ETLA Working Papers
No. 45
22 December 2016

Heli Koski
Helinä Melkas
Martti Mäntylä
Roel Pieters
Rauli Svento
Tuomo Särkikoski
Heli Talja
Juha Hyyppä
Harri Kaartinen
Hannu Hyyppä
Leena Matikainen

Technology Disruptions as Enablers of Organizational and Social Innovation in Digitalized Environment

Suggested citation: Koski, Heli, Melkas, Helinä, Mäntylä, Martti, Pieters, Roel, Svento, Rauli, Särkikoski, Tuomo, Talja, Heli, Hyyppä, Juha, Kaartinen, Harri, Hyyppä, Hannu & Matikainen, Leena (22.12.2016). "Technology Disruptions as Enablers of Organizational and Social Innovation in Digitalized Environment". ETLA Working Papers No 45. http://pub.etla.fi/ETLA-Working-Papers-45.pdf

ETLA ELINKEINOELÄMÄN TUTKIMUSLAITOS
THE RESEARCH INSTITUTE OF THE FINNISH ECONOMY

ISSN-L 2323–2420
ISSN 2323–2420 (print)
ISSN 2323–2439 (online)

Technology disruptions as enablers of organizational and social innovation in digitalized environment

Heli Koski[a], Helinä Melkas[b], Martti Mäntylä[a], Roel Pieters[a], Rauli Svento[c], Tuomo Särkikoski[d], Heli Talja[e], Juha Hyyppä[f], Harri Kaartinen[f], Hannu Hyyppä[a], Leena Matikainen[f]

a. Aalto University, Helsinki/Espoo, Finland, e-mail: heli.koski@aalto.fi
b. Lappeenranta University of Technology, Lahti, Finland
c. Oulu Business School, Oulu, Finland
d. University of Tampere, Tampere, Finland
e. VTT Technical Research Centre of Finland Ltd, Finland
f. Finnish Geospatial Research Institute, Masala, Finland

Abstract

This paper illustrates how disruptive technologies primarily shaking the functioning of service sector are spreading to the manufacturing industries, and vice versa, and further change the roles of consumers and users. Software and data that first transformed the provision of services now lead the transition of traditional manufacturing companies towards the production of smart, connected products and fundamentally transform their operation and management. Along with the datafication of manufacturing companies, certain advanced digital technologies such as robotics originally developed for manufacturing purposes find their applications in services. Co-evolution of technology and service innovation will be in the center of transformation of health services towards the adoption of new service and care models with assistive and socially intelligent robots. Our paper also addresses that technology disruptions in a digitalized environment enable and facilitate transformation of consumers from mere end-users to active market participants who may not only design or customize products for their own needs but also to become active market players on the supply side. Technology disruptions may also challenge existing institutions. For instance, convergence of robotics and surveying resulting in decentralized, distributed collection of geographic data by vehicles equipped with sensors may make national mapping agencies obsolete.

Keywords: technology disruptions, digitalization, IoT, robotics, point clouds, renewable energy

1. Introduction

The importance of new technologies for society arises from the discovery that ideas and their implementation generate growth and well-being (see, e.g., Jones, 2005). *Disruptive technologies* fundamentally change ways people live and work and how businesses operate, and they ultimately impact the global economy (see, e.g., McKinsey Global Institute, 2013). The definition of disruptive technology relates closely to *disruptive innovation* concept of Christensen (1997). Disruptive innovation are such new services and products that initially gain market share at the bottom of the market by making product or service available to a new group of “low-end” consumers that are less wealthy or skilled than consumers of such products historically. Eventually, disruptive innovation moves up to market and displaces established competitors. The fundamental difference between the definitions of disruptive technology and disruptive innovation is that the former does not restrict market entrants to first target low-end markets and then move from the bottom to upmarket.

This paper focuses on four technology disruptions that are expected to have wide-range implications on the development and adoption of various organisational and social innovation and which are, consequently, likely to have major socio-economic impacts: i) new digital technology stack of smart, connected products, ii) robotics, iii) miniaturization of sensor technologies and point clouds and iv) renewable energy. This set of rapidly developing technologies illustrates how technology disruptions transform traditional manufacturing industries as well as service sector and may further have substantial impacts on the roles of consumers and users as well as those of institutions.

The first aim of the paper is to enhance our understanding on how digital disruption of industry affects both the internal structure of a firm, its strategic management as well as on the firm’s relationships with its customers, partners, employees and investors. Secondly, we discuss the emerging field of service robotics and its potential role in future welfare services such as elderly care. This part of research outlines the multidisciplinary approach required for moving towards true organizational and social innovation in the context of service robots and health sector. Third, we discuss certain socio-economic implications of technology disruption related to the miniaturization of sensor technologies and the collection and use of point cloud data. Fourth, we briefly analyze the structural change of the electricity system due to smart, digitized networks disrupting the basic one-way traffic from generators through transmission and distribution to consumers.

The paper is organized as follows. Section 2 briefly describes four technology disruptions considered. Section 3 discusses the organizational and social impacts of disruptions. Section 4 concludes.

2. Technology disruptions: new digital technology stack, robotics, point clouds and renewable energy

2.1 The new digital technology stack

As observed by Porter and Heppelman (2014), digital disruption of manufacturing industry manifests itself in that the majority of manufactured products will become smart, connected "Tesla-like" products. In other words: i) Manufactured products are profoundly composed of "hardware" and "software", the latter residing not only embedded in the physical product, but increasingly in a "product cloud", enabled by the new technology stack of smart and connected products, especially *Internet of Things (IoT)* technology. Moreover and even more significantly, the value of the product to a customer will be increasingly dependent on (cloud) software, ii) Manufactured products are continuously connected to the network, giving the manufacturer a possibility to monitor comprehensively the performance of the product while it is actually being used. This opens the door to continuously improve the product by learning about its actual use and making it fit better the actual use patterns and user needs, and iii) Through the network, the product can utilize the full scale of Internet resources such as massive databases or machine learning and computational intelligence. Moreover, any functional improvement deduced with such resources becomes instantly available to all copies of the product, benefitting all its users.

The underlying technology stack ranges from physical products through other technology layers of embedded sensors and intelligence, network connectivity, cloud data storage, data modelling and analysis, and new digital services and user experiences, all the way to business and societal layers such as new business methods and models, ecosystem management, and implications to regulation and other societal institutions. Indeed, the innovation and competitive capability of industrial companies is increasingly dependent on their capability to master the various layers of the technology stack.

2.2 Robotics

Robotics as a research field has been around for many decades, with initial demand being driven by industry for the automation of car and semiconductor manufacturing (Garcia et al., 2007). The industrial setting has the advantage that the environment of the robot can be completely controlled. This is necessary in order to provide safety to any bystander, as the robot is essentially blind to its surroundings and only acts according to a predefined and programmed task. Other fields that have seen major benefits from robotic developments are, e.g., medicine and logistics. Particular cases can be identified for surgical robots such as the da Vinci Surgical System (Intuitive Surgical) and for warehouse logistics such as Amazon Robotics' automated storage and retrieval system. All these cases exemplify disruption in their particular markets as these have accelerated production, increased performance and have since become the state-of-the-art. From a technological point of view, field and service robotics typically operate in "the real world", i.e., in unstructured environments. This brings quite new safety and interaction demands for the design of robots.

Society as a whole has not yet been confronted at a large scale with robotics and autonomous systems. This might change, however, with the advent of autonomous cars. Autonomous driving is making a rapid progress and already millions of miles have been driven on public roads without human interruption and without considerable incidents (e.g., by Google's Self-Driving Car Project or Tesla's Autopilot). More recently, robotics has moved towards care and welfare. While early service robots were developed for a single task use (e.g., vacuum cleaner robots such as the Roomba, iRobot), contemporary service robots for care are designed as mobile assistants with navigation and manipulation capabilities. These developments are closely linked to new *personalization technologies* that increasingly enable customer/ user co-creation to become a major source of innovation.

Considering the Western world and its demographic changes, health and welfare services are specifically targeted for an aging population. Due to the versatility of robots, new robot-enabled health services may take variety of currently unforeseen characteristics. The markets of robots aiming at care of elderly or disabled people are still small, but the growth is huge; the markets quintupled from 2013 to 2014 (World Robotics 2015), and substantial growth is expected to continue, as developing new robot applications is becoming easier (Kyrki et al., 2016).

2.3 Miniaturization of sensor technology towards point cloud ecosystem

A point cloud is usually defined by X, Y, and Z coordinates, and often is intended to represent the external surface of an object. Point clouds can be created by 3D scanners using lasers or structured light, or by using digital photogrammetry by matching image correspondences in overlapping stereo or convergent imagery for block adjustment and object reconstruction.

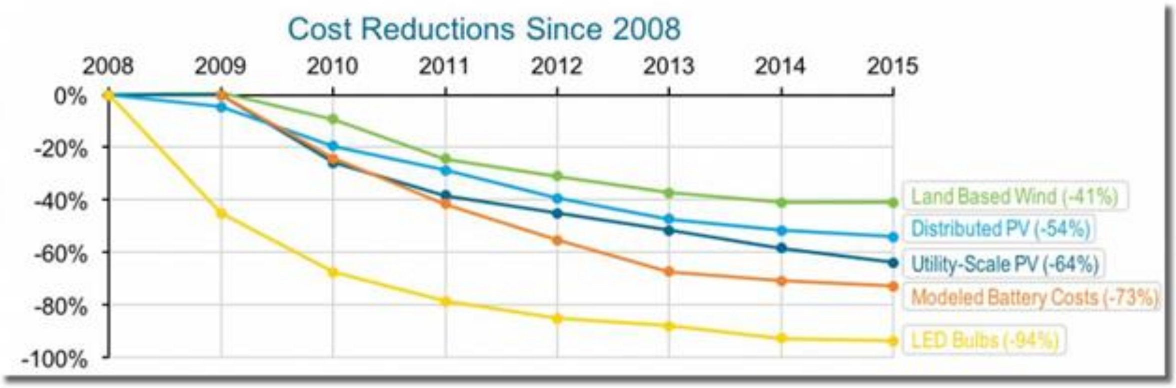
Large industrial actors and technology companies collect massive roadside datasets globally using laser scanning and photogrammetry basically on all roads and from all built areas. We see the images, e.g., from Google Street View, but we do not see the point clouds. Autonomous-driving technologies have attracted considerable academic and industrial interests in recent years. After the success of autonomous car technology competition The DARPA Grand Challenge, various car manufacturers announces that their future vehicles will rely on automatic or automated driving based on advanced sensor technology.

Sensor technologies related to the collection of point cloud data are rapidly developing. Sensor miniaturization is one of the key elements in this development. The penetration of this technology into practice is fast: with little exaggeration, it can be said that technology what Nokia bought from NAVTEQ with the value of 8B$ in 2007 will be available in an improved form in the majority of cars by 2030 at a very low cost. Additionally, smart phones and other portable products will include a point cloud generation sensors. During the 2020s and 2030s, there will be a great number of point cloud generation electronics omnipresent in everyday life. Point clouds and corresponding image data are the main technologies to provide up-to-date 3D maps, models and virtual realities. A large number of mobile laser scanners will build a point cloud-based ecosystem, complemented with information about the environment coming via Internet of Things and sensor web. In addition to the autonomous car ecosystem, we see other ecosystems with a large number of point cloud generation systems appearing: in forestry, built environment, and finally a point cloud cyberinfrastructure will be formed.

2.4 Renewable energy

Renewable energy is constantly increasing its share in electricity systems globally. There are several reasons for this development. International agreements such as the Paris Agreement 2016 are forcing nations to invest and assemble increasing amounts of renewable energy sources into their systems. Several cities (e.g., Oslo) have declared coal neutrality as their goal in mid-term perspectives. At the same time, technological development is making its way in decreasing the costs of renewable sources (see Figure 1).

Figure 1. Costs of renewable resources



In 2015, there was nearly 74 gigawatts (GW) of assembled wind farms and 14 gigawatts of solar farms installed. Wind power is projected to overtake hydropower as the number one renewable energy source in the United States. Utility-scale photovoltaic systems generated 15 billion kWh in the US in the first half of 2016 — a 34 percent increase over the same period in the previous year.

This increase in renewable energy production has substantial effects on CO_2 emissions but, at the same time, it increases uncertainties and balancing demand into the system. Renewable sources are intermittent by nature and this creates the need for rapidly adjustable balancing power technologies in the dispatchable merit order. These challenges create costs that are called integration costs in the literature (Joskow 2011, Borenstein 2012, Hirth et al. 2015, Gowrisankaran et al. 2016). Integration costs can be classified into profile costs, variability related uncertainty costs and locational costs. Profile costs relate to the fact the system must be in balance all the time: either capacity mechanisms or demand response mechanisms are needed to back up the intermittency profiles of renewables. UK and Ireland have chosen to create capacity markets while Germany is trusting on demand response.

One way to diminish the uncertainty element is to develop new types of energy-related weather forecasts. This necessitates developing weather forecasts to suit more accurately to wind mill power curves and pv panel transformation equations. One example of this type of development is the energy weather forecast developed in the BCDC project (http://www.bcdcenergia.fi/en/energy-weather/).

The disruption in the electricity system arising from renewable energy, however, arises from combining smart grid development into renewables usage. Digitalization networks are changing into smart grids that allow two-way traffic in them. This gives new opportunities to distributed production and small producers and creates new organizational, social and business possibilities. Small producers do not have the possibility or power to affect the system level processes like price formation. By forming new types of communities, small producers can aggregate their activities in virtual power plants and gain acceptance in the market dimension. The virtual power plants can then be developed into two-sided marketplaces that become active market participants in the system. Households change from passive out takers into active participants in the system through being able to sell their overproduction back into the system. The next wave of home automation emphasizes these demand response possibilities. At the same time, new types of pricing principles and contract types need to be developed.

Figure 2. Number of patent applications in the USPTO in selected technology fields, 2005-2014

Overall, an increasing importance and the future prospects of new digital technology stack in manufacturing, robotics in health care, point clouds and renewable energy are reflected by the growing number of patent applications in these technology areas. To roughly illustrate these developments we undertook a search of patent applications filed in the USPTO (i.e., The Unites States Patent and Trademark Office) comprising the words i) “Internet of Things” or IoT, ii) “robotics” and “health”, iii) “point cloud” and iv) “solar” and “energy”; “wind” and “energy” either in the title, abstract or description of the patent application.[1]

Figure 2 shows that robotics in health care, point clouds and particularly Internet of Things are emerging technologies. The number of patent applications comprising the words “Internet of Things” or “IoT” filed in the USPTO was close to zero until the year 2010, followed by a rapid increase in the number of patent applications. Instead, it seems that the number of patent applications related to solar and wind energy has already approached its peak indicating a more mature phase of technological development in these technological areas

3. Organizational and social impacts of disruptions

3.1 Digital disruption of industry

The ongoing transition towards smart, connected “Tesla-like products” is expected to influence deeply the position of industrial companies with respect to their ecosystem stakeholders, as well as to challenge their existing functional structure and strategic management.

Relationship with customers: The defining characteristic of smart, connected products is that they can maintain a 24/7 contact between customer and producer enabling the collection of comprehensive data on the use of a product in its actual use context. Consequently, companies can witness directly how customers actually use their products, how value is created, which product features are most useful, and where customers face deficiencies. This creates an entirely new intimate relationship with the customer, providing new inputs for the company to improve its offering.

Relationship with partners: A manufactured product rarely stands alone; rather, it is used in association with other products (possibly made by other firms) to solve a customer problem or create value. Recognizing this use context opens the door to find additional sources of value that can be appropriated by new business models. These nevertheless require new ways of cooperation with other firms that now become value creation partners, including novel forms of open innovation with them.

Relationship with employees: Much has been written about the job-destroying effects of digital disruption. While we recognize that digitalization endangers many industrial jobs, we believe that the dominant change in the relationship between a firm and its employees is the digitalization of industrial work. The welding machines of Kemppi that add value to the customer by storing plentiful data on the welding process give an illustrative example of this. For maximal benefit, the welder is expected to record digital information on his/her work, such as the work method applied, the materials used, and other conditions of the job.

[1] We acknowledge that this approach does not give a precise picture of the number of patents applied in each technology field. However, it gives a rough approximation of the trend in patented innovation in these technology areas.

Customers then use this data to improve the quality and productivity of their own welding process. With this, an increasing part of the value of welder's work is determined by his/her "digital work" in comparison to the "physical work". We believe that this shift of balance will be ubiquitous in industry. Various questions arise reshaping the relation between a firm and its employees: How should new digital workers be trained and motivated? How should their performance be monitored and remunerated? How can their own initiative and creativity be captured to make the new kind of work even more valuable? How collected data can be best deployed to support the worker?

Relationship with investors: We expect that an increasing share of the value of a product will become dependent on the "product cloud", storing abundant data of the product and running software that largely determines the valuable features of the product. If so, also an increasing part of the value of a company will be based on its "soft assets" (i.e,. data and software) rather than "hard assets" (i.e., machines or factories). This raises questions on how these asset should valuated and how investments intended to build them be formulated for investor decisions.

Impacts on company internal structure: We are already witnessing the first short-term adaptations of firms' functional structures and operations to cope with digital disruption.

- In *research and development*, short-term adaptations revolve around gaining the skills and competences required for effectively using the new technology stack. It appears that most industrial companies will rely on external partners following the principles of open innovation to gain these skills and competences. This drives, for instance, the "hackathons", whereby companies experiment new ways of interacting with startups and innovators and learning from them.
- In *customer relations,* Porter and Heppelman (2015) perceive adaptation emerging in the form of "dev-ops" teams or "customer success management" teams. Both aim at recognizing and utilizing new opportunities for customer added value in an agile fashion.
- In *production and logistics,* comprehensive digitalization of the factory floor operations is the goal of approaches such as the Industrial Internet popularized by General Electric or the German Industrie 4.0 initiative. Based on this, many firms are already developing new applications aiming at condition monitoring, predictive maintenance, or remote operations.
- With smart and digital products, data becomes a critical resource for a company. Hence excellence in gathering, processing, and deploying data across various functions of a company becomes an important success factor. The emergence of the roles of *Chief Digital Officer* or *Chief Data Officer* appears to be short-term adaptations deployed by companies to address this need.
- Similar adaptations are expected across the board of functional units in companies such as human resources finance and control.

Implications for strategic management: The new technology stack and related resources and capabilities are likely to become a new arena for strategic management for industrial companies. This follows the pattern already seen, for instance, in how Google implements it competitive strategy around the Android technology stack. This new form of strategizing largely plays out by granting controlled access to company resources by adjusting the level of openness to Application Program Interfaces (API's) and company data through various kinds of licensing models and other commercial conditions and also carefully modularizing the resources in various "packages" to control the co-operation/competition balance and prevent freeriding.

Impacts on society: An increasing role of "soft assets" as a source of revenues raises various societal issues: how, where, and by whom should these revenues be taxed? Which rules of jurisprudence should be observed? While many companies may welcome the opportunity to use the relative liquidity of soft assets to minimize their fiscal and regulative load, it is clear that in the long run sustainable answers to the above questions are needed. Other societal issues are likely to appear in areas of policy-making such as legal regulation and enforcement; innovation and technology policy; trade policy; and education policy. We also note that society will appear in digital disruption not only as the regulator or with fiscal interest, but also as an active party in the case of publicly built and run infrastructures for transportation, energy, health, education, and public safety. This will raise difficult issues of balancing the interests of society as a direct beneficiary of smart and connected products against the wider aims of technology and innovation policy.

3.2 Robotics in future welfare services

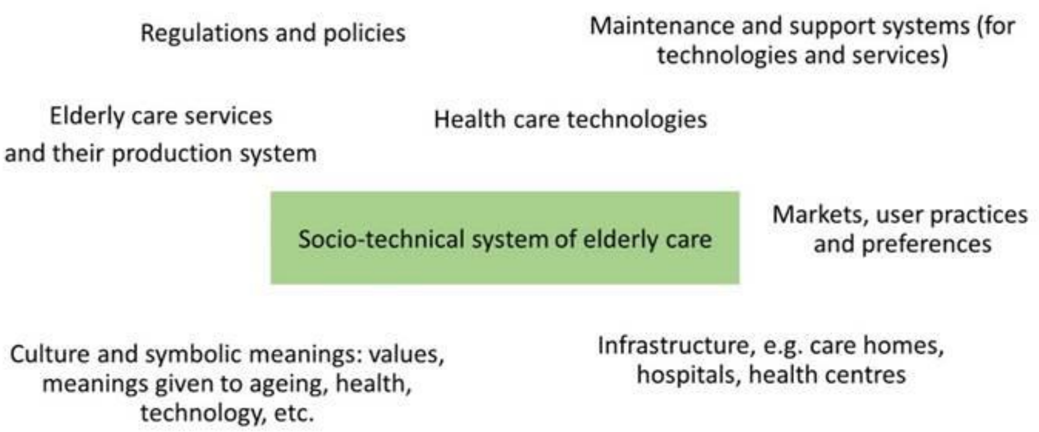
As technologies and services create preconditions and requirements for each other (Kivisaari and Saranummi, 2008), their simultaneous development becomes essential. The discussion about social innovations broadens the concept of innovation from mere technology to systemic innovations, service and process innovations and innovations concerning the market of wellbeing and health (Hämäläinen, 2005). These issues closely concern service robotics.

Robotics in elderly care has various impacts on both customers and care workers and further wider society-level implications (see, e.g., Melkas et al., 2016). Users have a crucial role in implementing disruptive technologies. The selection of new technologies and innovative practices is more than mere adoption; users also have to integrate novelties into their practices, organisations and routines (Geels, 2002). In socio-technical transition studies, user habits and patterns are often seen as barriers for change (Schot and Kanger, 2015). Confrontation between technologies, practices or both in elderly care may be due to technical incompatibilities between technologies; professional identities and roles; usability and accessibility problems; hard pace of care work; various fears; lack of orientation, training and systemic thinking; entry of new actors in the welfare provision; meaning of services vs. technology; the wide variety of technology, and ethical problematics and obscure responsibilities (Pekkarinen and Melkas, forthcoming). Dealing with and coordinating end-users who suffer from dysfunctions like memory disorders or Alzheimer's disease and are not able to communicate with their environment is particularly challenging.

Overcoming these confrontations and moving towards true organizational and social innovation can be expedited through **facilitating the user adoption of technologies, highlighting personally meaningful ways of using technology**. There are also landscape factors such as general digitalisation in the society that act as facilitators and accelerators. Skilled exploitation of those should be strongly focused on, and systemic thinking is the key here (e.g., Alkemade et al., 2011; Loorbach and Rotmans, 2006).

The interaction between disruptive innovations such as service robots and the contemporary service system has gained meagre attention in research. Service/care robotics is an example of advanced technology that is linked to a wider ‘ecosystem’. The complexity of this ecosystem impacts opportunities to commercialize individual innovations attached to it. The market mechanism favours technologies compatible with present solutions and thus short-term optimization, whereas disruptive technologies such as robotics require holistic change. Challenges in diffusion of technology use may be system- or actor-level ones (Mignon and Bergek, 2016), and interaction between companies, service providers and legislators has a major impact on social and technological innovation activities (Kyrki et al., 2016). A focus on different levels including the societal level (see Figure 3) and the innovation ecosystem of service robotics – that is, interaction of phenomena related to the emergence of service robotics and associated actors from different fields – is needed.

Figure 3. The socio-technical system of elderly care (formulated on the basis of Geels, 2002; source: Pekkarinen & Melkas, forthcoming).



The socio-economic impacts of service/ care robotics may be related to the elements of the system presented in Figure 3. For instance, maintenance and support systems for robotics are increasingly needed along with more frequent use. It is likely that maintenance and support requires increasing focus on non-technological issues in addition to purely technological ones. Another example is infrastructure: effective use of robotics may necessitate new structural solutions in buildings. Decision-makers and policy-planners also play a big role in a nation like Finland, where care services have been traditionally funded by the government. Despite their importance, the level of professional organizations in welfare services and caregivers’ perspectives are still widely ignored (Saborowsky & Kollak, 2015; Beane & Orlikowski, 2015).

Potential and so far realized organizational and social impacts of disruptions arising from service and care robotics require a multidisciplinary and holistic approach. In addition, the uptake of new services requires the study of ethical issues and stakeholder participation. All these disciplines will need to be active on three levels of analysis: individuals (human-robot interaction, ethics, individual support functions), services and service organization (welfare services enabled by robots in different roles) and the society (societal acceptance, renewal of service systems, innovation ecosystem), as in the ROSE research project (http://roseproject.aalto.fi/en/). As such, **the co-evolution of technology and service innovations and their societal implications in the context of service robots is a key issue**. Service robotics is an emergent field of which possibilities are extensive. So far, we have no clear vision of what kind of assistive or socially intelligent robots are the most feasible and effective in unstructured care environments. Brighter human perspectives on robotic technologies will provide a richer understanding of robots as companions in care.

Figure 4. Care-O-Bot 4 (left) and a Double telepresence bot (right) focused on in ROSE.

3.3 New services and applications based on convergence of robotics and surveying

Technology disruption is facilitating the convergence of automation and robotics, surveying and computer sciences. Laser scanning and photogrammetry in the field of surveying and robotics using laser and camera as perception sensors are integrating. Automation is mainly based on real-time applications, coarser accuracy and local coordinate systems, whereas post-processing, ultimate accuracy and global coordinate systems dominate in surveying. Thus, the roles are perfectly complementary. As an example from scientific work, the most cited paper in robotics in the best ranked publication forum according Google Scholar is “3D is here: Point Cloud Library (PCL)” (Rusu and Cousins, 2011). Additionally, computer science is applied for processing point clouds and related image data generated by the surveyors and automation experts.

Practically all cars will be equipped with point cloud generation mapping sensors (e.g., lidars, cameras, radars, sonars). This means that huge amounts of data will be acquired from urban and road environments on a continuous basis. If these data aimed for automated driving can be used as “big data” for other applications, it will open up completely new possibilities in the field of mapping. For example, current procedures in topographic mapping using data acquired for updating maps has not been properly solved due to high costs. Also, contemporarily national mapping agencies are centralized producers of maps and other geographic information for a nation. Continuous collection of car-based data could revolutionize these procedures by providing very interesting alternative solutions for keeping spatial databases up-to-date. Vehicles and pedestrians with mapping sensors in their smart phones can contribute to mapping. Technology disruption may turn centralized mapping into decentralized, distributed mapping with frequent updates. Crowdsourcing and wikimapping-type-solutions will spread.

Figure 5 illustrates an example of the coming technology disruption: building walls, other cars, trees and humans can be detected from the collected point cloud. Each car can comprise several laser scanners, each creating several hundreds of thousands or several millions of measured points from the surroundings every second. By the year 2030, 15 to 30 percent of new cars (or 15 to 30 million cars) will have a fully automated driving capacity. The capacity to create about one million points per sensor per second is today already available. In 2030, the capacity will be manifold.

Figure 5. Point cloud collected by autonomous car

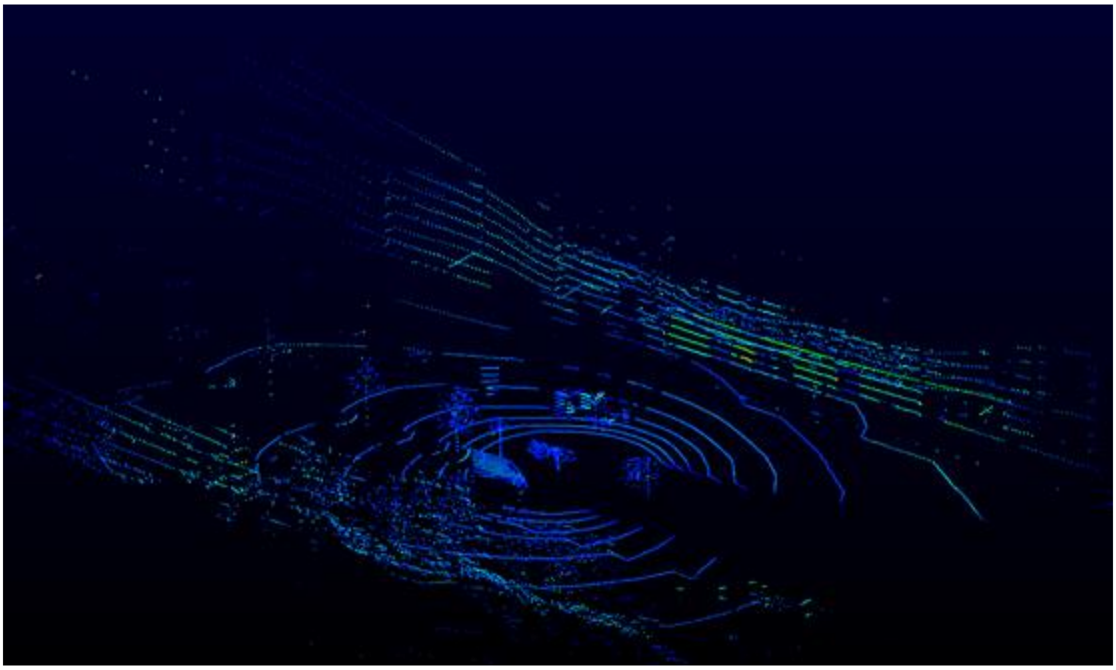
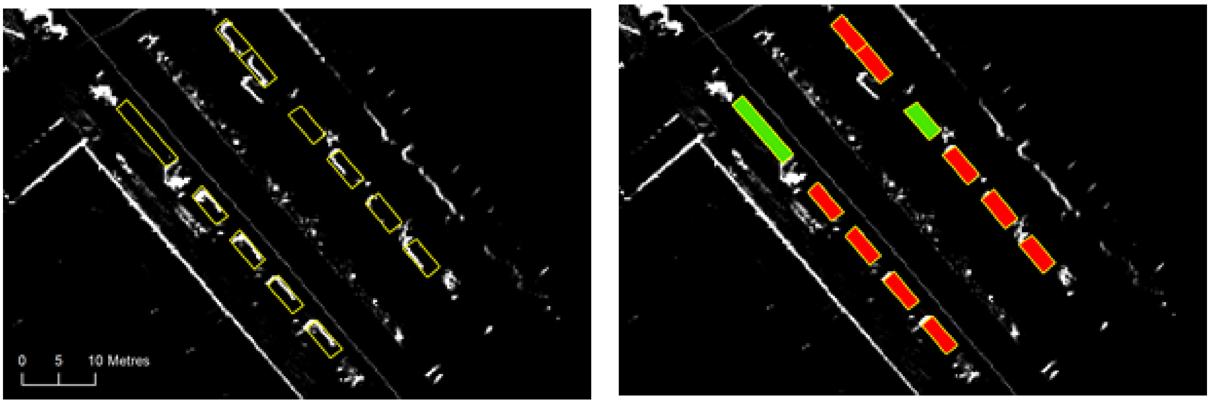


Figure 6a shows an easy application where such data can be used. One of the most needed applications in city areas is an up-to-date map of free parking places. Figure 6b shows an easy implementation of automated parking place detection. Information can be distributed to other near-by cars by car-to-car communication or by Internet of Things, where each smart car is linked.

Figure 6. Data from an autonomous car used for detection of free parking places. On the left (a) there are known parking places marked with vectors. Point coming inside the boxes means the place is reserved, and the automated classification result of free and reserved parking place in the right (b). Such information could be informed to other cars by car-to-car communication.



Miniaturization of sensor technology is disrupting surveying practices. The first mini-UAV (i.e., unmanned aerial vehicle) based laser scanning was introduced in 2009 by the Finnish Geospatial Research Institute (Jaakkola et al., 2010). At that time, it seemed that UAV laser scanning will become reality in 20 years after this demonstration. In only few years, the major manufacturers in the field of surveying started to support UAV laser scanning with new instruments. Today, UAV laser scanning is seriously developing into practical applications.

Miniaturization of sensors also has applications that relate to the smart city concept. The global market for smart city solutions and additional services required is estimated to be around B$400 by 2020. Smart cities mean that physical, intellectual and virtual world are merged. Up-to-date virtual reality of cities would be an excellent platform for future smart cities where novel, unseen applications can be built on top of. Interactive, collaborative 3D cities based on virtual world technologies and decentralized mapping would allow citizen, organisations and companies to participate on the daily planning of our urban environments. At the best, we could have seamless 3D indoor-outdoor models and further locate moving elements in our environment. Citizens could be located by wearable sensors (including smart phones) and also by additional sensors measuring the environment and moving around (i.e., from the cars). Thus, with moving objects the representation of 4D environment would become possible (the fourth dimension being the time). A large set of new location-based services could be accomplished. 3D spaces and their services could be optimized when knowing the flow of persons, vehicles and other objects. We are not there yet, but we are moving to this kind of smart geospatial society where location matters and location is provided by distributed, ubiquitous mapping sensors.

3.4 New roles of consumers in sustainable energy markets

The intermittency problem that arises in electricity markets with large shares of renewable resources needs to be solved by either creating new types of capacity markets or new types of demand response solutions. Demand response solutions lie strongly on the shoulders of consumers. There are several possible ways how consumers can become active demand response players in the new electricity markets. They can i) actively react with their consumption to spot prices, ii) assemble new types of home automation, iii) make new types of contracts, and vi) be active members in new types of aggregators or virtual utilities.

The share of consumers using real time pricing based contracts is growing slowly but surely. The real-time based contracts are currently the most profitable contract option for consumers in the Nordic countries. The study of Kopsakangas-Savolainen and Svento (2012) shows that the increasing share of real-time based contracts in the Scandinavian NordPool effectively cuts the highest prices during the heavy demand hours and increases demand during the low demand hours thus making the load and price curves flatter. Huuki et al. (2016) suggests that the increasing share of real-time price based consumers and wind production together optimised with the hydro reservoir usage further decreases emissions and increases the utilization rates of traditional thermal capacities.

With home automation drivers assembled, the home owners can code their preferences into automation gadgets which then start to manoeuvre the functioning of electricity using devices based on these preferences combined with real time knowledge and forecasts of the spot prices and energy related weather conditions.

Other new types of contracts, in addition to the real-time pricing based contracts, are also emerging to help solving the demand response problem. Consumers can make contracts which allow the utilities to curtail them from usage in hours when load is greater than production. Naturally consumers demand rightly priced compensation from being left without network based electricity in those hours. This opens up the question of new types of pricing in the emerging future electricity markets.

The pricing question is still more evident in connection with new types of institutional and commercial organizations that are evolving in smart grids. Small scale producers can join aggregators that combine large amounts of small production to become big enough to act as an active market player. Alternatively, consumers can join even more developed types of virtual utilities that combine electricity optimization with other types of services related to electricity usage. Interesting questions arise from these developments: which are the new business models, what kind of pricing rules shall they develop and use? And finally, what is the product that is sold and priced - is it electricity anymore, or is it some kind of new service that is built as a platform above the electricity stream?

4. Discussion

This paper illustrates how disruptive technologies primarily shaking the functioning of service sector are spreading to the manufacturing industries, and vice versa, and further change the roles of consumers and users in a digitalized society. Software and data that first transformed the provision of services now leads the transition of traditional manufacturing companies towards the production of smart, connected products and fundamentally transforms their operation and management. Value creation increasingly relies on consumer data collected 24/7 via smart and connected products and is also shared and utilized in novel open innovation practices with firms' business partners. The collection, processing and sharing of data become core activities for firms, and the data become a critical resource for companies across different sectors. A growing share of "soft assets", data and software, also calls for new methods for the assessment of firm value for, e.g., investor decisions.

Along with the datafication of manufacturing companies, certain advanced digital technologies such as robotics originally developed for manufacturing purposes find their applications in services. Technology disruption arising from the adoption of service/care robots in healthcare may have fundamental impacts on the division of work between humans and robots, e.g., in elderly care. This disruption also demands health service providers to adapt their organisations, practices and routines and will be likely to facilitate entry of new service companies with disruptive business models. The uptake of service robots requires not only renewal of health service system but also the societal acceptance of robots replacing humans in health care. This necessitates analysis and resolution of various actor- and system-level questions such as ethical questions related to human-robot interaction in health care and usability and accessibility issues (e.g., new structural solutions in buildings). Co-evolution of technology and service innovation will be in the center of transformation of health services towards the adoption of new service and care models in which assistive and socially intelligent robots play a central role.

Our paper also addresses that technology disruptions in a digitalized environment enable and facilitate transformation of consumers from mere end-users to active market participants who may not only design or customize products for their own needs but also to become active market players on the supply side. An increasing share of consumers use real-time pricing based contracts and assemble new types of home automation combining user preferences, real-time knowledge and forecasts of the spot prices and energy related weather conditions. These consumers actively react with their consumption to spot prices and consequently cut peak-demand electricity prices and flatten the load and price curves of electricity. Consumers may further become suppliers in the electricity markets by joining new types of aggregators or virtual utilities that combine electricity optimization with other types of services related to electricity usage.

Technology disruptions may also challenge existing institutions. For instance, contemporarily national mapping agencies are responsible for the centralized production of topographic maps and geographic information. Convergence of robotics and surveying resulting in decentralized, distributed collection of geographic data by vehicles equipped with point cloud generation mapping sensors may make such institutions obsolete. The capacity to perform maps will be everywhere and the future winners those who can use the distributed talent and infrastructure into practical work process.

From society's point of view, technology disruptions mean that the suitability of the existing regulation needs to be evaluated and requisite amendments undertaken. The European Commission's Better regulation Agenda aiming at simplifying legislation and regulation may be challenged by new regulatory questions or demands arising, e.g., from the new business models in health care changing the ways personal data are gathered, used and transmitted in robot-human interactions. Furthermore, careful assessment of requirements technology disruptions induce for various policies such as education policy and innovation policy needs to be done.

Acknowledgements
This work was supported by the strategic research programme “Disruptive Technologies and Changing Institutions” of Academy of Finland.

References

Alkemade, F., Negro, S.O. and Hekkert, M.P. (2011). Transition policy and innovation policy: Friends or foes? *Environmental Innovation and Societal Transitions,* 1(1), 125–129.

Beane, M. & Orlikowski, W. J. (2015). What difference does a robot make? The Material Enactment of Distributed Coordination. *Organization Science*, 26(6), 1553–1573. http://dx.doi.org/10.1287/orsc.2015.1004.

Borenstein, S. (2012). The private and public economics of renewable electricity generation. *Journal of Economic Perspectives* 26(1), 67-92.

Christensen, C. M., (1997). *The innovator's dilemma: When new technologies cause great firms to fail*. Boston, Mass.: Harvard Business School Press.

Garcia, E., Jimenez, M. A., De Santos, P. G., and Armada, M. (2007). The evolution of robotics research. *IEEE Robotics & Automation Magazine*, *14*(1), 90-103.

Geels, F.W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy,* 31(8/9), 1257-1274.

Gowrisankaran, G., Reynolds, S. and Samano, M. (2016). Intermittency and the value of renewable energy. *Journal of Political Economy* 124(4), 1187-1234.

Hirth, L., Ueckerdt, F. and Edenhofer, O. (2015): Integration costs revisited – An economic framework of wind and solar variability. *Renewable Energy* 74, 925–939.

Huuki, H. Karhinena, S. Kopsakangas-Savolainen and Svento, R. (2016). Real-time pricing as an enabler of variable renewable energy integration. Mimeo.

Hämäläinen, H. (2005). Innovaatiotoiminnalla ratkaisuja hyvinvointiyhteiskunnan haasteisiin. *Yhteiskuntapolitiikka* 70 (2), 197–204. (In Finnish)

Jaakkola, A., Hyyppä, J., Kukko, A., Yu, X., Kaartinen, M., Lehtomäki, M., and Y. Lin, 2010, A low-cost multi-sensoral mobile mapping system and its feasibility for tree measurements. *ISPRS journal of Photogrammetry and Remote Sensing* 65 (6), 514-522.

Jones C. 2005, Growth and ideas, ch. 16 in *Handbook of Economic Growth* 1B, Aghion P. and S. Durlauf (eds.), Elsevier B.V.

Joskow, P. (2011). Comparing the costs of intermittent and dispatchable electricity generation technologies. *American Economic Review Papers and Proceedings* 100(3), 238–241.

Kivisaari, S. and Saranummi, N. (2008). Vuorovaikutteisuus ja systeemiset innovaatiot terveydenhuollossa. In Saari (ed.): Sosiaaliset innovaatiot ja hyvinvointivaltion muutos. *Sosiaali- ja terveysturvan keskusliitto*, 280-300. (In Finnish)

Kopsakangas-Savolainen, M. and Svento, R. (2012). Real-Time Pricing in the Nordic Power Markets. *Energy Economics* 34(4), 1131-1142.

Kyrki, V., Coco, K., Hennala, L., Laitinen, A., Lehto, P., Melkas, H., Niemelä, M. and Pekkarinen, S. (2016). Robotit ja hyvinvointipalvelujen tulevaisuus. (Robots and the future of welfare services; in Finnish.) Suomen Akatemia, Helsinki.

Loorbach, D. and Rotmans, J. (2006). Managing transitions for sustainable development. In: X. Olshoorn & A.J. Wieczorek, eds. Understanding Industrial Transformation. Views from different disciplines. Springer, Dordrecht.

McKinsey Global Institute (2013). *Disruptive technologies: Advances that will transform life, business, and the global economy*. McKinsey&Company 2013.

Melkas, H., Hennala, L., Pekkarinen, S. and Kyrki, V. (2016). Human Impact Assessment of Robot Implementation in Finnish Elderly Care. International Conference on Serviceology, Tokyo, Japan, 6-8 September 2016.

Mignon, I. and Bergek, A. (2016). System- and actor-level challenges for diffusion of renewable electricity technologies: an international comparison. *Journal of Cleaner Production*, 128(1), 105–115.

Pekkarinen, S. and Melkas, H. (Forthcoming). Welfare state in transition: Focus on niche-regime interaction in Finnish elderly care services. Manuscript in review.

Porter, M and Heppelmann, J. (*2015). How smart, connected products are transforming companies. Harvard* Business Review 92, 11, 64-88.

Rusu, R. and Cousins, S. (2011). 3D is here: Point Cloud Library (PCL). Robotics and Automation (ICRA), 2011 IEEE International Conference on, 1-4.

Saborowsky, M. and Kollak, I. (2015). How do you care for technology?" – Care professionals' experiences with assistive technology in care of the elderly. *Technological Forecasting & Social Change*, 93, 133–140.

Schot, J. and Kanger, L. (2015). Conceptualizing the active role of users in shaping transitions. The 2015 Annual Conference of the EU-SPRI Forum. Innovation policies for economic and social transitions: Developing strategies for knowledge, practices and organizations. Helsinki.

World Robotics 2015 – Service Robots. International Federation of Robotics.