Smart Industry

A vision for Dutch Industry fit for the future

Prof Dr Ir Egbert-Jan Sol
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TNO Industry   - CTO Smart Industry
Smart Industry   - Director Program Office
EFFRA   - Vice chair of the European Factories of the Future Research Assoc.
Radboud University - Prof Research Management, Science Faculty
                Institute Society, Innovation & Sustainability

Introduction

The acceleration of digitalization is changing our society, our businesses, our industry and our way of living. Products and services become so-called smart. Our businesses and industry are entering the so-called fourth industrial revolution. Digitalizaton makes customization and servitization with *smart products* and services as well as flexible manufacturing and service platform possible. Zero-defect, zero-programming, zero-surprise production of single piece customized products for the price of mass produced products in flexible factories make *smart manufacturing* possible. Such factories will move close to the customer and bring production and manufacturing jobs back to town. With it benefits comes challenges. One risk is that the winner-takes-all platform providers grab the major chunk of the created value. Another challenge is that societies will face market and labor mismatches if we don't response with proper education to all.

The fourth industrial revolution has a much larger impact then on industry alone. For this reason we started in the Netherlands the *Smart Industry* action program. By Smart Industry we mean that our world is changing towards smart products and smart manufacturing. It implies that our industry should be made fit for the future.

This note provides a vision and describes why things are happening and what the results and the impact of four simultaneous game changers will be. These game changers are smart products and services (businesses), industry, technologies and needed societal response.

A recent history on digital paradigm shifts on hardware, software and bandwidth ….
We all know Moore's law. Micro electronics got smaller, more powerful and cheaper at the same time. This resulted in the most aggressive learning curve mankind ever
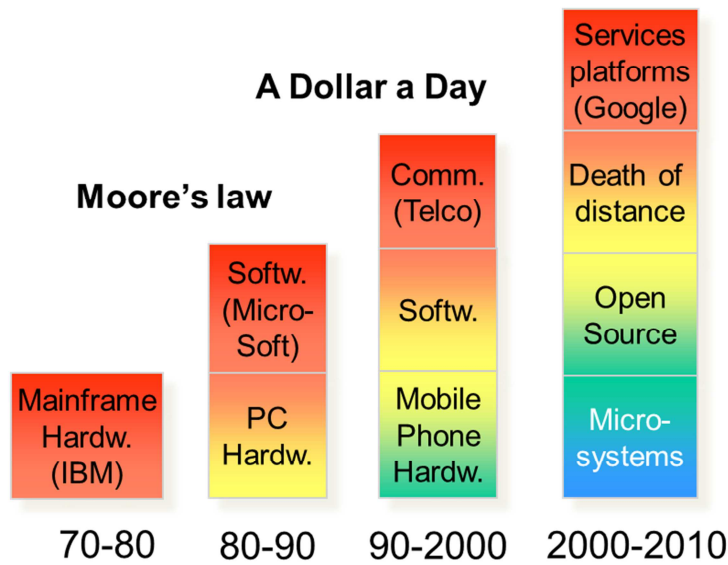
experienced with performance/price ratios doubling ever 1.5 year or 1000 times in 10-15 years. By 1991, Harvard Business Review published a paper on the computerless computer company. Since 1980 the big IBM mainframe computers were replaced by personal microcomputers. Large computer companies went bankrupt and by 1990 it became clear that computer software companies (without their own hardware) as Microsoft were more successful. Around 2000 the same happened with telecommunication operators. Until that time they monopolized bandwidth, but with Internet the learning curve on bandwidth expressed in the price/"Megabyte per day" followed the same fast speed as Moore's law. Today, three digital paradigm shifts, computer hardware, software and bandwidth, latter the game is on services with platforms as Facebook and Uber. And beyond that on ……
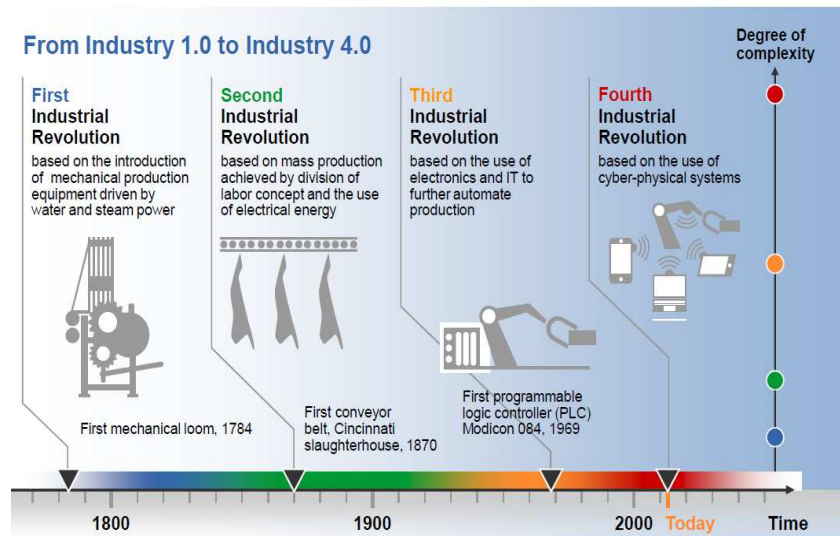
Metcalfe's law

A Dollar a Day

Moore's law

		Comm. (Telco)	Services platforms (Google)
	Softw. (Micro-Soft)	Softw.	Death of distance
			Open Source
Mainframe Hardw. (IBM)	PC Hardw.	Mobile Phone Hardw.	Micro-systems
70-80	80-90	90-2000	2000-2010

Digitalisation that does not stop but even accelerates and create new opportunities …
Nevertheless, the developments on hardware, software and bandwidth continue. Hardware costs, directly related to the size of a devices, goes further down as devices become smaller and smaller with full PC capabilities from desktop to notebook to the mobile phones of today. It continues tomorrow in flexible foil devices and pushpins into what we know call Internet of Things with not a billion PC's but with 1000 Billion devices, i.e. hundreds per human, and soon all interconnected. With all these devices Metcalfe's law is important. Metcalfe state that the value of a network increases with a factor n^2 for any given number of n nodes. This is the mechanism behind the fourth industrial revolution. In the third we

From Industry 1.0 to Industry 4.0

Degree of complexity

First Industrial Revolution
based on the introduction of mechanical production equipment driven by water and steam power

First mechanical loom, 1784

Second Industrial Revolution
based on mass production achieved by division of labor concept and the use of electrical energy

First conveyor belt, Cincinnati slaughterhouse, 1870

Third Industrial Revolution
based on the use of electronics and IT to further automate production

First programmable logic controller (PLC) Modicon 084, 1969

Fourth Industrial Revolution
based on the use of cyber-physical systems

1800   1900   2000 Today   Time

Source: DFKI (2011)

Zilverstraat 69, 2718 RP Zoetermeer   W www.smartindustry.nl
Postbus 190, 2700 AD Zoetermeer   E info@smartindustry.nl

automated single machines as robots, machine tools and programmable logic controllers, but interconnecting everything to everything was still too expensive as (industrial) hardware, proprietary software and bandwidth costs were very costly. But all these aspects are changing. Hardware, software, bandwidth all become cheap (Moore). And now we start interconnection everything and gradually realizing increased value (Metcalfe). Digitalization is accelerating, changing the rules-of-the-game in business and has impact on society, both in opportunities and needed, smart responses.

Servitization and the battle on platform dominance

Today the focus is on service platforms. We see in businesses the rise of "servitization" and the importance of owning the platforms, in most cases a web portal attracting and analyzing all traffic related to the use of a (smart) product. Customers pay for use rather than ownership. In stead of owning a car they pay for Uber. As a result, original product/equipment manufacturers (OEM) evolves into service providers with digital platforms and an accompanying hardware product with which the solution is be delivered. The idea is that you make more money if you can monopolize the service platform as Uber and AirBnB do and let other manufacture and run the hardware.

As OEM-ers change their business model the consequences propagate into their value chain. Industrial suppliers, once the cheapest supplier of a component, are now asked to take over the entire production process of the hardware product. Or will an automotive OEM-er become a supplier of cars for Uber? All this has an impact on our entire industrial landscape and has cascading implications for our society and employment.

So, it is eat or to be eaten …

Smart products and services, smart manufacturing, smart technology and a smart response by society are all interacting at the same time. If a society adapts on time, this development offers a job engine of the future. But the acceleration of digitization requires more dynamism and synergies in various areas. A strong position in wealth and welfare creation with a competitive economy must be fought for continuously.

And we need all to get out of our comfort zone ….

Given the speed of development, businesses, institutions and government need to get out of their comfort zone. Knowledge institutions have to adapt more quickly that once ever 4 years. Lifelong learning is a must for everyone, citizen, workers and business people. Companies must invest more in new services, innovative products and appropriate technologies. And the government should more actively help create new markets around challenges with a social, environmental and economic benefits.

Smart Industry Game changers

We distinguish four broad game changers:

(1) smart products and smart services (servitization),
(2) smart manufacturing - flexible factories and platforms to deliver goods and services,
(3) smart technologies - the enabling systems of systems technologies and
(4) smart response - the economic and social conditions, effects and our reactions to them.

Each game changer impacts respectively new business, new jobs, new science and new forms of education. And every game changer requires cooperation between companies, knowledge institutes and government.

Smart Products and Services (servitization)

This game changer examines innovation in products, product-service systems and business models. In particular, the human-product-content interaction is central and particularly should be relieving and unburdening humans in complex environments. The premise is that the Netherlands has a unique distinctive position in the multidisciplinary approach to product design, service innovation, technology platforms and content development. We also have a highly educated population and we have an excellent test market for new products and services.

Smart Products with sensors, embedded intelligence and connectivity ….

Socially and economically, we see a move to customization of products, energy, services, etc. This is made possible largely by digitalization and smart products with sensors, embedded intelligence and connectivity. Smart products observe what is happening in their environment, process that information into actions, and can thus interact with other products (in a network), but also with people, and (changes in) the product environment. In all cases, these are man-machine interactions, sometimes in increasingly complex environments, often with a "smart" feedback.

Examples of smart products …

Examples include the GPS system in a car enabling cooperative driving, smart meters in buildings and built environment, intelligent seat that detects sedentary and stress monitors, intelligent bed that collects information about sleep behavior, and machines in a factory with sensors gather information for the purpose of preventive maintenance. Smart products may be used by consumers, but may also be machines connected in a network in the smart factory, or cows or cars connected by wireless networks to the Internet.

Understandable for humans …

The challenge is to establish the correct (and safe) action and reactions by humans, the customer, the user. This requires creative design, content creation (in entertainment industry), excellent visualization / tactile / audio interactions, especially in more complex situations, to extensive simulation and gaming capabilities. Dutch Design will also have to make the human-technology interaction a success. Applications are in the creative industries by designers in the entertainment industry, but also in healthcare and other industries that have to do directly with the human user or customer. Digitization with smart products, platforms, systems or systems and personalized products creates more opportunities than necessary. It is essential at an early stage to recognized which opportunities create real value for the user.

Marketable, reusable and recyclable …

Smart, customized products requires moreover other sales and sales support / selection process than traditional store. The Smart Shop concept has significant impact on shopping centers. There are also consequences for durability, local repair services and

reusability or recyclability of product and / or parts / materials. Could this be a new function of yesterday's shopping centers?

The new Dutch Design ….
We will have to continue with the distinctive design of meaningful smart products (and services) in order to achieve impact at a global scale. In the old days, OEM-ers had their inhouse design departments. And as with Smart Industry with flexible production largely outsourced, design increasingly becomes detached from a production company into design houses, similar as in the electronic chip business. This can create new design jobs in the Netherlands. An example is the architectural firms and media companies that operate globally and have created quality employment. The challenge is to achieve this for smart product design too. In line with this development we will see development opportunities for servitization concepts too.

From ownership to use, from have to lease …
Traditionally, companies are product oriented. In the Smart Industry the revenue model is related to the value which is brought to the user in a dynamic way. This involves the interaction and experience by the user. The smart product is "only" a product or platform to trigger the interaction. The user uses a particular function, he / she wants to be "care-free" and seeks solutions rather than ownership of a product. In order to be able to continue to create this value, the product must (or service) constantly adapt to the needs of the customer and it has to use the developments in technology and market.

From listening to the customer, to continuous follow and adapt to the user …..
This requires the ability to understand and preferably predict the needs of the customer and the ability to respond quickly to changing needs. It is not enough the listen to the customer. Today you have to follow the customer. If they change, you should be able to change too. You want to monitor their usage, want to predict what the majority will do next. The last aspect is also the reason that yesterday product companies are shifting the research towards understanding and following/predicting customer needs and are losing their focus on classical manufacturing. We will get back to this development.

From product support to service with a hardware product …
Smart products generate in their use large amounts of data. This enables the service platform provider to follow the behavior and changing needs of a customer. The real-time analysis of these data ("big data analytics") makes it possible to use these data for a variety of additional or new services. It also allows for integration of the product bundled with services into larger systems. Therefore, we can speak of product-service systems. These embody the concept of servitization in which products are replaced or complemented by services. And with Metcalfe, the more connected the more valuable.

And so from OEM-er and supplier to service provider & hardware producer …
Classical producers will focus increasingly on the user and on solutions and less on manufacturing their products. That is outsourced. In economic terms, it is shifting the cash-flow of direct sales immediately after manufacturing a product to a stream of lease revenues over years, sometimes based on micro-payments. In the meantime, the traditional suppliers that previously could provide a component for the lowest price,

must now deliver a more complete product in an ever changing market. They must reinvent themselves as flexible producer-suppliers.

And the new key of the service providers: platforms
The type of products in which ICT and the Internet plays a large role is increasingly seen as a platform product. The value of a platform increases when it's ecosystem expands both in the number of users and content providers (double Metcalfe). Examples of platform ecosystems are (Google, Facebook, Apple, Arduino / Rasberry, but also Uber, AirBnb, ...). The development and application of smart products, the trend towards servitization and the struggle for platforms is currently gaining momentum. It creates disruptive innovations that affects many sectors. This is accompanied by radical business model innovations.

Examples are not only in the use of cars or leased ships, aircraft, equipment, but also in non-hardware-related products as the media industry. There all CD and video sales are now replace by monthly subscriptions to iTunes and Netflix. Also in the financial services sector we see the impact. The banking industry is still functioning as "incumbents" with centralized business models. But Fintech businesses and completely distributed models as block chain disrupt the existence of the current banking practices. The US-based ICT players are successful here and we will have to make our choices.

All with far-reaching consequences for the whole chain ...
All these developments are not limited to only the revenue (such as pay per use) and replacing a few old IT systems. It is the clever configuration of chains and partner networks around the customer needs, innovation in the customer interaction, cooperation between the parties during all phases of the life cycle, and how costs, revenues, risks and investments in the partner network around a smart product / service / solution are shared. This development requires not only other economic and legal insights on ownership, use of data and digital security, but has implications for work-related aspects such as digital capabilities too.
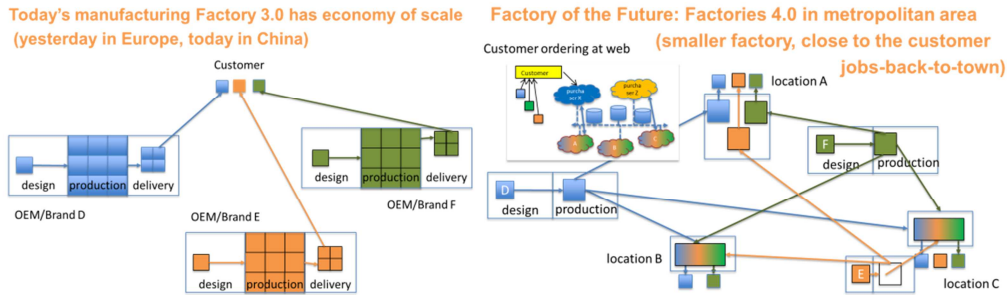
The game changes with smart products …
Concluding this game changer or paradigm shift we can state that it is mainly the creating of always connected smart products including the servitization with the (digital) platforms that is new. But there are more game changers to consider.

## Smart Manufacturing - flexible factory thanks to digitization
This section examines the renewal for automated production of small series and single piece of components and products . The game changer is the flexible factory in the form of "metropolitan manufacturing": small universal factories close to the customers where various types of products are produced (and later locally disassembled again) in small series for the cost price of mass produced products. Netherlands stands out in the high-tech systems industry with the production of very high tech production in small series for niche markets. Netherlands can improve its position with Smart Industry innovations as well as provider of new production machines for single pieces and small series production as for example in 3D and flexible electronics printing. Changing economy-of-scale as in mass production (as in China) to economy of networking through metropolitan manufacturing (jobs-back-to-town) has an impact on the current (SMEs) industry. As this change accelerates, old industrial continue for some time, but

evaporates on the long run. But it are the new players and entrepreneurs that wwill create / maintain jobs.

Today's manufacturing Factory 3.0 has economy of scale (yesterday in Europe, today in China)

Factory of the Future: Factories 4.0 in metropolitan area (smaller factory, close to the customer jobs-back-to-town)

"Manufacturing jobs back to town" in sea-container sized factories

Flexible production is the game changer in the industry that involves reducing changeover times in multipurpose plants and shorter campaigns in the process industry and that, with minimal delivery times in the manufacturing industry, produces single piece products for the price of mass production. In the ultimate case of the processing industry products it is a container, using process intensification, producing at the customer site (Chemistry 4.0). In the case of the manufacturing industry (Factory 4.0) (ref 1), we think of clusters of units of the size of sea-containers with robots, machine tools, 3D/electronic printing, assembly and storage warehouses that in urban areas (metropolitan manufacturing, maker movement, etc.), or ultimately at the back of a big shop, produces close to the customer products based upon product-production recipes of the owners of the product design. Very simply stated: it are 3D copy shops. This latest development brings back jobs back to town and has the ultimate consequence that individuals and designers will soon no longer need their own factory. They only need access to a location where their design can be converted into a production recipe. Once verified, the product can be produced at any similar "3D copy shop" elsewhere in the world on standardized manufacturing equipment.
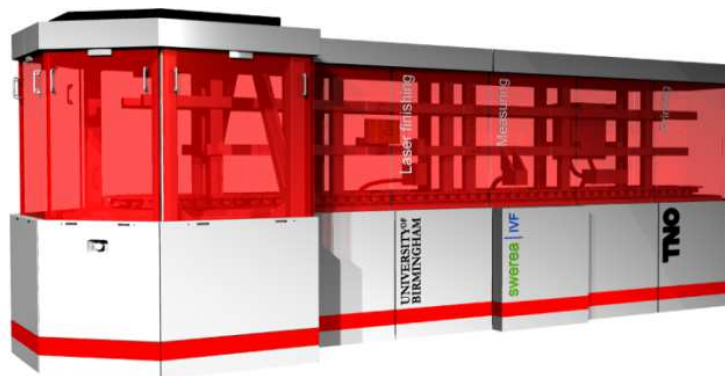
With a lot of technology and digital technology around such factories

All this becomes possible by far-reaching digitization and automation processes within and between players of value chains. In addition, we need zero-defect manufacturing processes, zero-programming capable production equipment like robots that configure their program based on a CAD-design and some sensors and zero surprises predictive

maintenance. All possible thanks to developments as Internet-of-Things sensors and data collection and big-data sharing, management and analytics.

Full digitization of the entire order process for components, suppliers and assembly process is required. This can be in digital market platform such the costs of transactions for a order of 1000 products is the same as 1000 times an order for single piece. To realize this over an entire value chain blockchain or distributed ledger technologies are promising new technologies that will make this possible.

And then there are even more possible … (recycling)

Realizing single-piece production for the price of mass production around the corner or in town is also enabling economical recycling. The same product-production recipe can later be used for recycling or refurbishment of returned products. Essential is the management of Product Data during design, production, use and later recycling. Here blockchain traceability can be put in as a kind of distributed database over time and across all concerned parties.

But also more is needed …

In this context of production and recycling materials plays an important role, c.q. has a number of challenges. Is it possible to apply developments in chemistry into functionality that can be applied by product developers and recycle players? Can digitalisation help by simulation, virtualization, quantum effect calculations to develop better materials and surface interactions. And, key for recycling, we know the properties of new materials, but can we predict the properties of used materials. This lead us to the next gamechanger.

Smart Technologies - Systems of Systems & block chain

This game changer concerns the technological base for Smart Industry as ICT infrastructure, data exchange, software, new sensors, nano / precision and process technology.

The consequences of unprecedented distributed interconnected systems

Systems of systems are collections of task-oriented systems that work together and thereby deliver more functionality or performance. Examples include co-operating robots, cars, drones or microsatellites, but also our road network as well as Internet and peer-to-peer file systems. Metcalfe states that the value of these systems increases quadratic (n^2) with the number of participants (n). Today we see an explosion of opportunities with never ever before possibilities. It started with the Internet between computers, but now we see the emerge of cyber-physical systems. These are systems which consist of networks of interacting physical entities that are monitored and controlled by computer algorithms and / or humans. The technological game changers here are the distributed non-hierarchical, non centralized systems such as the Internet with its routing protocols, totally distributed files as with peer-to-peer networks and even database sharing which unknown parties as in as block chain and the intelligent systems as high-frequency trading that can make independent choices. Link this development to hardware devices (Internet of Things), add to that platform technologies as block chain technologies and you can image some of the changes of the fourth industrial revolution.

So we got robots, computers, drones, instruments connected ….

The decreasing cost of sensors, robotics and software capabilities enables cyber-physical systems and zero-programming of robots. A robot can cooperate with a large number of sensors which observe the working space for that robot in order to perform a task in non-defined environment. By combining sensor measurements with adaptive simulation and optimization systems, processes can be continuously monitored in real-time and optimized, problems can be detected directly, and may be corrected automatically. The application for cooperative driving will improve road safety and reduce the social costs of accidents. Other examples include agricultural and horticultural robots working in warm, humid, high CO2 rich or outdoor environments, even 24-hour day and night during harvest time.

But the fastest evolving technological game changer is block chain

Decentralized technologies such as the internet router protocols, peer-to-peer file distributions algorithms as well as block chain protocols are technological enablers. The impact of the Internet on the telecommunications industry was seen in the years 1990-2000. The impact of peer-to-peer file distribution on the media industry is known too. Youngsters have no LP-records and CD anymore, but use streaming services as Spotify and iTunes. Blockchain is a distributed ledger technology where you can share a reliable database with known and unknown parties and is predicted to cause a similar paradigm change in the financial, government and commercial world. There are even blockchain visions where smart products during their design, make, use and recycling phase are followed. And in far reaching visions smart products even act independently and function autonomously as the autonomous driving taxis searching ala Uber for its customers who pay with bitcoins and with this money it can acquire it own energy and controls its own maintenance and even buy a replacement in due time.

Digital Market Place for manufactured goods - Legal Framework/ Standards to be used
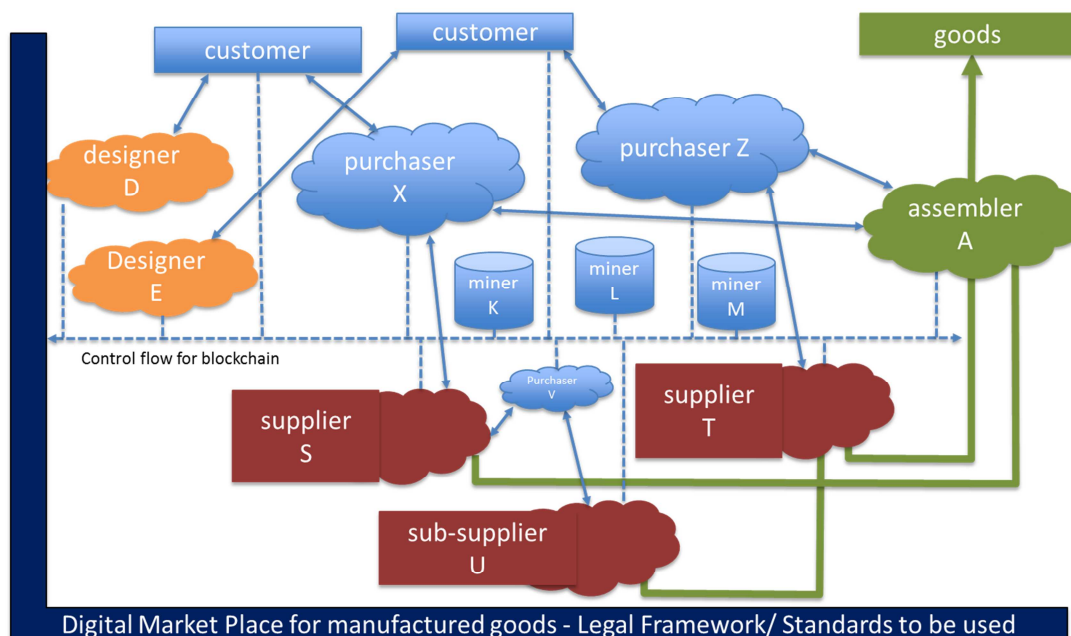
For distributed digital supply platforms

More realistic are the proposals for a transparent digital commerce platform using block chain with smart contracts. You put a request for quotation on a network of assembly

shops with the production recipe and the bill-of-materials for each component and requests a quotation and where the smart contract automatically select the suppliers with the best price and delivery time.

Smart Reponse - Social impact on smart jobs and skills

What is the social impact of the acceleration of digitization in a broad perspective and the smart and safe response as a society and individuals? How to change jobs, work relationships, sectors, organizations and business ecosystems / networks and what is the impact on employment? What new skills and abilities are needed for smart environments and the use of smart products? And what are the risks of open systems, as e.g. with regard to cybersecurity? Smart education is the main game changer here.

How do we react to the acceleration of digitization …

Digitization has a broad social impact on industry, business models and changes in consumption patterns. What is our "smart response' or smart interaction with consumers, workers, politics, media, etc.? Where do we need to be proactive and in which situations should we operate more defensive? Mostly it is a response to an unknown future. This requires explorations of possible futures (scenario studies). In any case, strengthening the resilience of the population, creating a learning economy are necessary. However, dealing with and respond well to the digitization also applies to the whole society. In simply words, it is about educations for all.

Can we change the way we learn for initial education to live-long education …

The discussion about vanishing functions over the next 20 years stating that between 10 to 50% of the functions and businesses disappear (disruptive innovation) can serve as a starting point. It makes clear that we need to work hard to get the new jobs and businesses off the ground. In history we always succeeded so far, but it is not automatic: accelerated development of new business models and new skills are needed. How can we develop new learning environments that can react much faster than the traditional education? How organizations can stimulate that learning and development is a continuous effort?

Educational therefore is not limited to initial education. It has to extend to education of workers and the elderly. How we can create more teaching in real business situations, on the factory floor and the office? How can we scale up the experiment with field labs, professional workshops and teaching factories? Education will have to expand from the "teacher" in front of a classroom to the "tutor" with (digital) individual arrangements for young and old. Dealing with continuous change, creative skills, digital skills, solving problems in complex environments are examples of Smart Industry related challenges for with a smart response is needed.

Conclusions and an outlook what is ahead of us

Our outside world is changing and provides all kind of new opportunities and challenges. If one wants to take active part in shaping the future one can contribute from all kind of disciplines. But tomorrow will be different from today, so start acting today different from yesterday. Changes are not linear extrapolation of what you are doing

today. A vision, or a description as a dot-on-the-horizon, helps to set course. In this case we have set four dots on different, but interlinked horizons. The challenge now is to determine your course. Be prepared for a bumpy, but interesting road.

The goal of personalization beyond servitization
Above the 1000 Billion smart Internet of Things devices, the flexible factory and servitization were described. But what is next: Personalisation. Apparently there is a trend away from the classical solutions (a kind of Gran Tradioze, or more of the same scenario), toward today's service mania, all possible because of digitalization. But with this digitalization also fundamentally new distributed solutions are appearing, first the internet, then peer-to-peer file systems (bittorrent/github) and new distributed ledger database technologies (blockchain). This trend combined with extremely powerful terminal devices as smart phones, smart watches etc, will lead to an up-and-away scenario around personalization. Bitcoin wallets where no bank is storing your money is a first example. Personalized food, personalized medicine, health, transportation, etc. are all to follow, including personal production of the good you need in a flexible 3D copy shop around the corner. Smart products produced with smart manufacturing is the goal of smart industry serving personalized solutions for the price of mass produced products, around the corner in hours or days instead of weeks.
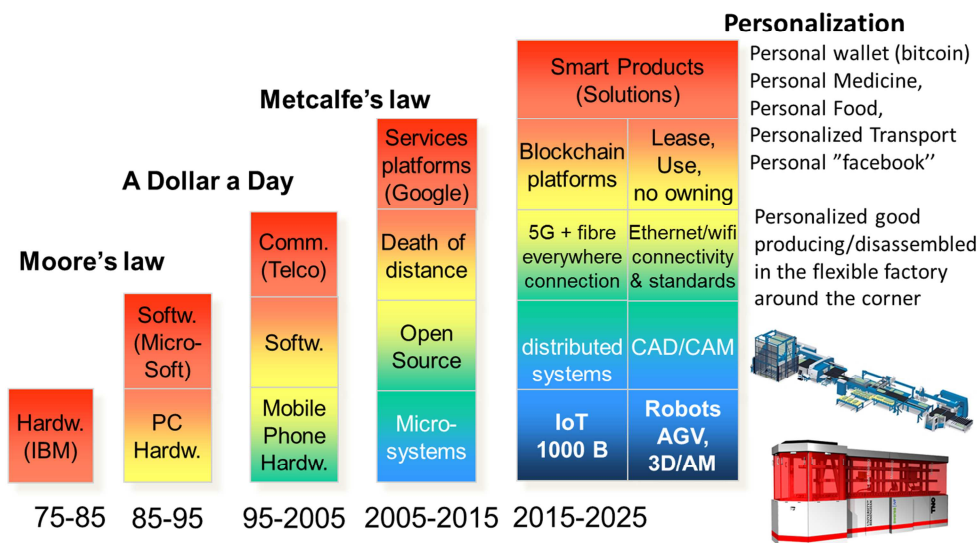
It is this outlook that indicated that today's fourth industrial revolution will go beyond the factory plant. It will impact businesses, work and society, positively and questionable. Responsible research should investigate these aspects on time to help innovate society and the members as the general public, workers and businesses to make them fit for the future.

References: www.smartindustry.nl
1) Factories4E - A vision for the 4th industrial revolution for Europe,
egbert-jan.sol@tno.nl

Zilverstraat 69, 2718 RP Zoetermeer   W www.smartindustry.nl
Postbus 190, 2700 AD Zoetermeer   E info@smartindustry.nl