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Business Innovation Observatory

Internet of Things

Smart machines and tools

Case study 45

Internal Market, Industry, Entrepreneurship and SMEs

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1. Executive summary

By connecting machines and tools used in work environments, the Internet of Things will enable a new range of applications, improve productivity, and increase efficiency. This includes Smart Machines and Tools. What makes machines and tools smart is their functionality to collect operation data in their environment, interact and communicate with other machines and make decisions on a decentralised level through embedded intelligence and predefined parameters. More specifically, Smart Machines and Tools enable:

- the automation of various tasks,
- the mass production of customised outputs, manufacturing systems and processes to adapt in an agile manner to varying conditions thanks to embedded systems and machine-to-machine communication;
- the connection to central intelligence and monitoring systems which allow operators to automate workflows, optimise maintenance or increase worker safety.

The socio-economic impact of Smart Machines and Tools, and larger trends such as Industry 4.0, is enormous. Automation of production processes using smart machines like robots will substantially increase productivity, allowing European companies to better compete with low income countries. These benefits will provoke substantial investments in these technologies, and provide opportunities for companies that develop Smart Machines and Tools.

The counter side of further automation in both manufacturing and service sectors are potential job losses. Although the rise of Smart Machines and Tools will generate new high-value adding jobs, it is yet to be seen whether these new jobs are numerous and whether the existing labour force in Europe can be (re)trained to match the required qualifications.

Challenges for adopting Smart Machines and Tools from a client-side perspective are limited. The most noteworthy challenge relates to service robots, which still struggle with safety issues and regulation. This often implies that a robot cannot function at its full potential (e.g. too many moving parts) or the robot needs to be supervised manually, largely nullifying the automation benefits.

Smart machines and tools are implemented across all economic sectors, starting with resource extraction and agriculture all the way up to the service industry. As a result of the introduction of Smart Machines and Tools, and the benefits they provide, in manufacturing, most Original Equipment Manufacturers (OEMs) open up their value chain more and more. The large data pools that Smart Machines and Tools generate during production enable a new range of applications, such as predictive maintenance, highly specialised supply chain management and inventory management. To make use of these new features and acquire full benefits, OEMs do have to closely collaborate with their suppliers and share crucial company information.

The main drivers for implementing Smart Machines and Tools are the productivity and efficiency gains resulting from (further) automation. Other contributing factors are technological progress in nano-electronics and photonics, which constantly reduce the price and size of crucial components, and the increase in worker safety and satisfaction by having robots take over monotonous, dangerous and unhygienic work. The key barrier for the further diffusion of Smart Machines and Tools is the substantial level of investment required for developing and commercialising this technology.

To alleviate this barrier for companies, policy makers could act as a potential launch customer for Smart Machines and Tools and provide more concentrated funding possibilities for both R&D and commercial activities. They could make sure that the rest of society, particularly the labour market, is ready for the coming change.

2. Smart Machines and Tools

What sets Smart Machines and Tools apart from their conventional counterparts is that they are connected to other machines, tools and (sub)systems in a production or working environment. Operation and production data are continuously collected through sensors that are embedded in the machine or tool and are transferred to a central monitoring system, a production (sub)system for autonomous processing or an operator. These machines and tools are considered smart in a sense that they collect operation data in their environment, interact and communicate with other machines and can make decisions on a decentralised level through embedded intelligence and predefined parameters.[1]

Smart machines and tools, similar to computers, can be connected through the Internet (or in some cases through conventional wires). The phenomenon in which not only computers, but all sorts of devices with embedded computing capacity are interconnected is often referred to as the Internet of Things. In most cases, however, Smart Machines and Tools operating in a production environment are (still) strictly fenced off from public internet (in contradiction to what the name might suggest). In certain occasions, maintenance service providers, component suppliers and/or customers are granted access to (parts of) the smart production network.

The application market for Smart Machines and Tools is very broad, covering almost all industries. Examples in this case study include small series manufacturing (OpiFlex), large series manufacturing (Admesy), the service industry (Robotics Inventions and EOS Innovation) and the agricultural sector (Nedap Livestock Management).

Smart machines and tools drive the spread of a global megatrends such as big data and Industry 4.0, (as it was first phrased by German policy makers). Industry 4.0 constitutes the next revolution in industrial automation. Industry 4.0 is all about the consistent digitisation and linking of all productive units in the economy.[2] Although IT components already play a central role in most advanced production systems, these components will become more and more connected with all parts of the production environment, supplier and customer systems and internal- and external objects.

Smart machines and tools will cause many changes for companies across industries: increased production flexibility will allow production outputs to be more easily customised on a large scale (mass customisation) and automation to be cost-effectively applied to small series production (OpiFlex); enhanced quality control and error reduction (e.g. Admesy); improved productivity and increased efficiency (e.g. Robotics Solutions and EOS Innovation); and a range of new applications through advanced data collection (e.g. automated heat detection and animal health monitoring by Nedap).

Besides conventional benefits of automation, such as productivity and efficiency gains, completely new applications are enabled. Smart machines and tools in general excel in data collection. This increasing pool of operational data provides managers and their suppliers with valuable insights to for instance conduct predictive maintenance, increase operational performance and enhance safety.

Table 1: Overview of the company cases referred to in this case study

Company	Location	Business innovation	Signals of success
Admesy	NL	Admesy has developed an advanced measurement system which combines a spectrometer, used for measuring wavelength characteristics of for example light sources, and a colorimeter, used to determine the colour of emitted light based on tri-stimulus sensors. This system can be fully integrated in the production process of for instance displays or LEDs.	• Admesy is able to offer its novel product, which offers substantial customer benefits compared to existing solutions, against a midlevel price. Admesy's technology is currently already implemented in the production lines of Samsung and HTC (e.g. S4, S5 and HTC One smartphones). • Realised approximately EUR 2.6 million in revenues in 2014, and prospects a revenue of EUR 10 million to EUR 15 million for 2018.
Robotics Inventions	PL	Robotics Inventions produces robots, which can improve the efficiency of service people active in routine jobs such as surveillance, cleaning and order picking.	• Currently expanding to Silicon Valley, from its initial location of Warsaw. • Received EU funding, and has acquired funding from angel investors and venture capitalists.

OpiFlex	SE	OpiFlex has developed a mobile robot platform, which allows a robot cell that is typically fixed in its place to be moved in its entirety, either manually or by means of Autonomous Guided Vehicle (AGV) software. The platform provides the same high stability and precision operation as fixed robots, through its docking station.	• As one of the first companies in the world, OpiFlex has developed a solution that makes automation economically feasible for small series production (and in the future perhaps even handicraft).
EOS Innovation	FR	EOS innovation has designed a robot for indoor surveillance of warehouses and industrial sites. It reduces the costs and the risks associated with security and it optimises the indoor surveillance on monitored sites.	• EOS innovation has already sold its first products to a logistics company, which in turn services many companies using the surveillance technology. • The firm has acquired a patent on parts of its invention.
Nedap Livestock-management	NL	Nedap Livestock Management develops Smart Machines and Tools for livestock feeding, separating, sorting, milking, heat detection and health monitoring. With technology based on Electronic Animal Identification, Nedap makes individual animal care and monitoring of production and health conditions easier.	• Nedap Livestock Management is already successfully active on the global market for livestock automation for over thirty years. • Awarded the 2014 IF product design award for its heat detection smart tag.

2.1. Presentation of the companies referred to in the case study

This section describes five European SMEs that have developed Smart Machines and Tools in response to a clear market need.

Problem 1 – Real-time measurement of colour quality in newly manufactured displays, LEDs, glass and other fabrics requires precise and high-speed measurement (in milliseconds). This was hardly possible against reasonable costs, until Admesy developed high-speed measurement systems.

Innovative solution 1 – Admesy has developed several measurement systems amongst which a combined spectrometer, used for measuring characteristics of light sources, and a colorimeter, used to determine the colour of emitted light based filters, which can be fully integrated in the production process of for instance LCD screens or LED systems.

The Admesy measurement device is connected to the production facility using cables and can provide fully automated quality control of individual products. Depending on the phase of the manufacturing process in which the device is integrated, LCD screens or LEDs that do not meet the quality criteria can automatically be adjusted or disposed (using an air pusher).

In addition, the quality control can automatically provide feedback to other machines in the production cycle for recalibration. The measurement device offers top-notch quality against mid-range prices (compared to competing technology). Naturally, the customer can calibrate the measurement device based on his/her needs.

Admesy's combined spectrometer and colorimeters

Source: http://www.admesy.nl/products/spectrometers/cronus/

Problem 2 – Many companies in western economies spend up to EUR 25,000 per year per FTE for overqualified service personnel to conduct routine jobs such as cleaning, surveillance and for instance order picking. To increase labour force efficiency and reduce risk of employees working in dangerous environments and with security clearances, an automation solution is needed.

Innovative solution 2 – Robotics Inventions produces robots, which can improve the efficiency of service people active in routine jobs: inspection and cleaning. Robotics Inventions tailors its robots based on customer's need. This includes inspection/surveillance robots equipped with various sensors (e.g. nuclear, biological or chemical receptors) and service robots equipped with cleaning instruments.

Using various sensors, the robots are able to scan their environment and operate fully autonomously. In addition, the robots can be connected to a central monitoring system for remote control and data acquisition/analysis, and/or can be connected to a mash system. A mash system functions like a swarm, with individual robots communicating with each other and transmitting/ forwarding each other signals. Robots that are out of direct reach of the central monitoring system can still stay connected through the 'swarm'.

The main benefit for the customer is increased productivity: for example by replacing manual labour with robots, Robotics Inventions aims to achieve 40 times faster 'cleaning' speed.

Robotics Inventions' autonomous mobile service robot family (above) and its autonomous robot swarm system (below)

Source: Presentation on 'Robotise manned processes', courtesy by Robotics Inventions

Problem 3 – SME production in Sweden constitutes approximately 70% of the total manufacturing industry. SMEs are often important for sparsely populated areas. To remain competitive on a global scale, however, manufacturing productivity of SMEs has to increase, while labour costs have to decrease. To achieve this, SMEs are willing to automate, but are hampered by several factors:

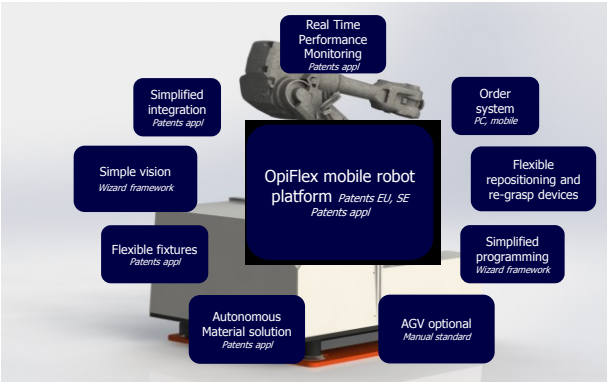
Manufacturing challenge at SMEs	Automation challenge
Large volume variance, low machine utilisation	Long pay-off with fixed robot
Bottlenecks in the production cycle vary over time	Unable to move fixed robot
Small series production with new products/ adaptations being included on a daily basis	High programming cost
Need manual access for handicraft	Fixed robot block machine

Source: Presentation on Mobile automation for increased productivity in small series production, courtesy by OpiFlex[3]

Innovative solution 3 – OpiFlex has developed a mobile robot platform, which allows a conventional fixed robot cell, which is normally mounted to the ground or production line, to be moved across the production line manually or by means of Autonomous Guided Vehicle (AGV) software. The platform provides the same high stability and precision operation as fixed robots through its docking station. The mobile platform provides easy manual access to the machine, allowing the operator to choose between automated production and manual operation.

Effectively, OpiFlex' mobile platform allows manufacturers to move a normally fixed robot to the section in the production cycle where bottlenecks occur, where extra production capacity is needed, and through simplified programming allows operators to quickly change the setup of the robot to a new production task.

A fixed robot mounted on top of OpiFlex' mobile robot platform. The installation provides benefits like flexible fixtures, simplified programming and real-time monitoring.



Source: Presentation on Mobile automation for increased productivity in small series production, courtesy by OpiFlex

Problem 4 – The founders of EOS Innovation first developed robot technology for surveillance of homes. This technology proved to be not yet suitable for this application domain. In an attempt to find a suitable application domain, the company conducted market research in the security sector. It visited 150 persons working in the security market. They were asked whether robots would be able to conduct surveillance activities, and if so, what should be the characteristics/features of such a robot. As a result of this study the company received 150 drawings containing desired robot specifications of the surveillance experts. The main features from those 150 drawings were extracted and used to develop the first surveillance robot.

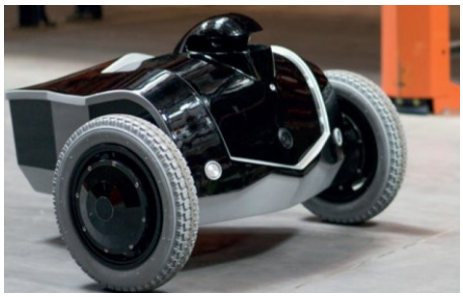
Innovative solution 4 - E-vigilante is a robot designed for indoor surveillance of warehouses and industrial sites. It reduces the costs and the risks associated with security and it optimises the indoor surveillance on monitored sites.

Mobile, autonomous and versatile, when e-vigilante detects an anomaly while on its automatic pre-programmed patrol rounds, it immediately alerts the remote monitoring

operator. The operator can then, in real-time, remotely take over the robot and dispel doubt using e-vigilante's camera, audio and speakers system. In case of an actual incident, the operator can contact the authorities.

E-vigilante overcomes the constraints of fixed surveillance systems. State-of-the-art security technologies are integrated in the robot, which moves about autonomously on site according to the customer's designated requirements. The customer no longer needs to constantly tele monitoring nor to pre-define precise viewing for such a system when installed. The product is not troubled by for instance blind spots, e.g. due to a forgotten handling pallet, as would fixed security systems. With e-vigilante the customer won't lose a second in case of an intrusion because he receives real-time feedback from close-up to the incident location combined with an intruder tracking system.

The e-vigilante is a surveillance robot for monitoring warehouses and other industrial sites.



Source: http://www.eos-innovation.eu/Produit/EVigilanteFr.sls

Problem 5 – Due to the globally increasing population and prosperity the demand for milk and meat is rising all over the world. This development is accompanied by increasingly stricter requirements with regard to the quality and safety of food. Simultaneously, there is a rise in the costs of raw materials, labour and energy. This sector faces the challenge of producing sufficient supplies of safe, affordable and sustainable food of good quality from scarce resources.

Innovative solution 5 - In response to these challenges, Nedap enables the automation of diverse processes in and around the livestock farm. This technology is always based on electronic individual animal identification. One of these technologies is cow heat detection and health monitoring. Each cow is equipped with a tag around its neck or leg, which collects and transmits information about the animal's behaviour towards a central monitoring unit, which is connected through the internet. This information is automatically analysed to provide the farmer with both local and remote insight into cow health and heat condition, or can be directly forwarded to an insemination service company.

Based on movement patterns, this technology can deduce both heat and health conditions of cows (e.g. jumping indicates health, whereas reduced feeding times indicate sickness).

Nedap's SmartTag for either neck or leg used for heat detection with health monitoring properties.

Source: http://en.nedap-livestockmanagement.com/solutions/ cows-and-cow-management/heat-detection/

3. Socio-Economic Relevance

The socio-economic relevance of Smart Machines and Tools is substantial. At one end the innovations mentioned in this case study can significantly reduce the costs for manufacturing and services while increasing productivity, which would allow European companies to better compete with low-income producers. At the other end, the increased level of automation and productivity that smart tools and machines achieve could be associated with job losses. A crucial question is whether the new range of applications (e.g. due to big data) and high end jobs (e.g. robotics engineering) that will be generated will be able to outweigh lost jobs.

3.1. The market potential of the trend

Many Smart Machines and Tools will be implemented in manufacturing environments, often referred to with the broader terms of Smart Manufacturing, Factories of the Future or Industry 4.0 (German concept). In Germany, the leading market for this development, the expected annual investments in further digitisation of industry are expected to amount up to EUR 40 billion until 2020.[4] Within 5 years, 85% of Germany companies is expected to have implemented Industry 4.0 solutions in all important business domains. Industry 4.0 solutions will result in increased productivity and resource efficiency (18% efficiency increase expected in Germany within 5 years).[5]

The market for quality control and monitoring of production lines consists of many niches. Admesy is already a major player in the display market, and is currently moving into the LED market. Its revenue model follows a phased approach, spreading from niche to niche. Currently, the global market for colorimeter and spectrometer based quality control is estimated at approximately EUR 250 million.

The global service robotics market will more than double, from roughly EUR 18 billion in 2014, to EUR 40 billion in 2020. Naturally, there is a division between military robots, agricultural robots and service robots. The military robot share is expanding quickly, with 7,000 robots per year, but other industries are also picking up fast. The agricultural sector is the runner-up, expanding with 4,000 robots per year. Robots based on telepresence platforms (e.g. surveillance and laboratory work) are currently still considered a niche market.[6]

"The global service robotics market will more than double to €40 billion in 2020" – ***Robotics Inventions***

The so called soft and 'not-so-much' programmable production and manufacturing robots for SMEs are also picking up speed, with 500 units growth annually (from 6,000 units currently).

Finally, the market for consumer electronics robots is also showing promising growth. For example, during national singles day in China (Chinese holiday during which singles buy presents for themselves) Ecovacs, Dyson and iRobot sold 70,000 household robots (e.g. vacuum robots) in a single day. The total market volume for household robots in Europe is EUR 1 million. Robotics Inventions, one of the case companies, is currently also moving into the household electronics robots market.[7]

3.2. The social potential of the trend

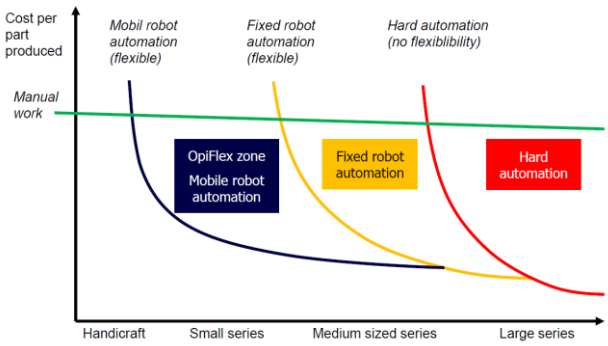
This section describes how companies that develop and commercialise Smart Machines and Tools create new markets and jobs, while perhaps destroying part of the existing ones.

OpiFlex opens up a new market segment for automation technology. There are already several solutions for the so called hard automation, which offers very high volumes (large series production) against minimal production costs and maximum productivity, but with limited to no flexibility. This type of automation is already widely used in various industries, for instance car manufacturing.

The same goes for fixed robot automation, with the difference that this automation technology compromises on cost per part/product produced for somewhat higher flexibility (medium series production). Currently, however, there is no automation solution that fits low volumes and high flexibility requirements.

OpiFlex' mobile robot platform opens up this automation segment for handicraft and small series of production. Up to now, small series production made it almost impossible to cost-effectively operate automation solutions, as displayed in Figure 1.

Figure 1: Illustrating the commercial tipping point for automation



Source: Opiflex company presentation, courtesy by Opiflex

In OpiFlex' experience, the purpose of robots is to takeover monotone and heavy workloads from manual labourers. By implementing automation robots at SMEs throughout Europe, even low series and handicraft production lines can get more competitive. Robots can focus on heavy, monotonous or high precision work, while the human workers can focus on more intellectually challenging and finger-fine tasks.

It is currently almost as expensive to automate in European countries as in low-wage countries. Workforce salaries are different, but automation costs are mostly the same. Introduction of robots might open-up new possibilities to create jobs in Europe. European SMEs, even those focused on low series or handicraft production, can get more competitive by implementing mobile manufacturing robots.

"OpiFlex' mobile robot platform opens up the automation segment for handicraft and small series production" – ***Opiflex***

Currently, Europe cannot compete with low-wage countries on low series production and handicraft. Through mobile manufacturing robots this wage effect can be mitigated. This way manufacturing capacity that is currently outsourced to developing countries can eventually return to Europe. If production costs are equal, the political and economic stability that Europe offers companies might convince them to relocate production sites.[8]

For quality control and monitoring automation technology, the effects on new markets and jobs are similar. An immediate effect of applying *Admesy*'s technology for *Samsung* was that they could substantially cut manual quality inspection. An eventual effect of this type of technology is that new quality control features and functionalities will be enabled (e.g. real-time measurement of nutrients/ingredients in food production), which do not kill

jobs, but instead open-up new vacancies for design, engineering, monitoring and maintenance of advanced technology. For example, ten years ago, display testing was done manually in a dark room. Several years later manufacturers adopted sample testing, in which small production volumes were rigorously tested in a laboratory. *Admesy*'s technology opens up a new market for real-time testing of displays (e.g. for detection of Mura, dark spots or patches in LCD screens).

The CEO of *Robotics Inventions* confirms this perspective: the market trend is to bring manufacturing back to the western world. This can only be done through the installation of robots, as a means to decrease production costs. Although in the short term it may appear as if service robots take over jobs (e.g. cleaning and surveillance), in the long run it will enable people to become more engaged in more creative and challenging jobs (robot engineering, manufacturing and maintenance).

"Production of robots is the only way to bring manufacturing back to the western world"
*– **Robotics Inventions***

Robots take away jobs that are very heavy, dangerous, or monotonous. *Robotics Inventions* intends to make the world safer and more pleasant. The company tries to limit threats to humans, for instance by introducing robots in power plants to reduce the chances of people being exposed to radiation. In the future, robots could for instance also be used for fire-fighting and other hazardous professions.

EOS Innovation states that its robot technology is complementary to manual labour and CCTV cameras. It can be an additional means to increase security of a warehouse. The robot is able to provide online information to the CCT operator, but the robot does not take a decision. Customers still need to employ an operator to interact with the robot. *EOS Innovation* thinks it is always important that a human takes the final decision. In addition, French Law prescribes that a human operator has to contact emergency services (e.g. policy or the fire department) in case calamities like trespassing or fire are detected during security patrol.

Compared to service robots, the market for heat detection is not new. Indeed, *Nedap* has been active in the field for 20 years. However, the combination with health monitoring via a SmartTag attached to the cow's neck (1.5 year ago) or leg (0.5 year ago) is new. In addition, directly forwarding livestock data to insemination service providers for remote access is also new. Within *Nedap* a large share of the R&D department is working on livestock management solutions. Including sales and other support functions, these are dozens of FTEs.

To conclude, Smart Machines and Tools do open-up completely new application markets and create new jobs, but it is still to be seen whether net job creation will be positive, due to the substantial destruction of jobs as a result of further automation.

3.3. Impact of Smart Tools and Machines on the value chain

This section describes which parts of the value chain are the most strongly affected by Smart Machines and Tools, e.g. with regard to job creation and added value generated.

Smart machines and tools are used throughout all sectors of the economy, from the primary sector (e.g. Cisco Systems already provides smart solutions for the mining industry[9]) all the way to the tertiary sector. More specifically, the companies in this case study cover agricultural production (Nedap) via manufacturing (OpiFlex) and quality control (Admesy) to the service industry (EOS innovation and Robotics Inventions).

The manner in which Smart Machines and Tools affect value chains differ depending on the sector concerned. In case of service robots (e.g. for cleaning or surveillance), the value chain changes as added value is shifted form the service provider to engineering, computing and science jobs at smart machine and tool companies. Here, robots takeover (parts of) jobs from human workers employed by service providers.

However, when a robot can conduct the same job as a human worker, service providers may consider replacing them. Certain supporting tasks at the service provider, like training and HR may be (partially) replaced by software engineers and developers, who can programme service robots. Of course it is also possible that this is also outsourced to the Smart Machines and Tools provider.

Effectively the Smart Machines and Tools provider appropriates a share of the value previously created by the service provider. An additional link is added to the value chain. For Smart Machines and Tools used in the secondary sector, the same effect applies (shift in job creation) but the total impact on the value chain is even larger. Smart machines and tools will provide numerous opportunities for further integration of value chains.

Data generated at the manufacturer during the production process by Smart Machines and Tools can be looped back to suppliers and warehouse management companies in real-time. These companies are then automatically informed of the amounts of stock to be produced and of error margins on supplied components.

The large amount of data generated by Smart Machines and Tools can also be used by other service providers for maintenance or supply chain management. By having real-time insight into the conditions of manufacturing equipment, suppliers of Smart Machines and Tools can prevent downtime through **predictive maintenance**.

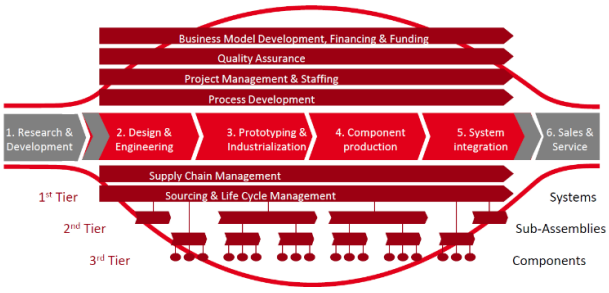
Progressive integration will eventually result in whole value chains competing with each other, instead of individual companies. Again a large share of the value created is now

being appropriated by engineers, programmers and scientist workers for suppliers of Smart Machines and Tools. As a whole, however, the value chain might increase its added value, meaning that also the OEM will benefit.

As mentioned afore in section 3.3, Smart Machines and Tools constitute a shift in employment from for instance OEMs and facility service companies (e.g. cleaning and security) to suppliers of these technologies. As figure 2 shows, core activities like R&D or customer contact and support are less prone to be outsourced.

By 2020, OEMs will transform into lean companies, further opening-up their supply chains to value chain partners. This movement is driven by further digitisation, incorporated in Smart Machines and Tools, as illustrated in Figure 2.

Figure 2: Transformation into lean companies



Source: Presentation by Brainport Industries[10]

To conclude, Smart Machines and Tools will penetrate many sectors of the industry and will destroy low-level jobs at manufacturing and service companies, while creating new high value adding jobs in engineering, computing, systems design and science at supplier companies.

4. Drivers and obstacles

This section describes the drivers and obstacles for diffusion of the Smart Machines and Tools trend. The drivers include cost savings, productivity gains and relief of workers from monotonous or hazardous labour. The obstacles are resistance due to potential job losses and high capital requirements for developing and commercialising Smart Machines and Tools.

4.1. Safety issues for services robots

Nedap's technology supports customers with their operational management of both milk and meat production. The technology is already an essential part in many modern livestock production facilities. Because the company employs many people with previous experience in the livestock sector, communication with clients is smooth and its product offering is highly aligned with market requirements.

For service robots, client challenges related to adoption are predominantly associated with safety issues. Currently, companies that sell service robots still have to make a lot of efforts to monitor/safeguard whether their robots actually conduct their jobs properly and safely. This is why most service robots are currently not yet functioning at full capacity and functionality.

Lack of certification of for example robots with many moving parts (e.g. arms) can frustrate market introduction. There are already certificates for assembly robots, but for the service sector certification is limited. Insurance for robot related accidents can help market introduction, but these can be very expensive. Safety is crucial, because as soon as robot-related accidents occur, public opinion will turn sour quickly.

4.2. Lack of a proven track record

For *Admesy*, one of the main barriers on the client's side was the absence of a proven track record for both the company and its technology. Supplier reputation plays an important role in such a sensitive sector and one of *Admesy*'s competitors within the quality control market for LCDs/LEDs has over 100 years of experience with photonics.

"Doing business with a new entrant also requires entrepreneurial spirit from the client's side" – ***Admesy***

Doing business with a new entrant such as Admesy requires risk taking on the client's side, as there are always risks associated with adopting a new technology. This is true especially considering the extremely expensive manufacturing lines of clients in which the technology needs to be incorporated (investments of EUR 500 billion are common). Clients require solutions that provide sustainable high quality, because costs of production down-times are huge. Considering that Admesy's technology is relatively affordable compared to competitors, conveying this image of quality is even more challenging.

4.3. Cost savings and productivity gains are primary drivers for Smart Machines and Tools

Cost savings and productivity gains are the driving factors for customers to consider adopting Smart Machines and Tools.

According to *Admesy*, a key criterion for deciding to automate using Smart Machines and Tools is the complexity of the operation for a robot compared to the price of the labourer needed to conduct it. Particularly tasks that are challenging for robots, but very easy for humans (no education/training required) remain off limits for automation (e.g. placing a smartphone in a certain socket). On the contrary a task like welding, which is relatively easy for a robot to conduct but requires skilled manual labour, is for instance an ideal activity for automation.

"A key criterion for deciding to automate is the complexity of the operation for a robot, compared to the price of the labourer needed to conduct it" – ***Admesy***

Robotics Inventions confirms cost savings being an important driver for smart service robots. As a result of the economic crisis, many companies are looking for cost saving opportunities. Jobs such as manning cleaning machines or forklifts do not require extensive training or skills, but are usually paid above minimum wage (on average around EUR 25,000 per year). By having robots conduct these jobs, companies can considerably save on labour costs. A cleaning robot can earn back its investment by reducing operational costs[11].

OpiFlex states that its mobile robot platform enables automation of small series production (and even handicraft), usually conducted by SMEs. By substantially increasing productivity, European SMEs can better compete with low-wage markets which often conduct similar production processes manually. This way production that was initially outsourced, for instance to East-Asia, can be brought back to Europe.

4.4. Technological progress in for instance nano-electronics, photonics and data analytics

Technological progress in nanoelectronics and photonics drives the price and size of smart machine and tool components down. Crucial components in most Smart Machines and Tools are sensors, ultra-low power microcontrollers, RF transceivers and supporting software (e.g. machine-to-machine protocols). With reducing size and price of these components, application in more and more machines and tools becomes feasible both technically and economically.

Admesy is for instance already able to offer its superior light and colour monitoring equipment against mid-level prices, compared to competitors. In addition, because the company was able to incorporate all calculating power in one compact package, the integration into existing production lines of customers is much easier. This in turn reduces the adoption barrier for customers.

Clearly, new developments in big data management and analysis amplify the benefits derived from Smart Machines and Tools, and the data they generate.

4.5. Smart Machines and Tools relief workers from monotonous, repetitive and dangerous labour

A major benefit of Smart Machines and Tools, and an important driver for their diffusion, is that they can relief workers from monotonous, repetitive or dangerous labour. As a result of this fewer company accidents might occur and worker satisfaction is likely to increase.

The technology provided by *Admesy* and *OpiFlex* reliefs manufacturing personnel from monotonous and repetitive tasks such as manual quality control or mechanical workshop jobs like brushing, pressing or nut welding. The service robots developed by EOS Innovation and Robotics Inventions can relief for instance surveillance and cleaning personnel from dangerous or unhygienic labour.

4.6. Resistance to Smart Machines and Tools due to anxiety of job losses

As a result of Smart Machines and Tools fewer workers are required to conduct the same amount of work, because the productivity of individual workers increases or workers become completely redundant for jobs. Naturally, people that might fear job loss as a result of Smart Machines and Tools are resistant to the introduction of this new technology.

Robotics Inventions' is currently entering the Hotel market. However, the affected worker unions are against the introduction of robots, because in their opinion robots take over jobs. The unions are, according to Robotics Invention's founder, already more positive towards robots that do 'dirty jobs' such as cleaning toilets or physically strenuous work.

The founder of Robotics Inventions recently moved to Silicon Valley to further develop his company over there. One of the reasons is that, from a cultural point of view, Europeans are very conservative towards new technology. In the perspective of Robotics Inventions' founder, most Europeans are negative towards robots. In the USA, on the contrary, people are generally more enthusiastic towards them. In addition, US companies are eager to introduce robotics in their operations, to disrupt the market, particularly in the Silicon Valley. As a result, the introduction of robots has already diffused much stronger in the USA compared to Europe.

It is likely that a share of low-paid jobs will disappear as a consequence of the introduction of service robots and further automation of production lines. Jobs that are most likely to disappear include those that entail repetitive

processing, clerical duties and support services in sectors such as sales, transportation, construction, mining and energy. Jobs that are considered 'safe' include those in computing, engineering and science, and those that require creative thought or interpersonal skills.[12]

However, it is also important to note that the destruction of jobs is already a naturally occurring event (e.g. 15% of jobs in the USA annually), meaning that this development is not something completely new.[13]

4.7. Financial markets prefer investments in software-based companies

Developing and commercialising Smart Machines and Tools is capital intensive. Simultaneously, the current investment climate prefers software companies above hardware companies, for reasons of scalability. This combination severely hampers smart machine and tool entrepreneurs to grow their business.

Robotics Inventions is currently developing a robotics platform for cleaning services with EU funding of EUR 500 million, while it is having difficulties to attract funding from private parties. Compared to software companies, start-ups focusing on hardware development need substantially higher capital investments. Every step in the development and production requires significant amounts of funding. Development of a typical prototype is ten times more expensive compared to that of software solutions. Adding to the problem is that sales of hardware are only increasing slowly. Sales cannot as easily be scaled as with a software solution. This combination makes it hard to acquire the resources to develop a prototype and a demonstration version of a product. In addition, since a company like Robotics Inventions has only limited amounts of prototypes, it cannot share/distribute these prototypes all around the world for sales purposes.

Admesy confirms that setting up a hardware company in the smart machines and tools domain is very expensive. However, the company was able to attract venture capital (from a regional investment firm), because it produces highly measureable results and market demand was evident.

OpiFlex also confirms that the biggest problem for growth is getting the required funding. Costs associated with developing a mobile robotics platform are substantial. There are opportunities to acquire public funding in Sweden, but this type of funding often comes with numerous requirements that applicants need to comply with, including mandatory involvement of universities or rules that limit the applicability of the funds to research activities only. Moreover these funding sources are often very fragmented. To make the problem worse, marketing costs for robot technologies are actually ten times higher than R&D. However, most government bodies will not provide funding for commercial activities. Finally, it is also very hard to attract venture capital without giving away the majority of company shares.

5. Policy recommendations

The companies in this case study do not indicate that there is a severe policy gap which policy makers should address for Smart Machines and Tools to become successful. The benefits provided by the technologies they develop are evident, also to their customers. However, there are some issues that might accelerate the rise of Smart Machines and Tools.

Aside from the policy measures that support companies developing Smart Machines and Tools, it is perhaps even more important that policy makers prepare society, and particularly the workforce, for the possible effects that further automation of manufacturing and service industries might cause.

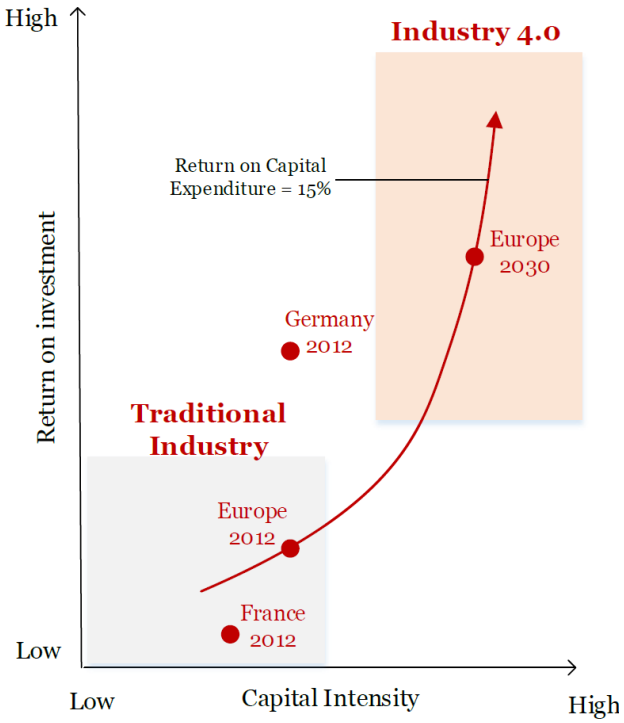
5.1. Increase funding possibilities through public funding or by stimulating private investments

The development of smart machines like robots and similar hardware requires substantial investments. Considering that private investors are currently more interested in financing highly scalable software-based solutions, public funding becomes more important. Public funding, however, is often highly fragmented and associated with long application trajectories and strict conditions on eligible costs. Interviewees report that even through H2020 it is still hard to acquire public funding for the development of smart machines and tools.

Hardware entrepreneurs would greatly benefit from public funds that are more concentrated, made available in a relatively short period of time, and that also cover commercial activities. Public measures that would persuade

public investors to invest in hardware-based start-ups and SMEs, instead of the quick-win software companies, would be most welcomed. Figure 3 illustrates that, although the Smart Machines and Tools sector can results in high potential pay-offs, it also requires heavy capital investments. This is something with which governments could help companies.

Figure 3: Smart machines and tools, which facilitate industry 4.0 have a high return on investment, but require huge capital investments.



Source: based on Roland Berger (2014) Think Act – Industry 4.0: The new industrial revolution[14]

5.2. Revenue-based tax relief measures are of little benefit to hardware start-ups

Most Member States (e.g. Poland or the Netherlands) offer tax facilities for revenues generated by innovative products. Although the products developed by companies qualify for these measures, most companies cannot really benefit from them, because they do not yet realise substantial revenues. Without revenues, companies cannot discount any costs from tax, and without funding these companies cannot scale their revenues. This results in a vicious cycle.

An improvement of these tax facilities, from a start-up/SME perspective, would be to make all, or some, R&D activities exempt from taxes, to stimulate R&D work. Most companies in this case study have been 'underwater' for several years. It is hard to pay for huge R&D costs, especially if these are being taxed and will not yield any return in the near future.

5.3. Support in realising pilot projects and acting as a launch customer

Public bodies can form an ideal launching customer for Smart Machines and Tools, particularly for smart tools and service robots, because governments generate an enormous amount of relative low-income service jobs such as cleaning, surveillance and security. Public bodies can either implement these technologies themselves, or oblige contractors to use them in case they make use of subcontracting.

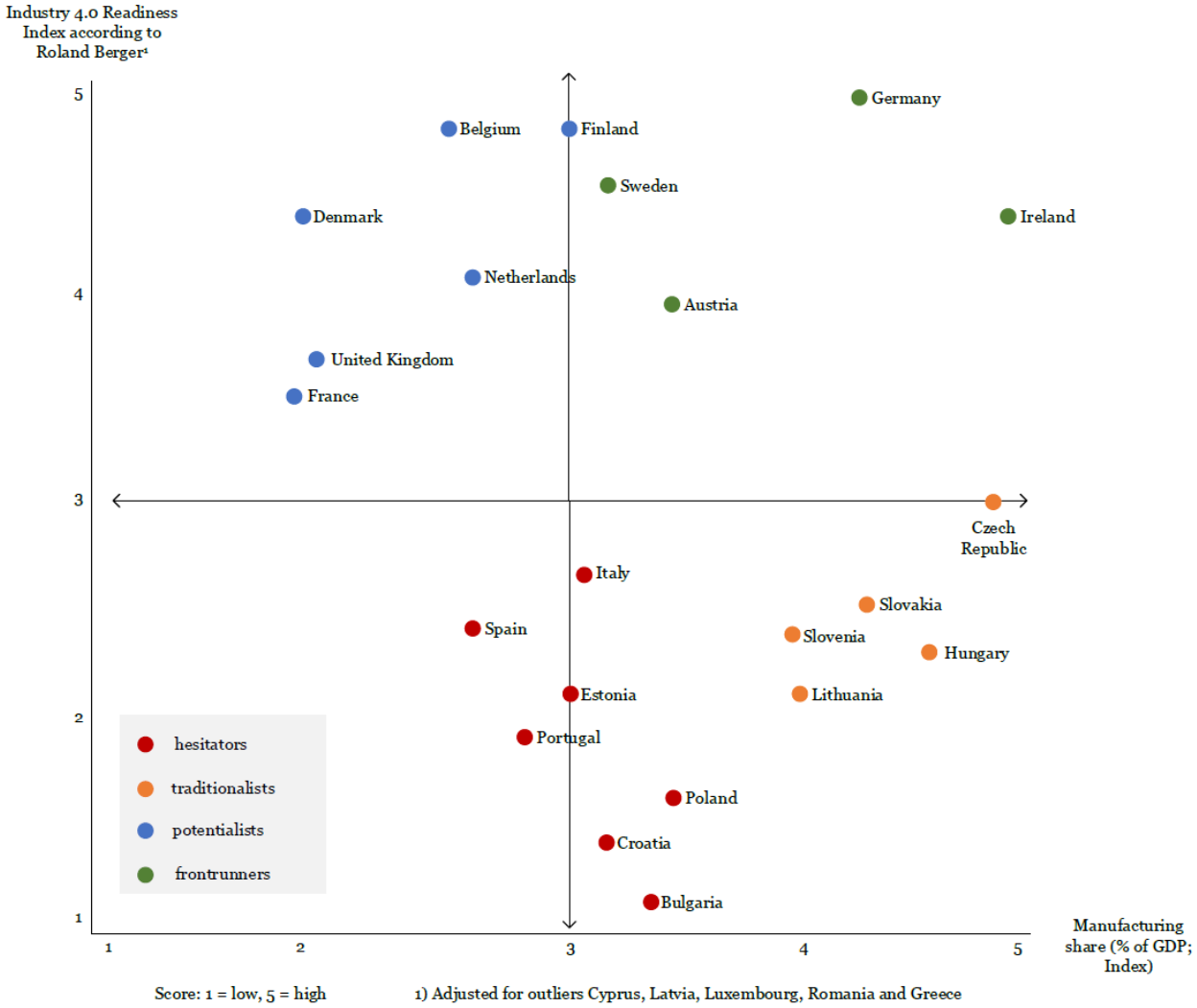
This not only saves public money, but also attracts foreign technology companies and bolsters domestic players in the development of Smart Machines and Tools. Although on the short-term a substantial amount of jobs might be lost, policy makers can increase the likelihood that the high-value adding jobs replacing them will emerge in Europe.

5.4. Anticipate changing labour market demands

The companies and technologies in this case study show that certain type of jobs are prone to be replaced by automation technologies and service robots. Policy makers would be advised to anticipate this shift by stimulating education and retraining for the labour force in sectors that are driving these technologies (e.g. engineering, computing and science) instead of those which are mostly affected by them in a negative way. Research indicates that inadequately qualified personnel is already one of the main challenges foreseen by industry in the shift towards Industry 4.0 and the increased adoption of Smart Machines and Tools.[15]

Simultaneously, by attracting and facilitating the growth of companies that develop and commercialise smart machine and tools, policy makers can ensure that high value adding jobs are created in the EU. Research into the 'industry 4.0 readiness' compared to the size of their national manufacturing sectors (as a share of total GDP) shows that Member States such as Germany and Ireland are European frontrunners within this domain, as displayed in Figure 4.

Figure 4: A clustering of EU Member States based on their 'readiness' for Industry 4.0 and the share of GDP that manufacturing makes up



Source: Roland Berger (2014) Think Act – Industry 4.0: The new industrial revolution[16]

6. Appendix

6.1. Interviews

Company	Interviewee	Position
Admesy	Steven Goetstouwers	CEO
Robotics Inventions	Marek Sadowski	Founder and CEO
OpiFlex	Johan Frisk	Founder and CEO
EOS Innovation	Odile Laborie	Partner and Business Development
Nedap Livestock Management	Jan Anne Kuipers	Manager R&D Livestock Management

6.2. Websites

Admesy	www.admesy.nl
Robotics Inventions	www.roboticsinventions.com
OpiFlex	www.opiflex.se
EOS Innovation	www.eos-innovation.eu
Nedap Livestock Management	nl.nedap-livestockmanagement.com

6.3. References

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[6] Extract from a presentation by Robotics Inventions.

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[8] Interview with Johan Frisk - OpiFlex

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[14] Roland Berger (2014) Think Act – Industry 4.0: The new industrial revolution – How will Europe will succeed.

[15] Strategy&, PwC (2014) Industrie 4.0: Chancen und Herausforderungen der vierten industriellen Revolution

[16] Roland Berger (2014) Think Act – Industry 4.0: The new industrial revolution – How will Europe will succeed.