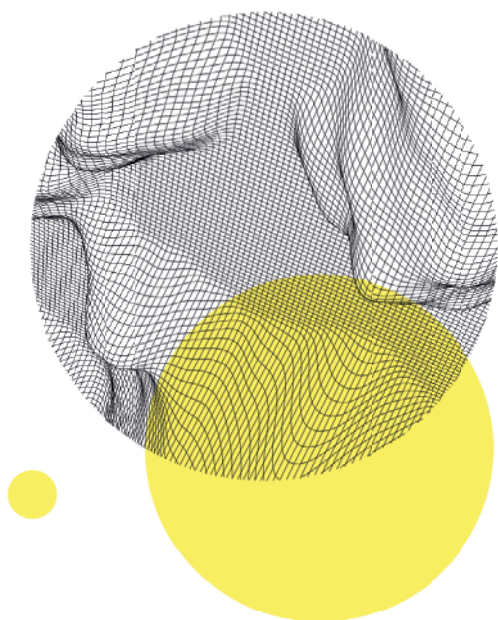




# THE GOLDEN STANDARD...

How standardization has strengthened the industrial sector  
- and the role it can now play in its ongoing digitalization.



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4S

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# Foreword

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## 4S - Strategies and Standards for Smart Swedish industry

4S is an initiative which is bringing together work in Sweden around the digitalization of the industrial sector with international efforts by the standardization organisations ISO and IEC focused on smart manufacturing.

The main parties in the project are the innovation programs PiiA (Process Industrial IT and Automation) and Produktion2030, along with Lund University, Blue Institute, and ISO and IEC as well as their Swedish counterparts SIS and SEK. The work is funded by VINNOVA through the Swedish Government's collaboration program for a smart, connected industrial sector.

The overall goal of 4S is to strengthen Sweden's position in the digital industrial sector by facilitating active participation in the extensive standardization work currently being undertaken worldwide. By providing key Swedish development initiatives with access to financial support, 4S has opened doors for communication between the various standardization organizations, Swedish researchers, technology suppliers and the Swedish manufacturing sector. The research results achieved have had practical impacts on international standardization work and have provided long-term benefits to Swedish research and the Swedish industrial sector.

Another goal of the project has been to increase awareness of the importance of standards for both the industrial sector and society at large; ongoing digital development is crucial if the Swedish industrial sector is to remain competitive and meet the high sustainability goals expected of it. We now stand on the threshold of a major shift in the industrial sector, with strong driving forces in play and changes occurring in energy and process – and digitalization is serving as an enabling technology. To this ends, the industrial sector is preparing to create a range of new standards that will provide an important foundation for industrial development and growth in the coming years.

This publication is part of 4S's mission, which includes defining and spreading knowledge about the role that standardization can play in creating value in industrial development. For the English language version, we have chosen the name The Golden Standard in acknowledgement of the engineers and administrators working with standards. Their work in industrial development has been creating significant social benefit and contributing to our prosperity for over two hundred years.

Standardization work has an exciting history and a future that's just as exciting!

**Charlotta Johansson**  
Lund University

**Peter Wallin**  
PiiA

**Björn Johansson**  
Produktion2030

**Niclas Widell**  
SIS

**Thomas Borglin**  
SEK

**Örjan Larsson**  
Blue Institute

The four parts of this report:

1

**The value of standardization**  
and its development since the  
beginning of industrialization.

2

**The digital transformation**  
of the industrial sector from a  
transformative perspective.

# Introduction

Structure, conformity, and rules? Most people think of standardization as maintaining order and engineers doing ongoing work to ensure that technology functions properly. And, of course, it is true that without such efforts the industrial sector would not work as effectively as it does today. But broaden your perspective a little and the true picture becomes clear. The key role standardization plays in both global growth and prosperity is growing, making sustained work in this area a heroic endeavour, as we hunt for hidden gold in our industrial systems.

That's what this report will discuss. How the standardization work underway since the Industrial Revolution of the 1700 and 1800s is still producing enormous social benefit. The Industrial Revolu-

tion occurred when mechanical approaches were standardized, allowing for components and parts to become interchangeable. During the second major industrial shift, mass production was made possible thanks to the systematic standardization of electrical technology. We are now facing the next industrial challenge with pressure for production techniques to become more sustainable and with digitalization changing global conditions. The world needs to once again go through a standardization process and to build a solid foundation for the next industrial paradigm, well into the 2000s.

**The first part of this report** focuses on the value created by standardization and the development of the standardization process since the start of the Industrial Revolution. The basic principles of

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3

**4S's Learnings**

Completed industry-related projects – summary of each project's character, stakeholders, challenges, and results.

4

**Reflections on the way ahead**

– challenges in complexity, rapid development towards moving goals and necessary global scaling.

|| With the importance of standardization for both global growth and prosperity growing, undertaking sustained standardization work suddenly feels like an heroic endeavour...

standardization contain concepts such as *'de facto'* standards and *'de jure'* standards. We will review these concepts and take a closer look at how the world organizes and coordinates standardization work. ISO, IEC, ITU are examples of organizations with vital roles.

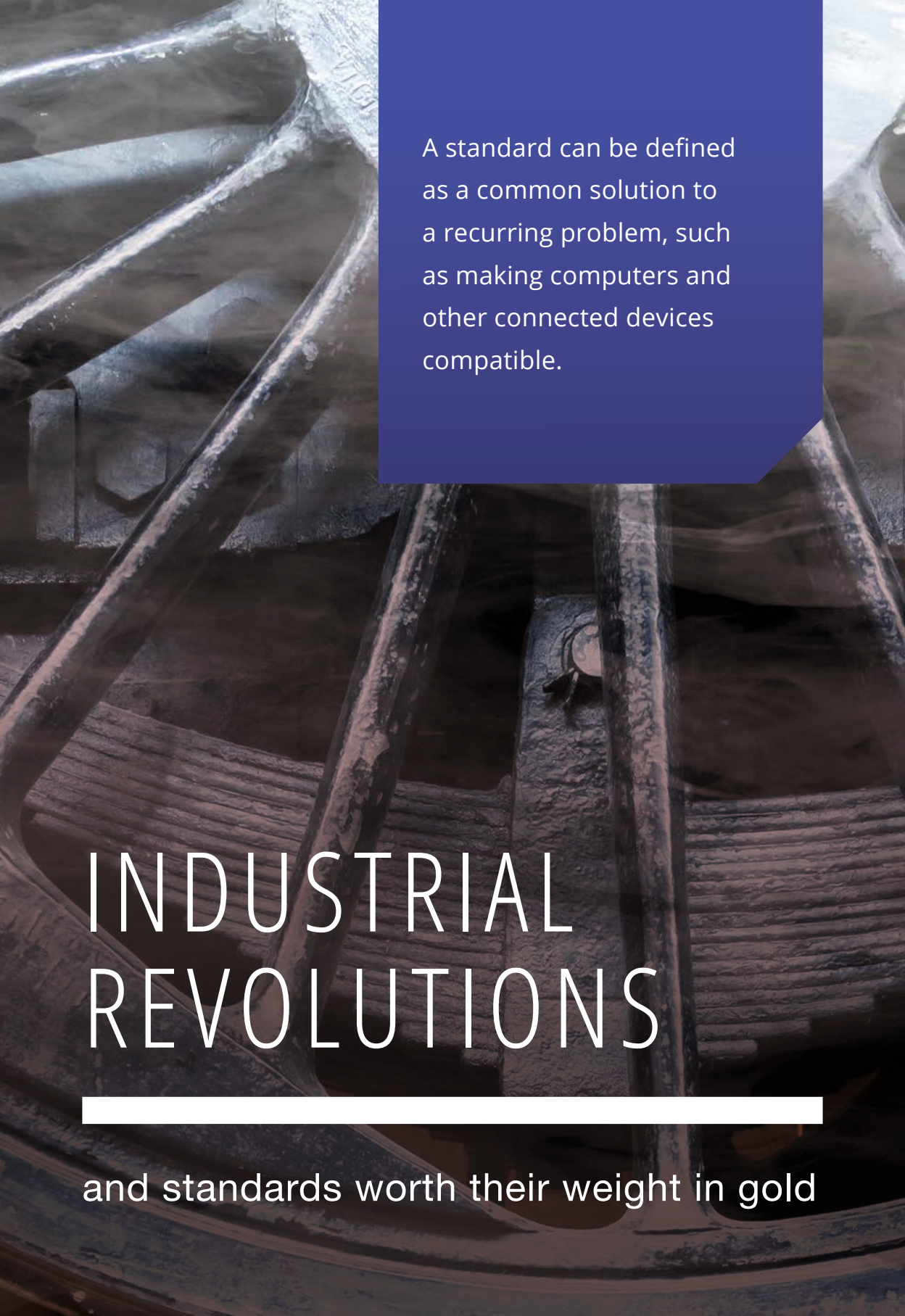
**The second part** focuses on digital transformation within the industrial sector. It includes an initial overview focused on adaptation, and the proven ability of the western world's industrial sector to manage and use in combination the opportunities that new technology provides. We will also take a closer look at a variety of significant digital standardization areas, including *reference models, interoperability, digital twins and the Industrial Internet of Things*.

**In the third part**, we will present a number of industry-related projects that have been implemented. Since 2019, 4S has been involved in a large number of developmental projects with a focus on industrial digitalization and standardization. This section provides details of the nature of the projects, stakeholders, challenges and results.

**In the fourth** and final part, we will reflect on ongoing development. Standardization work has never before faced a similar challenge in terms of complexity, rapid development towards shifting goals, and requirements for global scaling. All this creates the need for effective international cooperation between all parties involved. At the same time, it opens the way for creating more value than has ever been seen in industrial history.

PART





A standard can be defined as a common solution to a recurring problem, such as making computers and other connected devices compatible.

# INDUSTRIAL REVOLUTIONS

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and standards worth their weight in gold

## THE VALUE OF STANDARDS

*“It’s not money that makes the world turn - it’s standards.”*

The above quote is borrowed from the Swedish Institute of Standards (SIS) and aims to reflect the role of standardization in the market economy and as a creator of significant community good. Reflecting this report’s main theme around the digitalization of industry, the greatest benefits flow from network effects. But standards also reduce uncertainties and the need for manufacturers to be ‘locked into’ certain suppliers. It can create effective competition in the market for the benefit of the market system as a whole.

A standard can be defined as a common solution to a recurring problem, such as making computers and other connected devices compatible. Standardization reduces uncertainty when choosing products and reduces ‘lock-in’ effects by allowing offers from different suppliers to be mixed and matched with each other. The overall

purpose is to create united and transparent routines that all can agree on and that lead to interoperability between the connected devices involved. The transaction cost in markets with asymmetric information then decreases and the free flow of information provides an ability to reach the most remote of places. This, in turn, leads to efficiency and increased perceived value for the individual users or operators. In other words, standards solve coordination problems when choosing technology in markets with complementary products and services. And as interoperability increases, the networks and network effects become larger.

One way of defining the concept of digitalization is the free flow of information (in our case, within industrial value chains), with this free flow opening the way for standardization to function. Standardization then becomes an investment that continues to accumulate value over long periods of time, depending upon its inherent qualities. Usually, development is only

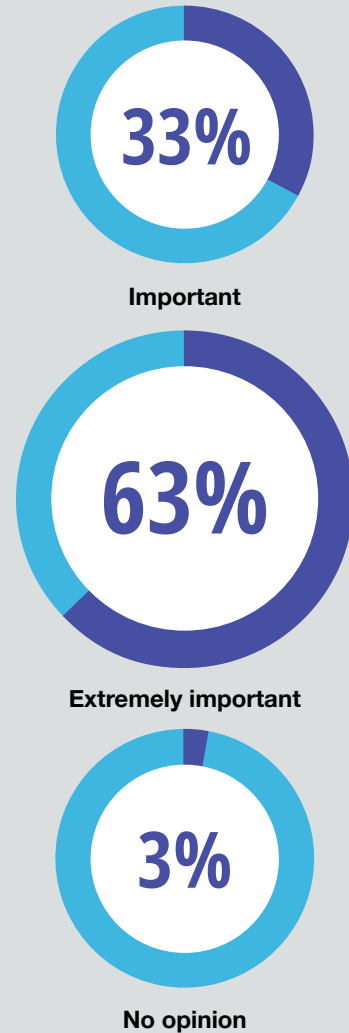


interrupted when there's a more radical shift in technologies, however technologies may also build upon one another, as was the case with the generational growth of mobile phones.

Within the field of industrial production, sub-standard products mean costly adjustments and reworking. Standardized production methods reduce errors and increase both the quality and efficiency of production. Using standardized methods makes it easier to introduce gradual improvements because these can be introduced uniformly throughout the production system. It also makes it easier to identify areas that need to be improved to increase efficiency. One of today's most wide-ranging initiatives in the area of quality control is the standard ISO 9000. It is made up of a number of different parts or required elements that refer to routines and processes within an organization. The standard was first published in 1987 and has since been published in revised editions.

Interoperability is the ability of different systems, often in the context of computers, to work together and communicate with each other. Examples of this could be that systems use the same protocol, such as TCP/IP or HTTP, or that they read and write the same file format or use the same semantic definitions.

## The importance of future standards



**Figure 1:** According to a survey by research company ARC, a majority of respondents believe that the future value of standards is important, while a full 63 percent see them as extremely important.

Source: ARC, What is the Value of Industry Standards in Today's World? 2020.

|| A common downside is that standardization may limit the variety of products produced and make it more difficult for highly novel inventions capable of generating great value to make it to market.

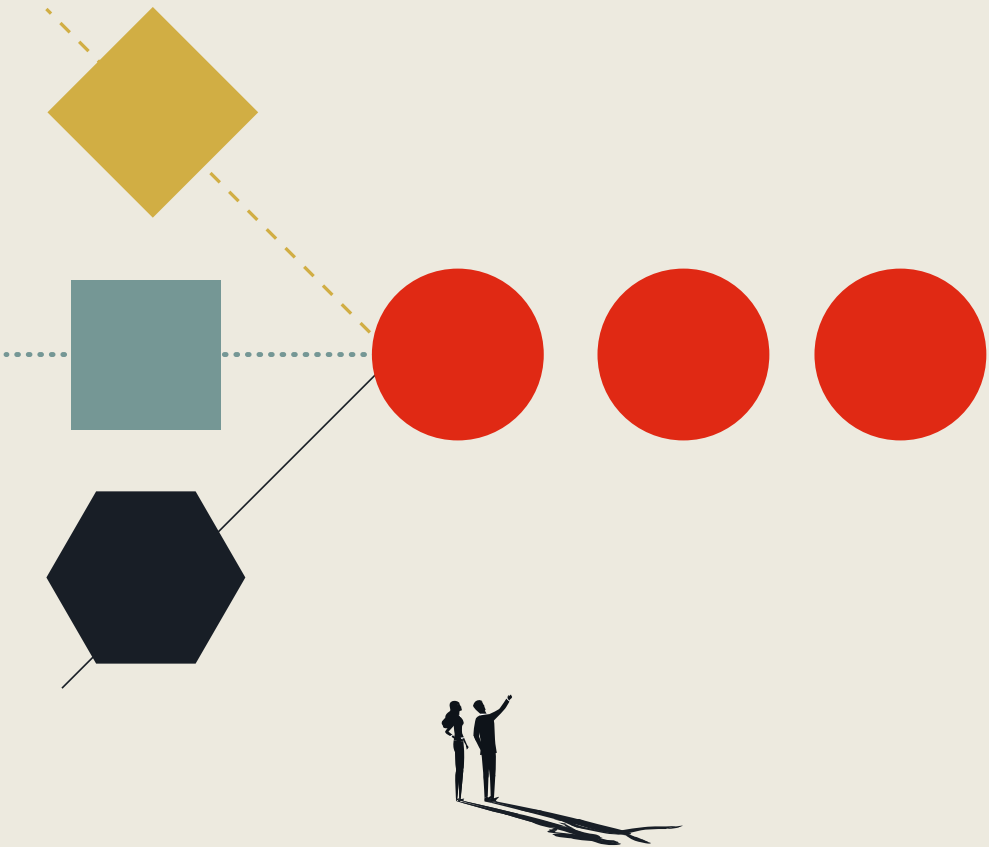
It is quite easy to see that the strength of standardization lies in allowing upscaling across markets in which many parties are involved, but there are undeniable disadvantages as well. A common downside is that standardization may limit the variety of products produced and make it more difficult for highly novel inventions capable of generating great value to make it to market. There is also no guarantee that the standardization paths chosen are the best for individual companies or consumers. For manufacturing companies, standardization can lead to increased price competition if the key properties of a product are 'neutralized' through the introduction of norms. As a consumer or user, you may also pull the shortest straw if you choose an early product iteration. A classic example is the videotape format war between JVC (VHS), Sony (Betamax) and Philips (Video 2000). The war lasted from the end of 1970s to the end of the 1980s and, as is well known, VHS emerged victorious. 'Format wars' is a recurring phenomenon throughout history, covering everything from the width of rail tracks, the choice of electrical current to today's battle over the charging standards for electric cars.

Developments in the area of standardization have shifted in recent decades from a question of politicized norm formation to market-based

self-regulation. In many areas, not the least in the area of digital information and communication, there are, as we will see, a large number of standardization initiatives characterized by willing participation and competition. An advantage of competition is that the standardization process can be more efficient. And effective processes are needed when a lack of standards becomes a market barrier as rival incompatible initiatives compete and lead to market fragmentation. Such situations can consume enormous amounts of resources and, in the worst case, kill promising technological development. Functional standardization at the level of modularization of system architectures can, on the other hand, lead to effective competition and shorten the time to market introduction for new products while contributing to faster industrial adoption. Now that the industrial sector is digitalizing, all these issues are in the spotlight.



|| The purpose of standards is to reduce unnecessary variations...



## WHAT STANDARDS ARE IN PLACE?

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The term *formal standard* or *official standard* refers to a specification that has been approved by a standardization organization such as ISO or IEC. Such formal standardization work is carried out by organizations on a national, regional and global level. Standards that are formally decided are also called *de jure standards* (de jure means 'according to the law') and indicate an agreement around a common solution to a certain problem. A common solution generally requires a choice between several different alternatives. The choice that takes place through organized decision-making before the technical implementation is also called an *ex ante* (in advance) standard. In other words, the term *de jure* refers to a chosen, agreed standard laid down in legal requirements, or generally refers to any formal standard. In reality, this process is continuously underway within international standards organizations such as ISO, IEC and ITU.

The term *informal standard*, *industry-standard* or *de facto standard* (de facto is the opposite of de jure) refers to a specification, protocol or technology that has achieved wide acceptance and usage often without being approved by any official standard organization or has received official approval only after it achieved widespread use. Examples of *de facto* standards that have not been approved by any standard organizations include Apple's TrueType font and the PCL protocol used by Hewlett Packard for computer printers. Such standards can be developed by interest groups and industry consortia with

varying geographical scope. Industries with rapid technical development also require that new standards be established quickly. This normalizes *de facto* standards, as the development of formal standards may take a long time. *De facto* standards are thus common in digital development. Typical organizations that contribute to creating industry standards in industrial digitalization include IEEE, OPC and the Industrial Internet Consortium.

Standards can apply to the design of a product or service, but also terminology, measuring units and symbols. The purpose of standards is, as mentioned, to reduce unnecessary variations in the design of components, spare parts and accessories and to facilitate the exchange of information. The difference between a standard and a specification is not large. A specification is always a description of a product or part of a product. A specification can be developed by a company that later hands it over to a standardization organization which turns it into a standard. Standards may generally be used freely, but access to the documentation of a standard may cost money.

New standards and groups of standards are often introduced in larger, general technology shifts as many companies simultaneously release new generations of products. For successful market introduction, compatibility is important in order to take industrial development further. In the next section, we will take a closer look at how a few standards have been of great historical importance in the realm of industrial development.

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## WHAT STANDARDS MEAN TO INDUSTRIAL TRANSFORMATIONS

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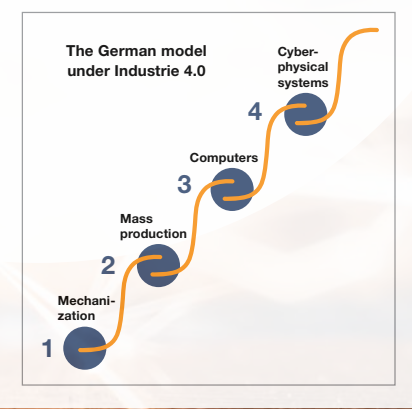
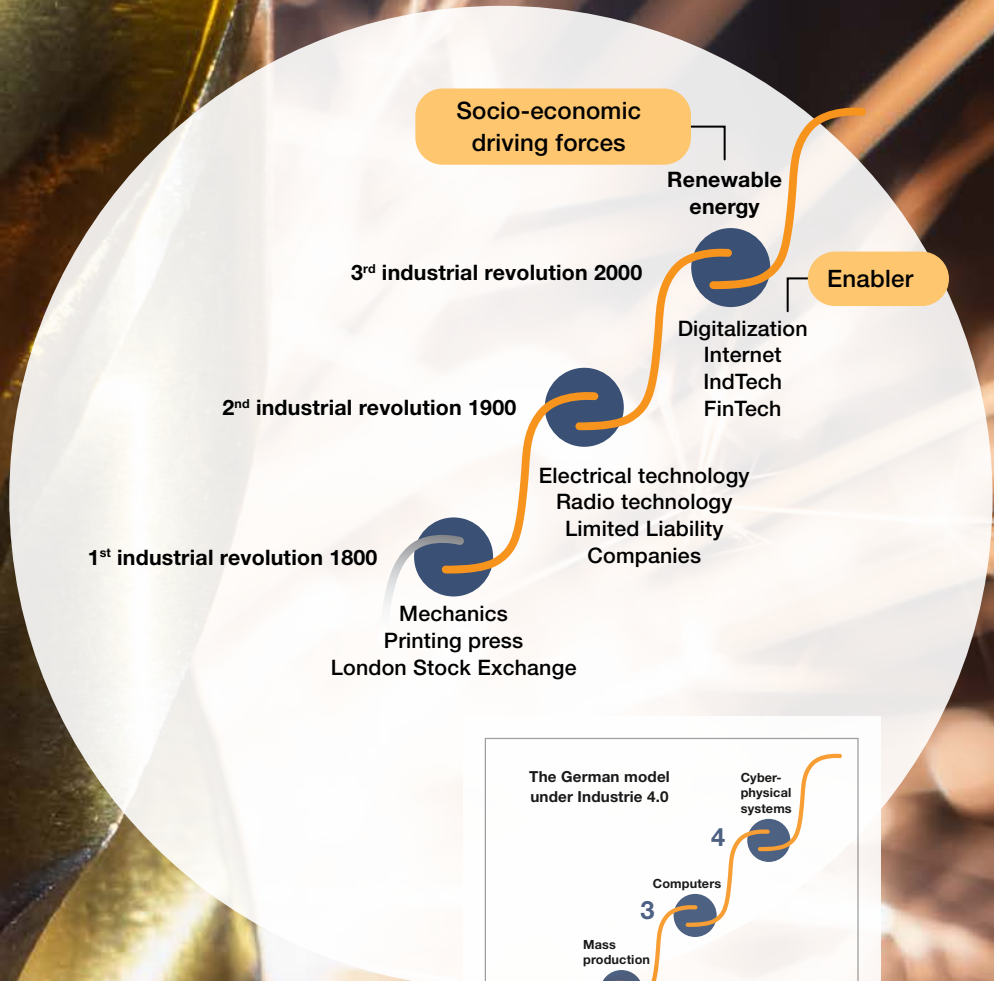
During times of major industrial technological shifts, standardization takes on particular, long-term significance. With the provision of good standards, transitions can take place more smoothly and more resource-efficiently, with a framework created that allows for continued development over a long period of time. In this section, we will take a closer look at the major industrial transformations of the past and, with the help of an S-curve model, learn how standardization has impacted upon them.

Sociologist Everett Rogers developed the S-curve in 1962. In the book *Diffusions of Innovations*, it is used as a model for how innovations (products and ideas) tend to spread over time in a social system. By aggregating all the innovations that at certain times have coincided to create industrial turning points, the curve can also be used to describe major industrial changes. As is the case for individual innovations and products, major industrial changes start gradually, then grow increasingly faster, before declining and eventually giving way for the next S-curve to take over, in the next paradigm.

There are various explanatory models for where we are in terms of industrial development and why we are there. A hypothesis put forward by many including the American economist Jeremy Rifkin in *The Third Industrial Revolution (2011)* assumes that large industrial shifts take place as a consequence of a change in energy supply in the world. When other enabling effects, such as information, communication and capital, coincide over time, major changes are set in motion.

**Figure 2:** The different industrial revolutions according to Rifkin's model (top) and the basis for the German program for industrial digitalization called Industrie 4.0 (bottom).



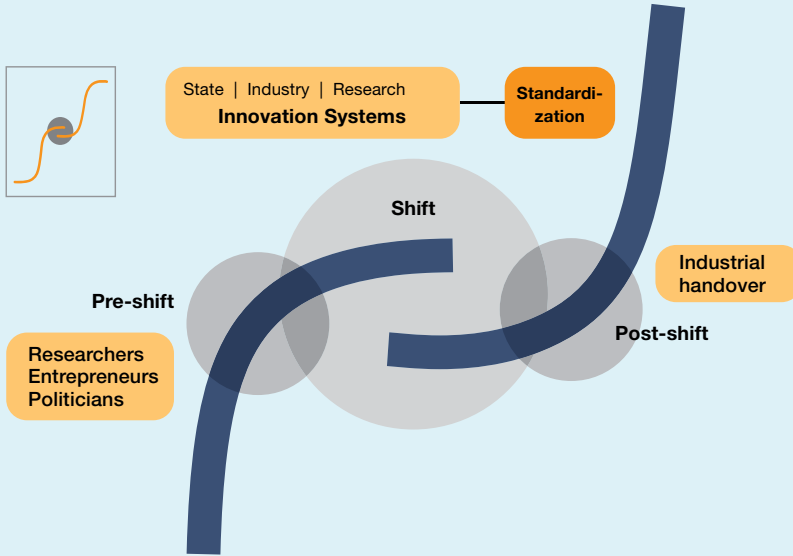




In the first industrial revolution, the use of coal coincided with technological breakthroughs within the field of mechanics (a prerequisite for the commercialization of the steam engine in the 1800s), communication technology (the rotary printing press, 1843) and the changing capital market (London Stock Exchange, 1801). Similarly, the second industrial revolution was driven by electrical energy, oil, electrical and radio technology, and corporate structures that limited personal liability (limited liability companies or LLCs). Based on this definition, we are now at the point of the third industrial revolution where the transition to a sustainable energy system combined with digitalization (through networks, internet, IndTech, FinTech and more), is leading to the next major transformation.

The German digitalization initiative Industrie 4.0, meanwhile, sees historic technological development as being divided into four phases: mechanization, mass production, electronics/computerization, and today's so-called cyber-physical development. In this way, the world of computers is intertwined with physical reality in such a way that they continuously affect each other. The consortium behind Industrie 4.0 has been successful in developing the concept and positioning the German industrial sector and German technology suppliers on the world market. The term has been adopted by the academic world, the industrial sector and suppliers as a synonym for general industrial digital development.

Industrial system shifts overlap with each other (in our model between two S-curves, see Figure 4)



**Figure 3:** Industrial shift in three phases where the innovation system as well as standardization play crucial roles in implementing and bedding in development.

with an initial visionary phase where researchers, entrepreneurs and often politicians push for development (while the established industrial sector for obvious reasons may hesitate). An innovation system with academic, industrial and public initiatives is eventually mobilized into a phase where the innovation system develops and tests new technologies to find out what the best applications for the industrial sector are. Finally, a period follows in which the market system flourishes and enters the steep part of the S-curve. Within the current digital transformation of industry, companies that depend on various sector and geopolitical conditions are spread over these three phases. Viewed from an international perspective, Swedish companies are generally far ahead of the competition, however there are

differences between the state of play in different Swedish sectors.

Standardization plays a crucial role in industrial shifts by consolidating development not only during the transition itself, but for an extended period afterwards. Standardization enables large-scale production of common, interchangeable components and makes communication between the industrial sector and its suppliers clearer. Conflict areas can be reduced, and properly implemented standards help avoid costly parallel development. To gain a broader perspective, it may now be worthwhile taking a brief look back at why the industrial sector's earliest attempts at standardization still matter today.

## THE FIRST INDUSTRIAL REVOLUTION

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The Industrial Revolution gained a foothold in the 18th century English textile industry, and gained momentum during the 19th century when it spread through Europe and on to America. Developments in the field of mechanization provided the impetus, and by the middle of the 19th century the world began to see the value of precision manufacturing and making interchangeable components for different mechanical systems. Standardization became a pioneering method that opened the way for value creation, and with time it played a decisive role in industrial development. Standard designs created value by bringing together the benefits of interchangeability and increased precision, and then scaled these by making the market more efficient.

Nuts and bolts that, with the help of threading machines and predefined specifications, could be produced identically in long series are an example of the resulting standardized precision, interchangeability and reduced costs. Because the threading machines used the same shaping

tool, nuts and bolts produced under the same standard now became interchangeable. This simple innovation had enormous effects on English industrial development and on industrialization in the rest of the world. British Railways' train tracks could be united under a common standard instead of using different types of nuts and bolts depending on the supplier and geographical location. Standardization was also of great importance in the Crimean War (1853–1856) when, thanks to the so-called Whitworth thread, the Royal Navy was able to mass-produce boat engines for the first time in marine history (see the fact box).

The first industrial standard (1841) is considered to be Joseph Whitworth's thread, later known as the British Standard Whitworth (BSW). The standard specified the angle, depth and radius of the thread, and was soon used outside England as well. In the United States, a thread with similar specifications was developed under the name the American Unified Coarse, later better known as UNC. Now, 180 years later, BSW and UNC are still viable mechanical terms.

|| Standard designs created value by bringing together the benefits of interchangeability and increased precision...



The Crimean War began, and Sir Charles Napier demanded of the Admiralty 120 gunboats, each with engines of 60 horsepower, for the campaign of 1855 in the Baltic. There were just ninety days in which to meet this requisition, and, short as the time was, the building of the gunboats presented no difficulty. It was otherwise however with the engines, and the Admiralty were in despair. Suddenly, by a flash of the mechanical genius, which was inherent in him, the late Mr John Penn solved the difficulty, and solved it quite easily. He had a pair of engines on hand of the exact size. He took them to pieces and he distributed the parts among the best machine shops in the country, telling each to make ninety sets exactly in all respects to the sample. The orders were executed with unflinching regularity, and he actually completed ninety sets of engines of 60 horsepower in ninety days - a feat which made the great Continental Powers stare with wonder, and which was possible only because the Whitworth standards of measurement and of accuracy and finish were by that time thoroughly recognized and established throughout the country.

*Source: D. Waller, Iron Men, 2016*



## THE SECOND INDUSTRIAL REVOLUTION


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The next industrial revolution began in the second half of the 19th century. As a consequence of industrial development in Europe and the United States, sudden expansions in capacity became apparent. At the same time, manufactured products had become so sophisticated that individual companies could no longer handle all the design and manufacturing tasks involved themselves.

Development resulted in specialization and division of production between different workshops. As a consequence, companies began to value market share, and competition increased. In order to counter the increased competition, additional investments were made in innovation development. But excessive development has the potential to diversify product lines too far, leading to complicated products and incompatibilities. In other words, competition within an immature market led to disorganization. This in turn would prove to

be an important driving force for the continued development of standards. This became especially evident in the field of electrical engineering.

The expansion of production in the late 1800s required cheap labour. The standardization of production equipment, raw materials and workplace design made workers highly productive after a quick and easy onboarding. The originator of *management science*, Frederick Winslow Taylor (1856–1915), wrote the famous book *The Principles of Scientific Management*, and with that, Taylorism came to prominence. Its crowning moment was the streamlining of car production by the Ford Motor Company. As the result of ongoing production improvements, a Model T Ford was coming off the assembly line every twenty-four seconds. This meant that the price could be reduced. In 1908, the initial price of the Model T was \$850, but at the end of its production life (1927), it would drop to less than a third of that. Standardization and scaling benefits made ‘Fordism’ synonymous with standardization work and mass production.



According to the old anecdote Henry Ford sold the Model T in any colour the customer wanted, as long as it was black. For twelve years, the car that revolutionized the automotive industry was painted with black, quick-drying asphalt paint. It was only in 1924, with the invention of cellulose paint, that a grey version appeared, followed by other colours. The last Model T manufactured was actually green.

|| The standardization of production equipment, raw materials, and the design of the workplace made workers highly productive after a quick and easy onboarding.

The increased attention paid to production methods gave birth to an industry of technology suppliers, as the desire to streamline and standardize production equipment grew. In the early 1890s, electric equipment began to take over the role of both steam engines and water wheels in the manufacturing sector. The electric motor was more efficient than small steam engines which suffered from poor efficiency and high energy losses through their central transmission systems. Electricity also provided flexibility. It became easier to change production flows when each machine had a built-in power source and, on top of that, reduced maintenance costs. Efficiency gains of more than thirty percent could be seen when electrification developed at its most intense speed, between 1900 and 1930. At the same time, power production and electricity networks were expanded and the price of electricity itself fell drastically.

The emergence of the electrotechnical industry represented a shift between S-curves that did not need to take into account existing installations, as the transition from steam engines and water wheels was a big change in itself – one we would call disruptive in today's terminology. Electricity and the electric motor became crucial for the efficiency of the value chains in the same way that data streams and computers are today.

The absence of historical baggage made the new electrotechnical industry one of the first to address standardization via an international system of standards, product liability and laws. This was necessary due to the risks that characterize

electrical engineering and it was soon clear that effective standards could only be developed with knowledge of what these were. This standardization work was gradually taken over by industry interests and the *International Electrotechnical Commission (IEC)* was founded in 1906. In comparison, the *International Organization for Standardization (ISO)* which deals with standards for outside the electrical engineering field was not established until 1947.

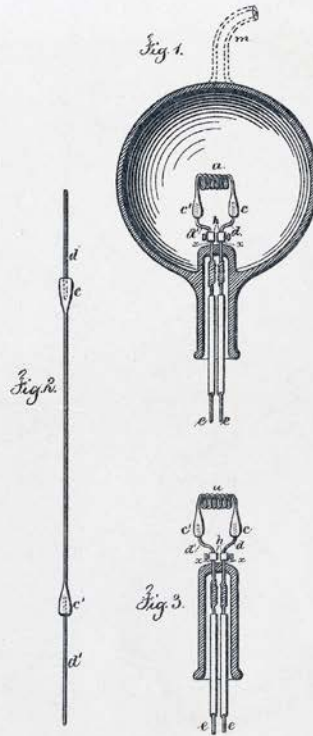
IEC became instrumental in developing and distributing standards for units of measurement such as gauss, hertz and weber and also proposed a system of standards, the *Giorgi system*, as a precursor to *SI - Système International d'unités*. In 1938, an international vocabulary was published that unites the terminology in electrical engineering, also known as *Electropedia*, and which is still important for the industrial sector.

Standardization of the physical dimensions of electric motors dates back to the 1920s and regulates things like shaft heights and flange dimensions, while other standards determine the output power on the motor shaft, as well as test protocols, system design and safety advice. The result is that motors of different makes are interchangeable within a given standard range and that machine builders in turn can standardize their designs. This greatly benefits the industrial sector as the efficiency and flexibility produced have generated enormous value over the past 100 years. It is also a clear illustration of how standardization brings huge benefit to our collective economy.

T. A. EDISON.  
Electric-Lamp.

No. 223,898.

Patented Jan. 27, 1880.



Witnesses  
Chas. M. Smith  
Geo. S. Pinckney

Inventor  
Thomas A. Edison  
for Lemuel W. Serrell

att'y

## STANDARDIZATION ORGANIZATIONS - A SYSTEM OF AND FOR COLLABORATION

Consensus is the foundation of standardization. When companies, users, stakeholder groups, standardization organizations and governments agree, this allows standards to create compatibility, interoperability, repeatability and security. Within social science, the idea of standardization has a close connection with coordination games and game theory. As with the well-known game theory concept of the 'prisoner's dilemma', the solution is cooperation. Everyone can benefit, but only through mutually consistent decisions. It is therefore not surprising that the UN and ISO have been working together since 1947 to make standardization a priority worldwide. Standardization is a high priority because it creates significant societal benefits.

As we have learned, by the end of the 19th century technical development had progressed so far that the difference between products from different companies began to become an obstacle to both trade and practical use. When design engineers and assemblers could not agree on dimensions and weights, serious economic resistance began to rise against the continued spread of industrialization. This prompted the formation of the world's first standardization organization, the *Engineering Standard Committee*, in London, in 1901. After World War One, similar national organizations developed around the world. The German *Deutsches Institut für Normung, DIN* was founded in 1917 and was followed a year later by the American National Standard Institute, NSI and the French *Commission Permanente de Standardisation*. In Sweden, it was the Swedish Confederation of

II... to avoid technical barriers to trade and ensure consistent technical regulations...

### The international standardization organizations ISO, IEC and ITU have strategic partnerships with the World Trade Organization.

The World Trade Organization (WTO) manages the rules for trade between its 162 member countries. An important part of the WTO's trade agreement is the TBT (Technical Barriers to Trade) agreement which ensures consistent technical regulations, standards and assessment criteria which can be used by countries to avoid unnecessary technical barriers to trade.

The International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC) and the International Telecommunication Union (ITU) all have strategic partnerships

Industry and the Swedish Academy of Engineering, IVA, which in 1922 took the initiative to form the Swedish Industry Standardization Commission, now SIS. But the body for electrical engineering, as mentioned earlier, came first in 1907 in the form of the Swedish Electrotechnical Committee or SEK. It was founded as a Swedish national committee by IEC. In 1919, the Electrical Standardization Committee, ESK, was formed with the Swedish Electrical Industry Association as its head. In 1937, SEK merged with ESK and formed the Swedish Electrical Commission, SEK, which in 2007 changed its name to SEK Swedish Electricity Standard (*Svensk Elstandard*)

The peak body for standardization in Sweden the Swedish Standardization Association (*Sveriges Standardiseringsförbund*) which is also responsible for the official registry of Swedish standards. The

three Swedish organizations that today, within their own areas, establish Swedish standards are SIS, SEK and ITS (the Swedish Information and Telecommunications Standardization).

Early initiatives led to standardization work being initially systematized locally and in fast-growing areas such as electrical engineering, and then increasing more broadly, regionally and internationally. Today, there is a comprehensive system of collaboration between recognized national, regional and international organizations, which in turn include thousands of voluntary interest groups working for useful standardization across all aspects of society. Only those with special interests will want to go into the details of these, but it's worth taking a closer look at the global structures that characterize large organizations like IEC, ISO and ITU.

with the WTO. Standards developed by IEC, ISO, and ITU comply with the WTO's TBT Committee's principles for the development of International Standards. Standards developed by these organizations respect the principles of openness, transparency, impartiality and consensus, efficiency and relevance, and context and development dimension, approved by the WTO's TBT Committee.

Politicians and other decision-makers can thus use IEC, ISO or ITU international standards with the assurance that they fulfil the WTO's obligations and will not create unnecessary barriers to international trade.





# IEC ITU ISO

## IEC – ITU – ISO

The transition to electrification which occurred in the early part of the 20th century was driven largely by enthusiastic entrepreneurship. Many individuals felt inspired to involve themselves in the rapidly expanding market. They did so in their own individual ways, with a wide variety of rules emerging for things like voltage, current and frequency, as well as for documentation and specifying methods. Depending on which supplier was chosen, even the most similar of machines could have completely incompatible electrical systems.

In the context of an expanding market, this situation, of course, eventually became unsustainable. To address the issue, the *International Electrotechnical Commission (IEC)* was formed at the World's Fair in St. Louis in the United States in 1904, with British Lord Kelvin as its first president. Some 14 countries participated in these early efforts, beginning comprehensive standardization work that continues to have impacts on the way the industry functions today.

Today, Svensk Elstandard (SEK) is Sweden's national representative member of IEC. In Germany,

DKE plays a similar role and deserves special mention due to its considerable influence. DKE's strategy of being a major player and contributing with experts and secretariats for international working groups is widely considered to be its 'secret weapon' in creating valuable capital within IEC over time. There are certainly parallels with Germany's current Industrie 4.0 initiative.

The first standardization organization with a truly international mission was the International Telegraph Union, now known as the International Telecommunication Union, (ITU). On 17 May 1865, some 20 countries signed the first Telegraph Convention, a prerequisite for the interconnection of various national telegraph networks. With the invention of the telephone and radio, ITU's work was soon extended to include standards for telecommunication in the broadest sense.

ITU divides the world into three regions, with the aim of managing the global radio spectrum. Each region has its own set of assigned frequencies (which is the main reason for having regions.)

**Region 1** consists of Europe, Africa, and the Middle East west of the Persian Gulf, including Iraq, the former Soviet Union and Mongolia.

**Region 2** consists of America, Greenland and parts of the eastern islands in the Pacific Ocean.

**Region 3** consists mainly of Asia, except the former Soviet Union, Iran and countries east of Iran, as well as most of Oceania.

The predecessor of today's *ISO* was *ISA*, the International Federation of the National Standardizing Associations. *ISA* was founded in 1926 with the ambition of coordinating all technical standards and norms. After World War Two, the UN and *ISA* approached each other with the intention of creating a new global standardization organization, and in 1946, delegates from 25 countries met in London and agreed to create the modern *ISO*. The organisation officially began operating in February 1947.

*ISO* usually has a local organization in each country, a National Standards Body (NSB) which can be private, public or combinations thereof. In Sweden, *SIS* has that role. In Germany it is *DIN*, in

the USA it is *ANSI* and in France it is *AFNOR*, and so on. There are a total of 165 members in the world, and about 2,700 technical working committees.

In order to provide a complete picture, coordination at the regional level should also be mentioned. In Europe, standardization organizations at this level exist in the form of the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI). The latter is an organization with 800 members in the form of national standardization organizations, manufacturers and users. *ITS* has been appointed to represent Sweden in *ETSI*.

In the European Union, only standards created by CEN, CENELEC and ETSI are recognized as European standards, and member states are required to notify the European Commission and each other of all suggested technical regulations on ICT products and services before they are adopted into national law. In Europe, there is also the Institute for Reference Materials and Measurements (*IRMM*). Another 15 regional organizations exist for different continents.

Together, *ISO* covers standardization in most areas with three exceptions. The first is electrical engineering and electronics, which is covered by the IEC. The second is telecommunications, which is covered by the ITU. The third is IT or information technology, which is managed through a collaboration between *ISO* and IEC. This collaboration goes by the name of the Joint Technical Committee 1 (JTC1) and its purpose is to develop, maintain and promote standards in information technology (IT) and information and communication technology (ICT). Many of these are relevant to the digitalization of the industrial sector, for example security, portability, interoperability, user interface, harmonized language use, performance, and quality.

Finally, it should be emphasized that IEC, *ISO* and ITU, unlike most organizations in the industrial sector and many private standardization initiatives, provide members countries with equal representation. Each country gets one equally weighted vote.

## The ISO standardization process

Wherever a national organization for a member country has an interest in the work of an ISO committee, it has the right to be a member of the committee. Standards are achieved through consensus, with each member organization representing the interests of suppliers, manufacturers, consumers, professional groups and the government in the country.

Each standard undergoes a six-step process before being published as an ISO standard:

When the draft is ready, it enters the committee stage and is sent out for comment until an agreement is reached. The result of this step is the Draft International Standard (DIS).

**2**  
The standard then goes through a preparatory step where a draft of the standard is developed.

**1**  
The first stage is the proposal phase where the need for a standard is determined and members who are willing to work on it are identified.



4

The DIS then enters the investigation phase where it is circulated among all members and then voted on. If a DIS does not receive 75% of the votes, it returns to a lower step and work on it continues.

5

If it passes the investigation stage, it becomes a Final Draft International Standard and enters the approval stage. During this stage, it will again circulate through all the member bodies for a final vote and again it must receive at least 75% of the votes to continue to the next level.

6

If the standard meets this level, it enters the publication phase and is sent to the ISO Central Secretariat for publication.

In Sweden, standardization activities are conducted in private. Special laws, ordinances and government regulations and references in general guidelines regulate the use of standards in various areas. There is no general legislation on standardization in Sweden.

**The Swedish Standards Institute (SIS), SEK Svensk Elstandard (SEK) and the Information Technology Standardization (ITS)** are the three standardization organizations that carry out formal standardization work. They are non-profit associations and their members are legal entities and public authorities. These bodies are coordinated by **the Swedish Standardization Association**, which since 2012 has taken over essential operations within the Swedish Standardization Council. The latter body was established in 2001 when the number of recognized organizations decreased from nine to the current three. The Swedish Standardization Association promotes standardization in Sweden, strives for the wider use of standards, streamlines standardization through collaboration, and applies for government funding.

Standardization work in Sweden is financed by subsidies from the state, membership fees, project fees and income from the sales of standards and other products and services.

## OTHER ORGANIZED STANDARDIZATION INTERESTS

It should be noted that it is possible to achieve technical coordination between companies through the use of mutually binding agreements, without the involvement of standardization organizations. However, if a project involves managing multiple technical issues and more than two parties, the process rapidly becomes both confusing and expensive. For this reason, participating in standard development and becoming members of standardization organizations helps companies avoid resource-intensive obstacles and to save money. Voluntary standards are a solution to coordination problems that would otherwise create inefficiencies.

The transition over many decades towards *externalized* standardization means that standardization via voluntary organizations can be seen as the second step, following on from coordination through mutual agreements. Over time, the industrial sector began to use not only its own standards but also those developed in coordination by industry associations and similar associations. These are standards that have often reached the national and international standardization organizations and were subsequently confirmed as official standards.

But in a market economy, companies still primarily make decisions based on their own strategies and business conditions. Standardization organizations, therefore, face market challenges and it is

essential that they are attractive to players in their sector. They must publish relevant standards in a timely manner. And because they are non-profit organizations, they must cover their own costs by selling standards and related services such as education. They need to attract and retain companies as members and ensure both the development and maintenance of standards in an open and concise manner.

Early independent standardization initiatives took the form of private associations. This 19th century phenomena led to the birth of many of today's key organisations through the formation of associations such as ICE (1818), IEE (1871), IMechE (1847), ASME (1881), VDE (1893) and AIEE (1883), which was the predecessor to IEEE. Standards developed by these bodies were classified as voluntary and were known as 'consensus standards'. The number of independent standardization players in the world today runs into the thousands if the entire breadth and depth of industrial sector areas subject to voluntary standardization is taken into account. All these associations are important for the emergence of official standards and for the markets to function.

Even if one limits the criteria to industrial IT, automation and digitalization, the number of national, regional and industry-oriented organizations working with standardization is significant.

This is especially true if one includes the telecommunications field in the mix in recognition of the role it plays in the converging area of industrial digitization. Among the best known organisations are the Institute of Electrical and Electronics Engineers (IEEE), the Internet Engineering Task Force (IETF), the World Wide Web Consortium (W3C), the Technical Association of the Pulp and Paper Industry (TAPPI), the Standard Solutions Group (SSG – a Swedish initiative which sprung up from the forest industry in the 1960s), the Association for Standardization of Automation and Measuring Systems (ASAM), the Alliance for Telecommunications Industry Solutions (ATIS), AUTomotive Open System ARchitecture (AUTOSAR), and the Telecommunications Industry Association (TIA).

An example of a privately organized standardization interest of great importance to the automation industry is the OPC Foundation. (The acronym now refers to Open Platform Communications, although it formerly referred to Object Linking and Embedding for Process Control.) The initiative has 750 members worldwide, including most in the supplier industry for automation and industrial IT. OPC was developed by the automation industry and Microsoft in 1995 and over the next ten years it became one of the most common means for data communication within the automation field. From the need for model-based

data and greater platform independence, the concept OPC UA (OPC Unified Architecture) later developed.

In this section, we have taken a closer look at the importance of standards and standardization organizations for industrial development. We have looked at how an advanced global ecosystem of standardization interests has developed over 200 years. And we have examined how this now interacts in a way that makes physical, mental and economic wheels spin in a rapid and friction-free manner that it adds to society's growth and prosperity.

In the next part of this report, we will examine a new phase of industrial development within which digitalization that is playing a key role. The section begins by examining the basics of digital transformation and it then takes a closer look from a market perspective and at the structural transformation of the supplier industry. The development of the digital industrial arena needs to be studied with market forces in mind. This is especially true now that we are on the verge of leaving the demonstration phase, in which development has very often been publicly subsidized, and entering a period in which commercial forces are taking over. The section is rounded off with an overview of some standardization areas of great importance for future industrial development.



|| The number of independent standardization players in the world today runs into the thousands ...

PART

# 2



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0 0 1 0



Digitalization involves the industrial sector's current operational production technology, along with the the area of administrative IT and various new digital developments (including the Internet of Things and AI) all coming together and being integrated to create a new paradigm for how operations are conducted.

# THE NEXT INDUSTRIAL REVOLUTION

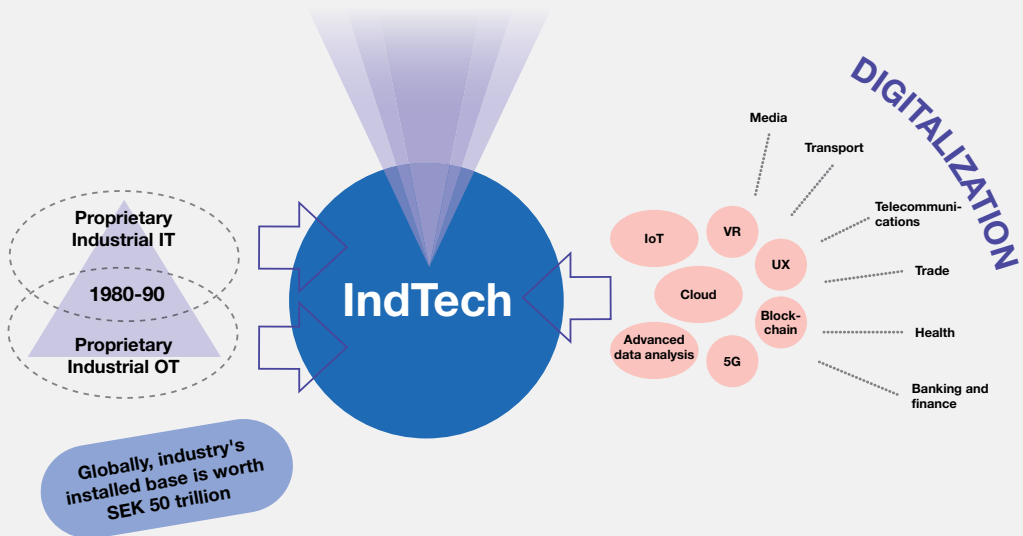
and the digital transformation

## THE DIGITAL SHIFT

Digitalization involves the industrial sector's current operational production technology, along with the area of administrative IT and various new digital developments (including the Internet of Things and AI) all coming together and being integrated to create a new paradigm for how operations are conducted. The core principles are increasing efficiency through productivity and resource use, and providing sophisticated customer benefits via new business models and network-based relationship systems.

Facilitating greater amounts of data in freer flows creates new opportunities. Both industrial OT and IT have their roots in the late 1970s with the development of computers, and both areas are now influenced by digital technology such as cloud services and advanced data analysis. The more efficient exchange of information between the OT and IT levels of the industrial sector points to the great value that can be unlocked through better integration. Meanwhile, increased data exchange in value chains increases efficiency between

IndTech involves technologies from different areas and times meeting, being developed, and then changing conditions within the industrial sector to enable digital transformation.



**Figure 4:** The model for IndTech: traditional automation and IT, often proprietary and with roots in the 80s and 90s, meets new digital technology that provides development opportunities in a world market worth over USD 400 billion. The digital solutions often have completely different origins to those in the industrial sector; the media, trade and banking/finance sectors are further along in their digital transitions.

companies and within the entire industrial system. On top of that, the sheer volume of data available creates opportunities for new business models and organizational forms.

Collectively, this change is usually called the fourth industrial revolution (Industry 4.0), the digital transformation of industry, smart industry or smart manufacturing. Another term used to indicate that practical digitalization involves the combination of existing technology with various new phenomena is IndTech. The IndTech idea also addresses the underlying market system, as it is of crucial importance in development. The companies and institutions that develop and manufacture the required underlying technology operate in a worldwide market worth over USD 400 billion. It is a market that is growing significantly faster than the global average, and one in which Sweden sits in an incredibly strong position. Another key element of the market system is a strong academic contribution, through which basic and applied research enables technology suppliers to develop competitive products.

In the western world, so-called greenfield industrial projects (developed completely from scratch) are quite rare, whereas brownfield projects (build on existing industrial facilities) are far more common. A large installed base of older but well-functioning technologies is sometimes considered to be limiting the pace of industrial digitalization. But the installed base of IT and computerized automation technology can also be seen as a positive reflection of the massive amount of knowledge capital that has gone into Sweden's past and present industrial successes. In most respects, Sweden's export success has been achieved through highly computerized and data-driven production processes, and these, if properly utilized, provide an effective springboard for further digitalization.

The word 'digitalization' usually refers to combinations of mobility, clouds, platforms, social interaction, the Internet of Things, AI and large

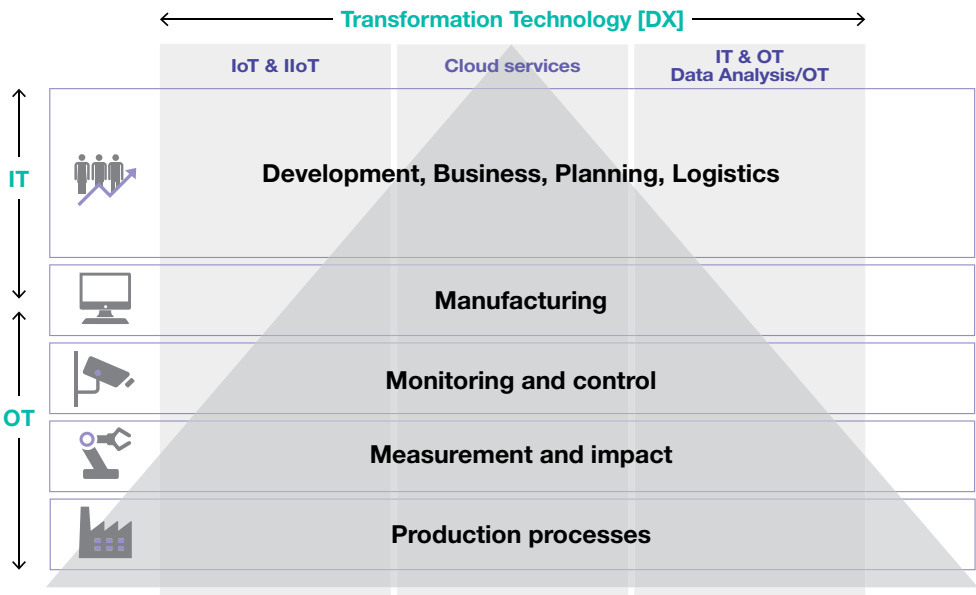
amounts of data. Industrial IT has been a growing market since the end of the 1970s, with demand for product development support, resource management, production, business and administration of maintenance and fixed assets. Meanwhile, operational technology (OT), which also has its roots in the development of the microcomputer in the 1970s, takes in installations on factory floors such as control systems, sensors, actuators, drive and electrical systems, instrumentation and robots.

There are compelling reasons for approaching these three areas. Undertaking system integration, advanced analysis and increased automation can deliver tens of trillions of Swedish kronor each year via efficiency improvements (PiiA and Blue Institute, AI & Digital Platforms, 2019). At the same time, the digital solutions driving change have mostly been developed outside the industrial sector. The media, trade and financial sectors are at the forefront of digitalization and there are challenges when IndTech technology from other sectors is adopted. Nevertheless, these opportunities are accelerating the innovation system and technical standardization and represent a major readjustment of the global industrial sector.

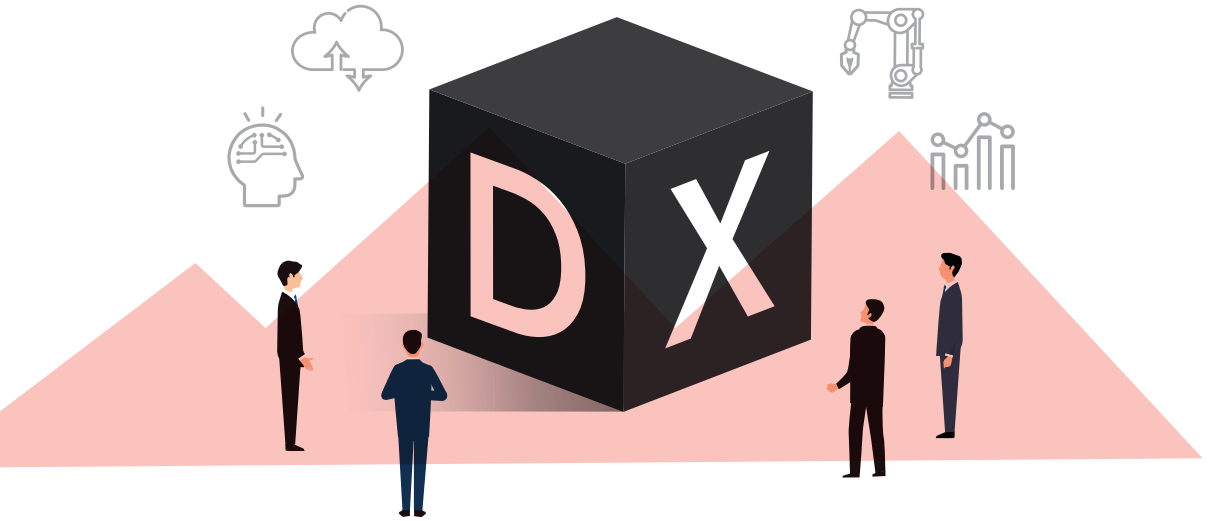
***DX is the current abbreviation for digital transformation*** used by both suppliers and other organizations. "DX is the integration of digital technology into all areas of a business, fundamentally changing how you operate and deliver value to customers. It's also a cultural change that requires organizations to continually challenge the status quo, experiment, and get comfortable with failure."

CIOWiki

In simple terms, the three headline areas shown in Figure 5 can be seen as verticals intersecting with existing IT and OT domains, with old and new being integrated one step at a time, and conditions arising for a digital transformation of businesses. **Following this logic, the triad of IoT, cloud and analysis is sometimes also called Digital Transformation Technology (DX).**



**Figure 5:** Diagram of the automation pyramid showing the areas covered in this report. The development involved can be summarized as integration in both vertical and horizontal directions. The three verticals of integration technology shown in the illustration form a digital platform capable of combining old and new architectures to allow for step-by-step modernization and ultimately consolidation as Digital Transformation, (abbreviated as DX).



II... through the practical integration of computers, organizations, people and companies, the elimination of information silos.

## TIME TO PULL DOWN THE PYRAMIDS

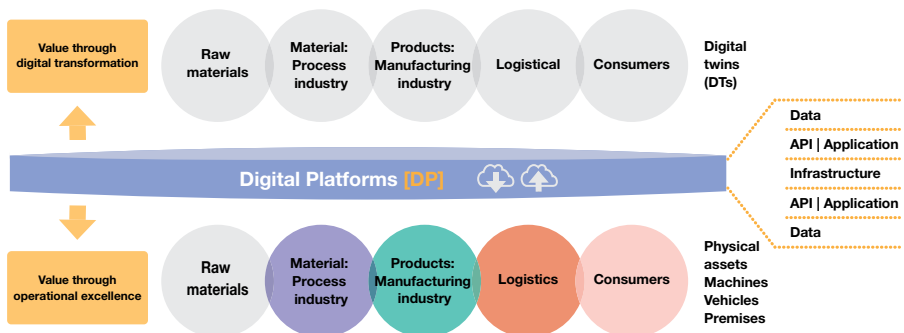
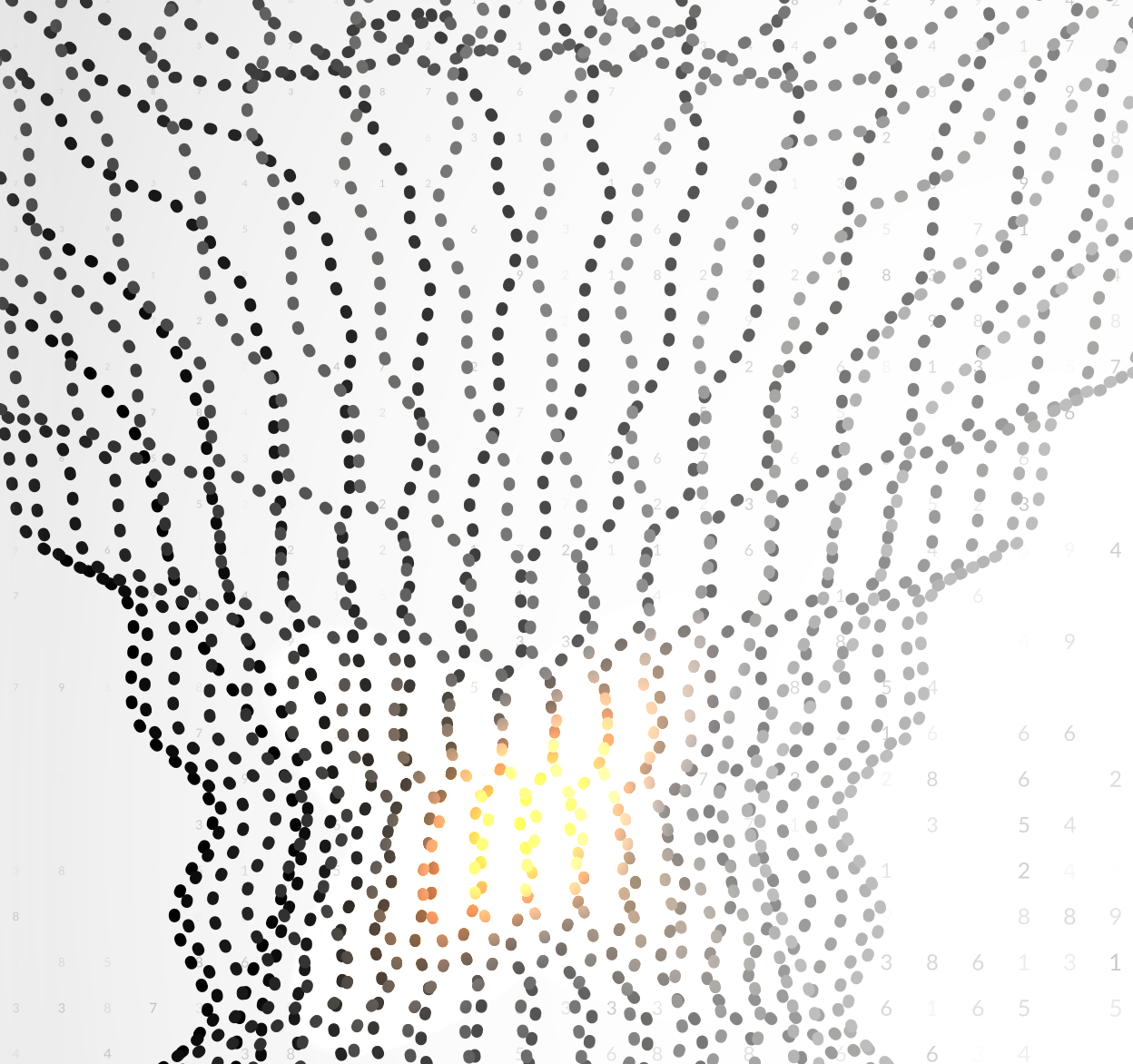
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Digitally integrated production, business concepts and organizational models represent an opportunity for the industrial sector to meet both increasing competition and the challenges of resource scarcity, climate change and environmental threats. The starting point for understanding this transformation is a widely accepted model known as the Pyramid of Automation (ISA 95, International Society of Automation). Within the model, operational technology (OT) is found closest to production, and IT for business support is placed above (see Figure 5). However, digitalization is all about releasing data to create value in everything from control circuits on factory floors through to administrative automation, highly developed business models and everything in between. There have long been arguments put forward that hierarchical viewpoints and architectures need to be dissolved. However, the industrial world's large installed base of working technology means radical changes are rare. In reality, the process involves successive improvements and, in the

short term, through the practical integration of computers, organizations, people and companies, eliminating information silos. In the slightly longer run, platforms with standardized interoperability are a reasonable development.

Other technological shifts in history have shown the importance of preparedness and setting appropriate goals. This leads to rapid readjustment and adaptation, with competitive advantages as a reward. Most industrial companies stand to make significant gains by allowing their existing IT/OT structures be further developed into concepts such as:

- 1) opening the way for digital capacity to be delivered cost-effectively as various types of cloud services;
- 2) using the Internet of Things for data collection and as a future platform; and
- 3) applying advanced data analysis within automation, optimization, and collaboration strategies between humans and machines.



## DIGITAL TRANSFORMATION

The industrial sector's value chains are built around the value processing of materials, from raw materials to consumer products and reuse. These chains need to be maintained over time. Seen from a digital perspective, new value is actually added by data flows through value systems (in time and space). One way of defining digitalization is the free, value-creating flow of data (information). Since the early computerization of the 1970s, this has also been the basis for everyday business support, operations, business and maintenance.

What is changing now is the importance of data for organizational and relationship models based on networks and metaphors of the natural ecosystems. Products themselves are being digitalized and supplemented with value-creating services through new business models. The connections between production and product data also become more important as the requirements for product variants and customer adaptation increase. This also applies to raw materials and basic materials where simultaneously sent pro-

**Figure 6:** Industrial digitization from a system perspective, with a layer at the bottom of physical assets within which efficiency is achieved via automation and optimization. Digital twins (top) will eventually reflect the complete real-world value chains, helping us to approach the goal of self-organization. The real value chain, like the digital twin, depends on the data-bearing platform in the middle of the illustration.

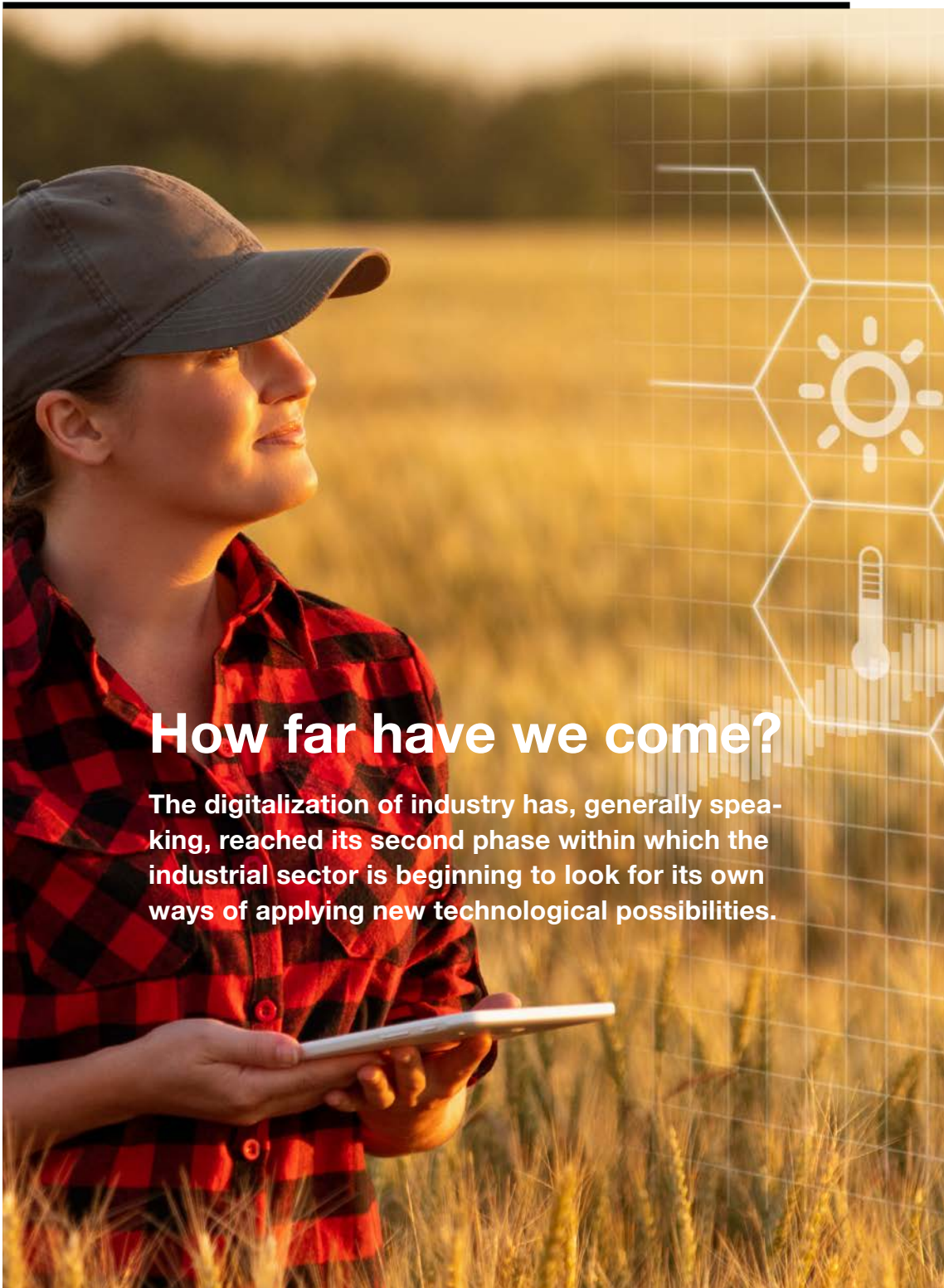
What is changing now is the importance of data for organizational and relationship models...

duction data describing various properties can increase the value that is added further down the chain, and vice versa.

Data already plays a crucial role in the efficiency of the industrial sector, but through more data, better order and new methods, the bar can be raised further. With a sufficient amount of data and computing power, dynamic models of operations, machines and products can be created. Live models on digital platforms are known as digital twins [DT] and can be used to develop new services and business models. Digital twins are already important instruments for planning, design and collaboration.

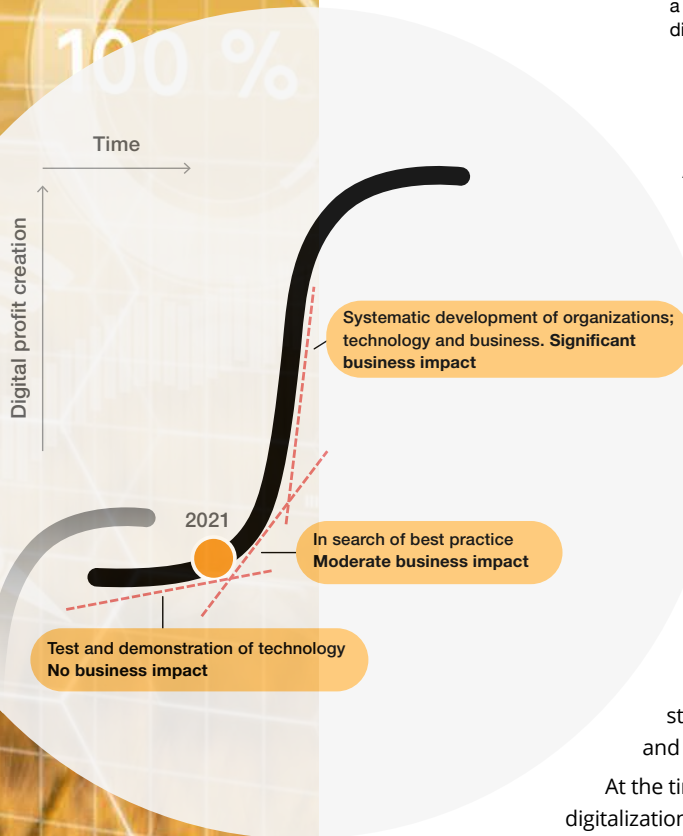
*Digital platforms*, indicated in the middle of Figure 4, are the infrastructural functions needed to collect, store, refine and distribute data. In practice, an individual digital platform usually consists of complexes of platforms adapted for different tasks provided by different companies and organizations.

In summary, digitalization is about *data*. The platforms ensure that data is collected, calculated, modelled and used for business support and automation. Model-based digital twins can use data to predict what will happen, thus providing a basis for new forms of business and business development. When all this happens at the same time as organizations and business models are adapted to the new conditions, what we call a 'digital transformation' of industry takes place.



## How far have we come?

The digitalization of industry has, generally speaking, reached its second phase within which the industrial sector is beginning to look for its own ways of applying new technological possibilities.



**Figure 7:** The curve portrays the digital development of the industrial sector, here divided into three phases, starting with testing and demonstration, followed by the efforts of individual companies to find suitable business models. The third phase involves very rapid development and a major impact on the sector through digital transformation.

As we have seen before, the S-curve is a model used to illustrate how new innovations create and shape markets. In this case, it describes the development of the digitalization of the industrial sector in three phases. In the first phase we leave an earlier paradigm. The figure to the left indicates the end of a previous S-curve and the beginning of a new one. This, in turn, begins with the testing and demonstration of digital technology and new systems.

At the time of writing in 2021, the digitalization of the industrial sector has, in general terms, reached the second phase within which the sector is beginning to look for its own ways of applying new technological possibilities. We call this phase 'in search of best practice'. The real business return is seen in the third phase and in the steep part of the curve where development moves rapidly, affecting organizations, processes and relationships, and leading to new means of production and doing business. At this stage, digital transformation yields major business impacts.



## MARKET DEVELOPMENT IN SWEDEN AND THE WORLD

A key part of industrial development involves the system behind the supply of technology. One useful descriptive model for this is to see the innovation system as a collaboration between the market (the industrial sector and its suppliers), knowledge generation via academia/institutes, and public initiatives. To date, the global innovation system has been investing some SEK 1.5 trillion annually (PiiA and Blue Institute, AI & Digital Platforms, 2019) to enable digital technology to improve the industrial sector.

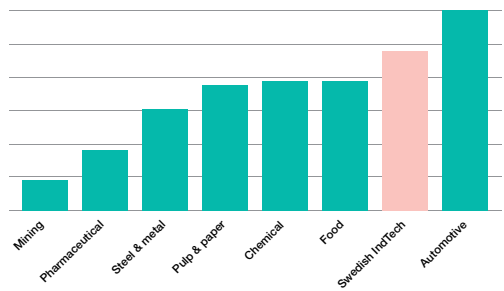
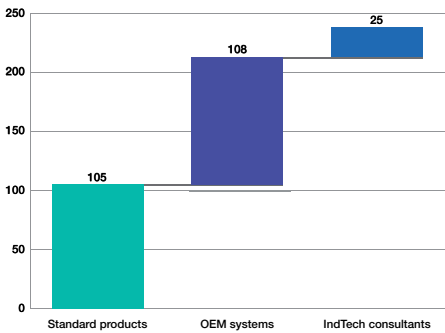
The PiiA innovation program, working with Automation Region and Mälardalen University, has been regularly measuring and assessing Sweden's supplier industry for industrial IT, OT and digitalization. The latest assessment, published in 2021 (PiiA, Blue Institute, Swedish IndTech 2021), shows

that the industrial sector in Sweden has a turnover of approximately SEK 105 billion. When compared with previous surveys in 2012 and 2015, this indicates an average annual growth rate of 8 percent.

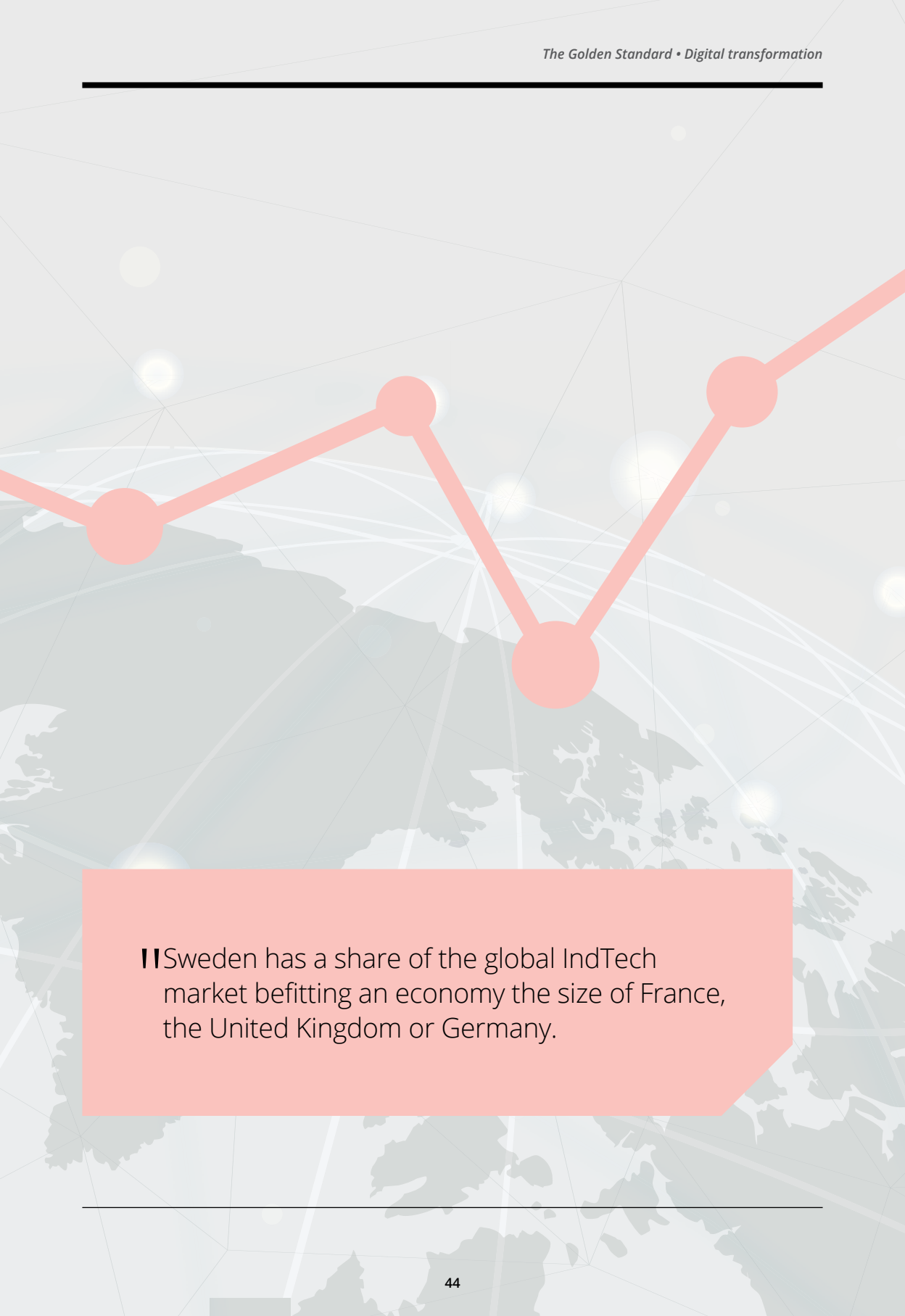
Beyond these IT/automation suppliers, Sweden also represents a significant part of the global export industry that is delivering machines with increasingly advanced digital content. We also have a prominent ICT and industrial consulting sector. According to the same study, these segments are worth an estimated SEK 108 billion (for system solutions) and SEK 25 billion (consulting services). This means that *Swedish IndTech* accounts for some SEK 238 billion and that the sector is comparable with the Swedish raw materials industry, the process industry and many of the larger sectors within the manufacturing industry.



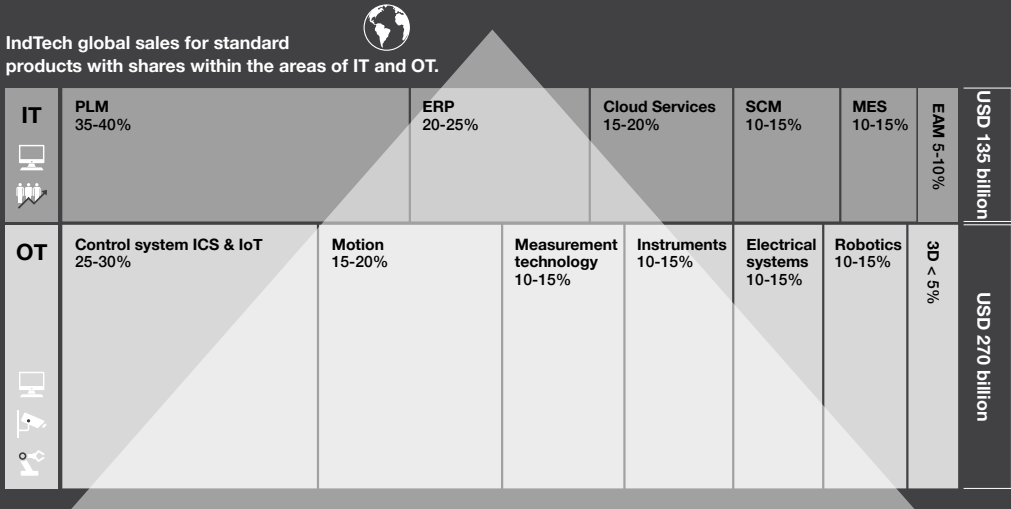
### Swedish IndTech



**Figure 8:** The complete Swedish IndTech industry consists of three parts: standard products, digital content from Swedish machine and system suppliers (OEM), and IT and technology consultants.



|| Sweden has a share of the global IndTech market befitting an economy the size of France, the United Kingdom or Germany.



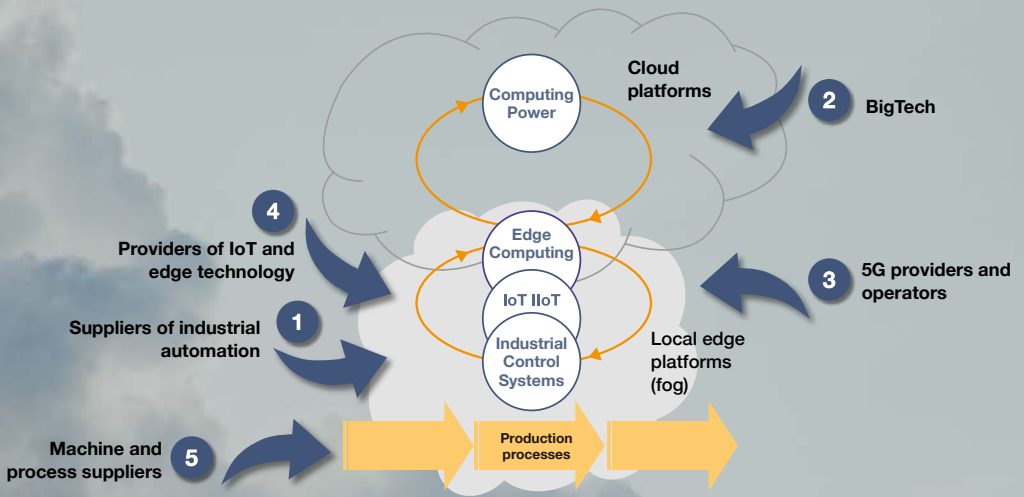
**Figure 9:** Global IndTech sales for standard products, showing shares in the areas of IT and OT. Explanations: PLM is product lifecycle management, ERP is enterprise resource planning, SCM is supply chain management, MES is manufacturing execution systems, and EAM is enterprise asset management.

## A WORLD MARKET WORTH SEK 3.5 TRILLION

The global market for IndTech is estimated at USD 405 billion (2020), with a growth rate of 6-7 percent. The share for industrial IT is USD 135 billion, with the remaining USD 270 billion going to technology for factory floors (OT).

The Swedish suppliers' share (of standard products) is estimated at approximately USD 12

billion (SEK 105 billion), which corresponds to a global market share of three percent for standard products. This is six to seven times what you would expect from an economy of Sweden's size (Figures 8 and 9). Or, in other words, Sweden has a share of the global IndTech market befitting an economy the size of France, the United Kingdom or Germany .



**Figure 10:** The changing IT/automation landscape. Traditional automation players face new competition as cloud services sweep across the industrial sector.

## DEVELOPMENT OF THE SUPPLIER SECTOR

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With expected continued high demand and a growth rate of seven percent, the market outlook is good for technology suppliers. The implementation of the IoT, cloud services and data analysis is increasing the breadth of their offering. At the same time, technological environments are becoming even more connected. Discreet and continuous automation technology is continuing to be integrated, as is the entire IT and OT area. At the same time, the exchange of information between companies is increasing within value chains.

These are examples of the kinds of innovation-driven changes that are creating industrial demand while also changing conditions for suppliers. The boundaries between IT, automation and digitization are shifting or fading away, and the nature of the marketplace is changing as BigTech, ICT companies and OEMs take on new roles.

Market conditions featuring powerful dynamism and strong underlying demand are creating opportunities. The fact that the logic of the market is changing is becoming especially clear to suppliers of industrial automation systems (1 in Figure 10) who are leaving behind a closed world with proprietary rules in favour of one with open standards, but also new competitors.

We are now seeing how cloud and platform service providers (2 in Figure 10), so-called *Hyper-scalers*, are creating alliances as market channels for different industry verticals. One such channel involves the suppliers of industrial control

systems. But the market oligopoly for cloud services means that, in reality, it is BigTech that sets the rules of the game. Automation companies, therefore, need to reduce dependency and increase their manoeuvring room by deriving value from the cloud in a way that creates clear customer value, is difficult to copy, and is based on the automation industry's domain knowledge and relationships.

This means providing offerings that have increased industrial IT and advanced data-analysis content – a development that can be accelerated through acquisition strategies and alliances. Siemens has undergone a long period of systematic acquisitions within the area of PLM. Another example is the merger between Schneider and the English software company AVEVA. The approach consists, in part, of IIoT platforms linked closely to production, as is the case with Siemens MindSphere and the GE-developed Predix. One probable result of these developments is consolidation, with space available for only three or four broad industrial platforms and about twenty-five industry-specific ones. According to the consulting firm *Oliver Wyman*, there are currently 150 initiatives.

At the same time, 5G suppliers (3) are seeing opportunities within IoT, with operators potentially able to increase revenue by as much as 34 percent if the industrial sector chooses to increase its use of wireless communication, according to Ericsson. Another result would be easily accessible techno-



logy. ICT and IoT companies are already developing interesting technological solutions for end users in the industrial sector. IoT as an industry (4) is young, fast-growing, general and covers many sectors. Development costs and production may be offset by large volumes, and many sectors such as transport, infrastructure and healthcare have quality requirements that correspond to those of the industrial sector. Technology and applications for IoT platforms are a great opportunity for Swedish IndTech companies. At the same time, the situation means that proprietary automation technology is now encountering competition from new sources, lowering prices of some parts of the automation offering.

Cloud platforms and IoT are also providing machine suppliers (5) with new tools for their automation and analysis needs, while these types of companies are also changing through digitalization. Machine builders and the automation industry are, in some ways, competing for the connected optimization and maintenance of customers' facilities, with strategies that take into account access to the valuable data that can be derived from industrial production. This is data that can be used to create new products and services.

In short, a new paradigm is emerging for the sector's suppliers, one which is based on platforms and within which the ability to offer real customer value will be a distinguishing factor. In order to avoid the risk of being marginalized amid these new dynamics, the automation industry needs to develop the advantages it already has within domain and process knowledge and customer relationships. Suppliers who succeed in this endeavour stand to gain a developed and defined role in the sector as 'vertical' knowledge providers of efficiency and quality standards. Others, meanwhile, may develop

cost-effective products based on open standards by embracing the economies of scale that IoT development entails.

We will conclude this part of the paper by looking more closely at some specific areas of development and the work that is going on to form common industry standards. We address the importance of reference models for development, take a closer look at digital twins, industrial data, and how data can be exchanged efficiently through interoperability, clouds and distributed platforms. We also look at how data creates value through the use of data analysis/AI, digital twins, and IIoT, and finally information security to guarantee robustness in the future industrial system.



|| With expected continued high demand and a growth rate of seven percent, the market prospects are good for technology suppliers.

# System-changing standardization areas

## ● REFERENCE MODELS

*A reference model is based on a small number of unifying concepts and it can be used as a basis for training and explaining standards to a non-specialist.*

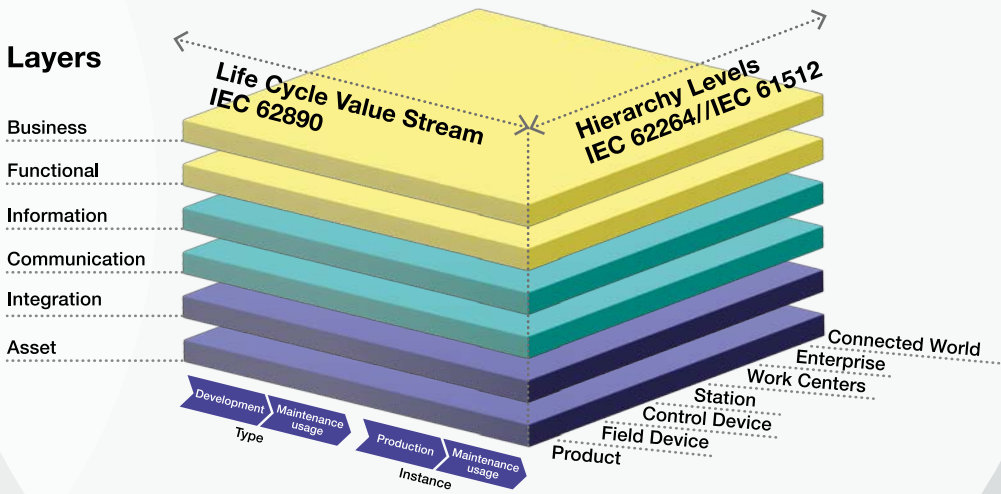
Without widely accepted standards, the potential benefits provided by the free flow of information within industrial value systems cannot be unlocked. Unlocking this value requires agreements that cover everything from system structures to components and the interfaces between them. A concept known as the 'reference model' can be useful in achieving the desired common understanding. The Organization for the Advancement of Structured Information Standards (OASIS) defines a reference model thus:

"A reference model is an abstract framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment. A reference model is based on a small number of unifying concepts and may be used as a basis for education and explaining standards to a non-specialist. A reference model is not directly tied to any standards, technologies or other concrete implementation details, but it does seek to provide a common semantics that can be used unambiguously across and between different implementations."

|| A reference model can represent all parts of a business...

A reference model for the digitalization of the industrial sector is thus a domain-specific ontology of defined and interconnected concepts that facilitates communication between different interests (e.g., the industrial sector, technology suppliers and standardization organizations). A reference model can represent all parts of a business, from business functions to technical system components. Reference models are often illustrated graphically as sets of concepts, with the connections between each implied in different ways.

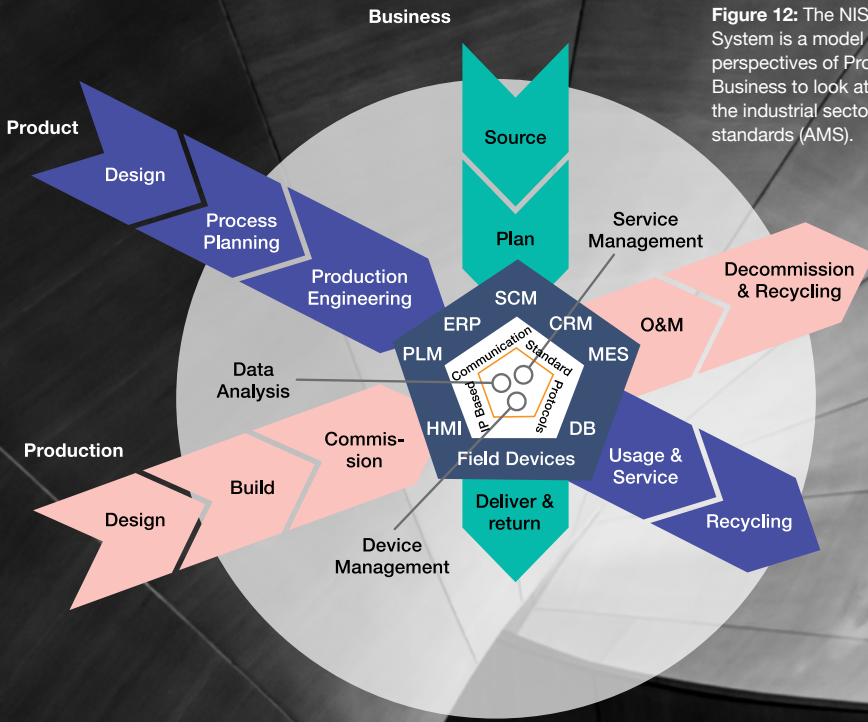
As part of ISO/IEC's work with *Smart Manufacturing (ISO/IEC JTC1, JWG21 and IEC/AWI 63339 Unified reference model for smart manufacturing)*, a project has been underway since the summer of 2017 with the aim of constructing a common reference model as a framework for standards



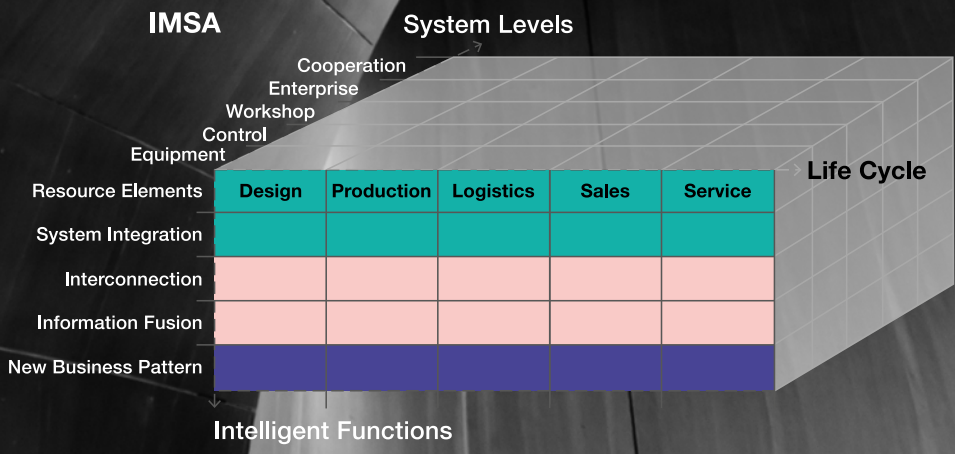
within the field of smart manufacturing. Within that work, there are a number of more or less well-known national proposals, industry initiatives and similar items as starting points. The best known of these is the German framework produced via that country's work with Industrie 4.0 – the Reference Architectural Model Industrie 4.0 (RAMI 4.0) model.

**RAMI 4.0** uses a multidimensional model of inventory to describe various aspects of industrial production. To illustrate the complexity involved, RAMI 4.0 is depicted in the form of a cube that shows elements and concepts, and how they relate to each other.

**Figure 11:** RAMI 4.0 is structured so that the first dimension represents the product lifecycle and the value-added flow based on the standard. The second dimension (vertical axis) represents interoperability, and the third dimension (the other horizontal axis) describes the hierarchy levels in a similar way to ISA's automation pyramid.



**Figure 12:** The NIST Smart Manufacturing System is a model that uses the three perspectives of Product, Production and Business to look at the digitalization of the industrial sector and link it to a set of standards (AMS).



**Figure 13:** IMSA covers three dimensions: lifecycle, system hierarchy and intelligent functions. The lifecycle dimensions describe value-creating steps. System hierarchy represents the organizational levels of manufacturing activities, while intelligent functions represent functions realized with IT, OT and digitization technology.

The cube (seen in figure 11) is structured so that the first dimension (first horizontal axis) represents the product lifecycle and the value-deriving stream based on the IEC 62890 standard and recognised through Swedish standard SS-EN IEC 62890. The second dimension (vertical axis) represents interoperability. The third dimension (the second horizontal axis) describes hierarchy levels in a similar way to ISA 95's automation pyramid and is modelled according to the IEC 62264 standard (Swedish standard SS-EN 62264).

**The National Institute of Standards and Technology (NIST)** is a US federal agency that sets standards. *Advanced Manufacturing Series (AMS)* is a set of standards from NIST for smart manufacturing systems (SMS) that together provide a cohesive reference model across three dimensions (see Figure 12) with the same ambition as RAMI. The 'product' dimension includes the six phases of the product-development lifecycle (design, process planning, production technology, manufacturing, use and service, and reuse/recycling). This perspective corresponds to the product lifecycle dimension in RAMI 4.0.

The 'production' dimension defines the five phases in the lifecycle of production equipment: design, construction, commissioning, operation and maintenance, as well as decommissioning and reuse/recycling. This perspective also corresponds to the RAMI 4.0 lifecycle & value chain, from the technology suppliers' perspective.

The third dimension, 'business', considers the phases of supply chain management according to a model called SCOR (Operations Reference Model). This perspective can also be compared with the lifecycle and value stream in the RAMI 4.0 model.

**Intelligent Manufacturing System Architecture (IMSA)** is China's approach to promoting standar-

dization work and the development of Chinese industry towards intelligent manufacturing. Developed by the Ministry of Industry and Information Technology (MIIT) and the Standardization Administration (SAC), the concept was presented in connection with the Made in China 2025 initiative, which has as its key focuses the integration of new information technology and the development of new materials, new equipment and machines.

IMSA can be seen as providing guidelines for standards that facilitate the interconnection of manufacturing processes within value chains. Interconnectivity and interoperability are considered the most important prerequisites for intelligent manufacturing concepts. The IMSA model (see Figure 13) is very similar to RAMI 4.0 and consists of the three dimensions: lifecycle, system hierarchy and intelligent functions. The lifecycle dimensions describe different value-creating steps. System hierarchy represents the organizational levels of activities at IT and OT levels according to the same principles as for the automation pyramid. Intelligent functions represents high-level functions using ICT and OT technology.

The development of international standards is not easy. In summary, there are currently both gaps and overlaps in the materials needed to digitalize the industrial sector. The key purpose of reference models is to create shared perspectives that open the way for consistent standardization which, in turn, allows interoperability to arise within industrial value systems. With this in mind, a common standard/meta model is under development within the working group JWG21 between ISO and IEC, with eight different models being compared and classified, including those described above.

## ● DIGITAL TWINS

*A digital twin can be described as a set of algorithms that so closely resembles certain objects or processes in the physical world that they can be used for predictions, experiments and tests, complementing or even replacing their real-world counterpart.*

The concept is usually traced back to NASA, who needed to develop and maintain technical systems with which they would not have constant contact. A benefit of digital twins is that they are always accessible, unlike their physical equivalent. In addition, they enable all stakeholders involved in the object or project in question to receive the same real-time information.

Within ISO/IEC JTC 1/SC 41, standardization work is underway for digital twins and the Internet of Things. One of the projects (PWI JTC1-SC41-5) concerns reference architectures for digital twins

that use a common vocabulary, reusable design elements and industrial best practice.

Within ISO, there is a standard called ISO 15926 which regulates data integration, sharing, exchange, and handover between computer systems. The purpose of ISO 15926 is to provide a common language for both computer systems and the information produced. While the standard was essentially set up for the process industry with its large projects involving many parties as well as requirements for operation and maintenance throughout the life of plants, it is

### **There are three main uses areas within the industrial sector:**

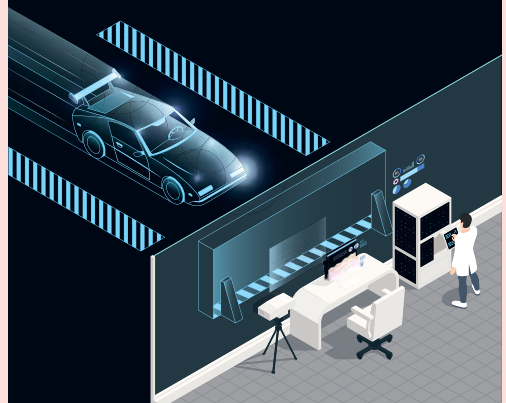
**1 Development and construction:** product development is increasingly being conducted via digital twins before real-world results are achieved. In the automotive industry, such twins consider the entire vehicle, its software, mechanics, electrical circuits, and physical behaviour, including in crash tests. This makes it possible to simulate and validate development and identify problems before the actual car parts are produced. The number of physical prototypes required can therefore be greatly reduced.

**2 Machines and processes:** real-world objects such as machines or composite production chains can supply measurable variables, such as speed, fuel consumption, temperature, pressure, and operating hours to their digital twins. This allows for inspection and troubleshooting to be done on the digital twin and for preventive maintenance models to be created using AI/machine learning and other methods. Giving the models simulation capacity through data that also addresses quality, costs, expected demand for a particular product produced, material supply and other business parameters means that they can contribute to achieving the vision of a self-organizing value system.

applicable to anyone with a need for common reference data. In Sweden, the Swedish Industrial Interoperability Association (SEIIA) has been formed through collaboration between the strategic innovation program PiiA and the Standard Solutions Group (SSG). Its purpose is to bring together the industrial sector and its suppliers in order to develop, provide and support the application of standards and methods in the field of interoperability. SEIIA is the result of the Life Cycle Data Management (LCDM) project within which some 15 industrial companies have participated.

**3 Facilities:** by supplementing each process's digital twins with facility data in the form of technical specifications and design and drawing data, entire factories can be viewed as digital twins. There are great advantages in being able to build multiple identical facilities that, through simulation, can be verified and run virtually before they actually exist in physical form. Existing facilities can be laser-scanned to keep 3D models up to date, avoiding the problem of the models becoming obsolete when changes in production layouts and flows occur in reality.

|| A benefit of digital twins is that they are always accessible, unlike their physical equivalent.



## ● CLOUDS AND DISTRIBUTED PLATFORMS

*As a distribution technology for computer power, cloud technology is one of the most important innovations of our time, perhaps comparable to the importance of mass production within industrialism.*

The IDC estimates that some 60 percent of all IT operations take place outside company walls, with that figure set to increase to 80 percent in 2025, according to Gartner. At the same time, the number of suppliers per company will also increase. This development can be put down to efficiency gains, flexibility and simplicity. The cloud reduces the cost of failures and makes success cheaper. These are basic growth drivers for a market that, according to Gartner, is approaching USD 260 billion and is undergoing intense consolidation, with

fewer and larger suppliers.

One definition of the term 'cloud computing' comes from the US National Institute of Standards and Technology (NIST) which describes a model that provides easy access to a combination of configurable computer resources (networks, servers, storage, software, and services) for both buyers and suppliers. There are additionally a number of prerequisites for an offer to be perceived as a cloud service: ►

Cloud Computing can be further described as a stack of services where the basic layers are:

- **SaaS (Software as a Service)** developed for end users and usually delivered via the web. SaaS is a fast-growing market where the service is delivered from one to multiple users, with APIs that integrate the applications.
- **PaaS (Platform as a Service)** – a set of tools and services for coding and distributing software. As development progresses, the concepts of the services are refined. For example, there is aPaaS (application Platform as a Service) which specifies application development within, for example, IoT or data analysis. Microsoft, Salesforce, IBM, SAP and Google are fighting for the leading market positions. Within the OT area, there are established collaborations within the automation industry. ABB works with Microsoft in the ABB Ability concept, while Siemens works with IBM and SAP in MindSphere.

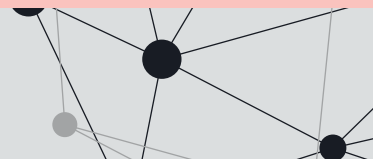
- **IaaS (Infrastructure as a Service)**

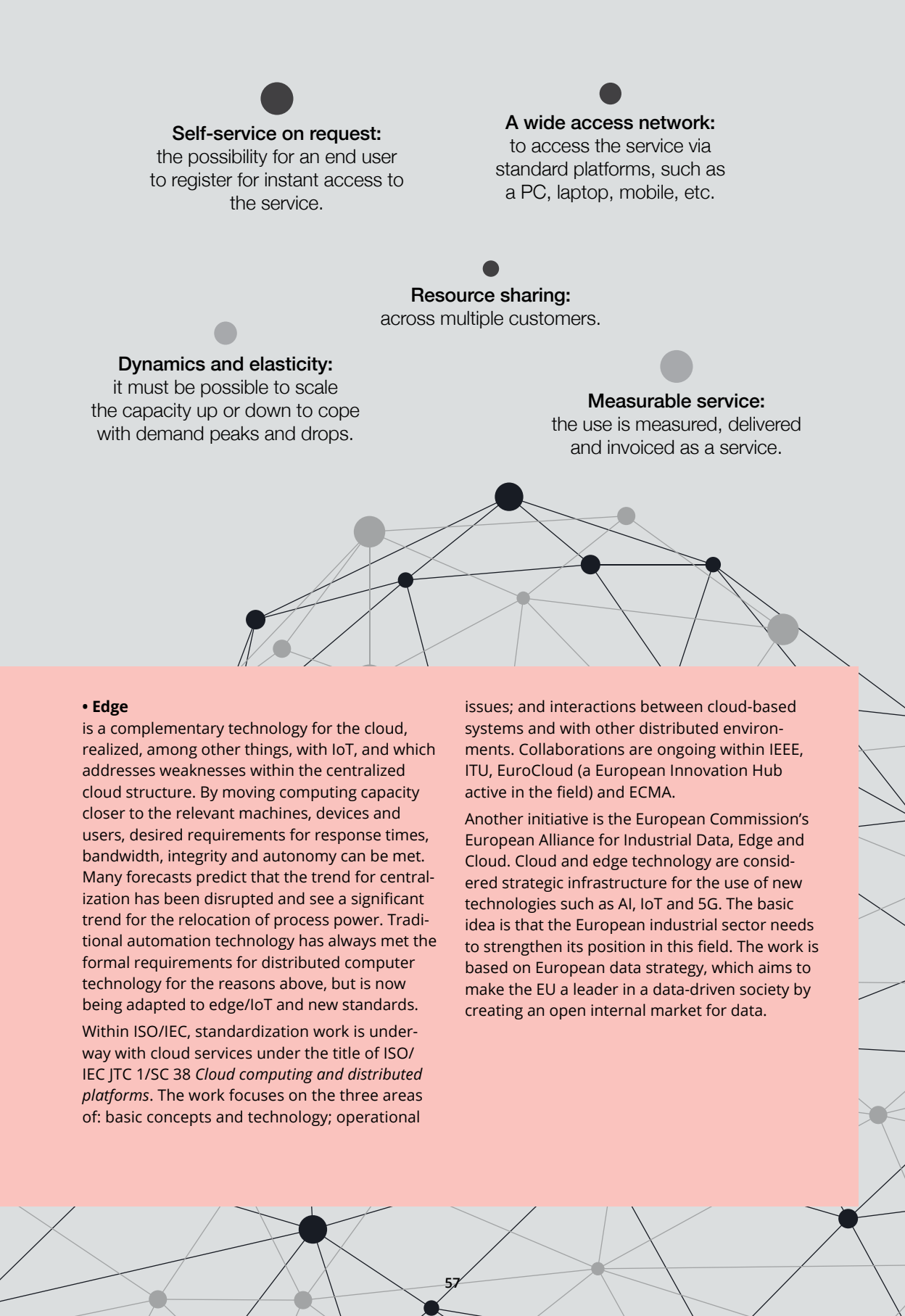
is hardware and software that drives servers, storage, network and operating systems. The business model is based on making it easier and cheaper to buy services instead of investing in systems and expertise. Amazon was an IaaS pioneer and has grown to become the world's largest cloud provider, followed by Microsoft.

Other current concepts are:

- **Hybrid clouds**

where a private cloud (a distinct data centre) and a public cloud, provided for example by Amazon or Microsoft, are combined. Hybrid clouds make it possible to segment information according to security classification and provide good control over the operating environment. Data can be moved between the private cloud and the public one to optimize security and costs. Business-critical information can, for example, be handled in the private sector while the company's website is placed in the public cloud to cope with traffic peaks.





**Self-service on request:**  
the possibility for an end user to register for instant access to the service.

**A wide access network:**  
to access the service via standard platforms, such as a PC, laptop, mobile, etc.

**Resource sharing:**  
across multiple customers.

**Dynamics and elasticity:**  
it must be possible to scale the capacity up or down to cope with demand peaks and drops.

**Measurable service:**  
the use is measured, delivered and invoiced as a service.

• **Edge**

is a complementary technology for the cloud, realized, among other things, with IoT, and which addresses weaknesses within the centralized cloud structure. By moving computing capacity closer to the relevant machines, devices and users, desired requirements for response times, bandwidth, integrity and autonomy can be met. Many forecasts predict that the trend for centralization has been disrupted and see a significant trend for the relocation of process power. Traditional automation technology has always met the formal requirements for distributed computer technology for the reasons above, but is now being adapted to edge/IoT and new standards. Within ISO/IEC, standardization work is underway with cloud services under the title of ISO/IEC JTC 1/SC 38 *Cloud computing and distributed platforms*. The work focuses on the three areas of: basic concepts and technology; operational

issues; and interactions between cloud-based systems and with other distributed environments. Collaborations are ongoing within IEEE, ITU, EuroCloud (a European Innovation Hub active in the field) and ECMA.

Another initiative is the European Commission's European Alliance for Industrial Data, Edge and Cloud. Cloud and edge technology are considered strategic infrastructure for the use of new technologies such as AI, IoT and 5G. The basic idea is that the European industrial sector needs to strengthen its position in this field. The work is based on European data strategy, which aims to make the EU a leader in a data-driven society by creating an open internal market for data.

## ● INDUSTRIAL DATA

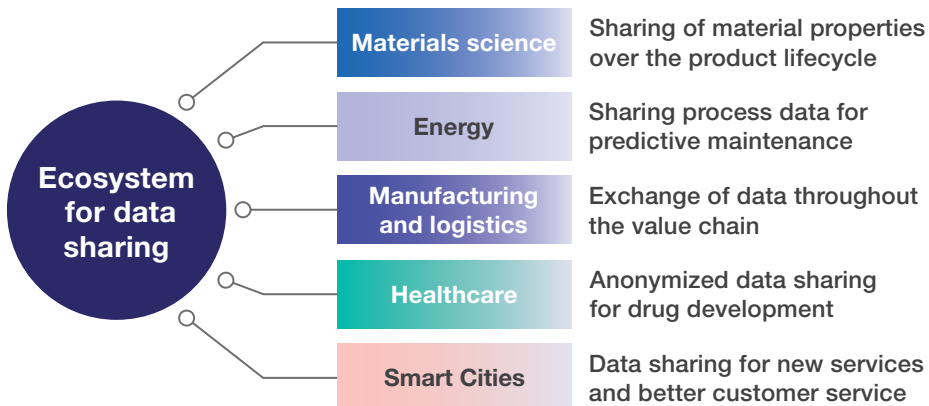
*In a digitalized world, data (including customer data, product data, production data, and logistics data) is a key factor for enabling companies to meet their customers' increasingly advanced requirements.*

The value of data is changing in relation to the development of business processes, with data becoming an increasingly valuable part of business models. Given this, being able to handle data in the same way as any other corporate asset is becoming important for maintaining competitiveness. A need exists to be able to value data beyond its place in traditional economic models involving purchasing, production and customer value. Data needs to be managed across the borders between different domains and categorized according to whether it is open public data, company-owned, internal data or one of the

many degrees of more or less openly shared data within different types of alliances.

All of these issues ultimately lead to a need for architectures and regulations for technical solutions and standards for efficient data ecosystems and marketplaces. Standards that guarantee data security and data protection for all parties involved create mutual trust and ensure similar conditions and respect of data sovereignty for all data owners.

Within ISO/TC 184/SC 4 Industrial data, standards are developed based on the fact that funda-



**Figure 14:** Data sharing in a cross-market ecosystem. With IDS Architecture, the International Data Spaces Association sets a standard for data exchange on a self-regulated basis. This is known as a standard for data sovereignty.

Source: International Data Spaces Association



## II Standards that guarantee data security and data protection for all parties involved create mutual trust...

mental similarities exist between sectors and that industrial data in itself can be regarded as a product (of industrial processes) to be used for activities in the production system. In this context, two models are used that partly describe the industrial environment within which ISO/TC 184/SC 4 standards are applicable by describing hierarchical structures in the supply chain. This, in part, highlights similarities between the types of information in the environments through the Life-Cycle Activities (LCA) model, which defines a generalized set of lifecycle activities.

Through the German initiative 'Industrial Data Space' with its representatives from industry,

politics and academia (with the Fraunhofer Institute in an instrumental role), the issue of industrial data began to be addressed in 2014. The initiative has progressed and is today called the International Data Spaces Association and has over one hundred member companies/organizations, most of them still German. A key task has been to propose reference architecture for data exchange and standardized interoperability.

Within Sweden's SIS, work with industrial data and interoperability is influenced by SIS/TK 280, which pertains to standards in industrial automation and smart manufacturing.



## ● INTEROPERABILITY

*From a holistic perspective, industrial digitalization is all about integration. This means bringing together the value chain's system support (vertically and horizontally) so that it can be seen as a whole from different specific perspectives and needs.*

Using a metaphorical image of development, we can see that pyramid-shaped system hierarchies are being transformed into networks and ecosystems of cyberphysical systems within the cloud. With this in mind, interoperability is *the* central concept in digital transition, enabling different systems to work together and to communicate with each other. Some examples of this might be that systems can use the same protocol, such as TCP/IP or HTTP, or that they are able to read and write the same file format or use the same semantic definitions.

In addition to the ability for two or more computer systems to exchange information, semantic interoperability provides the ability to automatically interpret the information exchanged to provide useful functionality in the relevant systems. In order to achieve semantic interoperability, further standardization is needed as well as a common reference model for the exchange of information. A number of reference models and architectures (see the section on reference models) have been developed in recent years in the form of physical



||... the ability of different systems to work together and be able to communicate with each other.

architectures for system components (automation systems, machines, software and production sections). The functional architecture represents the set of processes that will be performed, while the allocated architecture describes the match between the functional and the physical architecture. As mentioned, architectural models have been proposed by Platform Industrie 4.0 and also by the Industrial Internet Consortium (IIC), two of the largest organizations involved in industrial digitalization at the production level.

Within ISO, work is being done to develop standards for interoperable systems within ISO/TC 184/SC 5 – *Interoperability, integration, and architectures for enterprise systems and automation applications*. The Chair is Charlotta Johnsson from Lund University. The working groups include: *Modelling of Architectures*; *KPIs for manufacturing*; *Evaluation of energy efficiency and other factors relevant to environmental impact*; *Convergence*; and *Mass Customization*.

AI functionality is generally built into IT and OT systems and is becoming easily accessible and matter of fact.



## ● DATA ANALYSIS AND AI

*A clear value-creating opportunity within industrial digitalization is data analysis using mathematical/statistical methods including AI and machine learning.*

This conceptual apparatus also includes Big Data. In other words: the potential for managing very large amounts of data to achieve results that would not otherwise be possible.

As early as the 1970s, advanced online analyses were being made of production processes in sectors including the process industry, with the chemical, steel and mass production sectors also able to benefit from newly gained computing capacity via mini and microcomputer systems. Many of these algorithms are still in use in factories today and have proven able to withstand modern competitors surprisingly well. But what is now on offer is cheap, almost unlimited computer power wherever it is needed and machine learning systems that are evolving at a mindboggling pace. Much of this will be provided by the industry as standard products. AI functionality is generally built into IT and OT systems and is becoming easily accessible and matter of fact. It is increasingly a matter of how equipped the industrial sector is to make use of the opportunities available rather than a question of shortcomings in supply.

As AI, like digitalization in general, is a generic technology that can be used everywhere, for almost anything, standardization will also need to be adapted for different application areas. Self-driving cars have many more prerequisites for use than do surgical robots or processes to optimize a paper mill.

Broad technologies such as AI have the ability to continue to influence future generations through their long-lasting impacts. Many of these effects

are economic, such as the impact of AI on the industrial sector as a whole and on the workforce. Others fall into areas such as algorithmic distortion or eavesdropping and security directives in industrial AI. For example, how can algorithms be trained in a safe way and then, if necessary, be re-trained to work correctly? How can AI systems be prevented from correlating incorrect pieces of information or basing decisions on (inappropriately) biased factors such as age, gender or ethnicity? How can we ensure that a robot working with a human operator does not endanger the health of its human colleague?

This is where ISO/IEC's international standardization work comes in, with the SC 42 subcommittee addressing AI as an ecosystem with many different stakeholders. This includes aspects of AI that require a common vocabulary and common taxonomy and definitions. Eventually, such standards will form a common way of speaking. Another basic job is to track academic and commercial development from a technical and conceptual perspective. A third focus area is examining the credibility of the technology, with everything from security and integrity to the robustness, transparency and bias of systems being considered. The fourth focus area is to identify application domains, the contexts in which AI is used and to collect representative user cases. Autonomous driving and transport, for example, is one such category. Another example is using AI in the manufacturing industry to achieve efficiency improvements.

## ● AUTOMATION SYSTEM AND IIOT

*The Industrial Internet of Things is an area of development with somewhat grey boundaries. As open infrastructure for data collection and control, IIoT can function independently, but the real benefits come with integration with existing IT and OT environments.*

IIoT's architectures and open standards are gradually completely replacing older proprietary automation systems. The overall goal is interoperability within the OT environments and also in relation to the IT of companies. The difference between IoT and IIoT is the higher demands on performance, robustness and security required by the latter. From a development/cost perspective, IoT hardware and system product platforms can be shared with other demanding application areas, such as transport, real estate and healthcare. Development costs can be spread over markets many times greater than traditional industrial automation, while at the same time making the industrial market interesting for new suppliers. Industrial Control Systems (ICS) is the collective term for products that can monitor, control and optimize production processes. ICS can be divided into the three traditional categories: PLC, DCS and SCADA. IIoT is now also considered to be part of this product area, with functions including sensors, measuring technology and actuators.

Through ISO/TC 184, standardization in the area of automation systems is being monitored across

processes for everything from design, purchasing, manufacturing and production and delivery through to support, maintenance and product recycling. Standardization areas include information systems, automation and control systems, and integration technologies.

Within IEC, activities related to industrial measurement, control and automation have since 1968 been gathered together within IEC TC 65. This committee develops standards for systems and equipment for industrial process control and automation. The area is wide, and significant results have been achieved in areas such as safety-critical functions and OT security. Current focus areas include networks with low latency (TSN) and digital information management ('Asset Administrative Shell'). IEC TC 3 works, among other things, with standards for data elements. Swedish participation takes place through SEK TK 65 and SEK TK 3 respectively within the SEK Swedish Electricity Standard.



|| The goal is interoperability within OT environments...

- **PLC (Programmable Logic Controller)** was originally a simple computer system for logical program sequences. Common application areas are machine control in the manufacturing industry. PLC originated in the 1970s automotive industry as a replacement for relays, pneumatics and transistor technology.
- **DCS (Distributed Control System)**, originally developed for the process industry and combines process instrumentation with the management of digital objects and logical functions.
- **SCADA (Supervisory Control and Data Acquisition)** is a term for systems that communicate with PLC, control systems and remote terminal units (RTUs) and combine them with operator environments and storage space for, for example, trend and event data.
- **IIoT (Industrial Internet of Things)**, considered by many to be the development of the above concepts through open standards such as OPC and also new standards. The Industrial Internet Consortium and Industry 4.0 are two independent initiatives working for common standards. Built-in web servers in DCS, PLC and SCADA systems also enable these environments to be integrated with the IIoT concept.



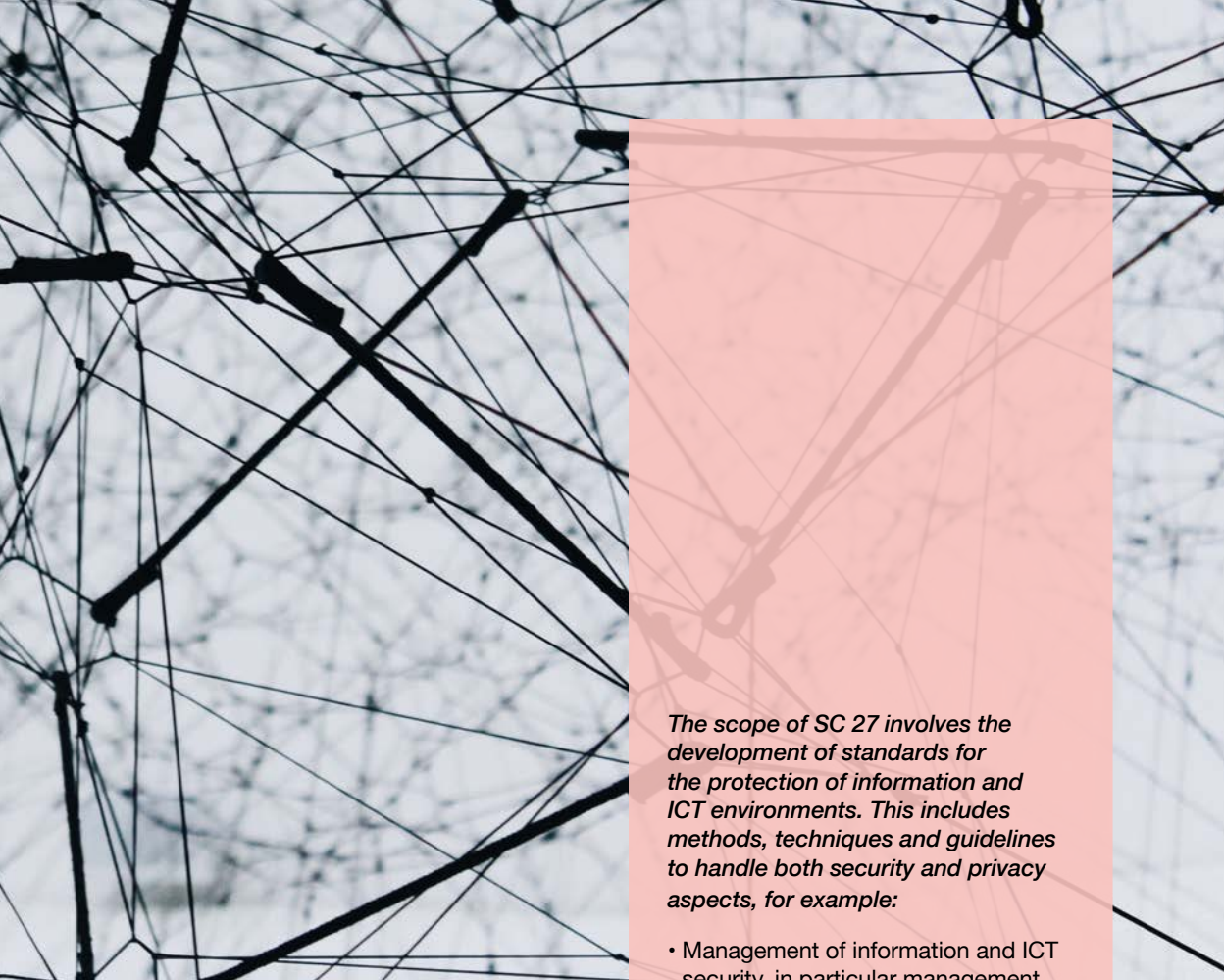
## ● INFORMATION SECURITY

*For a company, information can be considered an asset that needs attention in the same way as its personnel, fixed assets and patents.*

Systematic work with information security contributes to an operation's overall quality and can involve implementing and managing regulations, policies and guidelines, and also technological protection such as firewalls, encryption and physical protection. Starting this work using established standards within the field of information security increases the chance of success.

Within ISO/IEC, this area is managed through the work of ISO/IEC JTC 1/SC 27 *Information security,*

*cybersecurity and privacy protection.* SC 27 is an internationally recognized expert centre that supports both the business community and official bodies. Its work includes both administrative and technical standards. SC 27 has brought together many of the world's leading experts within information security. Work to date has led to more than 180 publications, resulting in one of the three most widely used standards within all ISO categories.



The development of generic standards has led to a large amount of contact and many collaborations involving standardization and industry organizations who use SC 27 standards as the basis for developing their own sector-specific safety standards.

With OT systems in mind, IEC TC 65 has developed international standards series IEC 62443, which looks at information security in OT systems. It focuses on which levels of protection are needed and how to achieve them. IEC 62443 has been written in collaboration with the American organization ISA and is therefore sometimes referred to as ISA99.

*The scope of SC 27 involves the development of standards for the protection of information and ICT environments. This includes methods, techniques and guidelines to handle both security and privacy aspects, for example:*

- Management of information and ICT security, in particular management systems for information security (ISMS), security processes, security controls and services.
- Cryptographic and other similar security mechanisms to protect data.
- Support documentation for security management including terminology, guidelines and registration procedures of safety components.
- Security aspects of identity management, biometrics and personal privacy.
- Requirements for assessment of conformity, accreditation and audit in information security.
- Safety evaluation criteria and methodology.

PART

# 3



A person is holding a handheld scanner, likely a Microsoft Kinect, against a background of bokeh lights. The scanner is black and has a lens on the front. The background is dark with many small, out-of-focus light spots in shades of yellow and white.

During the 4S project's operational period, a number of development projects with focuses on the digitalization of industry have been examined. This section provides a brief summary on the nature of these projects, as well as their stakeholders, challenges and outcomes.

# 4S'S LEARNINGS

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from industrial programs

*During the 4S project's operational period from 2019 to 2021, it addressed and examined a number of different development projects with varying perspectives on the digitalization of the industrial sector. The purpose of this exercise was to provide financial support to highlight the issue of standardization within various contexts. In this section, the nature, stakeholders, challenges and results of these projects are presented. In addition to the projects presented, projects including Smart Steel, Safety Standards for Collaborative Applications and Summit also received guidance or financial support through 4S.*

## **Projects**

**Nationell testbädd smart produktion**

**Digitala Stambanan**

**Digitala Stambanan – Forskningsutbyte**

**Internet of DevOps**

**Life Cycle Data Management – LCDM**

**Kirurgens Perspektiv**

**Innovative Agile Construction for Globally improved Sustainability – Acon4.0**

**Digital produktionsinfrastruktur – DigIn**

**Digitalisering av läkemedelslabb för processutveckling och pilotproduktion**

**Demonstration of Infrastructure for Digitalization enabling industrialization of Additive Manufacturing – DIDAM**

# Nationell testbädd smart produktion (National Test Beds for Smart Production)

## Project manager's contact information:

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Powertrain Manufacturing for Heavy Vehicles Application Lab (PMH)  
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henser@kth.se, www.pmh.itm.kth.se

## GENERAL PROJECT OVERVIEW

The project forms part of the 'National Test Beds' projects funded by Vinnova's Produktion2030 program. PMH's test bed has been developed around a five-axis CNC multi-operation machine as a sub-project within this project. Its goal is to increase the use of digital technology by Swedish manufacturing companies and thereby increase competitiveness. The concept of the PMH test bed is to provide a test and validation platform for the manufacture of drive trains in a value chain geographically spread over several locations.

Within the framework of the initiative 'SwedishGerman testbed for smart production', demonstrations have been made with PMH on KTH's campus. KTH has served as the central node and location for PMH's partners (Fraunhofer IPT in Aachen and Fraunhofer IWU in Chemnitz, Germany) to show concepts to industrial partners wanting to test and validate the connection of their sites to a production environment spread over several locations.

## PARTIES INVOLVED

Participants: Teknikföretagen, Chalmers, KTH, Scania, Volvo, Sandvik Coromant, PDS Vision Group, Virtual Manufacturing Sweden.

Financed by (cash contribution): Vinnova.

Financed by (co-financing): Scania, Volvo, Sandvik Coromant, PDS Vision Group, Virtual Manufacturing Sweden

## PROBLEM ADDRESSED (REFERS TO PMH'S PART OF THE PROJECT)

The research questions below were addressed in PMH's test bed:

1. Can a digital infrastructure for a geographically dispersed value chain in combination with suitable sensors provide details of the current technical condition of a component of such a value chain with the help of a digital twin, regardless of where the process owner is located?

2. Can model-based data analysis tools, provided in a cloud system, enrich the information in the digital twin with the help of simulation tools in such a way as to generate a realistic image of the component?
3. Is it possible to correctly evaluate the current quality and to extrapolate the final quality of a component from data stored in a digital twin?

## RESULTS AND EXPERIENCES

The results of the project include a digital infrastructure with various solutions for collecting and monitoring data and performing analyzes to improve manufacturing results. To succeed in this, standards for information management are a requirement. Both the use of and participation in the development of standards has been an important part of the project. The standardization activities that the researchers in the project have been involved in are:

- ISO/TC184/SC4/WG 15: ISO/DIS 23247 *Digital twin framework for manufacturing*

In this work group, PMH has participated in a successful demonstration in collaboration with STEP Tools Inc, Sandvik Coromant and the Association for Manufacturing Technology, AMT, [https://youtu.be/wbsC\\_qzB8us](https://youtu.be/wbsC_qzB8us)

- ISO/TC184/SC5 WG 10: *Evaluating energy efficiency and other factors of manufacturing systems that influence the environment*
- ISO TC 184/SC 5/WG 13: *Equipment behaviour catalogues for virtual production system*

## ADDITIONAL INFORMATION

In addition to the 4S project enabling active participation in standardization activities in the above-mentioned ISO work groups, membership for KTH in SIS for participation in TK 280 has been made possible.

## Digitala Stambanan (The Digital Main Line)

### Project manager's contact information:

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+46 73-072 35 00

### GENERAL PROJECT OVERVIEW

The goal of the Digitala Stambanan (The Digital Main Line) project was to clarify the currently limited picture we have of the needs of digital value chains, platforms and digital markets in the industrial sector. The improved picture is to be used to disseminate knowledge and demonstrate to decision-makers and companies, especially in the segment of small and medium-sized companies, opportunities and challenges in the transformation to digital value chains.

The project focused on data transfer in the interface between companies and organizations in value networks.

The needs map produced was developed based on identified needs in both the process and the manufacturing sectors that provided insights to create and develop proofs-of-concept within the application of digital platforms and digital technology. The work was carried out together with the project's value chains, technology companies, academia and network organizations to describe the requirements for The Digital Main Line in the form of various case studies.

### PARTIES INVOLVED

- In 2018, the collaborative project Digitala Stambanan started, initiated by the strategic innovation programs PiiA (Process Industrial IT & Automation) and Produktion2030. The project, which lasted from 2018 to 2020, was financed through the government's collaboration program 'Uppkopplad industri och smarta material'.
- The project included 28 parties from academia, research institutes, network organizations and industry (22 all in all). Together in the project consortium, seven industrial value chains were explored and mapped, from raw material extraction, via various supplier stages through to the final manufacturer (OEM).
- The project has also focused on information and knowledge dissemination outside the project consortium for increased effects on the industrial sector as a whole.

### PROBLEM ADDRESSED

Sweden is one of the world's most competitive export countries, but industrial digitalization is changing

conditions for everyone. This is why Swedish industry needs to quickly create an efficient digital infrastructure and a strong ability to compete in the new global digital market. Sweden needs a new 'digital main line' or digital infrastructure, to enable data streams that create value in flows between companies in a digital market. The digital main line connects the entire industry, from raw material suppliers, through the process industry and the manufacturing industry, to consumers. The combination of the digital and physical interconnection of supply chains enables a competitive Swedish industry.

### RESULTS AND EXPERIENCES

The project's results from examining value chains provided insights and concrete proposals for value creation via digitalization. A synthesis of the insights, in the form of both opportunities and challenges with digitalization, were compiled in a 'travel guide'. The purpose of the travel guide is to facilitate the digitalization of the industry by presenting a structured way of working when dealing with digitalization. Demonstrators were created in a lab environment. A neutral platform for knowledge and exchange of experiences was created by establishing Digitala Stambanan as a brand and concept, which satisfies the sector's desire for continued collaborative work.

### ADDITIONAL INFORMATION

One of the concepts of interest within the project was digital twins and there was an exchange with ISO's standard ISO 23247 'Digital Twin Framework for Manufacturing', which is under development. The project also provided insights into the value of digital twins in the manufacturing industry via interviews with project participants representing users in the sector, which have been published in the article:

**Barring, M., Shao, G., & Johansson, B. (2020).** *Digital Twin for Smart Manufacturing: the Practitioner's Perspective. Proceedings of the ASME 2020 International Mechanical Engineering Congress and Exposition.*

Volume 2B: *Advanced Manufacturing*. DOI: <https://doi.org/10.1115/IMECE202024037>.

## Digitala Stambanan - Forskningsutbyte (Research Exchange)

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### GENERAL PROJECT OVERVIEW

Digitala Stambanan (The Digital Main Line) aims to increase the exchange of information and data flows between operators in a value chain to support collaboration and strengthen competitiveness. Interoperability is a prerequisite for the success of the exchange of information as well as the use of existing data in various information systems. The background to the Research Exchange was the implementation of standards to support the exchange of information.

### PARTIES INVOLVED

- Digitala Stambanan project partners and the financier Vinnova
- NIST where the research exchange was carried out
- ISO and SIS as the work showed an extended use of existing standards

### PROBLEM ADDRESSED

Developing virtual models of production equipment – and more specifically of CNC machines – with their tools to support decisions across several stages of the production process is common in the industry today. It is also desirable and common to share virtual models between functions within the same organization, and also between organizations. This is where a problem arises in exchanging information about such models between different computer-aided programs (CAx) such as CAD. The ISO standard 10303, also called STEP, has been developed to support the exchange of data regarding models in a standard format, but today only geometric data can be exchanged automatically while kinematic data is lost.

### RESULTS AND EXPERIENCES

Through the project, a method was developed for the extended use of the ISO standard 10303 (STEP) so that a complete STEP file could be created with both geometric and kinematic data. This was to open the way for information sharing and to create interoperability between

different CAD programs, as it is common to use several CAD programs within an organization and in different organizations.

### ADDITIONAL INFORMATION

The results were presented to the standardization group ISO TC 184 SC 4 WG 15 'Digital Manufacturing' at a meeting in November 2019. The results have also been published in a conference paper for the ITU Kaleidoscope and were presented at the conference in the fall of 2020.

Barring, M., Shao, G., Helu, M., & Johansson, B. (2020). *A Case Study for Modeling Machine Tool Systems Using Standard Representations*. 2020 ITU Kaleidoscope: Industry Driven Digital Transformation (ITU K), 18.

DOI: 10.23919 / ITUK50268.2020.9303218

# Internet of DevOps

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## GENERAL PROJECT OVERVIEW

Participation in an international IEC/ISO standardization project to develop an ISO and IEC Standardized reference model for Smart Manufacturing. An important input from SIS/TK 280 'Information and automation in the product life cycle' is the Scandinavian (Sweden and Norway) framework for smart industry, SSIF 'Scandinavian Smart Industry Framework'. IEC/ISO Joint Working Group 21 Smart Manufacturing Reference Model (s) is a collaborative project for smart manufacturing between the parties of ISO and IEC that works with *Industrial standardization ISO/TC 184 Automation systems and integration* and IEC/TC 65 *Industrial process measurement, control and automation*.

JWG21 began with a feasibility study between 2016 and 2018 that analyzed the 16 participating countries' frameworks for Smart Manufacturing/Industry from their national perspectives. This resulted in the technical report IEC/DTR 63319 *A metamodelling analysis approach to smart manufacturing reference models* (JWG21 Smart Manufacturing Reference Model(s)). Thereafter, work began on the development of ISO and IEC standards. IEC/AWI 65815 *Unified Reference Model for Smart Manufacturing URMSM* will be a uniform, standardized reference model for Smart Manufacturing/Industry based on 16 national inputs exemplified by the US, German and Scandinavian frameworks.

URMSM is not a first model, but a specification for a family of reference models with different purposes that share structural and behavioural characteristics intended to promote interoperability. The purpose of each of these reference models is to enable developers of smart manufacturing standards and smart manufacturing practitioners to have better opportunities to implement models of production systems and products that take full advantage of technological innovations.

## PARTIES INVOLVED

Experts on the research group are nominated via SIS, the Swedish Institute for Standards. In addition, participants in Sweden include Syntell AB, KTH, LTH and Eurostep.

## PROBLEM ADDRESSED

To find a solution to the lack of standardized integrated models for manufacturing, products and industrial

ecosystems over their lifecycles, including access to the standards needed to achieve semantic interoperable information exchange (when implemented in digital technologies, whose developers are the first target group).

## RESULTS AND EXPERIENCES

In order to develop a common reference model, a meta-model-based method was first created in order to analyze and standardize the different description methods of the national frameworks. Here, the Scandinavian team helped to initiate the meta-model-based attack method that proved successful for the analysis. URMSM's standardized description methods make the models developed for different industrial needs compatible, which also includes models of the environment in which products are manufactured and used. Being able to integrate models of the product with models of the environment is important, particularly in the context of a sustainable transition.

In order to be able to achieve an overall description of all the information from the national frameworks, the information in URMSM needed to be structured mathematically in descriptive dimensions. Here, the Scandinavian team helped to explain the difference between mathematically handling 1-n dimensions in the model and being able to graphically show more than three dimensions.

Through the mathematical description model and its dimensions '*Industrial areas of knowledge*' with uniform concepts, users can develop models with the selection of dimensions that are needed.

The Scandinavian team is contributing specifically in that the SSIF 'Scandinavian Smart Industry Framework' is built up of dimensions according to similar principles as URMSM. SSIF has semantic "space" in the middle that expresses common semantics for the selected areas of knowledge (here six dimensions). Semantics is proven to be central to URMSM, and the Scandinavian team has made a strong contribution to the principles of semantics.

The theory of this (Semiotics) is illustrated by the semiotic triangle with its three distinct corners: Concept, Symbol (Term) and Real Phenomenon. This means that each Symbol on the dimension axes in the 'SSIF Cube' is linked to the concept that gives meaning to the real phenomenon referred to by the term. The Real Phenomenon organization can, for example, be anything from a corporate entity to a boat club.

## Life Cycle Data Management - LDCM

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### GENERAL PROJECT OVERVIEW

LCDM (Life Cycle Data Management) started as a project within PiiA to increase knowledge of industrial interoperability within the Swedish process industry. The LCDM initiative demonstrated that the issue – and the industry's need to have it addressed – were great. This led the industry to decide that a Swedish representative was needed to engage in both international standardization work and in Swedish standardization work within SIS, where there was a lack of representation on SIS committees. As a result of the LCDM project's final report, the Swedish Industrial Interoperability Association (SEIIA) was formed.

### PARTIES INVOLVED

Today, SEIIA has 30 members, and right from its earliest days the following industrial companies have been involved in and contributed to the formation of the association through the LCDM project: Stora Enso, SCA, Holmen, ABB, Siemens, Eurocon Sitebase, SSG, AFRY, Preem, XEAM, Plan B, Symetri, ForsCon, Roboet. Current members can be found on the website <https://seiia.se/medlemmar/>

### PROBLEM ADDRESSED

Many facility owners in the process industry have long had views on the problem area of the exchange of information from Projects to Management. Much of the information that needs to be exchanged is bound up in various document solutions, and manual work has been required to extract data for use in management systems and ERP/Maintenance systems. Knowledge of the international standards that exist in this area has been poor and adoption more or less non-existent. ISO 15926 is one of the most significant standards.

### RESULTS AND EXPERIENCES

During the LCDM project, an international network was created involving industry players who have been dealing with the same problem situation that we have long observed in Sweden. This network provided insight into

the solutions used in other industries internationally, with the oil & gas Industry proving to be at the forefront. Norway has taken a leadership position managing the development of ISO 15926 and has been addressing the issue for the past 30 years. Today, SEIIA is part of an international network that actively participates in ISO work within TC184SC4WG3 and WG22. We are trying to influence SIS and TK280 to prioritize the issue beyond the product perspective (ISO 10303), which is its historical commitment. The proposal is that the issues facing the process industry should form the basis of a separate working group within TK280 as there are other standards that are also closely related to this work, such as IEC/ISO 81346. A name change for TK280 is also proposed with 'production' being added to the title.

### ADDITIONAL INFORMATION

Those who are involved in SEIIA are quite satisfied with the impact we have made since we started the first LCDM project in 2017. A confirmation of this is that Vinnova in its call for proposals for the Swedish *'Forum för standardisering i digitaliserad industri'* (Forum for Standardization in Digitalized Industry) wrote that the project should sync its work with SEIIA, as it was the organization that had advanced the issue within the Swedish process industry. We are also involved in a new project where we will participate and shape PiiA's future calls for proposals and also help shape the view of interoperability. Otherwise, there is a risk that players within this area will continue to reinvent the wheel due to a lack of basic knowledge about what has already been done and established in terms of industrial solutions/standards for industrial interoperability.

## Kirurgens Perspektiv (Surgeon's Perspective)

### **Project manager's contact information:**

*Kiet Tran (medicine)*

*Anders Robertsson (technology), and others.*

### GENERAL PROJECT OVERVIEW

Currently, reports created following a surgical operation consist of an account in words, which the operating physician and their core team can understand. One goal is to improve future surgical reports so that they also consist of moving 3D images. In this way, they can become more comprehensive and more comprehensible to a larger audience. In addition, they will be able to be used for learning, for example within medical education or by other doctors undertaking similar surgeries. Collecting the images needed to facilitate moving 3D images requires robotics that can ensure that the cameras involved follow the surgeon's field of vision. The goal is to provide the healthcare sector with modern surgical reports. This would enable increased learning around surgery and healthcare, which in turn would also lead to fewer mistakes and thus increased accessibility within operating rooms.

### PARTIES INVOLVED

The project was funded by Vinnova, more specifically by the *Utmaningsdriven Innovation* (Challenge-Driven Innovation) program (step 1 and step 2). Participants in the project include Skåne University Hospital (SUS), Lund University (LU), and a number of companies in the medical and technology industries. The project was started in 2016. The project is still ongoing today but has no funding from Vinnova.

### PROBLEM ADDRESSED

Sweden enjoys advanced healthcare. The new opportunities that digitalization brings, with the introduction of new technological aids and tools, creates the potential to take another step forward in advanced care. The project addresses opportunities in robotics use, image processing, and 3D technology in surgery; before, during and after an operation.

### RESULTS AND EXPERIENCES

Today, a camera installation with seven cameras hangs in the operating room at SUS in Lund and several operations have been recorded. Some initial attempts have also been made to investigate whether it would be possible for the cameras to project images into the open surgical wound, for example as markers for where each stitch should be placed to give the sutured wound the highest possible durability. Initial attempts have also been made regarding a user interface for those who are watching the recorded material. Discussions have taken place around which standards exist (and which do not exist) in the field of medical technology, mainly in the field of collaborative robots (SIS TK278).

### ADDITIONAL INFORMATION

The 4S project has been involved in financing memberships in SIS for some time. This has been very valuable for the participants in the project to gain insight into the possibilities and limitations set by standards, as well as knowledge of which new standards are in demand in the field of medical technology.

# Innovative Agile Construction for Globally Improved Sustainability - Acon4.0

## **Project manager's contact information:**

*Anders Robertsson (control technology) and Mathias Haage (computer science), Lund University, and others.*

## **GENERAL PROJECT OVERVIEW**

The construction industry has major problems around productivity, building quality, gender equality, safe working environments, and environmental impacts. Today's tools are developed to support existing value chains and construction systems and can be seen as part of the sector's problems. The Acon project is working to develop solutions in construction by: reducing the current fragmentation of the construction industry; linking digital design to production automation; developing safer and more equal workplaces; and developing adapted robotization for collaboration with workers on the construction site.

## **PARTIES INVOLVED**

The project is funded by Vinnova, more specifically by the *Utmaningsdriven Innovation* (Challenge-Driven Innovation) program (UDI step 1 and UDI step 2). Participants in the project include Lund University (LU), as well as a number of companies in the construction industry (Cementa, Peab, FOJAB, AChoice, Cognibotics). The project was started in 2019.

## **PROBLEM ADDRESSED**

The construction industry has annual sales of approximately SEK 500 billion and the value of the property portfolio can be estimated at just over SEK 6 trillion, with 500,000 employees in 20,000 companies.

The construction industry is very sensitive to economic changes due to low margins and it is also globally one of the least digitalized industries, with the lowest increase in productivity.

The project aims to develop solutions in construction by connecting digital design to production automation connected throughout the entire chain. The goals are to: show new methods for small-scale productive robotics at a low investment cost; to digitally and modularly develop a robot-adapted and customer-driven construction system (mass customization); and to introduce automation in the construction industry that offers better ergonomics and reduces the number of workplace accidents to

the same level as other sectors in Sweden. This, in turn, would also provide the long-term conditions needed to increase equality and a sustainable society.

## **RESULTS AND EXPERIENCES**

At the Centrum för Byggrobotik (Centre for Building Robotics), LTH, Lund University, the project partners have developed both a mobile robot system with a conventional industrial robot and a parallel kinematic robot that is integrated into the digital tool chain for both updating digital models and sensor-based feedback for robustness. The mobile robot has been used in field studies at construction sites and both systems can be used in so-called prefabricated manufacturing.

## **ADDITIONAL INFORMATION**

The 4S project has been involved in financing memberships in SIS for some time. It has been very valuable for the participants in the Acon4.0 project to gain insight into ongoing standardization work in the field of robotics.

## Digital production infrastructure - DigIn

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### GENERAL PROJECT OVERVIEW

DigIn demonstrated how digital infrastructure can support smart manufacturing via a digital twin that is created based on existing IT applications for development and planning, and which is updated based on production results. The demonstrator was created in Scania's 'Smart factory lab' around an assembly line for pedal cars where instructions were created to order and delivered to the operator and robot. The resulting times and steps required were measured and then saved in the digital model as a baseline for improvement. The solution was based on communication via a 'service bus' and the use of the information standard ISO10303-239 (PLCS) to coordinate information between different stakeholders and lifecycle stages.

### PARTIES INVOLVED

The project was carried out within the framework of the Strategic Innovation Program Production 2030, Vinnova diariernr: 2017-02256. Participants were from Scania CV AB; Solme (IT supplier SMF); Rise Swerea IVF; Eurostep AB (IT supplier SMF); KTH Industriell Produktion; and PMH Applications lab.

### PROBLEM ADDRESSED

The project looked at the currently poor integration between IT systems for design and development and IT systems for production (sometimes referred to as OT). The aim was to study how integration can be supported via a distributed infrastructure with communication and coordination via information standards.

### RESULTS AND EXPERIENCES

DigIn led to increased knowledge about opportunities and challenges in coordinating information using information standards. We published articles and a thesis that analyzed the use of the PLCS standard in relation to IEC 62264 (ISA95) and RAMI (the information framework within Industry 4.0). The 4S project enabled participation in several collaborative projects within ISO via SIS, the

Swedish Institute for Standards. Within JWG21 (Joint ISO/TC 184 IEC/TC 65/JWG 21 Smart Manufacturing Reference Model (s)) we have contributed to the development of, among others: IEC/AWI 65815 *Unified reference model for smart manufacturing* and IEC/DTR 63319 *A metamodelling analysis approach to smart manufacturing reference models*. Within ISO TC 184/SC, we have contributed to the development of the standard ISO 23247 *Digital twin framework for manufacturing*, a set of protocols in different layers to create and maintain digital twins. We used the DigIn use-case for the processing of sprockets in pedal cars (working name Spikey) as the basis for the collaboration and have deepened understanding around how information can be communicated between different lifecycle phases. Participation in JWG21 has provided a deeper insight into the need for, and methods for, creating a common conceptual apparatus that crosses the boundaries between development and production. This experience has been used in the further development of the course MG2038 *Digitala fabriker på Masternivå* (Digital Factories at the Masterlevel) and lays the foundation for future research projects. In summary, the project has contributed to a clearer picture of how information and standards can be used to link development and production phases as a basis for circular and distributed working methods. These experiences have influenced both research and education at KTH.

# Digitalisering av läkemedelslabb för processutveckling och pilotproduktion

(Digitalization of pharmaceutical labs for process development and pilot production)

**Project manager's contact information:**

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## GENERAL PROJECT OVERVIEW

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The project aims to develop and demonstrate a concept for the digitalization of a development lab for biological pharmaceuticals, with elements such as automatic process design and autonomous pilot production, with a complementary digital and virtual lab environment. This will be accomplished by developing an open, general, modifiable digital platform for the integration of equipment for process development and pilot production of downstream processes. The vision is that the platform will, through the use of relatively small resources, give users the opportunity to connect entire production lines in a lab. Modelon is participating in the project to develop methods and general workflows for simulation and optimization of lab processes, and to give project participants access to these through the simulation platform Modelon Impact.

## PARTIES INVOLVED

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LTH Kemiteknik, Novo Nordisk, Cytiva, BioInvent and Modelon.

## ADDITIONAL INFORMATION

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The project has received support from 4S in the form of membership in a standardization organization. Much is happening within standardization around modelling and simulation, and it is valuable for the project to be involved in this, as well to be able to follow the development work that is ongoing. The project started in 2021 and has not yet reported any partial results.

# Demonstration of Infrastructure for Digitalization enabling industrialization of Additive Manufacturing - DIDAM

## **Project manager contact information:**

*Jonas Rosén, Eurostep and more*

## **GENERAL PROJECT OVERVIEW**

DIDAM develops and demonstrates priority parts of the digital infrastructure required to industrialize additive manufacturing (AM). Manufacturers, suppliers of digital platforms, along with institutes and universities, represent the players involved in a complex value chain. The goal is to demonstrate ways to ensure traceability (digital threads) and improved product and process quality through modelling/simulation with digital twins, which will lead to 30 percent fewer errors in printing, a 50-percent reduction in the need for external quality samples, and a 15-percent reduction in set-up times.

## **PARTIES INVOLVED**

Several different parties are participating in the project, including Chalmers, Rise, Epiroc, Brogrens, Eurostep, AB Volvo, Uddeholm, PrintSys, Gestamp and Valuechain.

## **PROBLEM ADDRESSED**

The project aims to enable:

- an efficient flow of and access to digital information through the additive value chain.
- new players to efficiently share and exchange digital information in new value chains.
- the introduction of resource-efficient production and 'remanufacturing' of next-generation products, in accordance with UN SDG 9 and 12.

## **RESULTS AND EXPERIENCES**

Cases from industrial partners are defined and capacity and gaps have been identified. The development of processes and information models is ongoing. Evaluation of a solution for increased IP protection will be studied.

## **ADDITIONAL INFORMATION**

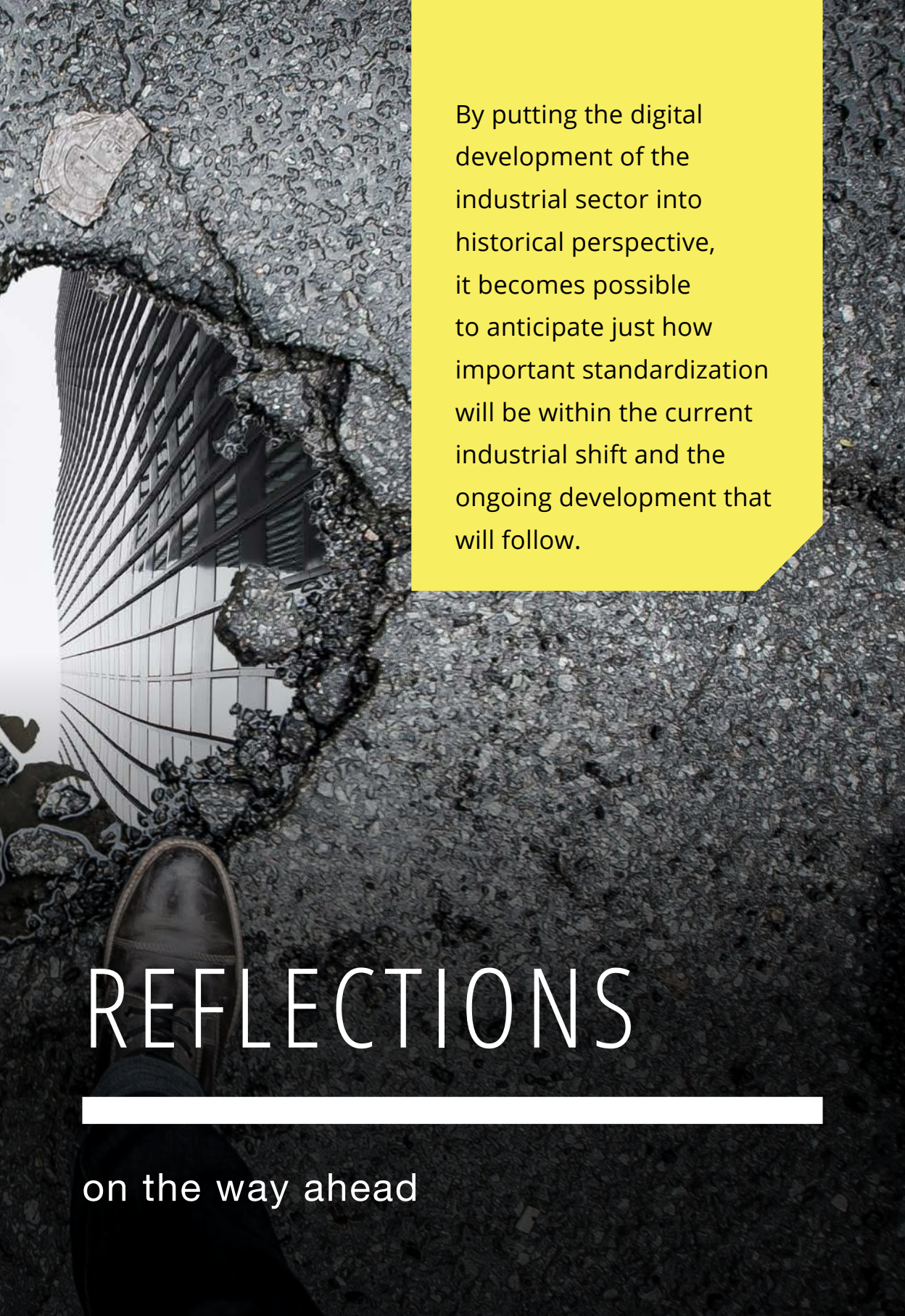
Some of the industry participants involved have a great awareness and knowledge of both national and international standards. The 4S project has helped some participants with funding linked to work with national and international standards.



PART

# 4



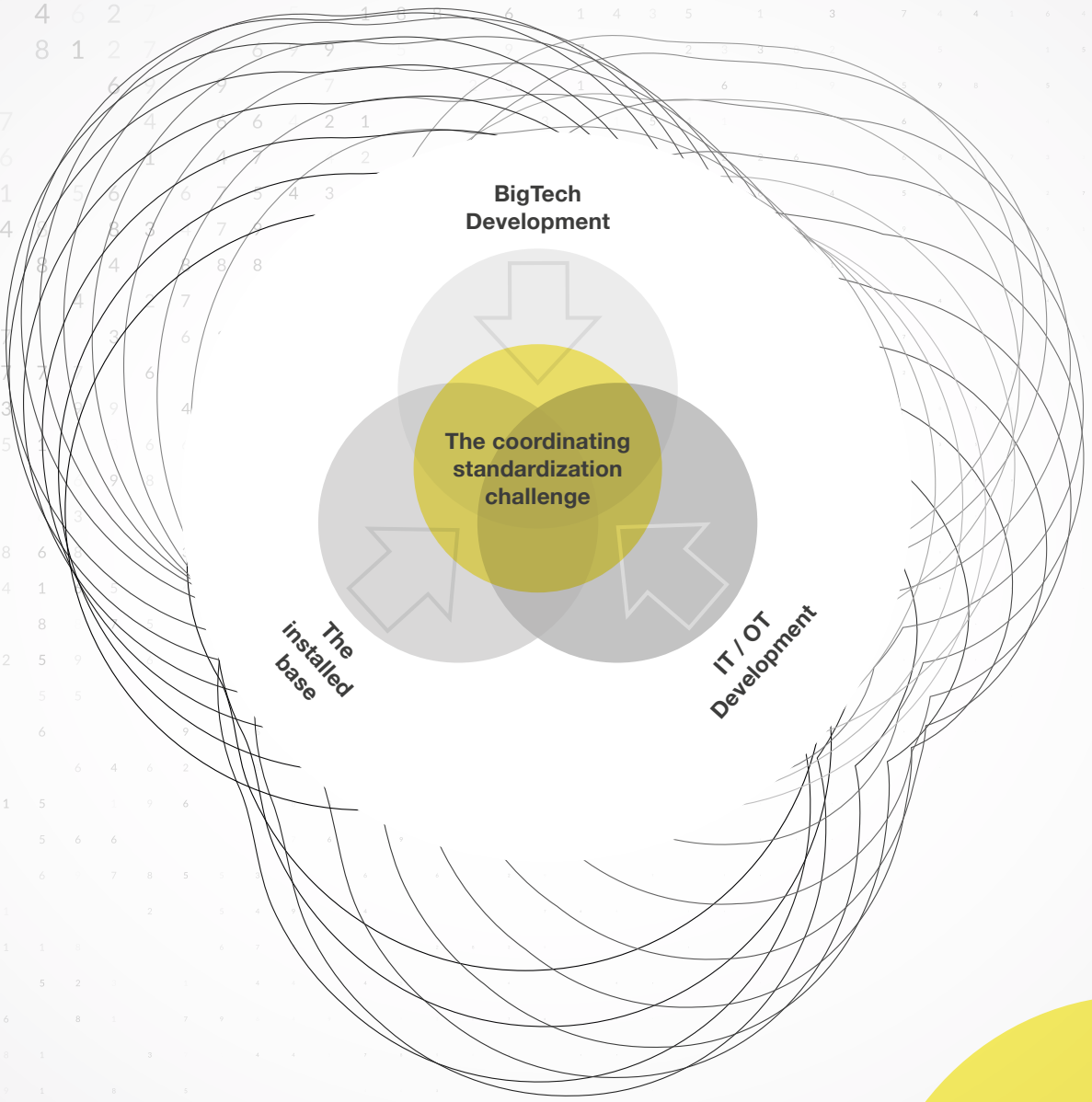


By putting the digital development of the industrial sector into historical perspective, it becomes possible to anticipate just how important standardization will be within the current industrial shift and the ongoing development that will follow.

# REFLECTIONS

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on the way ahead



## STANDARDS AND THE DIGITAL TRANSFORMATION OF THE INDUSTRIAL SECTOR

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Starting with the early development of the manufacturing sector, this report has tried to provide an overview of the role that standards play in creating value within society. They are so important that without them the world would probably look very different. By viewing the digital development of the industrial sector from an historical perspective, it is also possible to predict just how important standardization will be within the current industrial shift and the development that follows.

The world is in the midst of a climate crisis that requires change to how society uses energy. The rapid and harmonized transition of the industrial sector towards climate neutrality and the more efficient use of resources is dependent on digital support. The efficient digitalization of value systems also requires standards. Digital industrial standards will, in turn, be central to successful implementation within value chains on a global level, and also in facilitating further innovation work. The importance of these connections cannot be overstated as it is the interconnected world and the free flow of data between environments, machines and people that is creating this new social good, including the hope that we can save the climate and the environment.

**Figure 15:** The first force of change is preservation and the technological legacy present through the systems currently operating in the industrial sector. The second force is the influence of Big Tech companies. The third force is traditional ICT and OT industry mobilization. On top of the integration of this triad, standardization organizations have the task of reconciling sustainable global standards.

For these reasons, technology and systems are being driven towards convergence and the boundaries are being blurred between sectors, products and services, and between production and consumption. The disruptive effect of new industrial processes and the free flow of information is also tearing down industry boundaries and creating new, non-physical products. Digitalization is setting its focus on the industrial sector's delivery of measurable results for customers. In order to remain competitive, our understanding of customers' needs and the contexts in which products and services will be used must be deepened. Also required is for more of the official standardization system to keep pace with the current exponential growth of technological developments, not the least in the field of IoT. Standards must take into account that the delivery of digital solutions is dependent on many different actors. IoT and cloud sharing services cannot be built by individual companies or individual nations.

At the heart of the process lies the standardized exchange of data, as the industrial sector is increasingly reliant on the digital business ecosystem to understand customers' needs and behaviours and respond in a timely manner. An important part of development is, of course, the use of the internet. It makes it possible to track, measure and analyze production and product use through IoT technology, with sensors and

II The rapid and harmonized transition of the industrial sector to climate neutrality and more efficient use of resources requires digital support.

data streams from connected machines and people. Much of that development is now happening in dominant BigTech companies. Large sums are being pumped into cloud services, AI, machine learning methods and platforms. The R&D investments of handful of top BigTech companies' amount to an impressive SEK 500 billion per year (PiiA and Blue Institute, AI & Digital Platforms, 2019). This corresponds to the entire, collective investments of the global ICT and OT industries.

At the same time, rapid digitalization is creating a host of new de facto standards. According to the European Commission, there were already more than 600 standards in the IoT area in 2016. Such growth in itself is leading to a significant increase in complexity and has the potential to counteract rather than promote innovation development. To meet this challenge, surveys of relevant standards in various areas are required to help researchers, innovators and standard-setters to

navigate and work more efficiently.

According to an OECD report from 2017 (*Key Issues For Digital Transformation In The G20*), the ultimate and final solution for a complete digital transformation is a common, neutral, standards-based reference architecture. Ongoing development in the real world with its strong market forces that favour the interests of BigTech companies and with the industrial sector's very large, invested capital in computer technology with a long potential working life can all be brought into line with this standard. The industry we now have represents a form of knowledge capital, with past production technology algorithms built into its systems.

The market for creating tomorrow's digitalized industry has a turnover of SEK 3.5 trillion every year (PiiA and Blue Institute, AI & Digital Platforms, 2019). It should be noted that the legacy

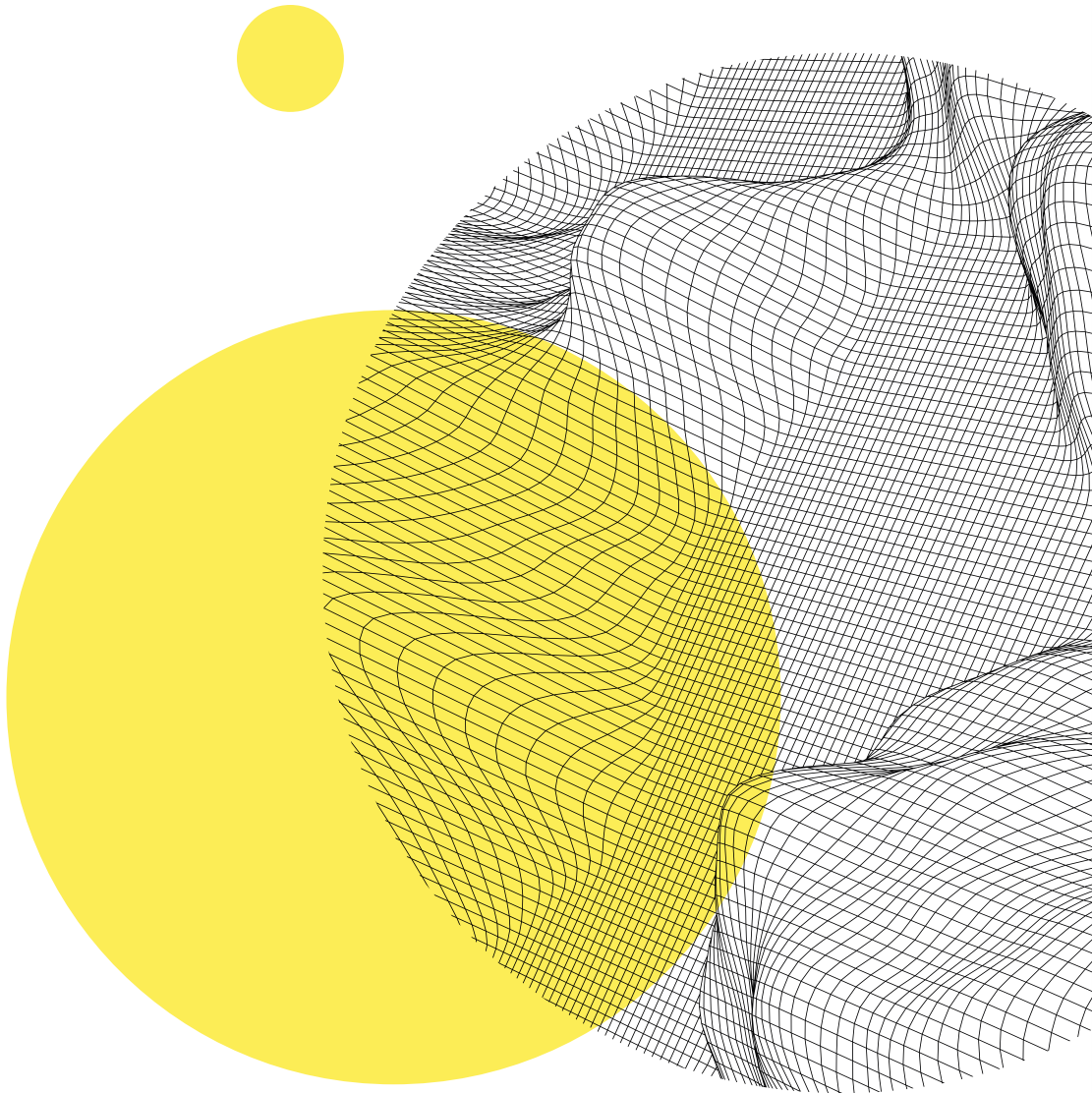


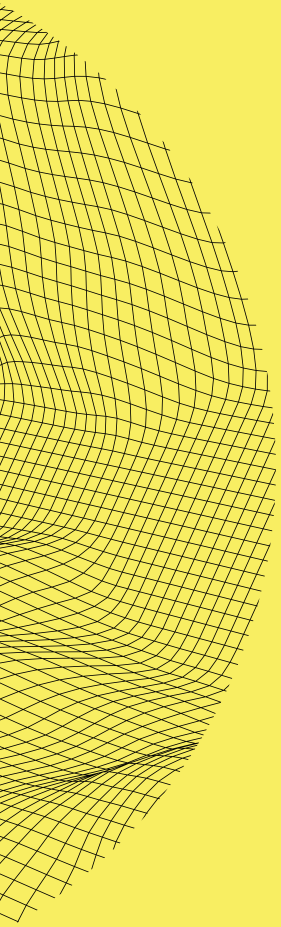
technology systems from the 1980s and 1990s represent a significant, market-influencing force, with many trillion of Swedish crowns invested in systems with long lifespans remaining. The other significant force is the influence of Big Tech companies on innovations and development, given their ambitions to govern their markets. The third is the traditional ICT and OT industry that must mobilize to find roles within the changing market (see also part 2). Overseeing this coming together of interests, standardization organizations have the enormous task of bringing together sustainable, global standards for the benefit of the market and society. In doing so, great value can be created not only for us but also for future generations.

For the Swedish industrial sector, digital development has only just begun and discussion around the significance of standardization for both the

industry that uses the technology and Swedish technology businesses that supply it needs to continue. Standardization is, as we have seen, a fundamental part of the global market system. It must be mastered at the same level as other variables that determine the success of individual companies and entire industrial nations. For this reason, there remains a need to mobilize and to challenge and guide the industrial sector using well-presented knowledge.

The large standardization organizations such as SIS, SEK Svensk Elstandard and ITS are, of course, at the forefront of this work. But responsibility also rests with private standardization initiatives and the strategic innovation programs, with PiiA and Produktion2030 as gateway programs for the process industry, the manufacturing industry and the technology suppliers.





# THIS REPORT IS ABOUT THE VALUE-CREATING ROLE STANDARDS HAVE PLAYED IN INDUSTRIAL HISTORY

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This publication, published by the 4S initiative, provides an overview of the value-creating role standards have played throughout industrial history and their role now that the industrial sector is being digitalized. The world is on the verge of restructuring the industrial sector to enable the more efficient use of resources and to help achieve climate neutrality. In order for this to happen, digital support is required. Industrial standards will be crucial for the successful introduction of digitalization into value chains and to facilitate ongoing innovation work. An interconnected world and the free flow of data between environments, machines and people are the keys to achieving sustainable societal value.

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