = Critically important, 5 = Not a factor)

	2014	2020 Process	2020 Total
Base	200	194	232
earlier.	1.77	1.63	1.59
with lower risks.	1.76	1.65	1.60
more reliable.	2.17	2.12	2.10
with lower efforts.	2.37	2.33	2.27

Q11. By the use of simulation questions during plant operations / production can be answered…

(1 = Critically important, 5 = Not a factor)

	2014	2020 Process	2020 Total
Base	200	190	226
with lower risks.	1.89	1.88	1.83
earlier.	2.03	1.98	1.92
more reliable.	2.21	2.21	2.17
with lower efforts.	2.29	2.31	2.28

Figure 22 Comparison with 2014 - By the use of simulation

Participants who do not use simulation regularly state that it is too expensive, too much effort or they don't see the added value for their applications.

If a participant is not always using simulation and stated this in the question before, then a filter question appeared. The question asked for the reasons why simulation is not used always. The main reasons are that simulation is too expensive, too much effort and finally the value add of using simulation is not seen (Figure 23). Not many participants stated that they are faster without simulation.
At a glance, simulation in the operation phase is only seldomly thought of (significant difference compared to the other phases) (Figure 23).

	Product design	Process and plant design / production planning	Engineering and commissioning / production engineering	Operation / production execution including service / maintenance
Base	173	175	175	198
Too much effort	50%	46%	47%	44%
Too expensive	45%	53%	49%	41%
Missing skilled personal	45%	47%	40%	40%
Value add not seen	32%	34%	33%	35%
Customers do not ask for it	25%	26%	25%	30%
I am faster without it	7%	9%	13%	11%
We have not thought about it yet	7%	8%	9%	↑ 15%
I don't know	14%	8%	10%	11%
Other	9%	8%	8%	8%

Figure 23 What are the reasons why simulation is not always used?

The next topic deals with the question which simulation types are used in the individual phases (Figure 24). Apart from the operation/execution phase, each phase has its own typical applications of simulation. In the product design phase, typically CFD- and FEM-simulations are being used. Whilst in the process and plant design or production planning phase, dynamic process simulation, static process simulation and material flow simulations are characteristic simulation types. Finally, in the engineering, commissioning and production engineering phase usually DCS simulation, simulation of input- and output signals from the automation system, simulation of device feedback towards the automation system and controller emulations are being used. Interestingly, notably many participants do not know which simulation types are being used in the operation phase.

	Product design	Process and plant design / production planning	Engineering and commissioning / production engineering	Operation / production execution including service / maintenance
Base	138	152	163	130
Dynamic process simulation	29%	↑ 42%	33%	35%
Simulation of input- and output signals from the automation system	27%	↓ 24%	↑ 48%	32%
System simulation	34%	30%	36%	28%
DCS emulation	↓ 22%	↓ 22%	↑ 45%	32%
Simulation of device feedback towards the automation system	↓ 19%	↓ 23%	↑ 47%	29%
Controller emulation	↓ 22%	27%	↑ 43%	25%
Static process simulation	28%	↑ 40%	↓ 22%	22%
Material flow simulation	27%	↑ 34%	22%	25%
CFD-simulation	↑ 36%	24%	↓ 10%	↓ 13%
FEM-simulation	↑ 37%	13%	↓ 8%	↓ 8%
Discrete event driven simulation	12%	↑ 20%	15%	13%
Robot simulation	9%	13%	10%	6%
Multi-body simulation	↑ 17%	8%	8%	↓ 4%
I don't know	13%	13%	12%	↑ 21%
Others:	4%	2%	1%	2%

Figure 24 What kind of simulations do you currently use within the individual phases?

Proprietary tools developed by end users lost importance on the market since 2014.

Investigating the tools which are used for simulation in the individual phases shows that the most used tools are different in each of the phases. We are now taking a short look at the most used tools (Figure 25). In the design and planning phases, MATLAB/Simulink (MathWorks) (always above 14%) is the most used tool, while in the engineering phase operation/execution it is overtaken by SIMIT (Siemens). ANSYS/Fluent is particularly strong in the design phase while Aspen HYSYS in planning. According to the survey participants the role of own developed tools lost importance in comparison to the 2014 results: With 24% usage across all different use cases compared to 6% usage in the 2020 results.

	Product design	Process and plant design / production planning	Engineering and commissioning / production engineering	Operation / production execution including service / maintenance
Base	172	172	172	172
Matlab / Simulink	26%	↑ 30%	20%	↓ 14%
SIMIT	↓ 5%	17%	↑ 39%	15%
Aspen HYSYS / Plus / Dynamics	↓ 6%	↑ 21%	12%	8%
ANSYS / Fluent	↑ 20%	9%	7%	↓ 5%
gPROMS	6%	↑ 15%	6%	8%
Plant Simulation	↓ 5%	↑ 15%	9%	↓ 5%
Process Simulate	↓ 3%	↑ 12%	9%	5%
NX MCD	↑ 10%	7%	9%	↓ 2%
Own developed tool	6%	6%	6%	6%
Simcenter Amesim	↑ 8%	3%	3%	↓ 1%

Figure 25 Which simulation tool do you currently use in each phase (10 most used tools)

The decision about which simulation tool will be purchased is made by management and engineering (Figure 26). Research and Development also play a role in the decision-making process

Engineering and Management decide which simulation tools should be used.

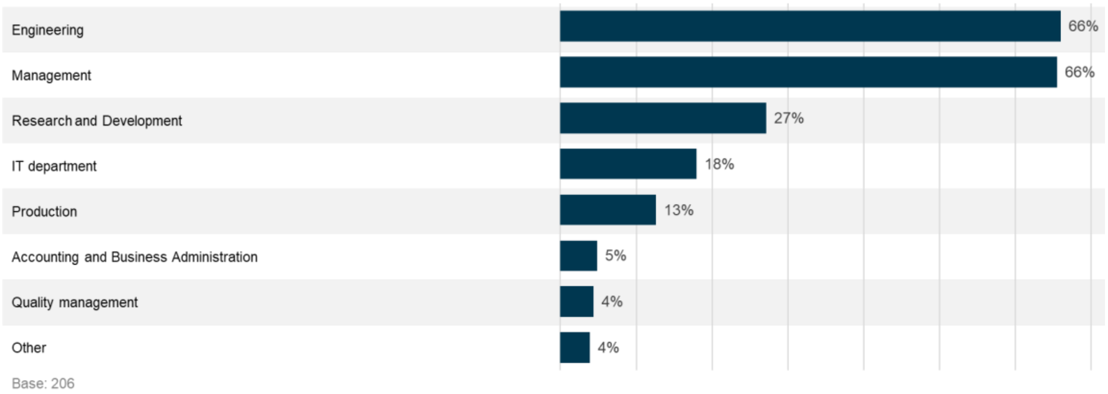

Figure 26 Who is responsible for the purchase decision of simulation tools at your company?

Looking at what the most important criteria are when choosing a simulation tool, the tool handling concept or usability is the most important factor (Figure 27). Directly followed by the current integration in the tool chain, the availability of libraries for model creation and of experts regarding this tool. According to the survey results, the least important criterion for choosing a simulation tool is the possibility of running simulations in the cloud.

The tool handling concept is the most important criteria when choosing a simulation tool.

Price and licensing are not so important in Germany compared to other countries. They are especially important in India.

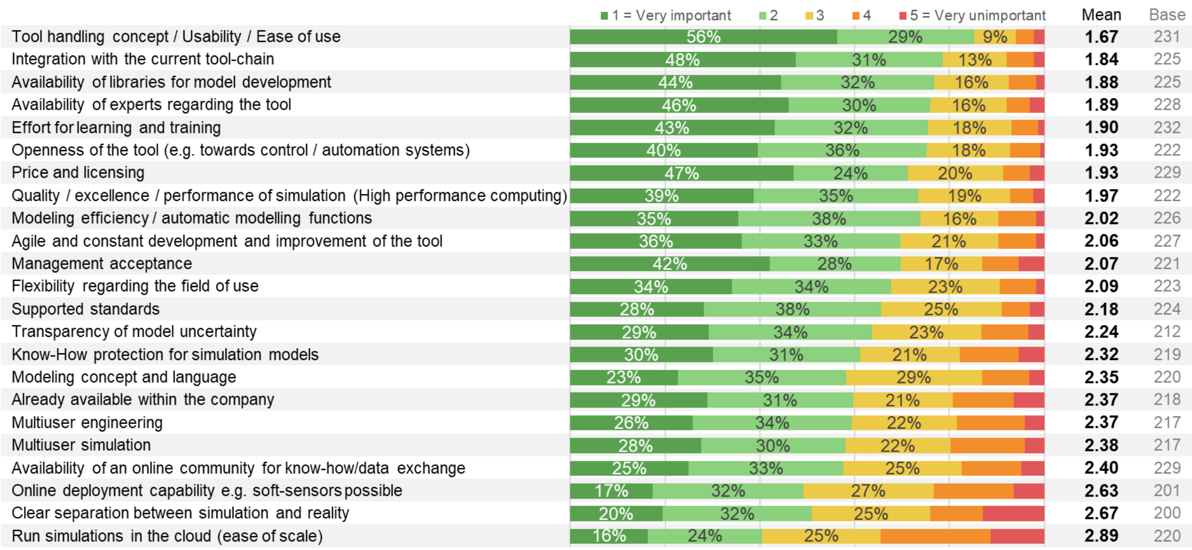

Figure 27 From your perspective: What are the most important criteria when choosing a simulation tool

Licensing models and delivery models for the tools are considered next. Regarding the delivery models, the participants prefer to download simulation tools and libraries for their simulation models in an app store (Figure 29 and Figure 30). The license model with the most support is a perpetual model with annual maintenance fee (Figure 28).

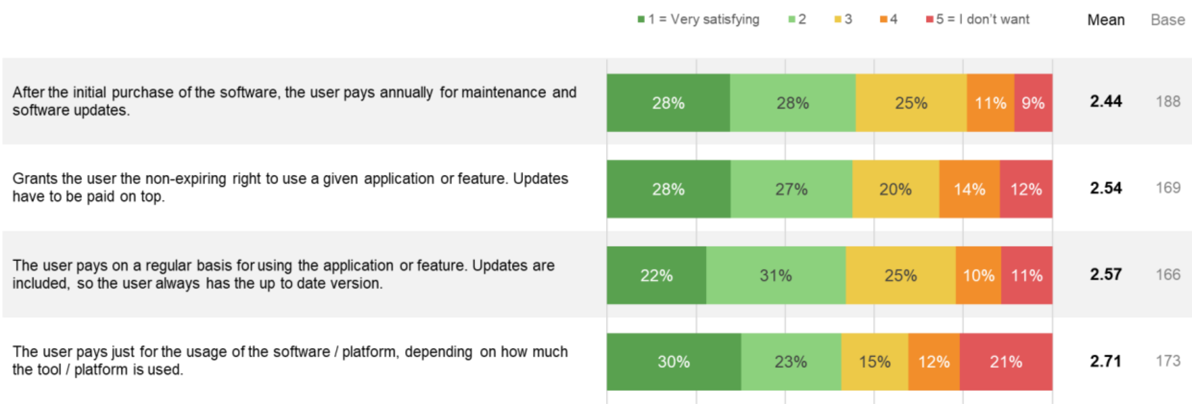

Figure 28 How do you rate the following ways of purchasing a simulation tool

Price sensitive customers prefer a usage-based pricing model or a one-time payment instead of reoccurring payments.

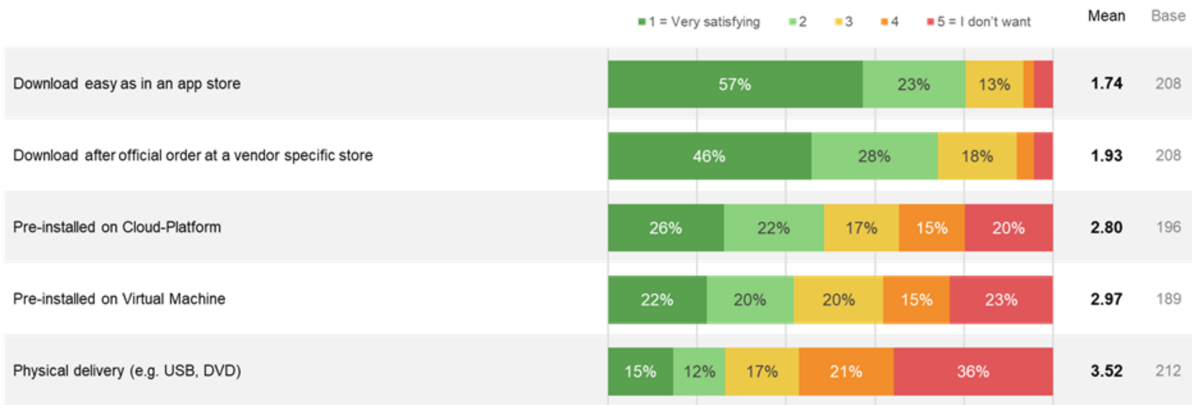

Figure 29 How do you rate the following ways of receiving models / libraries for your simulation software?

Customers prefer to download new or updated simulation tools rather than using a DVD or other physical storage.

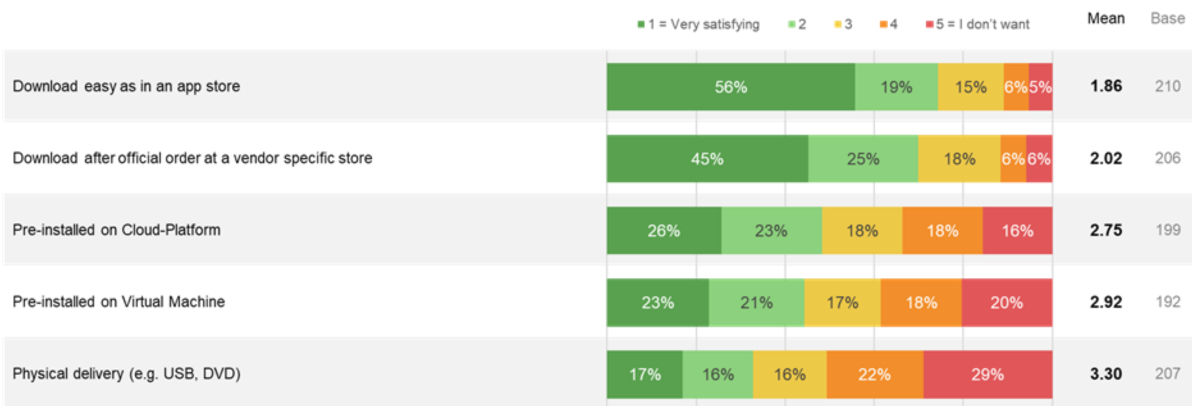

Figure 30 How do you rate the following ways of receiving a simulation tool?

Simulation is mostly used for milestone checks during engineering and commissioning.

In the following it is examined whether simulation is used for milestone and acceptance checks (Figure 32). The participants were asked if they use simulation for acceptance and milestone checks. During all phases almost every second participant answered that simulation is being used for acceptance and milestone checks. Many of the participants use milestone checks in general, but a particular large number carries out milestone checks during the engineering, commissioning and production execution phase (more than every 3 in 4 participants, Figure 32). In Germany especially fewer participants use milestone checks during the engineering and production execution phase, compared to the rest of the world. Notably more participants from India use simulation for acceptance or milestone checks, compared to participants from other countries. (Figure 31)

	Total	Germany	Europe (excl. Germany)	North America	India	Rest of the World
Product design	60%	70%	54%	50%	↑ 91%	50%
Process and plant design / production planning	63%	64%	50%	↓ 47%	↑ 100%	63%
Engineering and commissioning / production eng..	76%	71%	80%	83%	88%	90%
Operation / production execution including servi..	46%	↓ 37%	29%	61%	56%	↑ 80%

Figure 31 Is simulation used for acceptance or milestone checks? - Regional comparison

Next, the level of detail with which simulation is performed during the individual phases was examined (Figure 33). During product design simulation is often detailed on the level of single components, in the later phases it is detailed rather on the level of subsystems or units/modules.

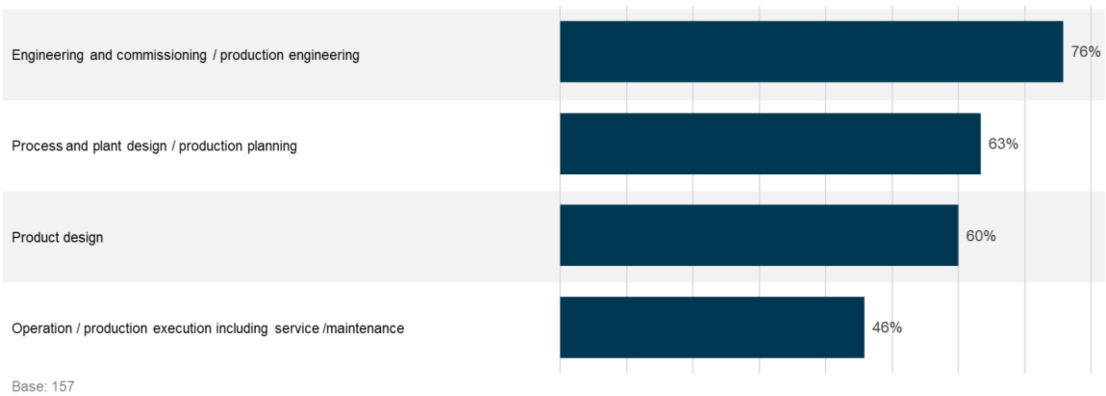

Figure 32 Is simulation used for acceptance or milestone checks?

	Product design	Process and plant design / production planning	Engineering and commissioning / production engineering	Operation / production execution including service / maintenance
Base	169	180	187	163
Subsystem of the plant/product	↓ 31%	48%	↑ 49%	39%
Unit / module	31%	36%	39%	30%
Complete plant/product	↓ 20%	34%	33%	30%
Single component	↑ 27%	↓ 14%	19%	20%
I don't know	↑ 33%	24%	↓ 18%	29%
Others:	0%	0%	0%	↑ 1%

Figure 33 What level of detail do you simulate within the phases?

The use of standards is examined in this section (Figure 34). The results show that it is still not very common to use standards for model creation or exchange. 38% of the participants, who answered this question, are not using standards and another 29% do not know if they are using standards at all. This number even increased since 2014: There, only 30% stated that they are not using standards (Figure 35). Some of the used standards are FMI/FMU, STEP, CAPE-OPEN, DEXPI and others.

It is still not very common to use standards for model creation or exchange, but the importance of standards even decreased since 2014.

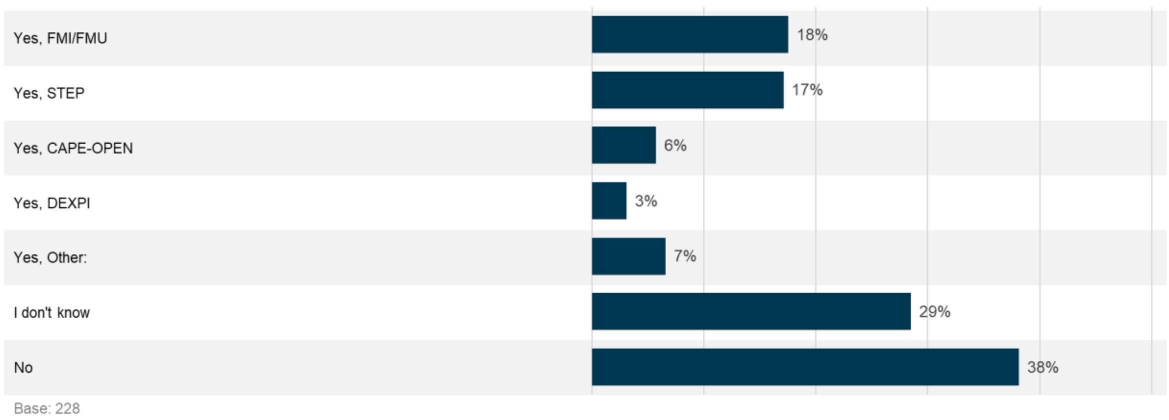

Figure 34 Do you use standards for model creation/exchange?

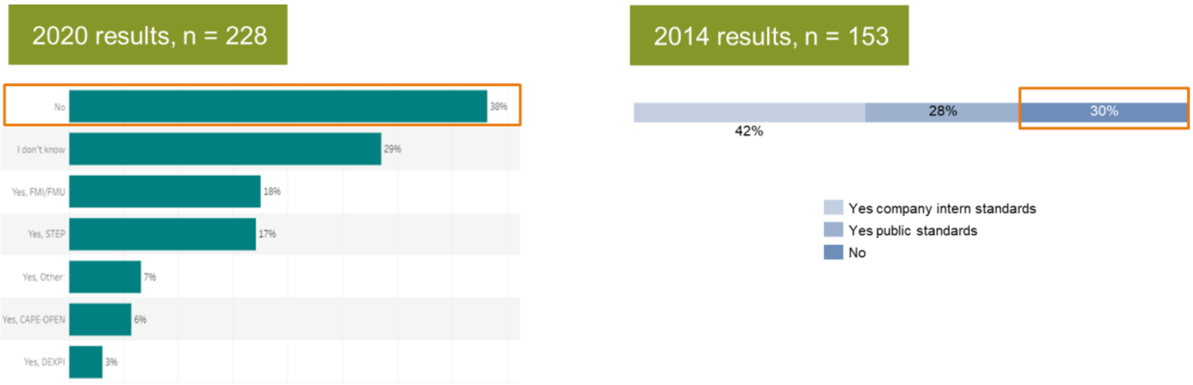

Figure 35 Comparison with 2014 - Do you use standards for model creation/exchange?

Many users would share their content with other users and would also use the content developed by others.

The following section deals with the provision and use of content by individual users (Figure 36 and Figure 38). It is noticeable that many participants would make their own developed content available to other users. Even though most participants share their content only under certain conditions, such as receiving payment or gaining access to the content of other users. 24% of the participants are not willing to share their content. This percentage is even higher among owners and operators, but lower within the group of system integrators (Figure 37).

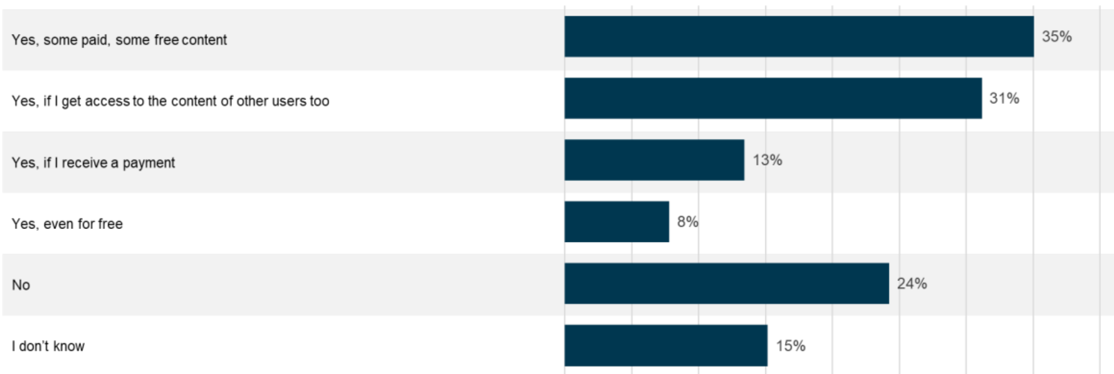

Figure 36 Would you be willing to offer your own content in a store for other users?

Owners and operators are least willing to offer their own content, whereas system integrators are most willing to offer content.

	Total	Consultant	EPCC	Equipment manufacturer	Owner - operator	System integrator	Other
Yes, if I receive a payment	12%	14%	8%	17%	8%	13%	24%
Yes, even for free	6%	9%	5%	5%	5%	4%	12%
Yes, some paid, some free content	34%	46%	27%	42%	29%	↑ 50%	41%
Yes, if I get access to the content of other users t..	31%	34%	30%	37%	26%	33%	↑ 53%
No	26%	14%	32%	22%	↑ 42%	↓ 15%	6%
I don't know	16%	20%	19%	15%	11%	16%	18%

Figure 37 Would you be willing to offer your content in a store for other users? - Company type

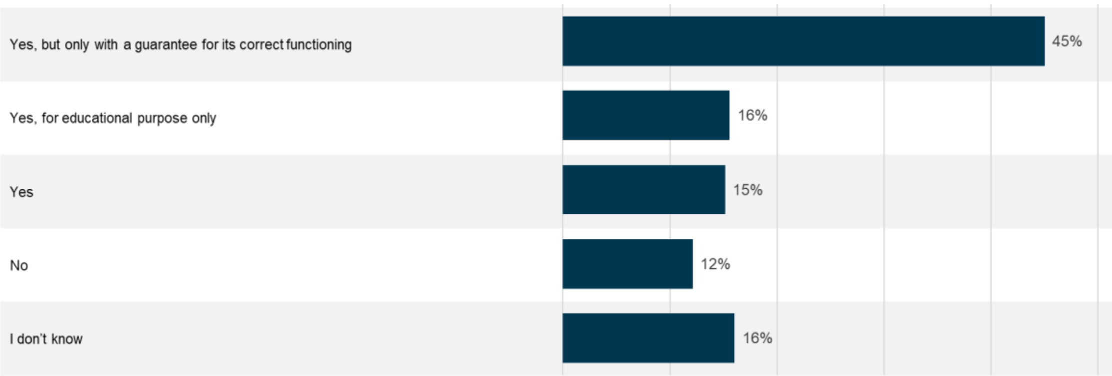

Figure 38 Would you be willing to buy content provided by other users in a store?

6. The future use of simulation

This chapter deals with topics and questions about the use of simulation in the future and a general vision.
The first question asks for the level of agreement to various statements about the vision on simulation (Figure 39). The most accepted statement is that the continuous use of simulation will be supported by a modular, open and flexible tool landscape. Another aspect relevant for the participants is that the information management of the process plant/production must be extended by simulation relevant aspects. Compared to 2014 there have not been any significant changes, just slight changes in the order of the statements, based on the mean values (Figure 40).

The continuous use of simulation will be supported by a modular, open and flexible tool landscape.

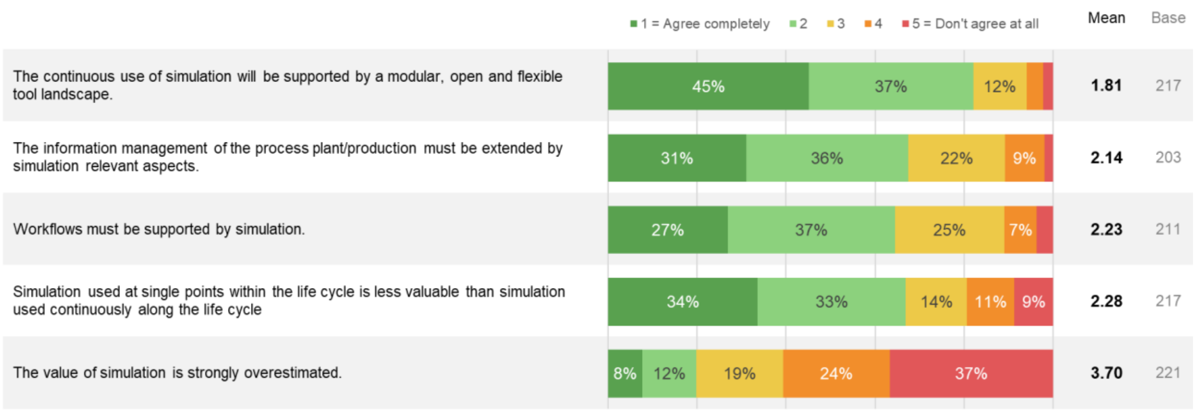

Figure 39 How much do you agree with the following statements?

(1 = Agree completely, 5 = Don't agree at all)

	2014	2020 Process	2020 Total
Base	184	186	221
The continuous use of simulation will be supported by a modular, open and flexible tool landscape.	1.95	1.83	1.81
The information management of the process plant/production must be extended by simulation relevant aspects.	2.25	2.16	2.14
Workflows must be supported by simulation.	2.35	2.27	2.23
Simulation used at single points within the life cycle is less valuable than simulation used continuously along the life cycle	2.19	2.35	2.28
The value of simulation is strongly overestimated.	3.64	3.68	3.70

Figure 40 Comparison with 2014 - How much do you agree with the following statements?

Users who consider the environment as important are also increasingly concerned about safety, even though safety, environmental protection and limited resources lost relevance since 2014

Ensuring quality and cost as well as time pressure are the most important challenges for industry in future.

According to the participants' answers, the most important future challenges in industries will be to ensure quality as well as to cope with the cost and time pressure (Figure 41). These three factors have remained the main challenges for the future since 2014 (Figure 42). This statement is also supported by the fact that there is no significant difference between the two individual industries in this respect (Figure 42).
Compared to the 2014, safety requirements, environmental protection and limitation of resources lost importance (Figure 42). Another interesting point is that the challenges of environmental protection & sustainability are strongly correlated with safety requirements (Figure 43). This might indicate that many environmentally conscious simulation users have a stronger focus on safety aspects as well.

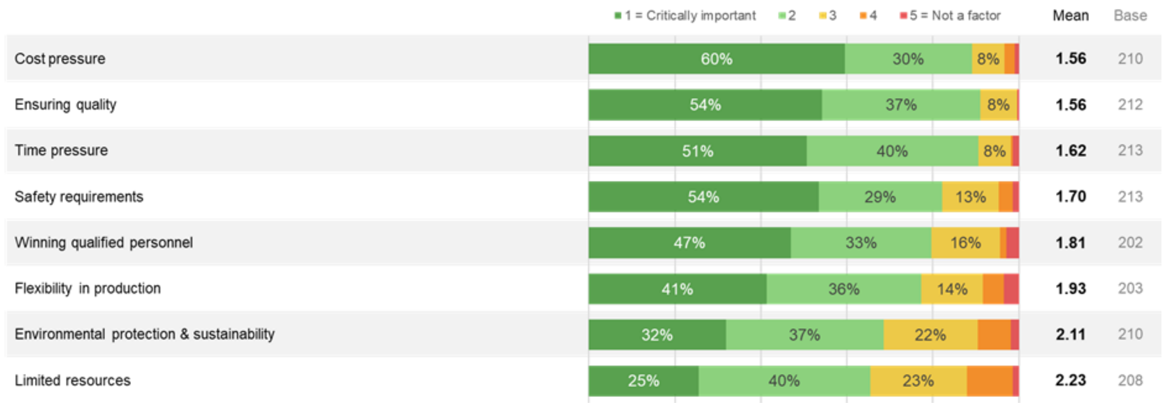

Figure 41 How important do you anticipate each of the following challenges will be for you in 6-8 years?

	2014	2020 Process	2020 Total
Base	187	175	213
Ensuring quality	1.55	1.56	1.56
Cost pressure	1.73	1.58	1.56
Time pressure	1.76	1.63	1.62
Safety requirements	↓ 1.46	↑ 1.73	1.70
Winning qualified personnel	1.75	1.81	1.81
Flexibility in production	.	1.97	1.93
Environmental protection & sustainability	↓ 1.77	↑ 2.11	2.11
Limited resources	↓ 1.83	↑ 2.23	2.23

Figure 42 Comparison with 2014 - How important do you anticipate each of the following challenges will be for you in 6-8 years?

Q4.1	How important do you anticipate each of the following challenges will be for you in 6-8 years? (1 = Critically important, 5 = Not a factor)	Cost pressure	0,124
		Ensuring quality	0,301
		Environmental protection & sustainability	1,000
		Flexibility in production	0,296
		Limited resources	0,392
		Safety requirements	0,639
		Time pressure	0,187
		Winning qualified personnel	0,293

Figure 43 How important do you anticipate each of the following challenges will be for you in 6-8 years? - Correlation

Simulation, cloud solutions and integrated engineering are the most relevant technological trends. Cloud solutions are especially important in India.

In this section it is examined how important different technology trends will be in the future. The survey responses show that simulation, cloud solutions and integrated engineering are the main technological trends (Figure 45). Interestingly, cloud solutions are significantly more important to participants from India compared to participants from elsewhere (Figure 44). However, the possibility of using simulation in the cloud is currently the least important criterion when choosing a simulation tool (Figure 27). Still, the key trend examined is simulation-driven solutions and products during plant/machine/product design and engineering. Using users as innovators is not considered a relevant trend in any of the two industries. Data driven solutions and products (big data) represent no major trend for the Petro-chemical and oil and gas industries. Whereas for the automotive sector edge-technology and the industrial IoT play a major role (Figure 46).

The relevance of almost all technology trends has increased over the last 6 years (except for integrated engineering and standards for interfaces) (Figure 47). Particularly, cloud solutions have gained much relevance since 2014. The same is true for Data driven solutions. The differences in mean values between the technology trends were much bigger in 2014, while they are much more equal now (Figure 47).

	Total	Germany	Europe (excl. Germany)	North America	India	Rest of the World
Cloud / web-driven / platform-based solutions and products	1,79	1,67	1,95	2,00	↓ 1,27	1,88
Edge-Technology / Industrial Internet-of-Things	1,97	1,92	↑ 2,29	2,04	↓ 1,47	1,56
Data-driven solutions and products (Big Data)	1,86	1,83	↑ 2,18	2,00	1,47	1,67
Simulation-driven solutions and products during plant/machine/product ..	1,57	↓ 1,43	1,66	1,78	1,40	1,47
Simulation-driven solutions and products during plant/machine/product ..	1,82	1,78	↑ 2,10	1,68	1,43	↓ 1,36
Modularization of plants/machines/products	1,94	1,93	1,78	2,25	1,86	1,56
Integrated/interdisciplinary engineering- and working processes	1,80	1,76	1,76	↑ 2,17	1,77	1,50
Standards for interfaces and architectures	1,90	1,92	1,83	1,96	1,93	1,60
Using consumers as innovators	2,68	2,60	2,84	3,00	2,42	2,36
Making business from data	2,52	2,70	2,53	2,63	2,14	↓ 1,94
Combined AI and simulation methods and models	2,06	1,99	↑ 2,44	2,22	↓ 1,53	2,00
Augmented Reality (AR) / Mixed Reality (MR) / Virtual Reality (VR)	2,53	2,45	2,57	↑ 3,04	2,57	2,47

Figure 44 How important do you expect the following technology trends will be to your daily work in 6-8 years? - Regional comparison

Cloud solutions have gained much relevance since 2014. The same is true for Data driven solutions.

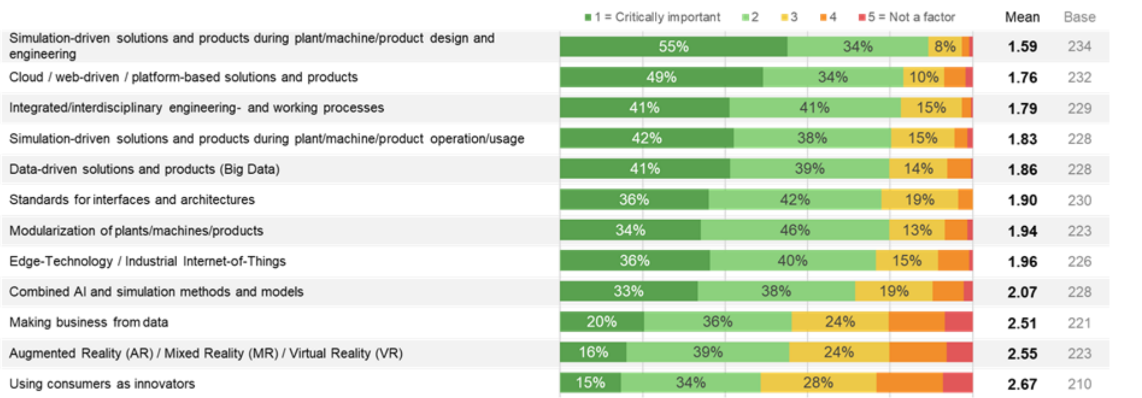

Figure 45 How important do you expect the following technology trends will be to your daily work in 6-8 years?

	Total	Other	Automotive	Chemicals	Electronics	Energy	Food and Beverage	Machine Production and Tools	Mining	Petro- Oil and Gas	Pharma and Biotech
Cloud / web-driven / platform-based solutions and products	1,79	1,66	1,70	1,83	1,82	1,74	1,53	1,70	1,75	1,80	1,67
Edge-Technology / Industrial Internet-of-Things	1,97	1,80	↓ 1,55	2,12	1,91	2,00	1,78	1,63	1,88	2,13	2,14
Data-driven solutions and products (Big Data)	1,86	1,73	1,77	1,97	1,85	2,00	1,85	1,60	1,75	↑ 2,13	1,77

Figure 46 How important do you expect the following technology trends will be to your daily work in 6-8 years? - Comparison over different industries

The importance of simulation driven solutions and products increased since 2014, even though it was already rated as very important at that time.

(1 = Critically important, 5 = Not a factor)

	2014	2020 Process	2020 Total
Base	203	197	234
Simulation-driven solutions and products during plant/machine/product design and engineering	↑ 1.97	↓ 1.63	1.59
Cloud / web-driven / platform-based solutions and products	↑ 2.60	↓ 1.77	1.76
Integrated/interdisciplinary engineering- and working processes	1.80	1.79	1.79
Simulation-driven solutions and products during plant/machine/product operation/usage	↑ 2.15	↓ 1.86	1.83
Standards for interfaces and architectures	1.92	1.86	1.90
Data-driven solutions and products (Big Data)	↑ 2.34	↓ 1.88	1.86
Modularization of plants/machines/products	↑ 2.19	↓ 1.93	1.94
Edge-Technology / Industrial Internet-of-Things	.	1.98	1.96
Combined AI and simulation methods and models	.	2.09	2.07
Making business from data	.	2.55	2.51
Augmented Reality (AR) / Mixed Reality (MR) / Virtual Reality (VR)	.	2.57	2.55
Using consumers as innovators	.	2.68	2.67

Figure 47 Comparison with 2014 - How important do you expect the following technology trends will be to your daily work in 6-8 years?

Looking at the relevance of simulation in each of the defined life cycle phases in 6 to 8 years, it is noticeable that the prospects of simulation are extremely good and the overall relevance of simulation in the future is expected to be growing (Figure 48). The prospects of simulation are especially good for the operation phase.

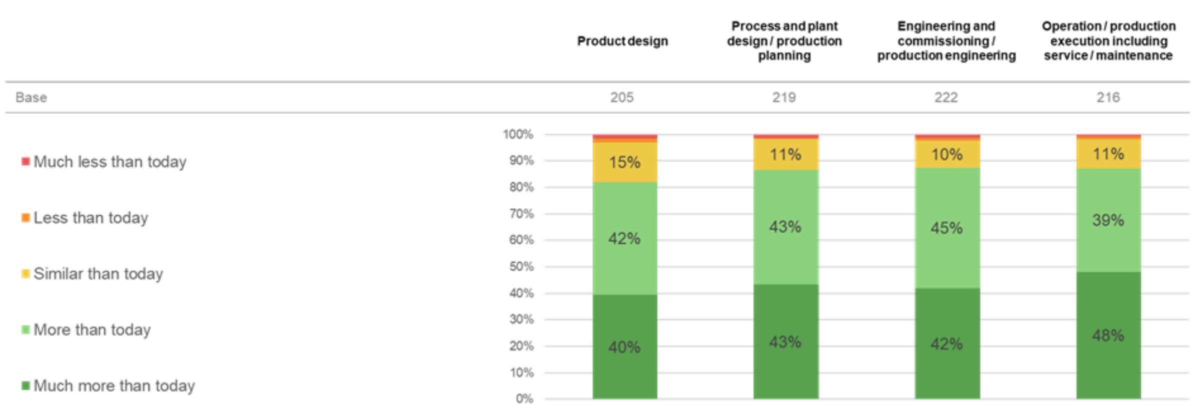

Figure 48 What will be the relevance of simulation within each life cycle phase in 6-8 years?

Prospects of simulation are especially good for the operation phase.

The concluding question on the future usage deals with the agreement to certain statements. Interestingly, according to the opinions of the participants, the future plant or machine or product engineering is to a high degree integrated and interdisciplinary and simulation is an important basis for this. Another highly accepted statement is that simulation models will accompany the life cycle of the product or production site as part of the digital twin. The acceptance of this statement has significantly increased compared to the results of 2014 (Figure 50), from last ranked in 2014 to second in 2020.

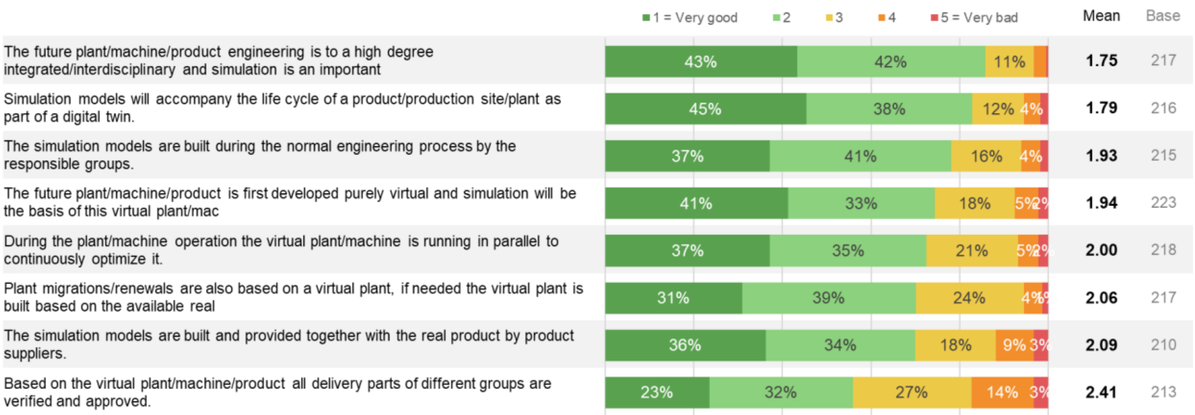

Figure 49 How well do these statements describe your expectations?

The perception of how well the statements describe expectations has increased in almost all aspects (except for the statement: Based on the virtual plant/machine/product all delivery parts of different groups are verified and approved).

The future plant/machine/product engineering is to a high degree integrated/interdisciplinary and simulation is an important basis to cope with complexity.

The expectation that simulation models will accompany the life cycle of the product/production site as part of the digital twin, has increased significantly since 2014.

(1 = Very good, 5 = Very bad)

	2014	2020 Process	2020 Total
Base	179	188	223
The future plant/machine/product engineering is to a high degree integrated/interdisciplinary and simulation is an important	↑ 2.01	↓ 1.77	1.75
Simulation models will accompany the life cycle of a product/production site/plant as part of a digital twin.	↑ 2.61	↓ 1.79	1.79
The future plant/machine/product is first developed purely virtual and simulation will be the basis of this virtual plant/mac	2.16	1.95	1.94
The simulation models are built during the normal engineering process by the responsible groups.	2.16	1.99	1.93
During the plant/machine operation the virtual plant/machine is running in parallel to continuously optimize it.	↑ 2.23	↓ 1.99	2.00
Plant migrations/renewals are also based on a virtual plant, if needed the virtual plant is built based on the available real	2.18	2.10	2.06
The simulation models are built and provided together with the real product by product suppliers.	.	2.14	2.09
Based on the virtual plant/machine/product all delivery parts of different groups are verified and approved.	2.57	2.43	2.41

Figure 50 Comparison with 2014 - How well do these statements describe your expectations?

Simulation will gain even more importance in the future.

The prospects of simulation are especially good for the operation phase.

In the following opinions of the participants about the vision about the use of simulation in six to eight years are shown.

"1. Simulation model as a digital twin integrated with physical system for real time prediction and monitoring
2. Simulation model with a good UI as a 'Decision Support System' for informed decision making"

-Survey participant

"A new drug will be developed completely in silico before any physical work is performed."

-Survey participant

"[Simulation] could be used in all aspects of engineering if the community is more aware of the benefits and the costs are sensible."

-Survey participant

"AI must become part of simulation."

-Survey participant

"Simulation is also used as standard during plant operation."

-Survey participant

"AI could be used to optimize the plant based on the simulation."

-Survey participant

"Liberated from hype and exaggeration, based on technically reasonable basic conditions."

-Survey participant

7. Conclusion

Simulation will become more important in order to support the decision-making process along the whole life cycle in the future. It is expected that digital assistant systems will more and more use simulations in different forms along the lifecycle. Thus, simulation is definitely one of the core components of the digital twin, as it brings the digital twin to life.

From the modelling content perspective an industry wide opening is happening and the willingness to join an ecosystem with shared content increases. Users should think about use cases, which should be provided by the manufacturers of the real twin and where in addition digital twin / simulation models should be provided.

As a certain amount of knowledge is necessary for the effective use of simulation, it should be as deeply as possible integrated into teaching and training.

Every company should reflect how and where the use of simulation is practical, efficient and helpful and if there is room for optimization of the company's current way of using simulation, as there are many different ways of how to use simulation efficiently. In addition, it is even more important to ensure that use cases are linked, and models can be reused. With this report everyone can evaluate themselves and where they are. In addition to this, as we have gained with our research over the past years a profound inside into various industries and the use of simulation, we are also able to help and share our expertise with you. Think about an individual benchmark of yourself compared to industry and deriving measures where simulation can improve your activities along the life cycle best. Feel free to contact Mathias Oppelt (oppelt.mathias@siemens.com) for further information.

About the Authors

Linus Bruckner is a young, innovative and aspiring individual combining educational and industrial viewpoints. He is currently graduating from the Karlsruhe Institute of Technology with a B.Sc. in Industrial Engineering and Management with a total of two years working student and internship experience during his studies in the fields of management, simulation and software development.
Currently he is researching on the matter of creating new business models for simulation software in a joint research project of the Siemens AG and the Karlsruhe Institute of Technology.
In the second year of his studies he moved to Singapore in order to develop software and assist the product management at Bosch Software Innovations.
He is a family person with four siblings who is looking for new ways and solutions for a better tomorrow.

Mathias Oppelt is a holistic thinker and enthusiastic leader of the Simulation Center for Process Automation at Siemens AG in Erlangen. With a multisided and interdisciplinary team Mathias is driving the business for Virtual Commissioning, Operator Training Systems and Process Optimizations. He has more than 10 years' experience in working with and developing automation, modelling and simulations systems for various domains such as production machines, machine tools, manufacturing lines, batch and continuous process plants.
He is working for Siemens AG since 2010, holding various positions among Strategy, M&A, Product Management and Project Management. Prior to Siemens he also worked for AUDI, a startup, as Consultant, for Jungheinrich and for Lufthansa Technik. He is always looking to unlock the potential of people, organization and portfolios.
Mathias graduated from the Hamburg University of Technology in 2010 with a Diploma (Dipl.-Ing.) degree in Mechatronics and from Northern Institute of Technology Management in 2010 with a Master's in Technology Management (MTM). In December 2015 he finished his dissertation about the use of simulation within the lifecycle of a process plant at the Technische Universität Dresden with a doctor's degree (Dr.-Ing.).
Mathias is a proud dad of 2 sons and a passionate windsurfer, which is more than a reason why he is dedicated to work for a sustainable and livable future on earth. Further he likes to share his knowledge and experience within papers, as speaker and as visiting lecturer.

Leon Urbas (IEEE Member, Namur, VDI GMA, VDI/GVC processNet), born 1965 in Munich, Germany is a computational engineering scientist by training and earned his doctorate in process systems engineering for research on operator training systems at TU Berlin. Several years of work experience in process optimization and automation in the process industries and basic research on Human-Machine Interaction laid the foundations for the research of his group at TU Dresden on the key elements of digital transformation in the process industry. Currently, the work focuses on semantic information models of process systems engineering and process automation with the core aspects process, product and resource and their potential for structuring the Digital Twin, accelerating and automating engineering workflows, and supporting human decision processes in modular plants. This applied research provides directions for the group's basic research on the design of human-technology co-creation and collaboration in cyber-physical production systems.

At TU Dresden he is Dean of Studies for Information Systems Engineering, board member of the Process-to-Order Lab and spokesperson of the DFG research training group Conducive Design of Cyber-Physical Production Systems. He is member of the advisory board of the ProcessNet Process and Plant Engineering Division and spokesperson of the VDI/VDE GMA 5.16 Task Force on Future Automation Architectures.

Mike Barth (NAMUR, atp magazine, VDI GMA, AALE), born 1981 in Pforzheim, Germany is a mechatronic systems engineering expert with a focus on simulation based applications. After studying mechanical engineering as well as product development methods he made his doctor`s degree (Dr.-Ing.) at the Helmut-Schmidt-University, Hamburg, Germany focusing on the automatic generation of plant simulation models for virtual commissioning tests. In 2011 he started to work as a project lead at the ABB research center, Ladenburg, Germany, leading a Big Bet project on new energy site management based on digital twin applications. Since 2013 he owns a professorship at Pforzheim University managing the department of mechatronic systems including Bachelor and Master courses. He led the VDI/VDE GMA 6.11 Task Force Virtual Commissioning from 2013 until 2018 and is part of several national and international conference program committees. Since 2018 he is responsible chief scientific editor of the atp magazine (www.atpinfo.de).

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