Experiences with industry 4.0 – a case based analysis

Krisztina Demeter [1], Bálint Horváth [2], Judit Nagy [3], Dávid Losonci [4]

[1] Dept of Logistics and Supply Chain Management, Corvinus University of Budapest, HU-1093 Budapest, Fővám tér 8., Hungary
krisztina.demeter@uni-corvinus.hu
[2] Dept of Logistics and Supply Chain Management, Corvinus University of Budapest, HU-1093 Budapest, Fővám tér 8., Hungary
balint.horvath@stud.uni-corvinus.hu
[3] Dept of Logistics and Supply Chain Management, Corvinus University of Budapest, HU-1093 Budapest, Fővám tér 8., Hungary
judit.nagy@uni-corvinus.hu
[4] Dept of Logistics and Supply Chain Management, Corvinus University of Budapest, HU-1093 Budapest, Fővám tér 8., Hungary
david.losonci@uni-corvinus.hu

Abstract

Recently we can read many consultancy papers and newspaper articles about industry 4.0 and its impact on our economy and society. Although some of them describe a real-life example about the implementation of a digital tool, but only in an isolated manner. Others remain on the surface without useful details. Our objective is to dig deeper and show the whole picture of a multinational company's efforts they make into the direction of I40. We describe and explain the steps, challenges and difficulties, advantages and disadvantages they have experienced during the process. The paper is based on three interviews and some company visits. Based on our results, the full implementation of I40 requires huge investments in the starting phase to build reliable and secure internet connections, tools to collect and process data, and knowledgeable employees for leading and implementing technologies. Altogether, I40 still appears to be an expensive toy of rich multinational companies, who have the time and resources to make experiments accepting the risk of no payoff.

Keywords: Industry 4.0, case study, automotive industry

1. Introduction

In the last couple of years Operations Management (OM) has become noisy of Industry 4.0 (I40). Both practitioners and researchers try to understand the conditions and consequences of I40 (or smart/digital factory) as well as look for new opportunities to adopt its practices (Huber, 2016; Valenduc & Vendramin, 2016). While companies usually think about I40 practices as a great potential for performance improvement in the near future (Behrendt et al., 2017), the number of well-documented digital transition efforts is still low. Both integrated and strategic approach of I40 transformation on the business side and the comprehensive investigation of this phenomenon on OM academic side are awaited.

At the beginning of the new industrial revolution, we have limited knowledge about how the key I40 practices work in company settings, what are the key success factors and hurdles of these. Our research objective is to present how the I40 transformation in the company operations take place in the case of a leading automotive supplier. Our methodology relies on case based research approach. We investigated some I40 practice related projects as a unit of analysis. After gaining an understanding of the applied I40 solutions, we identified the – awaited – performance impacts, specific and the common implementation difficulties and the variables critical to sustaining changes.

In the paper, we first discuss the key principles of the digital economy and its appearance in industries and factories. We pay particular attention to the automotive industry, which is ahead in implementations and where our case company belongs to. Then the characteristics and I40 practices of the company are described followed by discussion and conclusions.

2. Industry 4.0 – digitalisation of operations management and logistics

2.1 Principles of the digital economy

Industry 4.0 is a fashionable and popular concept in the manufacturing sector. However, digitalisation is an economy-wide phenomenon which requires renewal of almost any industries, e.g. fintech companies are real challengers in the banking industry. Valenduc and Vendramin (2016) pointed out that there are well-known concepts of the digital economy already existing for years, acknowledging that many of these digital concepts are getting more powerful and taking a changing role recently. There are additional new features, however, as they note, bringing novel solutions and remarkable changes. Altogether, according to their views, the founding principles of the digital economy are as follows

1. Digitized information has become a strategic resource due to the developments in data production, storing and analysing capacities.
2. Networks have become the basic units in organizing economy and society.
3. The principle of growing returns (due to positive network externalities) prevails with zero or quasi-zero marginal costs.
4. New business models (e.g. sharing economy based) and new business dynamics (the winner takes all) gain space.
5. There is a new model of industrial production (industry 4.0), with customized/small batch products, fragmentation of global value chains, networks of productive capacities (including the blurring boundaries between producers and consumers, or between manufacturers and services providers).
6. The drastic reduction of technology prices (both hardware and software) in parallel with the significant increase in performance and efficiency restructure investment decisions.

Many of these principles has shaped management's and OM's interests in the last decades and increasingly in the last few years. Management of production networks have gained special interest due to the expansion of large multinational companies and global value chains (2^{nd} and 5^{th} principles). Furthermore, the involvement of buyers/suppliers and deeper cooperation with them pushed OM to rethink the boundaries of the organisation (e.g., supply chains) and to mix services and products to a greater extent (e.g., servitization) (5^{th} principle). Additionally, the development of software and hardware (1^{st} and 6^{th} principles) offers new opportunities to manage both external (ie., value chain, customer requests) and internal processes for manufacturing companies.

Critics argue that since the growth of digitalisation can be traced back to the evolution of computer technology, thus the time we live now is more a new wave of the third industrial revolution (built on electronics symbolized by the personal computer) than a completely new, forth revolution (Holodny, 2017; Jensen, 1993). We disagree, and think that the basis of the fourth industrial revolution is ***the digital network and data***, the computer is only a tool.

2.2 Digital industry, digital factory – Industry 4.0

Former production systems have recently met several social challenges which cannot be resolved by existing approaches. Their survival is threatened since they have led to environmental damages (climate change), and have consumed too much non-renewable energy. Furthermore, due to ageing societies, the expected number of working population will reduce (Wang et al., 2016). As listed in the previous paragraphs, there are also several business issues to overcome, e.g., customers prefer small batches and customised or even personalised product-service mix. Technology might offer some new solutions to social and business challenges and enables the reshaping of production.

Robots and automation have already been with us for decades. The use of the internet – to connect them – revolutionise process management. The developments in internet and technology create a continuously connected network of people, machines and companies, and by sharing real-time data about value-creating processes it becomes possible to produce personalised products for customers. The machines and systems, or even the products themselves produce an enormous amount of data, the storage, processing and interpretation of which is a big challenge. The source of competitive advantage stems not only from synchronising or completely refurbishing production (e.g., additive production), but rather from how products are surrounded by digital services, and how companies are able to filter out relevant information from data to support their decisions (Heynitz et al., 2016; Deloitte, 2015; Geissbauer et al., 2016).

2.3 Technologies of industry 4.0

Big consulting companies (e.g. BCG, PWC, McKinsey) have collected several tools of I40 (e.g. Rüßmann et al., 2015; Geissbauer et al., 2016; McKinsey&Company, 2016). The suggested toolkit is very similar, there are only slight differences. The toolkit can be structured (based on the idea by Schwab, 2016) as tools of the *digital world*, the *physical world* and the *sensors* which connect the two worlds to each other (see Table 1).

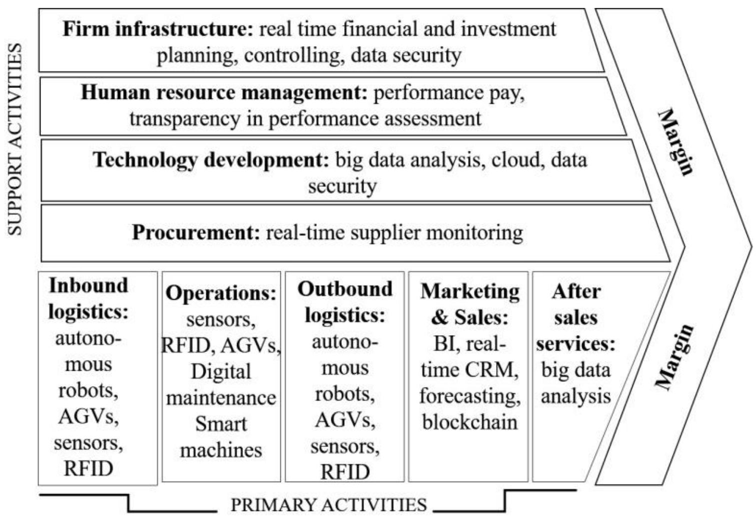
Data are the main inputs and outputs. There is an *integrated network* in the centre of future's industry, centralised in the *cloud* and key data are available in a central data warehousing system. Each tool uploads and download the necessary data and information to/from there (*Internet of Things*). *Big data* and their analyses serve not only the understanding of our data, but they also make it possible to predict certain problems, trends (errors, variances). Relying on these data operating processes can become more balanced, which can be the basis to build agile companies. There are intelligent manufacturing technologies and robots capable of receiving and providing data without human interaction. This big amount of data make sample based and time restricted statistical calculations unnecessary (Mayer-Schönberger and Cukier, 2013). Another important change, that data is available in real time. The real-time analysis makes proactive and immediate intervention possible. For example, as soon as the intelligent machine predicts error or increasing scrap rate, it can right away order maintenance. Management level decisions can also be supported by this integrated system: since all company data (e.g., about purchasing, manufacturing, sales) are available in one system, thus advanced simulations, automatic inquires, built-in analyses can be carried out in seconds.

Appearance	**Industry 4.0 technology**	**Description**
Digital world	Big Data	Large volume, large variety, real time data, which can be used for advanced simulations and automatic inquiries.
	Internet of Things (IoT)	Network of physical items which connect and exchange data.
	Cloud computing	Users are able to access software and applications from wherever they need, while they are being hosted by an outside party.
	Virtual and augmented reality	Virtual reality offers a digital recreation of a real-life setting; augmented reality delivers virtual elements as an overlay to the real world.
"Glue"	Sensors	Collect and transmit data, more intelligent ones are also capable of self-calibration or sending warning signals.
Physical world	Global positioning systems (GPS)	A global navigation satellite system that provides geolocation and time information to a GPS receiver anywhere on the Earth.
	Additive manufacturing (3D printing)	Material is joined or solidified under computer control to create a three-dimensional object, with material being added together.
	Robotics	Machines that can substitute for humans.

Table 1. I40 practices.

The *cloud* provides hardware capacity for data storage and processing. A big advantage that data can be reached at any time and any place, not only from the company intranet. This advantage, however, brings the issue of IT security to the fore. Tools of *virtual and augmented reality (VR/AR)* can be used in several processes. Information can be transmitted immediately and without any unnecessary motion to workers through smart glasses, everything is in front of their eyes. There is potential in this technology to carry out warehousing tasks (picking), but it also contains opportunities for further use (e.g. training). *Machine-to-machine (M2M) communication* is the IoT in manufacturing setting. In M2M systems automated tools, intelligent machines are capable of communicating with each other directly. Intelligent tools can download and analyse the generated (and necessary) data in real-time, making it possible to change the production plan, the parameters of the production, or stopping the production line in case of serious errors. Enabling and utilizing this ability, companies can significantly reduce (or eliminate) failures, waste and response time, heavily enhancing the quality and the flexibility of their production. *Additive manufacturing* makes rapid prototyping and small-scale production possible by printing 3D products designed in computer aided systems. There are different 3D technologies using different kinds of materials. The latest generation of manufacturing *robots* can use artificial intelligence and cooperate with humans. Automated guided vehicles (AGV) are robots for transport.
When the entire manufacturing process is developed in sense of I40 and instead of isolated solutions a comprehensive system is created, we achieve the digital factory (or smart factory), that is what really makes difference.

2.4. Use of industry 4.0 tools in the value chain
To go beyond manufacturing and make a more business oriented-approach to I40 tools, we have placed the tools into Porter's value chain concept (Porter, 1985). As Figure 1 depicts the value chain divides business activities into two categories. We differentiate primary activities (e.g. logistics, operations) and support activities (infrastructure, human resources). First, Figure 1 makes it clear that I40 tools pervade both the primary and support activities. By applying these tools, transparency, integration and predictability can be improved and there is much more information about internal processes, as well as about customer needs. I40 considerably transforms value chain and it also requires the establishment of new value-creating areas, just think about how extreme pressure is placed nowadays on product design and development, or on data security (Porter-Heppelmann, 2015).



BI: business intelligence, CRM: customer relationship management

Figure 1. I40 practices in the value chain.

At this point, it is evident, that I40 influences all activities of the value chain, and it can even have a considerable impact beyond the boundaries of the organisation. In the following section we will focus on operations and logistics and review the current practice of automotive companies.

2.3 Tools in the automotive industry

Huber (2016) studied the use of I40 tools in German OEMs (Audi, BMW, Daimler, VW, see Table 2 for summary).

Technology	Audi	BMW	Daimler	VW
Big data, real time company	Predictive maintenance and predictive quality; real time evaluation of suppliers	Partners IBM, SAP, cortexDB; SPSS Supply Chain "Radar" – real time data about the logistics chain	Predictive maintenance at cylinders (IBM SPSS, other IBM programs) "Integra" (American factory) – all data are in real time	The company opened a Data Lab in Munich in 2014
Cyber-physical system, CPS) (M2M)	"intelligent forming die" project (2009); the die performs quality inspection	Autonomous guided vehicles	Automatic material supply	Autonomous guided vehicles
Cloud technology	-	-	see big data	
Digital factory	Vision: assembly line → competence island, based on decentralisation and big data usage (drones and automatic guided vehicles perform supply)	Siemens product 3D scanner + digital camera for data collection followed by process simulation	"virtual use" (Siemens NX MCD) simulations (e.g. lacquering)	Technomatrix product family (Siemens)
Supporting technologies in production and logistics (e.g. augmented reality, virtual reality)	Pick by light, pick by voice AR tools (the use of smart glasses was not economical; pilot for projecting information on hand)	Smart glasses; faults are visible on photos or videos 3D camera in quality inspection Smart watch	RFID (it exists at other companies, as well) AR in quality and logistics, e.g. smart glasses in picking, quality inspection by camera	Smart glasses
3D printing	Used since '90s for prototyping, and from 2014 in production for metal components; customised seats	Used since 1989 for prototyping, since 1991 for serial production; typically for small volume products	Used in prototyping and production	Planned to be used soon in production (metal)
Sensitive robots	Final assembly for heavy or not handy components, for monotone, non-ergonomic activities	For highly repetitive activities, or due to ergonomic reasons, learning robot cleans the dies (KUKA)	Used for ergonomic, demographic and/or cost reasons	Used for exacting and ergonomically problematic tasks (within vehicles or above heads); cost reduction and demographics (in 2015 ten thousand employees retired)

Source: based on Huber (2016)

Table 2. I40 practices at German automotive OEMs.

He argues that the launch of I40 initiatives has foremost been motivated by business goals. OEM companies have reached their limits to manage complexity with traditional production approaches. I40 can be a solution to significantly improve their flexibility further and manage the complexity required by their customers. In Audi's vision the fully customised products are supplied by automated logistics and production processes, and smart products organise their manufacturing in a decentralized and networked structure instead of going through the takt time-paced assembly lines. Furthermore, he also points out that I40 can help companies to overcome the pressure of ageing workforce.

The investigated companies have had experiences with all the tools discussed in chapter 2.2. However, these experiences are very diverse, although we have to take into account that this area went through considerable changes in the last couple of years.

Big data and real-time company appear in each company. Besides the use in maintenance, it is important to highlight that external programs are determinative. Although real-time decision making is frequently noted, the description of the actual practice is too general.

There have been big steps taken forward in M2M systems. Particularly autonomous material supply is in the forefront. We get to know very few concrete information about cloud systems. The digital factory has proved to be an efficient field for simulations, process optimisation and factory optimisation. Concerning augmented reality, alongside the almost traditional solutions (like pick by voice) smart tools have started to spread. Experiments with smart glasses are popular, but there are already results about non-economical operations. In the physical world sensitive robots are starting to spread. These robots can work with people, execute tasks jointly, or after they are taught they can do the job alone.

German OEMs use plenty of I40 practices or make experiments with them. They made the most progress with the technologies of the physical world, like sensitive robots or 3D printing. They have good results in autonomous material supply as well. This M2M can be connected to both the digital world and the Internet of Things.

In case of digital world technologies companies can show off some well-documented projects, but they do not appear to achieve a systematic and strategic approach at the time of the study. Unfortunately, descriptions of several I40 practices are too general, so they do not really help other companies and managers. Finally, very little is shared about the bottlenecks and critical points of I40 projects.

3. Methodology

Our research relies on qualitative information. Three interviews were prepared at the analysed company by two of the authors independently. The head of the company's process development team was the interviewee twice, and a member of his team, a business analyst gave one interview. The role of the head of the team is important not only within the Hungarian I40 activities within the corporation; he also takes part in forming the regional I40 development strategy. Three of the authors had the chance to visit the factory personally.

The relationship between the university and the company is not new. Members of the research team already visited the company several times, and supervised student thesis works there. They also prepared a case study about the Hungarian unit in previous research.

4. The case company

The Hungarian subsidiary is part of a global company, TE (i.e., Tyco Electronics) Connectivity (we call it Tyco from now on) with American roots, headquartered in Switzerland. It produces half a million different precision products in almost 100 factories, with 75,000 employees worldwide. The case subsidiary operates with about 1500 employees belonging to the automotive division and the EMEA region. Product variety, size differences and volumes are all large in the factory. The factory primarily delivers cables and jacks to TIER1 customers. They do both fabrication and assembly. Beyond these products, ambient lighting and electronic components get a place in their product portfolio, as well.

The factory is the most modern unit within the corporation. The first experiments with digital solutions have started 4-4.5 year ago here. In the last three years they have received significant organizational support for digital transformation.
In 2014 Tyco convened a one-week workshop in Germany, in the cradle of I40. The representatives of the automotive division worked out a list of potential areas and business processes, where digitalization can lead to cost-cutting, and where they have to start developments as soon as possible. The list has contained 160 items, which were categorized into the following groups:

- Real-time KPI (key performance indicators) visualisation
- Visualisation of process parameters
- Digital quality inspection
- Full digital tracing of tools
- Production warning, signals (Andon)
- Total productive maintenance
- Big data
- Agile supply chain planning
- Digital education

On the workshop participants also decided that within the region the German and Hungarian subsidiaries are designated to be the pilot factories. It means that these two factories can first test the I40 tools and technologies planned to be implemented, and after achieving positive results, these factories will coordinate further adaptations in other factories. The distribution is not equal: 70% of the tools are assigned to the Hungarian factory, and "only" the rest of 30% goes to the German factory. The German factory primarily deals with the tracking and tracing of tools, with life cycle analysis of tools, and other digital solutions related to tools. Production efficiency is in the centre of all the experiments and developments.

5. Digital factory in practice

5.1 IoT at the case company

To exploit the potential of I40, the factory realised the need to collect data. Therefore, the first step towards I40 was the installation of tools and/or software that can capture the desired observations. They established a central database by which all data are collected and in which all data are available. So tools like machines, laptops, PC with data analysis program, Android devices, smart screens and kiosks on the shop floors, sensors etc. in the factory are connected to this central database. The factory has not finished the installation throughout the whole production yet, but many machines are already equipped with sensors, scanners, 3D cameras to get a more reliable picture of the processes taking place. Some of the tools are capable to communicate to each other, as well.
A vital example for IoT, and for the importance of interconnectedness is the Operator Learning Management System (OLMS). OLMS is about the digital monitoring and permanent match of employee's skills (and authority) with the specific activity. If a worker logs into a machine to accomplish a task, the machine gives immediate feedback whether s/he has the qualifications and/or the authority to perform the specific task. If the worker has not got the right or up-dated qualification, the system directs her/him to an e-learning interface on the shop floor where s/he can quickly learn the necessary routines. Recently, the factory has launched a new module of the system. This module analyses the previous performance of an employee (e.g., topics, points), and based on it the module proposes a personal and customized capability development plan. The module covers about 1000 employees. While this tool has a relatively long history at the factory, measurable indicators about its impact are not available.

5.2 Big data – data visualization

Real-time performance management system is based on the central dataset. The real-time indicators are on the smart TV screens of Go Meeting areas, a designated shop floor area for operational personnel. Employees have access to operational measures like running products, scrap rate, efficiency, downtimes, actions to be executed, customer complaints etc. The real-time data are foremost descriptive data. By now the company cannot make predictions. Furthermore, they can only use a little fraction of the central dataset.

5.3 Cloud – local servers

The firm mainly stores data on in-house or group level servers and relies only to a limited extent on external partners. These internal servers do not only store data, they also do the required calculations and data processing tasks. Tyco prefers the local solutions because the company’s cybersecurity competence is rather underdeveloped. Furthermore, local internet lines (and general internet infrastructure) cannot deal with the system requirements of proper cloud services. In a pilot project, regional factories of Tyco are connected, and these factories share a specific set of operational data with each other. The comparison of data throughout many factories bears the opportunity to find potential improvements.

5.4 Sensors – smart and intelligent sensors, andon

In the Hungarian factory there are many thousands “smart” sensors in operations to collect and transmit data, and about twenty “intelligent” sensors, which can intervene if needed (Yurish, 2010).

The “smart” (or traditional) sensor is built into the machine. If production has stopped it sends a notification to the operator to intervene. When the worker reaches the scene, s/he sees the machine's visualized performance measures at a monitor placed on the machine and the detected problem. If s/he knows the solution, s/he can intervene and restore the production process. If not, s/he has to notify her/his supervisor. It is practically a digital andon system. One great advantage of the presented solution is that by relying on real time data about operations and machines, and on elaborated intervention protocols of decision making, they can solve problems faster and hence the downtime is reduced considerably.

Quality tasks and predictive maintenance are supported by “intelligent” sensors at the plant. The “intelligent” sensor measures pressure curve and based on the measured data it predicts the quality of the product (if it meets the standard or not). Vibration sensor works similarly to predict maintenance. If the data measured by the sensor significantly differs from the reference data measured during the tests, the sensor suggest maintenance because of abrasion or a predicted failure. Tyco devotes specific interest to sensors. Recently, the firm bought a sensor company to have know-how and R&D knowledge in-house.

5.5 Augmented reality – smart glasses

The factory has no project with smart glasses yet. However, a pilot project is planned based on the experience of a North American Tyco factory. There smart glasses have been used by maintenance workers and operators. Workers can follow the instructions visualised by the smart glasses while performing specific maintenance processes. The smart glasses depict the list of the process steps to be executed. Workers perform the steps according to the list, and by the end of each step they can mark the list with eye movement. So, it is an instruction list and a quality check at the same time. However, local managers’ opinions are rather critical about this solution. They say that many workers do not like smart glasses. Many of the workers are disturbed by them. This can be partially explained by generational differences.

5.6 Additive manufacturing

The factory is the centre of excellence in the field of injection moulding. First they started with a metal-based additive technology. This pilot's main purpose has been to collect experience about the technology. In near future, a new industrial 3D printer will arrive with own cooling system. The additive technology is limited to prototype development and internal tests. It is more efficient, since it needs fewer components, so maintenance also requires fewer resources. Beside prototype production, the factory relies on this technology in spare parts production where the standards are not so strict. By now, this technology cannot be used in batch production due to standards of the automotive industry. These machines have not get certification for specific material and chemical standards.

	Industry 4.0 technologies	**Practical implications at the case company**	**Expected advantages**	**Factors obstructing implementation**
Digital word	Big Data	real time performance measures visualised on smart screens at GO meeting areas	- more accurate forecasts - optimised production - real time process control, visualise process parameters - central database is created	- extremely costly - requires great expertise both in planning and execution
	Internet of Things	Operator learning management system	- improved work safety - increased efficiency - efficient handling of customer complaints	- effective only in case of regular content production
	Cloud computing, cloud services	local servers, factories connected to each other	- real time data processing, facilitate data saving - additional computing capacity involved - strengthened integration of the supply chain	- requires high trust towards partners and suppliers - extremely high cyber-security risk
	Augmented reality solutions	smart glasses	- practical learning process - more efficient human processes due to additional information	- difficult to reach employee acceptance - costly, immature
"Glue"	Sensors	intelligent sensor (self-calibration)	- improved workplace safety - Big data provided - efficiency increase	- requires high network - big data requires high capacity to analyse
		smart sensors (andon)	- quick response to production errors reduced quality costs	- wrong signals slow down operations
Physical world	Additive production	3D printer (metal)	- increased production flexibility - more productive and faster at smaller batches - rapid prototyping, efficient spare part production	- costly - slower in case of larger batches (if possible et all) - difficult to meet quality specifications
	Robotics	Robots with zero change over time	- increased productivity, reduced scrap - more productive at smaller batches - reduced costs (stocks, tools)	- extremely high investment requirement - shortage of experts and engineers on the labour market

Table 3. Findings of using I40 technologies at Tyco.

5.7 Robotics

Robots perform precious tasks during the production of high value-added products. In the near future, the factory has serious plans to use robots for aftermarket products. Robots would be able to produce a homogenous set of about 15-100 similar items with close to zero change-over time. This solution would completely change the role of warehousing: due to the flexibility of the process, the factory would need hardly any stocks of the products and the stocks of tools which are expensive and occupy a lot of space, can also be eliminated.

5.8 Factors hindering implementation

The manufacturing unit is in an *experimentation* phase now. This phase already implies high level informatics network (common platform, ERP system, physical network). At our case company this cost takes 60% of the total digital budget, what was not expected in the design phase. In other factories of Tyco, where the well performing solutions will be adapted, the cost ratio of developing the informatics network can be even higher, around 80%.

The implementation of industry 4.0 *technologies* is another big portion of costs. The reason behind is that there are very few turnkey solutions available, so the company has to develop them for itself.

Beside costs, the other interfering factor is the lack of *knowledge*. The lack of knowledge is a problem not only on the market of engineers and informatics experts. There is a lack of knowledge also at consulting companies to support the adaptation of technologies. Therefore, they are not able to offer technical assistance to companies due to the lack of special know-how. The generation of know-how would make it possible and fasten in case of the availability of unified platforms and standards. A lack of knowledge exists in peer-to-peer relations, as well. Very few manufacturing companies deal with this problem currently, so the opportunity for learning from each other (benchmarking) is limited. Those few companies, which have opened towards digitalisation, keeps all information in secret to protect their technologies. The case company organised internal training for employees with six-sigma experience on R language, a data analysis software.

The big pressure for short and medium turn profit also appears to be a hurdle. Beside the high costs of tools, the time of return on investment is uncertain. Frequently happens that after using a technology for 1-2 years new investments become necessary in order to be able to exploit the potential in the solution. Therefore, the foresight, support and openness of management are crucial.

Lack of *acceptance*, however, is a problem not only at the top of the company hierarchy. Operators also not always like new technologies and procedures. They are afraid of being laid off due to automatization. Acceptance can be supported by taking the new tools to the field in experimental stage, where operators can give suggestions and become developers themselves. Their ideas usually increase the usability of tools.

At the case company the highest emphasis is placed on persuasion and education. These two activities take the largest part of projects' time. Based on company experiences the implementation process can be successful only if people are persuaded that the new technology or method will make their work more efficient. Then they have to teach employees and persuade them again about the advantages of implementation.

Finally, the issue of cybersecurity is continuously on the table and requires a lot of costs.

6. Conclusion

The cutting-edge technologies of I40 are *interrelated*: the proper use of big data analysis assumes IoT (network of machines with sensors), data storage and calculation capacity (cloud) and the availability of software solution and human knowledge at the same time. The physical sphere of I40 like smart machines, RFID systems etc. can only be embedded into this interrelated digital network. That is why even the first steps of an integrated digital transformation are very expensive. Since a well-planned chain of pilot projects requires high quality technological infrastructure and human capacity from the very beginning, the I40 phenomenon might result in an even wider gap between superior and laggard companies than it is today (Andrews et al., 2016). The I40 is also an expensive experiment for our case company that relies on advanced technological solutions in their processes, has modern infrastructure in the light of 3rd industrial revolution, and operates in a lucrative industry. Companies with less sophisticated technologies (e.g., old machines, machines hard to equip with sensors), weak IT and physical infrastructure face a real challenge to overcome their limits. These latter companies probably will go on with a fragmented digital agenda, if at all.

We have also pointed out that one of the greatest obstacles is related to *human capacity*. The need for high-skilled workers has already been increased in the manufacturing sector, while the need for low-skilled workers has been dramatically decreased in the last decades (Rodrick, 2016). The same trends are valid in the automotive industry, in which also the role of capital has been appreciated (Timmer et al., 2015). Predictions awaits these trends to continue on the job market (Frey and Osborne, 2017). Our micro level experience refines these megatrends. Now the need for unskilled and low-skilled workers is generated by increasing volumes in the region, but on the medium run it is not sustainable. Clearly, I40 is based on technology, so the role of capital in relation to workforce will strengthen. Finally, nowadays the evolution of I40 at Tyco is temporarily impeded by the lack of workforce with proper data analysis skills. It is not easy to resolve this situation, since companies compete globally for talented people, and more productive regions/industries have advantage. Even leading multinationals face these problems in Eastern Europe. So, our company's experience have shown that the digital factory concept spreads but the roll out of it can be hindered by the lack of skilled people.

The application of modern technology brings radical organisational changes. The successful digital change also requires *high quality change management and project management skills*. However, little is known about specialities of this digital turnaround. It might have two *specific characteristics*: (1) this comprehensive digitalisation is a novelty even at leading companies, so they are not willing to share with and learn from each other; (2) it is partially pervaded by generational gaps (ie., different attitudes of X, Y, Z generations to technology).

Although Tyco has started to invest in I40 to cut costs, in the short run they experience huge initial investments, and are *not able to measure the results* directly. This can make other companies hesitant to start the process.

7. Limitations and future research

The main limitation of this research is methodological. One case study based on a limited number of interviews can provide useful information in case of an emerging topic like industry 4.0, but definitely not enough to generalise findings. But this is only the first step of our research. Further case studies are to be expected, and a survey is planned in the next couple of years. Another limitation is the Hungarian context. Although many subsidiaries in the country are well developed, but still the control is not in their hands which can influence the circumstances. Therefore, other case studies from countries with leading subsidiaries and/or headquarters would help to eliminate this limitation.

8. Acknowledgements (Optional)

We are grateful for the support provided by EFOP-3.6.2-16-2017-00007 program to do this research.

9. References

Andreas Behrendt, A., Kadocsa, A., Kelly, R., Schirmers, L., 2017. *How to achieve and sustain the impact of digital manufacturing at scale*, McKinsey&Company, 2017. August

30th. https://www.mckinsey.com/business-functions/operations/our-insights/how-to-achieve-and-sustain-the-impact-of-digital-manufacturing-at-scale (02.01.2018)

Andrews, D., Criscuolo C., Gal P. N., *The Best versus the Rest: The Global Productivity Slowdown, Divergence across Firms and the Role of Public Policy*, OECD Productivity Working Papers, 2016-05, OECD Publishing, Paris.

Deloitte, 2015. *Industry 4.0 –An introduction*. Deloitte, The Netherlands.

Frey, B. C., Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? Technological Forecasting and Social Change, 114, 254-280. doi:10.1016/j.techfore.2016.08.019

Geissbauer, R., Vedso, J., Schrauf, S., 2016. Industry 4.0 – Building the digital enterprise (2016), PWC 2016 Global Industry 4.0 Survey, https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf (02.01.2018)

Heynitz, H., Bremicker, M., Amadori, D.M., Reschke, K., 2016. *The factory of the future*. KPMG AG, Germany. https://assets.kpmg.com/content/dam/kpmg/pdf/2016/05/factory-future-industry-4.0.pdf (02.01.2018)

Holodny, E., 2017, A key player in China and the EU's „third industrial revolution" decribes the economy of tomorrow. *Business Insider*, 2017.07.16. http://www.businessinsider.com/jeremy-rifkin-interview-2017-6. (20.10.2017)

Huber, W., 2016. *Industrie 4.0 in der Automobilproduktion*. *Ein Praxisbuch*. Wiesbaden, Germany: Springer Vieweg.

Jensen, M.C., 1993, The modern industrial revolution, exit, and the failure of internal control systems. *The Journal of Finance*, 48 (3), 831-880.

Mayer-Shönberger, V., Cukier, K., 2013. *Big Data: A Revolution That Will Transform How We Live, Work, and Think*. Boston: Houghton Mifflin Harcourt Publishing Company.

McKinsey&Company, 2016. *Industry 4.0 at McKinsey's model factories*. https://capability-center.mckinsey.com/files/mccn/2017-03/digital_4.0_model_factories_brochure_2.pdf (10.01.2018)

Porter, M.E., 1985. *Competitive Advantage: Creating and Sustaining Superior Performance*. New York.: Simon and Schuster.

Porter, M.E., Heppelmann, J.E., 2015. How smart, connected products are transforming companies. Harvard Business Review, 93 (10), 96-114.

Rodrik, D., 2016. Premature deindustrialization. *Journal of Economic Growth*, 21 (1), 1-33. doi:10.1007/s10887-015-9122-3

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., Harnisch, M., 2015. Industry 4.0 – The Future of Productivity and Growth in Manufacturing Industries. The Boston Consulting Group. https://www.zvw.de/media.media.72e472fb-1698-4a15-8858-344351c8902f.original.pdf (10.01.2018)

Schwab K., 2016. *The fourth industrial revolution*. Portfolio Penguin

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., de Vries, G. J., 2015 . An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production. Review of International Economics, 23 (3), 575-605. doi:10.1111/roie.12178

Valenduc, G., & Vendramin, P. (2016). *Work in the digital economy: sorting the old from the new*. Brussels: ETUI. https://www.etui.org/Publications2/Working-Papers/Work-in-the-digital-economy-sorting-the-old-from-the-new (15.08.2017)

Wang, S., Wan, J., Li, D., Zhang, C. (2016): Implementing smart factory of industrie 4.0: an outlook. *International Journal of Distributed Sensor Networks*, 12 (1), ID 3159805

Yurish Y.S., 2010. Sensors: Smart vs. Intelligent. *Sensors and Transducers Journal*, 114, 1-6.