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Industry 4.0

Challenges and solutions for the digital transformation and use of exponential technologies

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Contents

Introduction and Executive summary	1
What is industry 4.0?	3
Definition and development	3
Main characteristics	6
Where is Switzerland in the industry 4.0 process?	9
Competitiveness	9
Opportunities and risks	11
The question of resources	13
Potential for individual business segments	15
Impetus from exponential technologies	17
Industry 4.0 solutions	22
Vertical networking	22
Horizontal integration	23
Through-engineering	24
Exponential technologies	25
Endnotes	26
Contacts	27

About the study

This study sets out the key challenges Switzerland's manufacturing companies face in achieving the digital transformation of the industry and benefitting from exponential technologies.

It focuses on the Swiss mechanical and electrical engineering, and metalworking industries, and the chemical and construction sectors.

Between March and August 2014, more than 50 manufacturing companies operating in Switzerland completed questionnaires and took part in personal interviews.

The companies taking part included among others ABB, agta record, Alstom, Autoneum, Bühler, Burkhalter, Burckhardt Compression, Cicor, Eaton, Faulhaber Minimotor, Fisba Optik, GF Machining Solutions, Gurit, Hilti, IHI Ionbond, Jungheinrich, Kaba, Meyer Burger, Mikron, Rapid, Reichle & De-Massari, Rieter, Siemens, Sonova, Trisa and Walter Meier.

Introduction and Executive summary

Dear reader

Around the world, traditional manufacturing industry is in the throes of a digital transformation that is accelerated by exponentially growing technologies (e.g. intelligent robots, autonomous drones, sensors, 3D printing). The pace of change reflects 'Moore's law' on the speed at which information technology-driven change happens. Companies and their industrial processes need to adapt to this rapid change if they are not to be left behind by developments in their sector and by their competitors.

These trends are not to be compared simply with a greater level of production automation, a process that has, since the 1970s, been driven by developments in electronics and information technology. The widespread adoption by manufacturing industry around the world of information and communications technology is now paving the way for disruptive approaches to development, production and the entire logistics chain.

This networking within an 'internet of things, services, data and people' will transform the future of manufacturing. Commentators use the term '**industry 4.0**' to refer to a fourth industrial revolution with four main characteristics:

1. The **vertical networking** of smart production systems, such as smart factories and smart products, and the networking of smart logistics, production and marketing and smart services, with a strong needs-oriented, individualised and customer-specific production operation
2. **Horizontal integration** by means of a new generation of global value-creation networks, including integration of business partners and customers, and new business and cooperation models across countries and continents
3. **Through-engineering** throughout the entire value chain, taking in not only the production process but also the end product – that is, the entire product life cycle
4. **Acceleration through exponential technologies** that, while not really new in terms of their development history, are only now capable of mass-market application as their cost and size have come down (e.g. sensor technology) and their computing power has risen massively.

This study investigates the extent to which Swiss manufacturing companies have already positioned themselves in relation to this digital transformation and the opportunities the **switch to 'industry 4.0'** offers them.

- **Increase competitiveness:** a clear majority of companies surveyed believe that the digital transformation to industry 4.0 will increase their competitiveness. Only a small minority of companies see this transformation affecting their current business, although they believe that major change is inevitable. A few individual companies argue that industry 4.0 could slow down the trend towards relocating production to low-wage countries, but this argument overlooks the fact that, as a result of automation, the trend towards relocation is often driven more by the need to produce goods locally in new growth markets than by the ability to produce goods more cheaply. Our last report (*Innovation reinvented*, published in September 2013) clearly demonstrated the vital importance of innovation for the Swiss manufacturing industry and its competitiveness. The digital transformation to industry 4.0 will have an impact right across both local and global value chains in low-cost as well as high-cost countries.
- **Utilise opportunities and reduce risks:** industry 4.0 represents a number of major opportunities for Swiss manufacturing. It will open up new ways for companies to integrate their customers' needs and preferences into their development and production processes, including via direct data-sharing with their machinery. It will also make it easier to analyse machine data, helping to enhance quality and avoid faults in the production process. In terms of risks, companies believe that the digital transformation to industry 4.0 could further increase the already heightened cyber risk to manufacturing industry. Leading manufacturing companies are taking a proactive approach to both opportunities and risks.

- **Adjust talent and IT resources:** most of the companies surveyed note that in many areas, they do not have all the staff they need to make the digital transformation to industry 4.0. One-third of companies have an appropriate IT infrastructure in place for the switch to industry 4.0, but just under half believe that their infrastructure is not wholly suitable. The remaining companies report that they lack the appropriate infrastructure for change on this scale. If the digital transformation to industry 4.0 is to be successful, however, it is essential that businesses invest in appropriate skills and an excellent IT infrastructure.
- **Develop potential for individual business segments:** research and development (R&D), procurement and purchasing, production, and warehousing and logistics are currently at the heart of the digital transformation to industry 4.0, while sales and services are the segments with the greatest potential to benefit from it. In these segments, more strongly individualised solutions have the capacity to take manufacturing into a whole new era of customisation. This will require the sector to switch from the 'push into the market' of better products for their customers to an individualised understanding of customers' needs and specialised, industry-specific solutions ('pull from the customer').
- **Use impetus from exponential technologies:** a majority of companies surveyed agree that the key technology 3D printing (additive manufacturing) will accelerate the transformation of the Swiss manufacturing industry to industry 4.0. According to our survey findings, only very few manufacturing companies are so far making full use of the scope offered by 3D printing technology in their development, production and logistics processes. Just one-half of those surveyed plan to invest in 3D printing technology in future. Most companies are only just beginning to use this new technology and there is a risk that they may miss the opportunity, because some companies have already been working with 3D printing for several years and are developing the next generation of applications. The same can be also said for other exponentially growing technologies.

To help Swiss manufacturing companies successfully manage the transformation to industry 4.0, we have devised a range of **solutions** geared to its four major characteristics, i.e. vertical networking, horizontal integration, through-engineering and exponential technologies.

Preparing your companies as learning organisations for radical change will become an increasingly urgent priority.

We would like to thank the management of the companies that took part in our survey and interviews for their views and comments. Their input has enabled us to assess the challenges and solutions that digital transformation represents for Swiss businesses.

We hope you enjoy reading the study and look forward to your feedback.



Dr. Ralf C. Schlaepfer
Managing Partner

Head of Manufacturing Industry
Deloitte AG



Markus Koch
Consulting Partner

Head of Manufacturing Consulting
Deloitte Consulting AG

What is industry 4.0?

Definition and development

The term industry 4.0 refers to a further developmental stage in the organisation and management of the entire value chain process involved in manufacturing industry. Another term for this process is the 'fourth industrial revolution'.

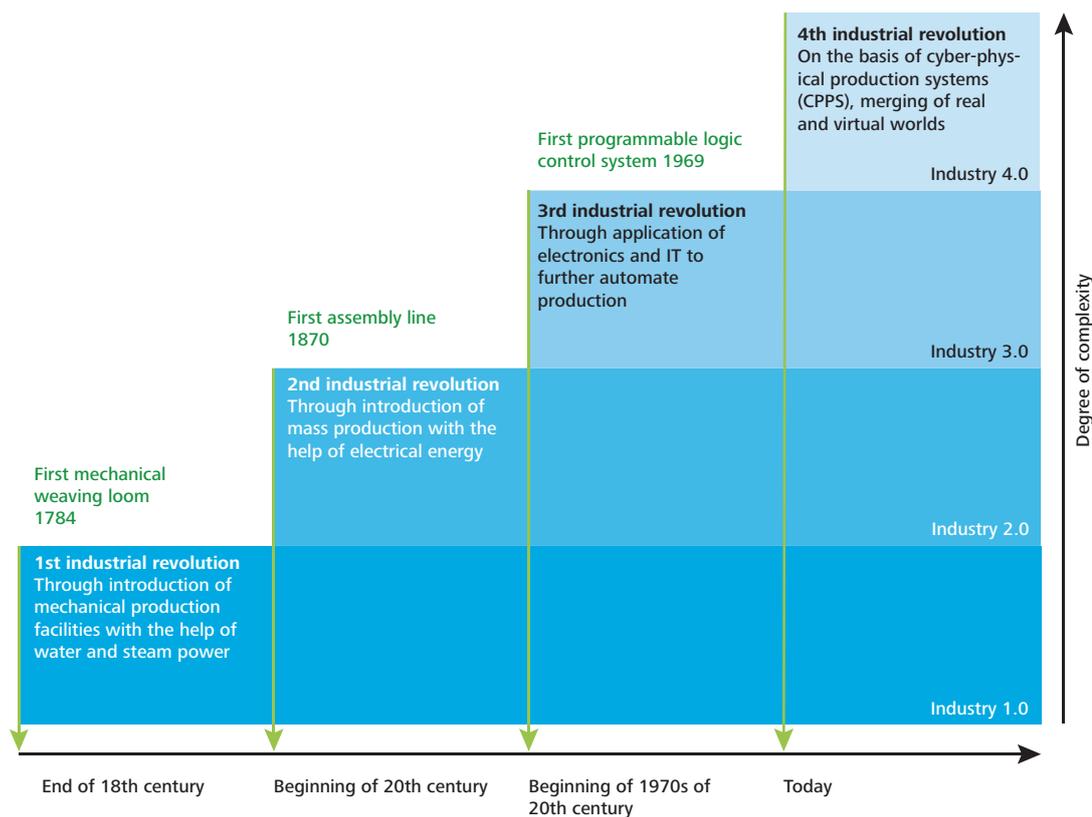
The concept of industry 4.0 is widely used across Europe, particularly in Germany's manufacturing sector. In the United States and the English-speaking world more generally, some commentators also use the terms the 'internet of things', the 'internet of everything' or the 'industrial internet'.

What all these terms and concepts have in common is the recognition that traditional manufacturing and production methods are in the throes of a digital transformation. For some time now, industrial processes have increasingly embraced modern information technology (IT), but the most recent trends go beyond simply the automation of production that has, since the early 1970s, been driven by developments in electronics and IT (see Chart 1).

"The question arises with industry 4.0 of whether it is an evolution or a revolution."

Robert Rudolph, Swissmem, Head of Training and Innovation

Chart 1. Definition of industry 4.0¹



The widespread adoption by manufacturing industry and traditional production operations of information and communications technology (ICT) is increasingly blurring the boundaries between the real world and the virtual world in what are known as cyber-physical production systems (CPPSs).

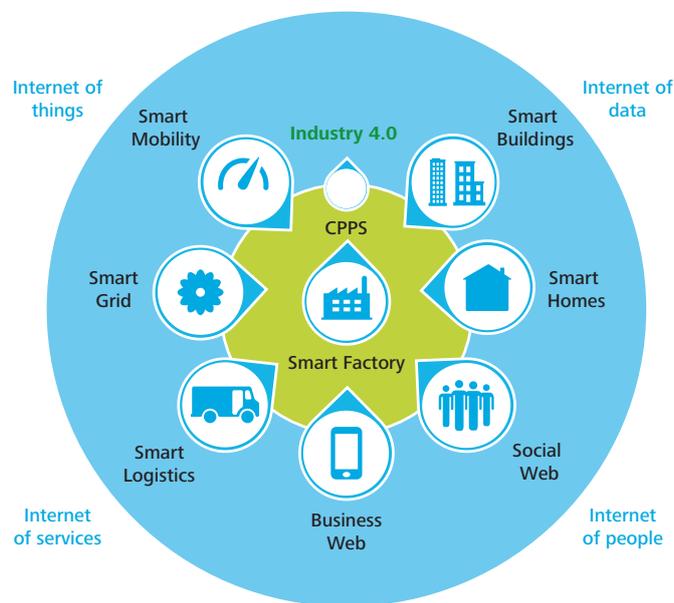
CPPSs are online networks of social machines that are organised in a similar way to social networks. Simply put, they link IT with mechanical and electronic components that then communicate with each other via a network. Radio frequency identification (RFID) technology, which has been in use since 1999, was a very early form of this technology.

Smart machines continually share information about current stock levels, problems or faults, and changes in orders or demand levels. Processes and deadlines are coordinated with the aim of boosting efficiency and optimising throughput times, capacity utilisation and quality in development, production, marketing and purchasing.

CPPSs not only network machines with each other, they also create a smart network of machines, properties, ICT systems, smart products and individuals across the entire value chain and the full product life cycle. Sensors and control elements enable machines to be linked to plants, fleets, networks and human beings.

Smart networks of this kind are the bedrock of smart factories, which themselves underpin industry 4.0 (see Chart 2).

Chart 2. The industry 4.0 environment²



“New technologies sometimes follow an inverse trend. They are initially successful in the consumer business area and are subsequently adapted by industry. Manufacturing companies can learn a lot from the smart home environment.”
 Dr. Kurt Kaltenecker,
 ABB Venture Capitals,
 Head of Technology

Of central importance for industry 4.0 is its interface with other smart infrastructures, such as those for smart mobility, the smart grid, smart logistics and smart homes and buildings.

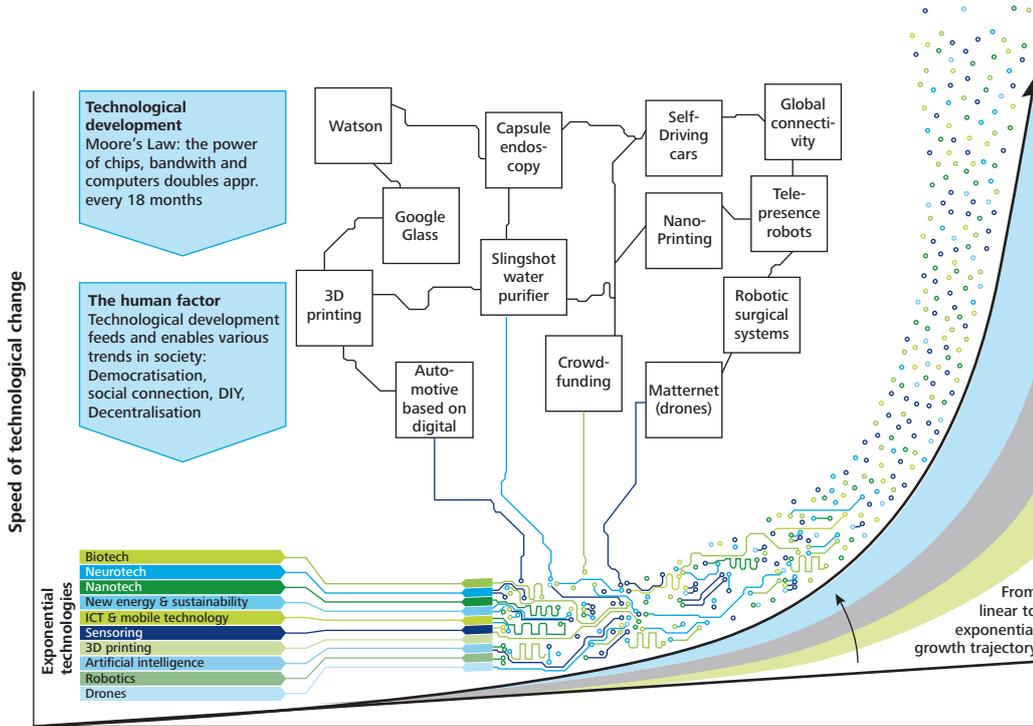
Links to both business and social networks – the business web and the social web – also play an increasingly important role in the digital transformation to industry 4.0. All these new networks and interfaces offered by industry 4.0 within an ‘internet of things, services, data and people’ mean that manufacturing is set to undergo enormous changes in future.

This trend is still in its infancy in some manufacturing companies and industrial sectors, but in others, the transformation to industry 4.0 is already well under way.

Traditional industrial economies, such as Germany and the US, expect this fourth industrial revolution to bring many advantages, ranging from enhanced global competitiveness to a reversal of the trend to relocate production to low-wage countries and the opening of more domestic production locations in Europe and North America.

Exponentially growing technologies will be the key to the transformation to industry 4.0 (see Chart 3).

Chart 3. Exponential technologies³



“Using 3D printing for rapid prototyping is like using a computer to write letters. While it is certainly useful, it significantly underutilises the true potential of the technology. When the experience changes, there will be rapid adoption.”
 Dr. Girish Nadkarni,
 ABB Venture Capitals,
 Managing Director

Research has shown that Moore’s law – which states that the capacity of microchips, bandwidth and computers doubles every 18 months, representing exponential growth – also applies to other technological developments.⁴

3D printing, sensor technology, artificial intelligence, robotics, drones and nanotechnology are just a few examples of exponentially growing technologies that are radically changing industrial processes, accelerating them and making them more flexible.

Many of these technologies are not new and were, in fact, ‘invented’ some 20 or 30 years ago. However, the recent massive boost in computing power (Moore’s law) and the reduction in cost, along with miniaturisation, now make them suitable for industrial use.

New technologies can be overrated and can cause concern, because of the slow development curve in absolute terms at the beginning. When the exponential development takes off, the influence of such technologies is often underestimated and disruptive market changes are missed.

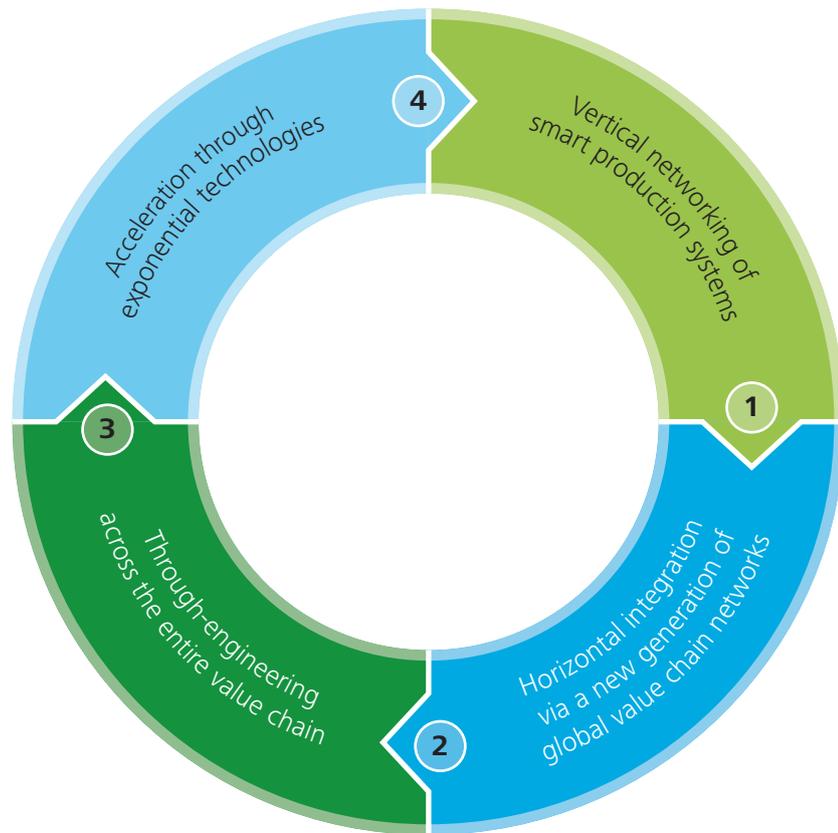
Several of these exponential technologies will be leaving their linear growth paths in the coming years and we are expecting exponential growth.

This exponential growth will fundamentally shape industry 4.0.

Main characteristics

The following four main characteristics of industry 4.0 demonstrate the huge capacity that industry and traditional manufacturing have for change: **vertical networking** of smart production systems, **horizontal integration** via a new generation of global value chain networks, **through-engineering** across the entire value chain and the impact of **exponential technologies** (see Chart 4).

Chart 4. The four characteristics of industry 4.0⁵



“The biggest challenge of the digital transformation is going to be guaranteeing that different systems communicate with each other.”

Marcel Wenzin, agta record ag, Head of Supply Chain Management

“The internet of things allows even more predictive maintenance with condition monitoring, which offers real added value for customers.”

Dr. Kurt Kaltenecker, ABB Venture Capitals, Head of Technology

1. Vertical networking of smart production systems

The first main characteristic of industry 4.0 is the vertical networking of smart production systems in the factories of the future.

This vertical networking uses cyber-physical production systems (CPPSs) to enable plants to react rapidly to changes in demand or stock levels and to faults. Smart factories organise themselves and enable **production that is customer-specific and individualised**. This requires data to be extensively integrated. Smart sensor technology is also needed to help with monitoring and autonomous organisation.

CPPSs enable **not only autonomous organisation of production management but also maintenance management**. Resources and products are networked, and materials and parts can be located anywhere and at any time. All processing stages in the production process are logged, with discrepancies registered automatically. Amendments to orders, fluctuations in quality or machinery breakdowns can be dealt with more rapidly. Such processes also enable wear and tear on materials to be monitored more effectively or pre-empted. All in all, waste is reduced.

Significant emphasis is attached to **resource efficiency** and in particular, the efficient use of materials, energy and human resources. The demands on workers engaged in operational tasks such as production, warehousing, logistics and maintenance are also changing, meaning that new skills in efficient working with CPPSs are required.

2. Horizontal integration via a new generation of global value chain networks

The second main characteristic of industry 4.0 is horizontal integration via a new generation of global value chain networks.

These new value-creation networks are real-time optimised networks that enable **integrated transparency**, offer a **high level of flexibility** to respond more rapidly to problems and faults, and facilitate better **global optimisation**.

Similar to networked production systems, these (local and global) networks provide networking via CPPSs, from inbound logistics through warehousing, production, marketing and sales to outbound logistics and downstream services. The history of any part or product is logged and can be accessed at any time, ensuring constant traceability (a concept known as 'product memory').

This creates transparency and flexibility across entire process chains – from purchasing through production to sales, for example, or from the supplier through the company to the customer. Customer-specific adaptations can be made not only in the production but also in the development, ordering, planning, composition and distribution of products, enabling factors such as quality, time, risk, price and environmental sustainability to be handled dynamically, in real time and at all stages of the value chain.

This kind of horizontal integration of both customers and business partners can generate **completely new business models and new models for cooperation**, representing a challenge for all those involved. Legal issues and questions of liability and protection of intellectual property are becoming increasingly important.

3. Through-engineering across the entire value chain

The third main characteristic of industry 4.0 is cross-disciplinary through-engineering across the entire value chain and across the full life cycle of both products and customers.

This engineering occurs seamlessly during the design, development and manufacture of new products and services. New products need new and/or modified production systems. The development and manufacture of new products and production systems is integrated and coordinated with product life cycles, enabling **new synergies** to be created between product development and production systems.

Characteristic of this through-engineering is that data and information are also available at all stages of a product's life cycle, enabling new, more flexible processes to be defined from data via modelling to prototypes and the product stage.

"With the widespread adoption of 3D printing, customers will prefer to download the CAD file to print the part themselves – in the quantity they need and when they need – rather than have the parts shipped to them. This will require the manufacturer to get into the DRM business, not unlike Apple with iTunes or Amazon with Kindle."

*Dr. Girish Nadkarni,
ABB Venture Capitals,
Managing Director*

"As technology evolves, it makes sense to move from referring to products themselves to referring to actual customer experience chains."

*Dr. Andreas Häberli,
KABA, CTO, Group
Innovation Management*

"3D printing has the capacity to transform the supply chain. Reliance on highly specialised suppliers for complex parts can be reduced with 3D printing, as can the number of suppliers involved across the supply chain, bringing down the cost of supply chain management."

*Raphael Urech, Alstom
Schweiz, Knowledge
Manager Hybrid Parts,
Thermal Power Sector*

“Today’s products are designed so they can be assembled quickly by unskilled workers. 3D printing will introduce much more design freedom, allowing manufacturers to reduce their reliance on unskilled labour and also to create unique designs that could not be executed with traditional manufacturing.”

*Dr. Girish Nadkarni,
ABB Venture Capitals,
Managing Director*

“The aftermarket is a huge opportunity for additive manufacturing. However, the printing of spare parts at client sites is still a long way off.”

*Paul Ryan, Alstom
Schweiz, Additive
Manufacturing Project
Manager, Thermal Power
Operations*

4. Acceleration through exponential technologies

The fourth main characteristic of industry 4.0 is the impact of exponential technologies as an accelerant or catalyst that allows **individualised solutions, flexibility** and **cost savings** in industrial processes.

Industry 4.0 already requires automation solutions to be highly cognitive and highly autonomous. Artificial intelligence (AI), advanced robotics and sensor technology have the potential to increase autonomy further still and to speed up individualisation and flexibilisation.

AI cannot only help to plan driverless vehicle routes in factories and warehouses more flexibly, save time and cost in Supply Chain Management (SCM), increase reliability in production or analyse big data, but can also help to find new construction and design solutions or enhance the cooperation between humans and machines to the point of services.

Functional nanomaterials and nanosensors can also be used in production control functions to make quality management more efficient or allow the production of next generation robots that work ‘hand in hand’ and safely with humans.

Flying maintenance robots in production halls and using drones to make inventories of warehouse stock levels and deliver spare parts, at any time of day or night and in any terrain and weather, are further applications that will become simply routines in the autonomous and smart factories of the future.

A prime example here of an exponential technology that is accelerating industry 4.0 and making it more flexible is 3D printing (additive manufacturing). 3D printing allows new production solutions (e.g. functionality, higher complexity without additional cost) or new supply chain solutions (e.g. inventory reduction, faster delivery times), or a combination of both that lead to disruptive new business models (e.g. disintermediation of supply chain members, customer integration).

More important will be the scanning for quality assurance or changes in SCM and warehousing through on-location printing of spare parts. Significant questions still need to be answered regarding intellectual property, product liability, customs duty and value-added tax.

While 3D printing already exists for all materials (metal, plastic, ceramic, living cells etc.), not all materials fulfil industry requirements with regards to porosity and other characteristics. In the cases where the required quality has already been achieved, long lasting material qualification processes are under way, comparable with the processes for any other new material.

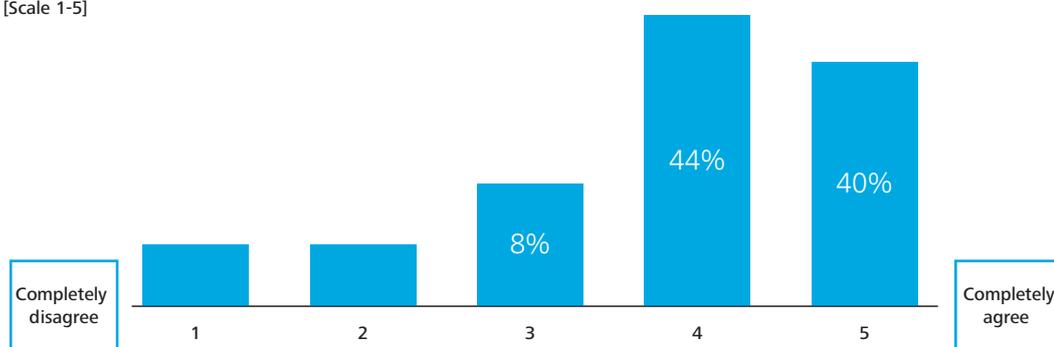
Where is Switzerland in the industry 4.0 process?

Our survey and personal interviews show that the digital transformation to industry 4.0 in Switzerland is making partial progress. This transformation is not only influencing companies' **competitiveness** and opening up new **opportunities and risks**, it is also highlighting **resource issues**, identifying key **future potential** for individual business segments and facilitating **new manufacturing technologies**.

Competitiveness

The majority of the manufacturing companies surveyed agree that the digital transformation to industry 4.0 could boost Swiss industry's global competitiveness (see Chart 5): 40% of respondents strongly agreed and a further 44% agreed that this was the case.

Chart 5. Swiss manufacturing industry and industry 4.0
[Scale 1-5]

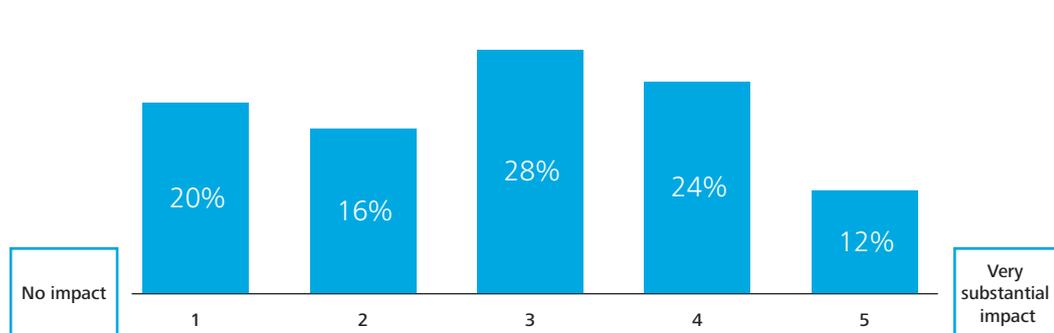


Question: Do you believe that the digital transformation to industry 4.0 could boost Switzerland's global competitiveness?

In interviews, representatives of manufacturing industry stressed the vital importance of industry 4.0 and emphasised that it would become even more important in future.

Asked about the extent to which Swiss manufacturing companies are already feeling the impact of the digital transformation to industry 4.0, respondents gave varied responses. Just over one-third said their company was either not feeling the impact (20%) or feeling only a slight impact (16%); just under a third gave a neutral response (28%), while the remaining third were already feeling the impact strongly (24%) or very strongly (12%) (see Chart 6).

Chart 6. Swiss companies and industry 4.0
[Scale 1-5]



Question: How strongly is your company feeling the impact of the digital transformation to industry 4.0?

“SMEs have the potential to build new industry 4.0 processes from scratch. Large companies, by contrast, have a greater problem of data integration across different business segments.”
 Robert Rudolph,
 Swissmem, Head of
 Training and Innovation

This divergence of views is partly determined by company size and by the sector in which the companies are operating.

Very large manufacturing companies and multinational groups already consider the topic very important. Small and medium-sized companies do not yet appear to consider industry 4.0 to be of great relevance to them, even though these companies are most likely to be the big winners from the shift.

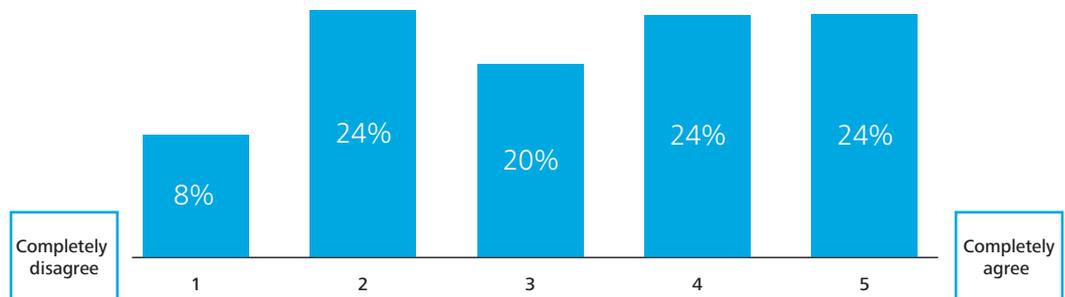
Small and medium-sized companies are often able to implement the digital transformation more rapidly because they can develop and implement new IT structures from scratch more easily. Very large manufacturing companies and multinational groups, by contrast, have more complexity to deal with in terms of their existing, organically grown structures.

Nor is the digital transformation to industry 4.0 of equal importance to all sectors. Companies from the mechanical and electrical engineering industries and the chemical sector see it as having the greatest potential, while companies in the metalworking industry and construction sector currently see it as less important.

Most Swiss manufacturing companies surveyed believe that industry 4.0 has the potential to make Swiss business more competitive. On the whole, however, they do not agree that the digital transformation will slow down the trend towards relocating production to low-wage countries (see Chart 7).

Question: Do you think that the digital transformation to industry 4.0 will be able to slow down the trend towards relocating production to low-wage countries?

Chart 7. Relocation of production and industry 4.0
 [Scale 1-5]



“Production relocation can be both slowed down and fast-tracked by industry 4.0. Industry 4.0 solutions can help to bring down costs and reduce the pressure to relocate for cost reasons, but the same solutions allow also businesses to organise global structures more efficiently.”
 Robert Rudolph,
 Swissmem, Head of
 Training and Innovation

Just under half of the companies surveyed agreed or agreed strongly with this statement (24% and 24% respectively). 20% of those surveyed took a neutral view, while just over 30% disagreed.

Moves to relocate production tend to be a response to pressure from new growth markets to produce goods near to where customers are. Industry 4.0 will see digital networks spreading across all global locations and structures and becoming widespread. Industry 4.0 applications have the potential to be pioneers or to create impetus for geographically diversified production and supply networks in new growth markets. The developers of innovative industry 4.0 applications are, however, more likely to continue to strengthen domestic research and development operations.⁶

Opportunities and risks

The digital transformation to industry 4.0 brings with it both new **opportunities** and new **risks**.

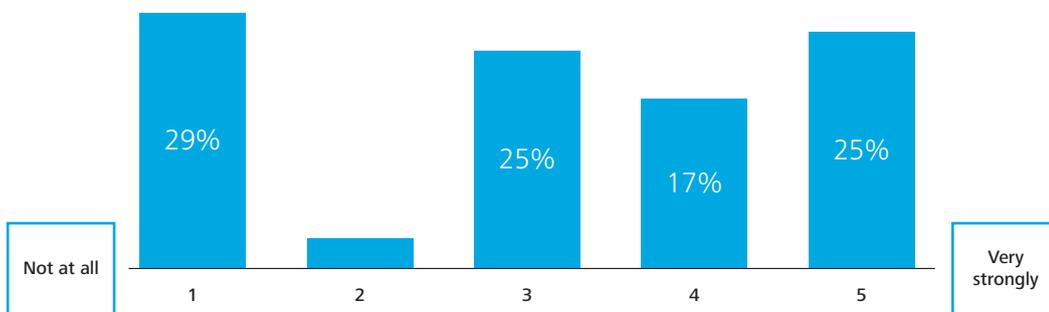
Opportunities for flexible customer integration and for boosting quality and efficiency

The companies taking part in the survey see greater scope to integrate their customers’ needs and preferences into the development and production process as a major new opportunity.

Some individual manufacturing companies are already strongly integrating their customers’ needs and preferences in this way (17%) or very strongly (25%), but almost one-third (29%) are not doing so at all (see Chart 8).

“The greater possibilities of new technologies allow to be even more customer-centred and always to start from what customers need.”
 Dr. Andreas Häberli,
 KABA, CTO, Group
 Innovation Management

Chart 8. Integrating customers
 [Scale 1-5]



Question: To what extent is your company already integrating customers’ needs and/or preferences in its development and production processes, for example through data exchange directly with machines?

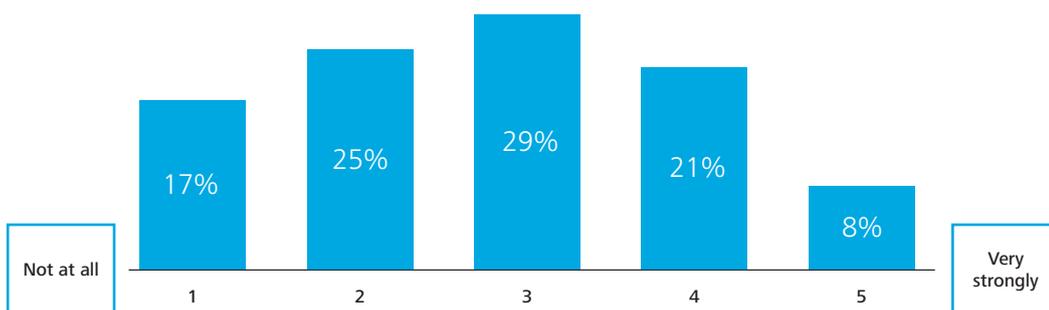
Customisation is a global trend and is likely to spread even more rapidly across manufacturing industry in future. Customers increasingly want to determine how their products are designed and made, and will be having an input into development and production processes at an early stage.

The scope for networking represented by industry 4.0 offers interesting opportunities for manufacturing companies to make more extensive, more efficient, more intelligent and more flexible use of this trend than they are currently able to. However, one major challenge posed by industry 4.0 will be managing the large quantities of data that are generated, for example, by analysing production data and coordinating the findings with customer information systems.

“Demand for customisation (or customer-specific adaptations) continues to grow. Industry 4.0 will allow even more customisation options in the future.”
 Dr. Kurt Kaltenecker,
 ABB Venture Capitals,
 Head of Technology

Swiss manufacturing companies are using this ability to analyse big data to different degrees. The majority of those questioned do not yet analyse their machinery and sensor data, for example to remedy defects in production or to enhance quality (see Chart 9).

Chart 9. Resource efficiency
 [Scale 1-5]



Question: To what extent is your company already making use of the opportunity to analyse machine data, for example to avoid defects in the production process?

“Online monitoring is very important with 3D printing. It’s currently possible to identify faults only after production. Online monitoring enables problems to be reported and rectified during the manufacturing process, meaning that manufactured products are fault-free.”

Raphael Urech, Alstom Schweiz, Knowledge Manager Hybrid Parts, Thermal Power Sector

This indicates that most of the manufacturing companies surveyed have yet to position themselves to make use of the opportunities offered by industry 4.0 in this area.

Among other things, analysis of big data can enable managers to identify defects, faults and shortcomings in the production process at an early stage, optimise automation processes and carry out trend analyses, use resources more efficiently and carry out predictive maintenance.

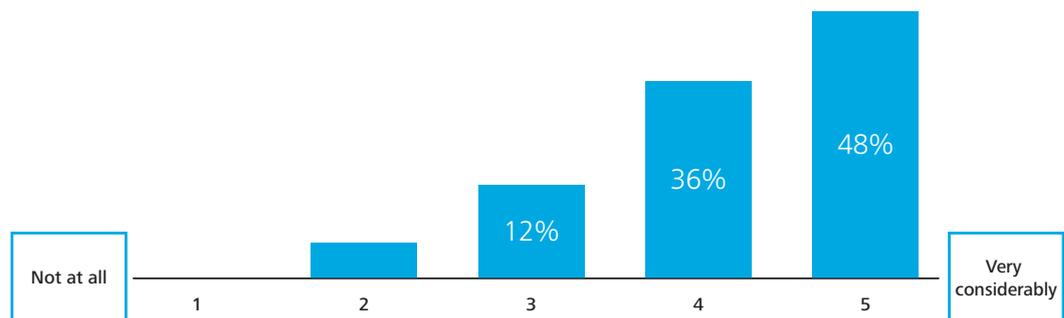
However, as well as offering these advantages in terms of the scope to analyse big data and to boost quality and efficiency, the digital transformation to industry 4.0 also brings with it some non-negligible risks.

Risks to data security

The ‘internet of things, services, data and people’ also opens up new avenues for data theft, industrial espionage and attacks by hackers.

A majority of survey respondents believe that the level of cyber risk could increase strongly (36%) or very strongly (48%) as a result of industry 4.0 (see Chart 10). All respondents believe that the potential for cyber risk will increase.

Chart 10. Cyber risk
[Scale 1-5]



Question: Do you think that the digital transformation to industry 4.0 could further increase cyber risk for manufacturing companies?

“The cyber risk is not necessarily higher in an industry 4.0 environment. New cyber security will be introduced at the same pace as industry 4.0 applications. Technology development goes hand in hand with the development of cyber security systems.”

Dr. Kurt Kaltenecker, ABB Venture Capitals, Head of Technology

Cyber-attacks and viruses can have a devastating impact on industry 4.0, potentially bringing networked and smart production systems to a standstill at substantial cost.

In our interviews, most representatives of manufacturing companies emphasised, however, that these risks could probably be managed through tailored risk management and an appropriate security strategy. Many cited modular safeguards/solutions, decentralised structures and limited access rights as sensible measures in this context. They also thought that developments in cyber security would keep pace with the ever changing nature of cyber-threats. A number of respondents also stressed the need for new and, where appropriate, binding cyber security standards.

However, some manufacturing companies or business segments are having to install completely new security systems. Both software and hardware are affected, with the latter slightly less affected.

The priority for manufacturing companies is not only to prevent cyber-attacks but also – and particularly – to learn how to deal with them, since respondents believe that cyber risk will be as much of a problem in future as it is now. IP security will inevitably become more difficult (for example in the spare parts business).

The question of resources

The question of resources is key for companies facing the digital transformation to industry 4.0. Of particular importance in this context are the appropriateness of their existing **IT infrastructure** and the availability of the necessary **talent** and skilled employees.

IT infrastructure

In most Swiss manufacturing companies, the IT infrastructure is not wholly ready to support the digital transformation to industry 4.0.

When questioned about the extent to which they had an appropriate IT infrastructure in place that could gather data to support the switch and/or transfer to industry 4.0, only 32% of respondents said their company had. 48% of companies surveyed stressed that they had at least some elements of such an infrastructure in place, while the remaining 20% lacked any appropriate infrastructure.

Industry 4.0 requires existing installations to be adapted and, in some cases, entirely new types of IT infrastructure. Diverse systems need to be networked and to learn to communicate with each other, and new communications networks need to be developed from scratch.

The first step is to analyse the current state of all systems. The aim is not to superimpose the new solutions and technologies of industry 4.0 on existing structures, but rather to identify the most meaningful approach and to establish where existing systems and networks can be built on.

A range of systems in differing business segments, such as research and development, procurement and purchasing, production, warehousing and logistics, marketing, sales and services, need to be taken into consideration with regard to networking.

This will be a major challenge for manufacturing companies, although the priorities set by differing business segments in relation to the digital transformation to industry 4.0 will vary.

Very large manufacturing companies and multinational groups often have to harmonise and network their existing IT infrastructure systems rather than put entirely new systems in place; unless new exponential technologies allow for an exchange of existing ERP systems with manageable effort and justifiable risk. Some smaller and medium-sized manufacturing businesses are better placed to develop entirely new structures from scratch.

The cost implications are, however, a key factor for all manufacturing companies, regardless of size, when making decisions as to whether to improve existing IT infrastructure or to design and develop new systems.

Many Swiss manufacturing companies therefore still have a long way to go in adapting their current IT infrastructure to the needs of industry 4.0 and/or designing a new infrastructure.

“A strong cross-linking of diverse databases, production systems and customer information systems is needed to be able to add real value for customers and to meet their needs. Adapting and coordinating legacy systems is, therefore, an enormous challenge.”

Dr. Andreas Häberli, KABA, CTO, Group Innovation Management



YES

32%



PARTLY

48%



NO

20%

Talent

The talent requirements and number of skilled workers that Swiss manufacturing industry will need to implement industry 4.0 remains unclear because of uncertainty about the areas where staff is needed, the time required to source talent and the actual numbers. Just 4% of those surveyed said that they already had the skilled workers they needed, while 80% said that they had the skills in certain areas. Only 16% said they completely lacked the necessary skills.

The digital transformation to industry 4.0 will bring new challenges for many employees.

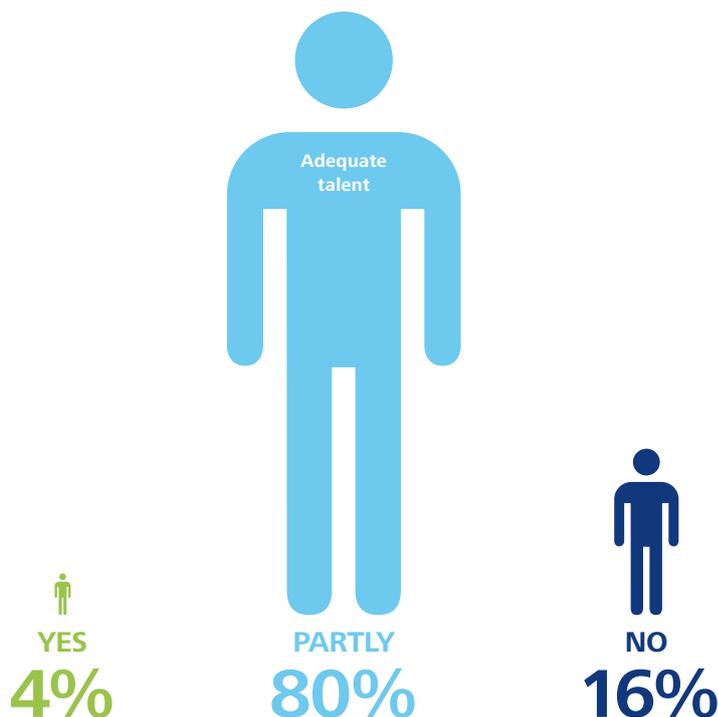
Creative working processes, such as strategic planning or research and development, will have a greater need for the skills required to identify, introduce and implement the new and innovative business opportunities offered by industry 4.0.

New business models and new models for cooperation constitute the real added value of industry 4.0, however, this is not always apparent. Space for creativity needs to be established. This is a challenge for senior management: exploiting the new, innovative business opportunities offered by industry 4.0 is not always easy while running a business on a day-to-day basis. To answer the questions how companies can learn and how change can be managed will be of key importance for senior management.

Digitisation increases also the importance of new technical skills, notably in the case of operating activities and mechanical working processes in production, purchasing and warehousing and logistics. New, process-dependent systems making greater use of technology may prove to be a major challenge for existing employees.

In some cases, employees require retraining or further training in operating these new applications if they are to make full use of them.

In future Swiss manufacturing companies will have to pay even greater attention to developing the competencies of their employees and recruiting a digitally sophisticated workforce.



Potential for individual business segments

The responses of the Swiss manufacturing companies surveyed showed a very mixed picture in relation to the extent to which individual business segments have already been transformed in line with industry 4.0 criteria and the potential they have to benefit from the digital transformation in future.

Current transformation segments

When asked which segments had so far undergone the greatest transformation in line with industry 4.0 criteria, companies most frequently cited **research and development**, with 30% indicating strong transformation and a further 30% very strong transformation (see Chart 11).

Further segments that had already undergone strong or very strong transformation included **procurement and purchasing** (26% and 17% respectively) and **production** (26% and 9% respectively). This is not necessarily surprising, since all these business segments traditionally embrace new and innovative manufacturing technologies.

“Industry 4.0 solutions are often introduced initially in individual production processes and only then repeated in other business segments and processes.”

Robert Rudolph, Swissem, Head of Training and Innovation

Chart 11. Current transformation segments and future potential

[Scale 1-5]



Question: Which business segments in your company have undergone the most and the least transformation as part of industry 4.0?

Question: Which business segments within your company have the greatest potential to benefit from the digital transformation to industry 4.0?

Marketing, sales and services, by contrast, present a much more uneven picture in terms of transformation and preferences. Roughly similar proportions of companies surveyed reported strong transformation, weak transformation and no transformation at all.

The two segments that have so far undergone the least transformation to industry 4.0 are **warehousing and logistics** (13% of the companies surveyed reported very little transformation and 35% no transformation at all) and **internal company administration** (17% reported very little transformation and, as with warehousing and logistics, 35% reported no transformation at all).

This is surprising in the context of warehousing and logistics, since this is also an area that has traditionally been heavily dependent on, and open to, new technological applications including, since the late 1990s, RFID (radio frequency identification) technology. 3D printing will also gain a substantial impact in this segment.

Many Swiss manufacturing companies need to act urgently to continue to transform business segments in line with industry 4.0.

“The biggest future benefit of industry 4.0 for Swiss industrial companies will be greater cost efficiency and/or productivity.”

*Robert Rudolph,
Swissmem, Head of
Training and Innovation*

Future potential

The segments that the manufacturing companies see as offering the greatest potential for benefitting from the digital transformation to industry 4.0 include **research and development** (in which a total of 78% of companies see great or very great potential), **warehousing and logistics** (74%), **production** (73%), **services** (72%), **procurement and purchasing** (69%) and **sales** (56%) (see also Chart 11).

There is huge demand for transformation in research and development, in procurement and purchasing and in production. These areas are traditionally heavy users of technological applications and innovations and are likely to remain so in the future. In the companies we surveyed, warehousing and logistics, sales and services seem to be the business segments that have so far undergone relatively little transformation to industry 4.0 but that offer substantial potential for benefitting from it.

Most respondents agree that Swiss manufacturing companies are not yet making full use of the increased productivity and improved efficiency that industry 4.0 applications offer. Many respondents see the main advantage of industry 4.0 as the ability to reduce costs further and to remain competitive. They see substantial potential across all segments of their company and across the entire value chain.

However, delays in achieving industry 4.0 standardisation remain a challenge. There is a need for standardised interfaces so that the machines in smart factories are able to communicate with each other and share data seamlessly with other smart infrastructure in the ‘internet of things, services, data and people’ to achieve smart mobility, a smart grid, smart logistics and smart homes and buildings.

In a world that is changing exponentially, there is a need to shift from ‘push’ to ‘pull’. The world has traditionally been organised around labour, with many assets and knowledge pools focused on efficiency. Superior engineering from Switzerland allowed higher prices, and planning and driving change (‘push’) was required. To benefit from exponential growth, companies need to organise around digital power, tap in to external pools of knowledge, combine assets, gain better knowledge about markets, industries and customer preferences (‘pull’) and focus on scalable learning.

“Standards can be a barrier to new technologies. Industry bodies are too slow to develop new standards for industry 4.0. If big companies collaborated more, then changes could be achieved more quickly.”

*Dr. Kurt Kaltenecker,
ABB Venture Capitals,
Head of Technology*

Impetus from exponential technologies

Emerging and exponential technologies are of great benefit in promoting the digital transformation to industry 4.0. They accelerate change and have the capacity to boost customer focus, individualised production, flexibility and cost savings.

Our survey focused on one prime example of such a key technology – additive manufacturing (AM)/3D printing – that has the potential to accelerate the transformation of the Swiss manufacturing industry to industry 4.0.

Relevance of 3D printing for manufacturing industry

Additive manufacturing is also widely known as 3D printing, with these terms often used interchangeably. The terms refer to a cluster of technologies that produce objects by adding material rather than by mechanically removing or milling material from a solid block.

Additive manufacturing involves constructing a product from sequential layers of fine powder or liquid. The materials involved include a range of metals, plastics and composite materials. There are four types of process, each using a different *additive process* or *additive technology*:⁷

1. **Lightpolymerisation:** a light-sensitive polymer is hardened through *stereolithography*, *digital light processing (DLP)*, *film transfer imaging (FTI)* or a *polyjet process*
2. **Extrusion accretion:** a wire-shaped plastic is applied in layers in a process of *fused deposition modelling* or *plastic jet printing*, similar to the process used by a hot-glue gun
3. **Compounding of granular materials:** a powder material is melted on to a work platform using a printer head or laser jet. Additive processes are *selective laser sintering*, *selective laser melting*, *direct metal laser sintering*, *electron beam melting*, *gypsum-based 3D printing* and *3D powder printing*
4. **Layered lamination:** a component is built up layer by layer in a *laminated object manufacturing (LOM) process*.

New technologies always require high levels of investment in development and roll-out, and 3D printing technology is no exception.

With conventional manufacturing, the cost of each manufactured unit is initially high but falls as more units are produced. Investing in a factory represents substantial start-up costs, but with mass production, these can be fairly easily recouped over time (see Chart 12).

With additive manufacturing initial investment is also very costly (although the cost of tools is lower). However, a number of studies have shown that in contrast with conventional manufacturing, the prototypical cost curve then flattens out.⁸

“The introduction of laser-based technologies in addition to powder-based technologies changed a lot. It helped 3D printing to take off more quickly in different industries.”

*Dr. Robert Sekula,
ABB Corporate Research,
Head of Manufacturing
Technologies*

“3D printing seems to offer cost savings of between 40% and 60% right across the process chain. There are major savings to be made from the advantages offered by new design, the reduction in the number of manufacturing stages and the resulting shorter delivery times, and the possibility of global production in local markets.”

*Raphael Urech, Alstom
Schweiz, Knowledge
Manager Hybrid Parts,
Thermal Power Sector*

“It is not inconceivable that in future, 3D printing will achieve production times that are ten times faster than the existing ones.”

*Dr. Robert Sekula,
ABB Corporate Research,
Head of Manufacturing
Technologies*

“3D printing often means a complete redesign, but the entire process chain needs to be considered, so that time and cost savings at the 3D printing stage do not simply mean more expenditure of time and greater cost at later stages in the process.”

Raphael Urech, Alstom Schweiz, Knowledge Manager Hybrid Parts, Thermal Power Sector

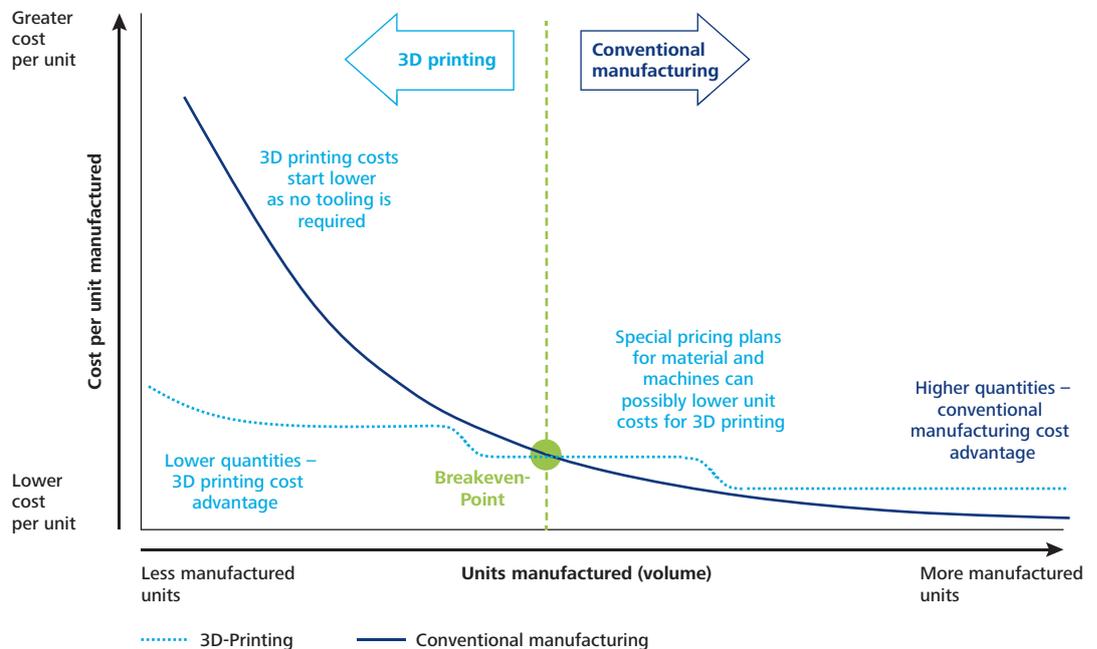
“3D printing will become the central production technology once 3D design has been introduced across the board and new products can no longer be manufactured simply by conventional means.”

Marcel Wenzin, agta record ag, Head of Supply Chain Management

“To make it a repeatable lean process is the main objective of a successful industrialisation of 3D printing.”

Paul Ryan, Alstom Schweiz, Additive Manufacturing Project Manager, Thermal Power Operations

Chart 12. Break-even analysis of conventional manufacturing and 3D printing



The break-even point is where the two cost curves intersect. At present, conventional manufacturing offers cost advantages when volumes and production runs are high, although this is likely to change. 3D printing is, by contrast, **attractive even for small volumes**. Special pricing plans for materials and printers may well bring unit costs down in the long term.

Further advantages of 3D printing compared with traditional manufacturing are its greater scope for **more complex designs**, a **more rapid market launch** (because fewer tools are required and savings can be made on development time) and **waste reduction**, resulting in a more efficient manufacturing process.

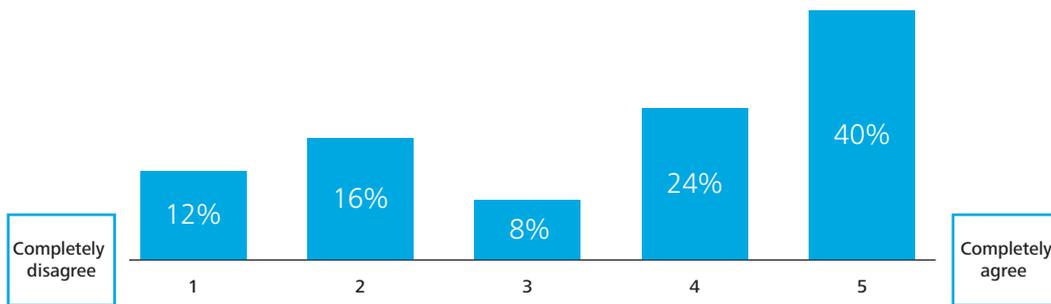
Against this backdrop, 3D printing technology is gaining in importance beyond its initial use for producing prototypes and is already in widespread use for small production runs, market launch series and customer-specific solutions.

The small number of disadvantages of additive manufacturing, which may continue to constitute advantages for conventional manufacturing, are the **high cost of mass production** mentioned above, the as yet **limited range of printable materials** (particularly polymers, metal powders and ceramics) and **limitations on the size of the components that can be printed**.

Relevance of 3D printing for Swiss manufacturing companies

When asked whether Swiss manufacturing companies view 3D printing as a key technology that could speed up the digital transformation to industry 4.0, two-thirds of respondents said they did (24% agreed and 40% agreed strongly) (see Chart 13).

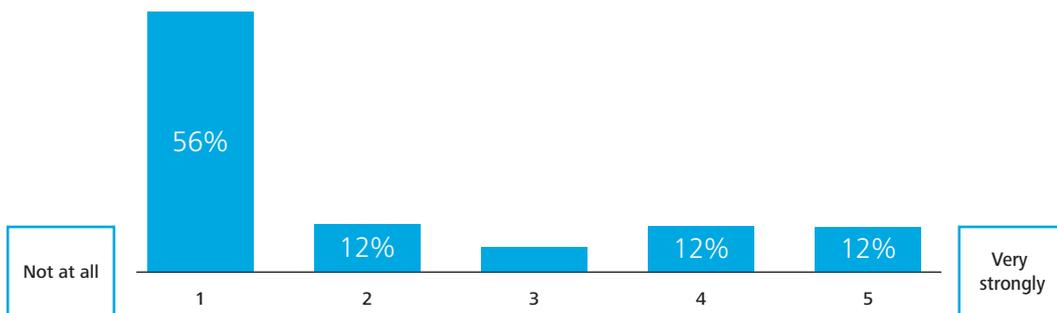
Chart 13. Potential to be a key technology
[Scale 1-5]



Their responses indicate that Swiss manufacturing companies are already aware of the significance and enormous potential of 3D printing technology to transform manufacturing industry in future.

However, very few of them are currently using this key technology: more than two-thirds of the companies surveyed are either not using it to any extent (12%) or are not using it all (56%) (see Chart 14).

Chart 14. Current use
[Scale 1-5]



Our interviews showed that most 3D printing applications are still used at the **prototype** stage.

In some cases, 3D-printed small parts are already being used in **first series**, which can then be launched rapidly to test the market, before investments are made in moulds and production lines. Only a few Swiss manufacturing companies are already making use of 3D printing for low-volume production, and most companies are not yet considering its use for mass production for cost reasons.

Question: Do you share the view that 3D printing has the potential to be a key technology that could speed up the digital transformation of Swiss manufacturing industry to industry 4.0?

“There is already a very high level of acceptance of 3D printing for prototypes. However, suppliers’ and customers’ confidence in 3D-printed parts has to increase further. Quality and cost factors play a key role here.”

Marcel Wenzin, agta record ag, Head of Supply Chain Management

Question: How intensively is your company already making use of the opportunities that 3D printing technology offers development and production processes?

“Large parts of manufacturing revenues are coming from the premiums charged for spare parts. As customers migrate to printing on demand, this will adversely impact the revenues of manufacturers and logistics and warehousing companies.”

Dr. Girish Nadkarni, ABB Venture Capitals, Managing Director

“The whole services and spare parts area offers huge potential for 3D printing. This could become even more interesting if spare part storage and transport costs were to increase in the future.”

Marcel Wenzin, agta record ag, Head of Supply Chain Management

“The biggest obstacle to the industrialisation of additive manufacturing is the extensive material qualification, which normally takes years. It is important to find ways of speeding up the qualification process.”

Raphael Urech, Alstom Schweiz, Knowledge Manager Hybrid Parts, Thermal Power Sector

“3D printing means major investment. Manufacturers need to ask themselves whether they want to do it themselves and develop capabilities in-house or commission it externally. The cost of printers and materials will come down, however, when more suppliers enter the market.”

Dr. Robert Sekula, ABB Corporate Research, Head of Manufacturing Technologies

Swiss manufacturing companies are currently making only very limited use of the potential of 3D printing technology. However, they are observing trends and new developments and keeping an eye on what their competitors are doing. They identify prototyping, small parts, spare parts and new service solutions as the first areas where they might introduce the technology.

They are also paying particular attention to the weaknesses and problems that arise with 3D printing technology, including achieving the **same quality** as conventionally produced goods (particularly in relation to porosity, durability, temperature and resistance). There is also a high level of interest in using materials with functional properties (for example, electrical conductivity) for 3D printing and in multi-material 3D printing, which will in future enable a number of materials to be printed simultaneously. Confidentiality and protection of intellectual property are further problems.

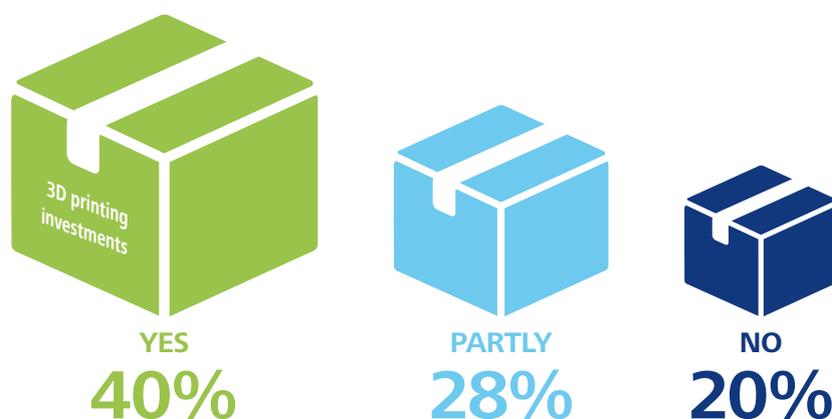
From the viewpoint of most of those surveyed, overcoming these weaknesses and problems will mark the final breakthrough for this key technology.

Future investment

Almost half of those surveyed (40%) plan to invest or to continue to invest in 3D printing technology in future, while 28% said they were planning some investment and just 20% had no plans to invest in the technology.

Many Swiss manufacturing companies adopting 3D printing initially partner with external providers with the necessary skills, such as business start-ups, universities or research bodies. There are differences between small and medium-sized companies – which tend to establish cooperation agreements with external suppliers and delay their own investment until costs have come down – and very large manufacturing companies and multinational groups, which are already investing in their own production capacity.

3D printing is, however, just one example of an exponential technology with the potential to accelerate the digital transformation. Greater investment in artificial intelligence, advanced robotics and sensor technology, drones and nanotechnology represent interesting opportunities for Swiss manufacturing companies to maintain and boost their competitiveness.



Further trends

Further significant future trends (cited by more than five respondents in each case) were ongoing **global optimisation**, tackling **existing pressure on costs and prices**, the launch of **new services** and **new process innovations** and/or other innovative solutions.

Against the backdrop of ongoing global optimisation, there was a particular focus on adapting production locations to globalisation, better global procurement and the development in the emerging economies.

With regard to new services, local service provision – such as specific spare parts and service businesses and one-stop shops for products and services – was a particular focus.

The next most significant trends (cited by between three and five companies) included a **greater customer focus** and **more customer-specific adaptation**, efforts to **reduce lead times**, **new forms of marketing and distribution channels** (especially in the e-commerce area) and greater **energy efficiency** across the production operation. Further trends cited by individual respondents included **preventive maintenance**, **automation of inbound logistics**, **smart data-gathering** and **miniaturisation**.

These additional trends and challenges are closely linked to the issues raised by industry 4.0 and exponential technologies or may be seen as an integral part of them.

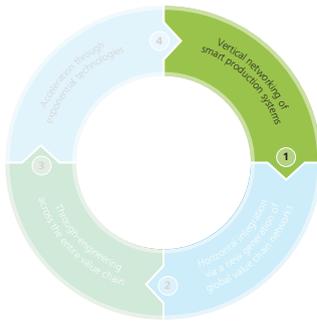
The digital transformation of Swiss industry and the roll-out of additive manufacturing technologies in the manufacturing sector, along with the use of other exponential technologies, will enable companies to take a more holistic approach to finding responses to many of these trends and challenges.



Industry 4.0 solutions

In the following section, we present a range of initial solutions to help Swiss manufacturing companies manage the transition to industry 4.0.

Vertical networking



Vertical networking solutions

IT Integration

The vertical networking of industry 4.0 requires new IT solutions. In many cases existing IT infrastructures are very fragmented and result in poor networking.

New, combined solutions need to be developed from a range of components from suppliers of sensors, modules, control systems, communications networks, business applications and customer-facing applications.

Companies making the right choice of these components and adapting and integrating them into a new over-arching solution will secure long-term market advantage.

Analytics and data management

Industry 4.0 will generate enormous quantities of data. Gathering, analysing and processing such big data will generate new insights, support decision-making and create a competitive advantage.

Companies need to develop new specialist skills in the areas of analytics and efficient data management, and put new business processes in place on the basis of the insights that this analysis reveals.

Companies who set themselves apart from their competitors in this respect will overtake existing sector leaders.

Cloud-based applications

The simple networking of cloud-based solutions offers excellent opportunities to host and make efficient use of the big data generated by industry 4.0. Cloud-based solutions will become increasingly crucial to industry 4.0.

There are particular advantages for decentrally networked smart-production systems, where previously unimaginable computing power will enable cloud-based applications to deliver universal, anytime access to all key data. This makes it simpler to gather, monitor, distribute and analyse data not only between factories but also across the entire global value chain network.

This forms the basis for providing over-arching market solutions that seamlessly integrate all stages from suppliers' value chains to end customers and allows innovation beyond products.

"Operational efficiency 2.0"

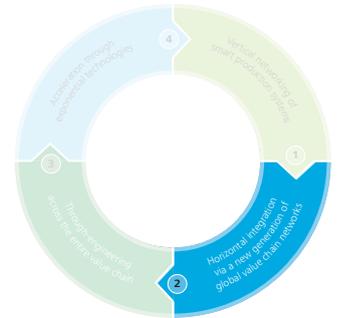
The digital transformation to industry 4.0 also offers new opportunities to drive forward operational efficiency.

The effective analysis, assessment and application of the data collected from machines and sensors enable rapid decision-making to improve operational safety, work processes, servicing and maintenance.

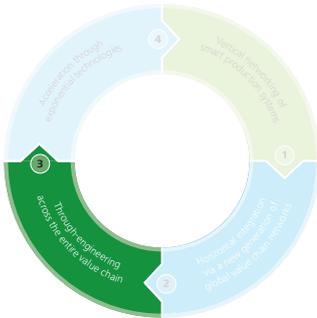
Transparency not only makes development and production processes more efficient but also offers substantial operational cost reductions for customers, because maintenance work is carried out in a needs-oriented manner (e.g. only a short while before a risk develops). This creates long-term competitive advantages in both reliability and price.

Horizontal integration

Horizontal integration solutions	
Business model optimisation	<p>Industry 4.0 means getting to grips with radical new approaches to business rather than merely making incremental improvements to established business models.</p> <p>To achieve this, companies need to develop new skills, both at individual employee level and within the organisation as a whole. A solely top-down approach will create resistance in the organisation, while introducing pockets of innovation within traditional business will provoke a reaction from less engaged employees.</p> <p>Successful companies will develop new segments on the edge of their current business that will, in time, become central to the business.</p>
Smart supply chains	<p>There will be a particular focus on new models that are tailored more closely to individual customer needs and enable new cooperative models with business partners. However, this will place new demands on the supply chain.</p> <p>The digital transformation will create a single database, making supply chains smarter, more transparent and more efficient at every stage, from customer needs to delivery.</p> <p>Research and development, procurement and purchasing, production and sales functions are becoming more closely aligned as digitisation advances.</p> <p>The most successful companies will use better communications to integrate suppliers and customers' needs into all value-creation activities.</p>
Smart logistics	<p>In the wake of digitisation, logistics processes will have to become smarter right across new generations of global value chain networks ('smart logistics'). This applies to inbound logistics, intra-logistics and outbound logistics.</p> <p>Major challenges are posed by the integration of autonomous technologies, flexible logistics systems, new services, new warehousing and distribution models and the interlinking of internal production, pre-assembly and external service providers. All these areas need to be addressed to remain competitive.</p>
IT security management	<p>The extensive networking already cited and the high levels of data sharing involved in industry 4.0 will greatly increase the demands made on data security.</p> <p>Companies urgently need a tailored risk management system and a security strategy geared to cyber security and aimed at improving operational security and protection from attack right across the value chain. In this respect, manufacturing industry currently lags a long way behind the financial services sector.</p> <p>New products, data, intellectual property and so on will have to be protected against unauthorised use and/or abuse. Existing factories and structures will have to be equipped and will also have to develop secure solutions for the new networks.</p>
New taxation models	<p>In future 3D printing technology will allow the printing of products across countries and continents, with no physical crossing of national borders anymore. This will make new demands in terms of value-added tax and customs duty regulations.</p>
New IP management	<p>Management of intellectual property (IP) will also have to change as a result of the digital transformation to industry 4.0.</p> <p>New business models and new models for cooperation that arise as a result of industry 4.0 will require new, individual solutions to the digital IP issue.</p> <p>A broad application of 3D printing will make special demands in this respect. Issues of intellectual property focus not only on printers, printer technology and materials but also on systems and plans.</p>



Through-engineering



Through-engineering solutions

The “ten types of innovation”⁹

Industry 4.0 will enable integrated and cross-disciplinary engineering throughout the value chain and throughout product and customer life cycles.

Industry 4.0 applications are designed to help ensure that innovation is not limited to the traditional area of product innovation.

Innovation has traditionally related predominantly to product offerings, but its major potential lies in the areas of company structures, processes, networks and profit models, together with customer-facing functions, such as new services and distribution channels, new uses for a strong brand and distinctive customer engagement (as categorised according to Deloitte Monitor’s “ten types of innovation”).

Empirical research shows that the share price of companies deploying more than just two types of innovation performs better on the stock exchange – and that top innovators deploy five or more types of innovation.

Efficient management of innovation

Successful management of innovation takes in the entire company and covers strategy, organisation, project portfolio management and product development.

The digital transformation to industry 4.0 will make it possible to improve further the efficiency of innovation management in all these areas.

Interactive and tailored curricula make individualised learning possible, thereby speeding up strategic implementation and organisational development.

In project portfolio management, industry 4.0 solutions make it easier not only to track the return on investment (ROI) in innovation but also to identify risks by using global comparative project data for monitoring and remedial purposes. In the area of product development, information technology can be used to speed up research and development. This transforms the sharing of information between existing technologies within global networks along the same lines as the ‘game networks’ that the global online gaming community use.

Efficient life cycle management

The digital transformation to industry 4.0 will make it possible to provide relevant data for life cycle management at any time and from anywhere.

These data will comprise not only information and reports but also the results of big data processing to generate relevant early indicators through the use of artificial intelligence (AI).

AI will use global cross-checking and assess the plausibility of generating relevant bases for decision-making supported by data. It will enable companies to understand and meet their customers’ needs better, as well as to customise product cycles.

Exponential technologies

Exponential technologies solutions

Corporate venturing Corporate venturing offers companies good opportunities for investing in new trends at an early stage and for benefitting from disruptive innovation and exponential technologies.

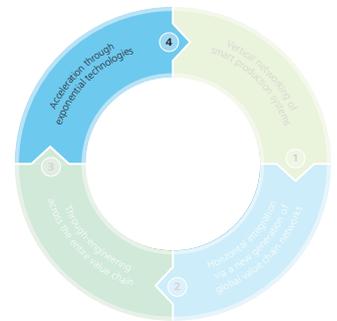
Investing in start-ups enables companies to be involved in developing innovations and to secure their long-term competitiveness. Such investments allow early and convenient insight into new technologies.

Companies need to give themselves more freedom to 'look around the next corner.' Only then, a new business area can be created that can become the new centre of the business in the future. If such opportunities are missed, the survival of companies could be at risk.

The learning organisation Companies need to become learning organisations if they are to make full use of the potential of exponential technologies in achieving the digital transformation to industry 4.0.

The use and integration of exponential technologies need to be gradual but steady. Learning is the key to sustainable organisational development. Change that is too rapid can be counterproductive.

New ideas, processes and business segments are most successful when they start off as a niche where learning goes on, and then gradually migrate to the centre of the organisation to establish themselves as a new leading segment.



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Contacts



Dr. Ralf C. Schlaepfer
Managing Partner,
+41 (0) 79 402 20 30
rschlaepfer@deloitte.ch



Markus Koch
Consulting Partner
+41 (0) 79 773 48 14
markkoch@deloitte.ch



Dr. Philipp Merkofer
Manufacturing Research
+41 (0) 58 279 60 46
pmerkofer@deloitte.ch

Notes

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Deloitte Basel

Steinengraben 22, 4002 Basel

Tel: +41 (0)58 279 90 00, Fax: +41 (0)58 279 98 00

Deloitte Berne

Schwanengasse 11, 3011 Berne

Tel: +41 (0)58 279 96 00, Fax: +41 (0)58 279 96 50

Deloitte Geneva

Route de Pré-Bois 20, P.O. Box 1808, 1215 Geneva 15

Tel: +41 (0)58 279 80 00, Fax: +41 (0)58 279 88 00

Deloitte Lausanne

Avenue de Montchoisi 15, P.O. Box 460, 1001 Lausanne

Tel: +41 (0)58 279 92 00, Fax: +41 (0)58 279 93 00

Deloitte Lugano

Via Ferruccio Pelli 1, P.O. Box 5520, 6900 Lugano

Tel: +41 (0)58 279 94 00, Fax: +41 (0)58 279 95 00

Deloitte Zurich

General Guisan-Quai 38, P.O. Box 2232, 8022 Zurich

Tel: +41 (0)58 279 60 00, Fax: +41 (0)58 279 66 00

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