Social sustainability and continuous learning in the Circular Economy framework

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The social sustainability is never a single observable entity. It is highly entwined with economic and technical sustainability of the companies. According to United Nations (2018) the social sustainability is about identifying and managing business impacts, both positive and negative, on people. Continuous learning is one of the key aspects when considering the social sustainability in the framework of manufacturing and it's future business models.

Main Body Text

Introduction

Manufacturing, defined as the transformation of materials and information into goods for the satisfaction of human needs, is one of the primary wealth-generating activities of any nation (Chryssolouris et al. 2013). According to OECD's definition "Sustainable manufacturing", also sustainable production, is a formal name for an exciting new way of doing business and creating value. In general, manufacturing industry, regardless the size or activities, aims to enhance their competitive edge, reduce risks, build trust, drive investment, attract customers and generate profit. With the sustainability considerations taken into account, the aim is also to build and foster a healthier working and operation environment. (OECD, 2018)

Social sustainability is defined to be one of the key factors to the future of manufacturing (Abdul-Rashid et al. 2017), especially in Europe. The social sustainability includes among others the continuous life-long learning. Human capital is the main enabler for adopting the emerging technologies such as robotization and digitalization, and new business models including the platform and outcome economies as well as the circular economy. Human skills and engagement to manufacturing field will determine the manufacturing development direction in Europe. Promoting excellence in manufacturing emerges as a strategic goal in the years to come, both for industry and society (Chryssolouris et al. 2013; Secundo et al. 2013, Lanz et al. 2014).

The societal impact of the manufacturing on local environments needs to be considered also in terms of energy demands, utilization of natural resources, factory surroundings and safety. (Lanz et al. 2014) The nature of the work in future factories will determine the engagement of young talents. The next generation workforce is brought up in a society governed by the rules of the Internet and a vast range of continuously growing computer-based technologies. The engineering education needs to prepare the workforce for the factories of the future, by adopting new methods of knowledge communication, skill and competence development and advanced training.

This chapter aims to provide a bridge between large topics of sustainable production, circular economy and continuous learning, and highlight how these terms are connected. The chapter is composed as following; first the chapter will discuss about manufacturing paradigms and sustainable production in general, then the chapter will proceed to compare main features and differences between linear and circular economy (CE), and their impact to manufacturing sector. This will form the basis for the main topics of the social sustainability and continuous learning in field of manufacturing sector. With this as a background the chapter will discuss of continuous learning and future skills and what is needed for companies to be sustainable in new business environment. Finally, this chapter provides a set of concepts and models for continuous learning.

Aspects of sustainable development and manufacturing

Sustainability has been recognized as a global challenge. Public authorities, institutions and individuals representing the scientific, technological and industrial environment have started discussing how they should contribute to address this issue (Fantini et al. 2013). In order to understand the multitude of sustainability concepts, addressing different levels of abstraction, we have to understand the technological development route that took place during the 2nd and 3rd industrial revolution. Manufacturing industry has undergone several revolutions, followed by improvement periods, induced by various drivers, from economy (market) to society (environment), and to technology (R&D based innovation) (Jovane et al. 2003).

The second industrial revolution brought the seeds for increased productivity. The age of mass-production was realized with new and more efficient automation solutions, supply chain development and advanced quality control systems. According to Du Pisani (2006) expectations of unlimited economic growth were dampened when a worldwide recession occurred in the mid-seventies (1974 – 1976), following in the wake of the first oil crisis of 1973, which had demonstrated the potential consequences of resource shortages. During the 80's the mass-production paradigm in discrete part manufacturing started to give a way to mass-customized and finally to personalized products. The modern concept of sustainability emerged at the end of the eighties with the World Commission on Environment and Development report (WCED 1987), later on known also as Brundtland Report. This report, instead of assessing the state of natural resources, highlighted possible ways to combine economic growth with environmental and societal issues (Fantini et al. 2013). In particular the following definition of sustainability was provided: '*Development that meets the needs of the present without compromising the ability of future generations to meet their own needs'* (WCED 1987).

It is expected that in future the European production paradigm will have more prominent characteristics of on-demand production of personalized products delivered by highly versatile manufacturing ecosystem, that is characterised with ecological values. This means that products are recycled and re-used much more than previously as the regulations will push towards closed loop supply chain. While the observation point is Europe, it is not limited to only European economic area.

Table 1 Manufacturing paradigms (Adapted from Jovane et al. 2003)

Paradigm	Craft Production	Mass Production	Flexible Production	Mass Customization and Personalization	Versatile ecosystems and on-demand production
Industrial Revolution	1st	2nd	3rd		4th
Paradigm started	~1850	1913	~1980	2000	2030
Society needs	Customized Products	Low cost products	Variety of products	Customized products	Highly customized on-demand products, eco-products
Market	Very small volume per product	Steady demand	Smaller volume per product	Global manufacturing and fluctuating demand	Global value chains, local manufacturing
Business Model	Pull, Sell-design-make-assemble	Push, design-make-assemble-sell	Push-Pull, design-make-sell-assemble	Pull, design-sell-make-assemble	Pull, design-sell-make-assemble-re/de-manufacture, re-use, recycle
Technology Enabler	Electricity	Interchange able parts	Computers	Information technology	Internet of Things, Cyber physical systems, robotics, computational power
Process Enabler	Machine tools	Fixed assembly lines	Flexible Manufacturing Systems, robots	Reconfigurable Manufacturing Systems	Digital tools, sharing economy, Circular economy, closed loops
Required Skills	Crafting, highly skilled people	Low skills, repetition	Dedicated work areas, skills on mechanics, electrics,	Dedicated work areas, skills certifications	Problem solving skills, multi-skilled work force, high-skilled workforce,

			automation…		continuous learning
Re-Education cycle (years)	50	40	30	30	5-10

While the general message of sustainable development is rather clearly stated in the political forums the implementation of different activities may not be clear to the individual actors. It might appear, that the definitions are clear, however, the understanding of the sustainability concepts in regards of manufacturing requires profound understanding and perspectives that are currently lacking in the narration of the public discourse and thus hardly intuitive. The definition and actual message of sustainable manufacturing is rather narrow (Roeder et al. 2017; Abdul-Rashid et al. 2017)

One of the major mind-set changes along the manufacturing paradigm change is the movement from linear to circular economy (CE). Linear economy refers in many cases to the more commonly known way of consuming things i.e. take-make-use-dispose (Lieder and Rashid 2016), which is considered to start during the industrial revolution in the 17th century (Prieto-Sandoval 2017). The industrial capacity to produce is constantly growing, and at the same time the consumption of natural resources is growing. Linear economy does not take into consideration the planetary resource boundaries, and therefore can be considered as unsustainable. Circular economy is seen as a way of closing the loop of materials in the end of product life cycle (Romero and Molina 2012). Ideally, CE enables a continuous cycle of resources without the need for disposing used material and extracting new resources to the product life cycles (Rashid et al, 2013). The transition to circular businesses requires the development of high value-adding de- and remanufacturing systems to re-use and upgrade functions and materials from post-use products (Gray and Charter 2006). Recently, the idea of a closed loop concept especially in the manufacturing has been extended to other kind of resources such as information, energy and value (Ghisellini 2016). CE has evolved from linear, exploitative way of thinking economy towards restorative, cyclical and finally ideally into regenerative economy (Prieto-Sandoval 2017). The loops are enabled by different circular economy strategies such as share, reuse, remanufacture, and recycle. The more so called inner cycles the products make in the end of their life cycle, such as share, reuse and remanufacture, the less resources and energy is required for recovering the resource to the next cycle (Korhonen et al. 2018).

All in all, the circular economy is seen as a way for more sustainable growth for decoupling the economic growth from the use of natural resources (Tomiyama, 1999). It seems to be commonly accepted among the scholars that CE is seen as a transformation from a traditional linear economy towards a more circular kind (Tomiyama 1999; Rashid et al. 2013; Prieto-Sandoval 2017; Korhonen et al. 2018). The linear and circular economies are not opposites, but they complement each other. In the current level of manufacturing, we can see different levels of circularity taking in place (Leider and Rashid 2016).

Drivers for social sustainability

Societal, Technological and Economical push

The baseline assumptions for discussing about the sustainability drivers are as following: 1) the European manufacturing paradigm is shifting from mass-production to mass-customization and to personalization, 2) the high-value products are produced in smaller lot-sizes, and 3) this requires more flexible and agile production methods, adaptive systems and human know-how (Lanz et al. 2015; Eberhard et al. 2015; Järvenpää et al. 2016; Hämäläinen et al. 2018).

In order to stay competitive companies and their workers need to be able to quickly adapt to new market conditions and customer needs, which require more and more problem-solving skills (Eberhard et al., 2015; Lanz et al. 2018). The key requirement for companies to stay competitive is development of a talented workforce and trustful collaborative relationships with stakeholders (Lanz et al. 2018). This means that the competence and career development are highly important today and even more in the future. Based on the research made in European Commission funded project FP7 SO-SMART the company considerations, the actual working environment and surrounding society plays a great role for keeping the capable individuals in the company (SO SMART, D4.2, 2014). These requirements and their influence can be observed from three different angles, namely Technology, Society and Economy, illustrated in Figure 1.

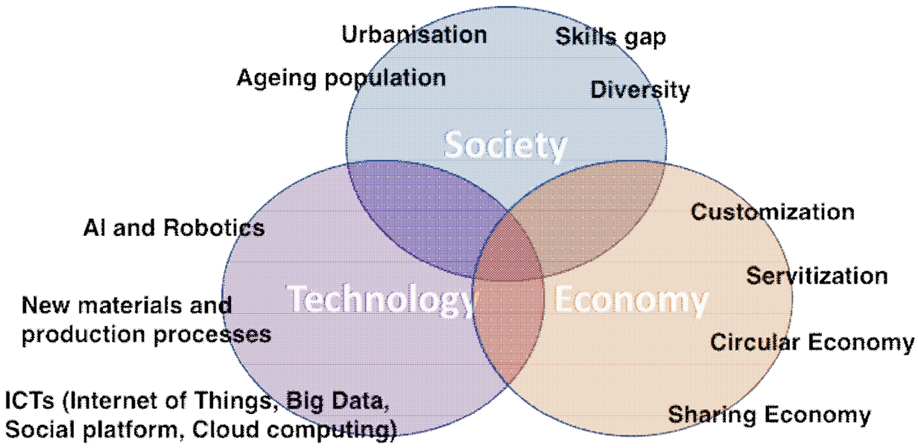

Figure 1 Trends influencing manufacturing and society (adapted from SO SMART D4.2, 2014)

Societal angle: According to the 2018 UN World Urbanization Prospects, urbanization is expected to continue rising in both the more developed and the less developed regions so that the proportion of the world’s population living in urban areas is expected to grow steadily. In 2018 55% of the world population was residing in urban areas. The growth in the urban population, also known as urbanization megatrend, is driven by overall population increase and by the upward shift in the percentage living in urban areas. Together, these two factors are projected to add 2.5 billion to the world’s urban population by 2050, with almost 90 % of this growth happening in Asia and Africa (UN, 2018). The population growth and urbanization are megatrends that provide means for continuous growth and offer business opportunities for industry globally. The resource scarcity, as another megatrend, is setting the boundaries for consumption. This means that the companies will need to understand and be able to design products that follow circular economy principles in more efficient waste management, resource re-use and sustainable production technologies.

The third megatrend affecting to the European manufacturing is the aging of working population and skills gaps due to the population reduction. The population in the Western and Nordic countries, and in Japan is growing older and living longer. The careers are expected to be longer and more versatile due to the faster emergence of new technologies and aging population. These trends will impact profoundly to the societal development within Europe and globally. At the same time, the EU’s workforce is expected to become smaller and older, but better qualified. The younger generation is the most highly qualified in Europe's history. (Cedefop, 2015; Lanz et al. 2018, Eurostat, employment, 2018)

In global terms, a surplus of low-skilled workers and a potential shortage of high-skilled ones are expected in near future (Eurostat, employment, 2018). The demographic profile of European nations indicates that the workforce shortage is evident in 2030-2040. Currently, socio-cognitive skills and strategies for handling and producing new information play a crucial role in the emerging manufacturing environments. As an example, the need for problem-solving abilities in technology-enhanced settings as well as the ability to use ICT tools in decision-making is increasing among the companies in manufacturing sector (Hämäläinen et al. 2018).

Economic angle: It is likely that there will be an increasing demand for personalized products and services over the next 20 years (SO SMART D4.2 2014). Manufacturing companies increasingly offer services along with their physical products. According to Neely (2011), 55% of US manufacturers offered services in 2011, less than 2% of Chinese manufacturing firms had servitized by 2007 but the percentage grew up to 18% by 2011, and rapid growth in servitization was also seen in Europe. The large-scale shift from selling products or services to selling measurable outcomes is a significant change that will redefine the base of competition and industry structures. Based on the definitions and observations of the World Economic Forum (2015) the outcome economy will be built on the automated quantification capabilities of the industrial internet. It is combined and entwined to a vision of sharing economy. This will range from social networks and communities of practice to real industrial networks relying to the emerging technologies (e.g. clouds and blockchains), and it is changing how the companies and networks do business. The emerging technologies allow new ecosystems to emerge and dissipate based on market pull.

Technology angle: The continued rise of artificial intelligence (AI) and robots certainly seems to be an inevitability being driven by a variety of production demands. This includes the need for safer and more "simplified" robotic technologies to work in collaboration with humans, increased resource efficiency, and continued adaptation to the proliferation of automation and the IoT. The demand for industrial robots (market) is anticipated to be growing to 65 billion € by the year 2023 (Fagella 2017). According to Block et al. (2018) the digitalisation as envisioned in the German Industrie 4.0 strategy introduced concepts for smart factories and cyber physical systems. In this strategy the digital tools are expected to maximize the transparency of processes, increase flexibility and by this increase productivity while reducing operational costs and resources. The envisioned roadmap to Industrie 4.0 focuses on new concepts and technologies, but considerations to the required skills are missing (Block et al. 2018).

Sustainable manufacturing

Several frameworks have been elaborated to address the evaluation of sustainability, taking into account several dimensions and levels. The development of sustainable manufacturing concepts and technologies can be observed from three levels, i.e. product, process and system (Hamia et al. 2015). At the product level, traditional 3R concept (reduce, reuse, recycle) has been transformed to a more sustainable 6R approach (reduce, reuse, recycle, recover, redesign, remanufacture), changing paradigm from single life cycle to multiple life cycles (Jayal et al. 2010) and later on 9R (Jawahir and Bradley 2016; Kirschherr et al. 2017). In the broadest version, the different Rs represent R0) refuse, R1) rethink, R2) reduce, R3) reuse, R4) repair, R5) refurbish, R6) remanufacture, R7) repurpose, R8) recycle, R9) Recover (Kirschherr et al. 2017). Traditionally in the main dimensions of sustainable business models is described via Economic, Technical and Environmental factors.

For example, Edum-Fotwe (2008), has created an ontological representation to represent all the issues in construction projects, the stakeholders and the impacts for three different spatial scales, which were social, environmental and economic. On the sustainable production and manufacturing side, for example Paju (2010) proposed the Sustainable Manufacturing Mapping approach, which was based on value stream management in order to assess sustainability along the temporal dimension of the product life cycle. A social LCA (Life-cycle assessment) stream of research has emerged to extend LCA to consider the impact of the companies' actions to the stake-holders. PESTEL model was discussed by Kolios and Read (2013). In this model the Political, Environmental, Social, Technical, Economical and Legal drivers were discussed.

Social and Political implications

The UN (2018) defines social sustainability as following "Social sustainability is about identifying and managing business impacts, both positive and negative, on people." According to Vinnova (2011) the inter and intra-generational equity, the distribution of power and resources, employment, education, the provision of basic infrastructure and services, freedom, justice, access to influential decision-making fora and general 'capacity-building' have all been identified as important aspects of the socially sustainable development paradigm. Though the concept of sustainable development originally included a clear social mandate, for two decades this human dimension has been neglected amidst abbreviated references to sustainability that have focused on bio-physical environmental issues, or been subsumed within a discourse that conflated 'development' and 'economic growth' (Vallance et al. 2011). Kolios and Read (2013) made similar observations and found out that social aspects of technology are often overlooked by developers at early stages, potentially being a costly mistake for tidal developers as this group of stakeholders have in several cases delayed and even stopped projects completely.

Political and legal stakeholders have the potential to affect dramatically to the future with different regulations and political initiatives. These present naturally many opportunities alongside with many risks to existing and future developments in regards the sustainability in general. (Kolios and Read 2013) For example, the emergence of environmental regulations and development technologies that are applicable for manufacturing sector and use minimal amount of energy to produce highest total quality. The requirement for especially environmental sustainability arises from stringent regulations imposed by governments and regulators. Based on analysis of Abdul-Rashid et al. (2017) regulation imposed by government is a coercive driver for companies to pursue environmental activities. The European Commission (2010) set a target for countries within the EU by 2020 to achieve a 20% reduction in EU greenhouse gas levels from 1990. In most of the cases the regulations are a driving force for new product and process development. The introduction of Machine Directive EN/2006/42 forced the European actors to obey the worker safety regulations and over the years resulted new product innovations that are safer and more efficient to be used than previous machinery. CO2 emission directive with the initiative towards to the emission reduction challenge in the transport sector is an irreversible shift to low-emission mobility. By mid-century, greenhouse gas emissions from transport will need to be at least 60% lower than in 1990 and be firmly on the path towards zero (EC, 2016). The mentioned regulations have high impact on economy. The short-term impact seems to be negative, while the long-term impact is rather positive. The regulations push the companies to develop better or different products, this has impact on both R&D activities and manufacturing in general.

Expectations and future visions for Socially Sustainable manufacturing

The European enterprise sector is being influenced by intensified discussions around the globe on the "business case for gender diversity" (Vinnova, 2011). Manufacturing is strongly male dominated; only between 27% (Deloitte 2015) and 20% (World Economic Forum 2016) of the manufacturing workforce are women. The 'Future of the Jobs Survey', commissioned by World Economic Forum forecasts for the 'manufacturing and production' sector a lack of 1,609,000 in all 'focus countries' by 2020 (World Economic Forum 2016). According to Vinnova's report (2011) the gender diversity is considered as a driver of creativity and innovation. Apart from the values-based case for gender equality, there is also a business issue as women are an untapped pool of talents. Promoting career-development of female workers may prevent the waste of talent. This is crucial for overcoming the skill shortage in the manufacturing sector. In other words: 'closing the skills gap includes closing the gender gap'.

Based on the vision for the socially inclusive and productive society in FP7 CSA SO SMART (2014) was described as following *"Manufacturing enterprises, collaborating with policy makers, education players and individuals, will explore and exploit the creation of stimulating physical and virtual work systems, which are enabled by the emerging technologies."*

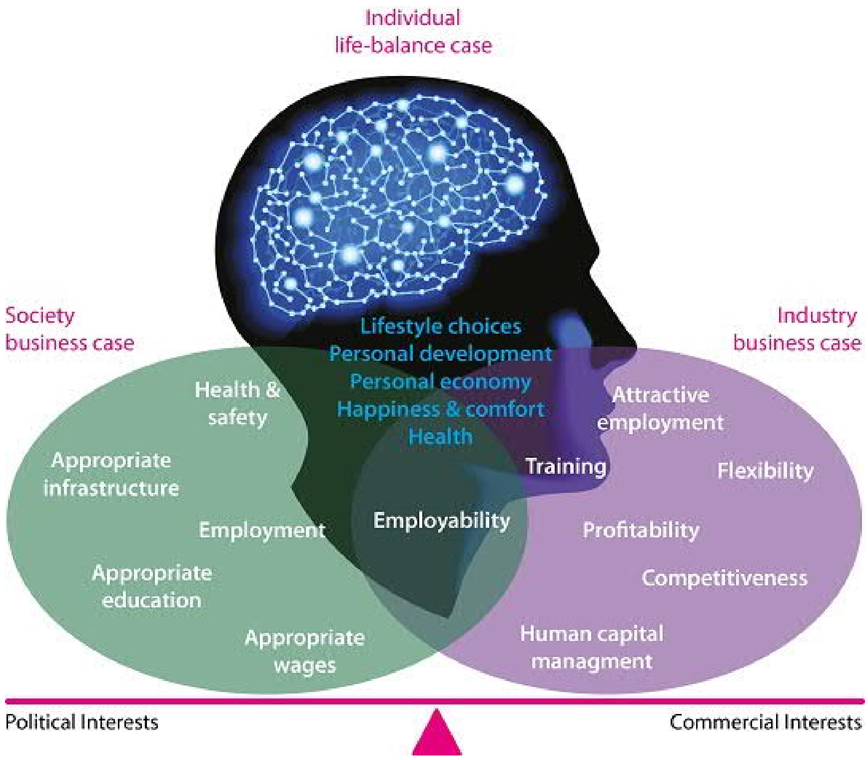

Figure 2 Work-life balance (Berlin et al. 2016)

The SO-SMART project identified the recipe for work-life balance that includes the perspectives from the view of the Individual worker, Society and Industrial Employer (from a factory perspective), illustrated in Figure 2.

- Individuals: This is mainly comprised of employees, potential employees and ex-employees. Their points of interest related to social sustainability can be such as lifestyle choices, personal development, job security, and health.
- Society: This is mainly comprised of people who are in a relationship to the social sustainability of a factory in a broader sense. For example, they could be the family members of the employee of the factory or people living near where a factory is located. They receive benefits, profits, or advantages

from a factory which practices good social sustainability. Their points of interest have to do with better infrastructure, high employment-rate, social stability, living and working environment.

- Industry: This is mainly comprised of the company shareholders and/or the individuals acting as managers. Their interest focuses on profitability, competitiveness, productivity, and human capital availability. (SO-SMART, D1.2, 2014).

Finding the balance between these different views is usually difficult. However, it is observed that the employee well-being affects to the motivation to do work and in the end to the quality of production (Lanz et al. 2014). The European industry's prime mission is to attract and retain highly skilled employees and foster a working context that enables professional and personal growth in order to maximize the capabilities for current value creation as well as the competences for future (SO SMART, D4.2, 2014; International Labour Office, 2018). New public-private collaborative forms should be adopted to build, challenge and develop knowledge, skills and attitudes needed in the manufacturing of the future. This can be realized by combining engineering and diversified education with experience in innovative and stimulating jobs. The 6 theses defined in SO SMART (2014) were as following;

Enabling work and education: Engineering and manufacturing are attractive as inclusive centres of socio-technical innovation and development, where employees have a meaningful work, can satisfy their diverse personal and professional needs, and continuously grow their talents, while sharing knowledge and innovating with others.

1. Promoting a social product culture: Social and environmental impacts are included into the concept of product/service quality in the single European market for sustainable products. Manufacturing enterprises strategically take into account social life-cycle aspects for innovating products/services and developing new businesses aimed at enabling customers' sustainable behaviours, consumption and daily habits.
2. Boosting the sharing economy: Societal ethos shifts from owning goods to using and sharing goods and from passively consuming to actively contributing and creating the product/service. Customers are expected to appreciate the value of personalized services/functionalities and trust manufacturing enterprises, which provide products and sell their utility, including the possibility to personally enhance products' functionalities and create services.
3. Spreading trust in value networks: Manufacturing systems and supply chains become more and more complex, versatile and interconnected, as outlined in the Table 1. Co-design schemas, customers involvement, crowd sourcing and distributed manufacturing evolve towards smart manufacturing networks that involve a wide range of actors. Manufacturing enterprises and stakeholders establish collaboration rules and/or joint objectives for sustainable business and innovation, leveraging on new models for sharing resources, investments and benefits. In order to enable this, there is a need to formulate and implement actions to improve the protection of IP rights and cyber-security, and to create a supportive legal and institutional context for the network governance.
4. Collaborating with the local community: Factories are perceived as "one of us", being fully embedded in the community. Urban and community development is a long-term value creation opportunity and manufacturing companies are pro-active in addressing it, in collaboration with community residents, who are empowered to shape collective activities that influence the area they live in, and local authorities, which establish governance and policy arrangements that are sensitive to local needs and adaptive to community's expectations. Furthermore, factories contribute to building and diffusing technological knowledge and knowhow. They stimulate and support education, training and skills development in the fields related to engineering, manufacturing and business.

5. Harmonizing governance and opening policies: Manufacturing enterprises have sustainability-oriented corporate-wide culture that allows also radical changes to the core business logic in order to achieve business success. The technological progress needs to be exploited frequently in order to respond to risks and/or opportunities arising, but also to proactively make the best use of social, economic and environmental resources and to allow the empowerment, equality and well-being of individuals and communities in industry and society. Stakeholders proactively seek out enterprises to help them reduce negative impacts and enhance the positive ones. With the support of a policy environment that encourages self- and co-regulation processes and trans-disciplinary research and education for sustainability and new types of business. Parallel efforts are spent towards the financial sector to foster funding of sustainable business.

The results from the SO-SMART project emphasize that there is a clear need for assessment frameworks that include the six sustainability drivers. A successful integration of Social Sustainability aspects into a productive and prosperous European Manufacturing industry must be achieved in an “ecosystem” balance between the needs and capabilities of the Individual, Industries and Society, balancing commercial and societal interests within the overall European landscape (Fantini et al. 2013, Berlin et al. 2016). While the consideration was for the European manufacturing environment, it could be generalized to consider companies operating in high-cost countries producing high-value and mass-customized or personalized products with strict environmental regulations.

Continuous learning as basis for sustainability in Europe

The sustainable development requires continuous improvement. On the social sustainability side this focuses rather strongly on the continuous and life-long learning. The emergence of circular economy paradigm is demanding the companies to change and take broader role in the value chain. This also puts a pressure to the education system, which traditionally are highly focused on own priority areas (Toivonen et al. 2018). Traditional education has separated the theory and practice. One of the main educational challenge is to combine the theoretical knowledge with industrial practices (Toivonen et al, 2018). Emerging technologies, such as digitalization and robotization, have enormous impact to the skills needed in future among industry. The general assumption is that the automatization will reduce the low-skill tasks, thus eliminates the routinely done jobs, but at the same time increases the need for high-skilled workers who are able to work in versatile environments and adapt to the changes with relative ease. The risk in this scenario lies in the labour market polarization as discussed by Nokelainen et al. (2018). Frey (2017) came into conclusion that this polarization may very well lead to a growing demand for highly cognitive-based jobs and manual low-income jobs, hollowing out of middle-income jobs requiring routine manual and cognitive skills. Nevertheless, in both scenarios the highly cognitive skills including ICT skills as well as more generic skills requiring creativity and social intelligence (Nokelainen et al, 2018) are needed. To meet these needs in the future, companies must be able to make advances in emerging technologies, contextual and social resources through continuously improving the working methods. The use of workplace learning technology, such as social software with built-in social intelligence for supporting inter-professional problem-solving in the work context, is still needed in the European manufacturing sector (Hämäläinen et al, 2018)

The key challenge in addressing the evolution of future education in the manufacturing sector involves developing skills and expertise as well as pedagogical and technological approaches that match the changing needs of today’s and future workplaces (Hämäläinen et al. 2018). This addresses the theses no 1 outlined in the SO SMART (2014) report. The importance of both science, technology, engineering and mathematics

(STEM), and ICT-related skills and “soft skills” grows for a large number of occupations (European Commission, 2014). OECD policy frameworks’ cornerstones for developing a suitably skilled workforce are defined such as 1) broad availability of good-quality education as a foundation for future training, 2) a close matching of skills supply to the needs of enterprises and labour markets, 3) enabling workers and enterprises to adjust to changes in technology and markets, and 4) and anticipating and preparing for the skills needs of the future. By adopting the cornerstones OECD expects this to nurture a virtuous circle in which more and better education and training fuels innovation, investment, economic diversification and competitiveness, as well as social and occupational mobility – and thus the creation of more but also more productive and more rewarding jobs (International Labour Office, 2011).

Needs from the field

As the introduction of new technologies is speeding up the re-education cycles are shortening. The Table 1 highlighted the change in production paradigms, skills change and re-education cycles. The Table 2 continues with the concrete needs from the industry. It has to be noted, that while the modern information and communication technologies allow us to shorten the development cycles, the end-results may not be fully validated before taking into use. This affects severely to the skills and re-education in principle. Previously, the educational institutes in the technology field could be relatively certain that the specific technologies they teach are still relevant after the students graduate and have reasonably long lifetimes afterwards. Today the cycle is short, especially on the ICT sector. The technologies published taken into testing and production may not be mature. If we consider the timeline, this means that the educational institutes should have been familiar with the emerging technologies 5-10 years prior the industry in order to train capable workers. The ICT skills, problem solving skills and decision-making capability are not only needs in future, but also the need for higher-order thinking and collaboration skills. In future, it is even more crucial that workers understand cause-effect impacts in manufacturing chains. (Eberhard et al. 2015)

From the industrial perspectives, a small study done among SMEs (Lanz et al. 2018) resulted needs in three categories; technology, education and learning, and business models. While the research material was not extensive, it indicated what primary industrial needs exist today. The problem-solving skills and learning to learn were highlighted. The industrial need, that became obvious, was the need for both formal and non-formal education.

Table 2 Classification of the industry requirements (Lanz et al. 2018)

Technology	Education & learning	Business models
Technologies are available, the challenge is how to exploit them. Collaborative robotics is coming to shop-floor, this is completely new. Production simulation in optimizing production will become common along with the real-time follow-up of production. ‘Field Agents’ following	SMEs need a new kind of IT-competences; are there enough talents and training available in the region? Life-long learning is both workers’ and SMEs’ responsibility; new forms for training are needed. Digital manufacturing and Internet of Things (IoT) are big game changers and need commitment (mindset) from managers at the shop-floor. Short webinars and workshops are	Data analytics and ownership is a big question; new business models will arise from this field. Ownership of data and the contract jungle are challenging. Fast pilots before investment

technology development are needed.	preferable rather than long training courses. Benchmarking and learning from other companies.	decisions.

Methods to teach future workers– Learning and Teaching factories

During the past decades sets of continuous education concepts combining academia and industry have emerged. The learning factories for education, training and research have been built up in industry and academia. In recent years, learning factory initiatives have been elevated from a local to a European and then to a worldwide level (Eberhard et al., 2015). The main goal of the learning factory concepts is to provide an industrial production environment for education purposes inside the real industrial site. The learning factory is to be used for systems that address both parts of the term including the elements of learning and teaching, and industrially relevant production environment (Wagner et al., 2012). A set of interactive education systems, listed in Table 3, have been established to meet the criteria of learning and teaching factories.

Table 3 Examples of Teaching, Learning and Training Factories

Learning Factory name and location	Established	Setting	Learning content
FMS Training center, Fastems Oy, Finland (Hämäläinen et al. 2018, Toivonen et al. 2018)	1997	Industry	Focuses on education about flexible manufacturing systems, factory operations and energy and resource efficiency, and is targeted for secondary and university level education, company staff and customer education
Anglo American Learning Factory (Makumbe et al. 2018)	2016	Industry	Focuses on teaching Lean practices for mining industry employees.
LPS Learning Factory (Wagner et al. 2015)	2009	Academy	Focuses on process optimization, lean management, resource efficiency, and for users to learn factory operations for management and organization perspective for students.
LMS teaching factory (Rentzos et al., 2015)	2009	Academy	Focuses on providing engineering activities and hands-on practice under industrial conditions for university students while taking up the research results and industrial learning activities for engineers and blue-collar workers
SEPT Learning factory (Elbestawi et al. 2018)	2014	Academy	Focuses on teaching how to apply modern manufacturing approaches such as Industry 4,0, IoT, IIoT, and additive manufacturing for students.

While there exist a multitude of training, learning and teaching factories, it is notable that the area they cover usually reflects the linear economy. This means that while the sustainable manufacturing and continuous learning aspects can be catered to users, the circular economy perspective is missing, at least from the main stream literature. This might be partly due to timeframe. The timeframe from design to manufacturing, use, re-cycle and re-use is very long, possible years or decades.

Conclusions

The chapter started from the sustainable development and its implications to the future of manufacturing and manufacturing paradigms, and society in general. The social sustainability cannot be easily observed as sole entity, but when observed within the technology, economy and environmental entities together it can be seen how crucial role it plays. Based on the analysis by Berlin et al. (2016) it is evident that the changing demographics, renewal in technological paradigms in manufacturing industry, skills gaps that threaten the staffing of future manufacturing, new business models for products and services and the quest for organizational structures that can handle all of the above, will be a tremendous challenge for both European companies and European employees struggling with future work-life balance.

Social sustainability is one of the key factors considered when envisioning to the future of manufacturing, regardless of the location. Human capital is the main enabler of the factories of the future around the globe. Human skills and engagement to manufacturing will determine the manufacturing development direction of Europe, and globally in the decades to come. Promoting excellence in manufacturing emerges as a strategic goal in future, both for industry and society alike (Mavrikios et al. 2011).

The change will not come by itself. While the discussion is buzzling around the emerging technologies and circular economy, and their possibilities, it is highly important to understand that any change requires learning. The continuous learning is one of the areas when considering the social sustainability and wellbeing of the working population in general. Without the continuous education the emerging technologies will not penetrate the society or industry, thus hinder the competitiveness of the companies in the long run. One possibility for ensuring the life-long learning among the industry was the development and utilization of learning or teaching factories for both entry and re-education levels. Utilisation of learning, teaching and training factories to realize phenomena-based learning has been proven to be more effective compared to traditional classroom-based education as it leads to greater retention and ability to apply the education regardless if it is formal or non-formal (Makumbe et al. 2018). Several studies show that the problem-based and action oriented learning is more efficient in terms of educational effectiveness and efficiency compared to traditional more formal educational sources (Makumbe et al. 2018, Hämäläinen et al. 2018; Nokelainen et al. 2018).

Cross-References (*if applicable*)

Social Manufacturing

Lean Manufacturing

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