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To cite this version:

Rosanna Fornasiero, Andrea Zangiacomi. Reshaping the Supply Chain for Society 5.0. IFIP International Conference on Advances in Production Management Systems (APMS), Sep 2021, Nantes, France. pp.663-670, 10.1007/978-3-030-85906-0_72 . hal-04022107

HAL Id: hal-04022107

https://inria.hal.science/hal-04022107v1

Submitted on 9 Mar 2023

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Reshaping the Supply Chain for Society 5.0

Rosanna Fornasiero[a,12] and Andrea Zangiacomi[b,3]

[a] CNR-IEIIT, Via Gradenigo, 6, 35100 Padova, Italy
rosanna.fornasiero@ieiit.cnr.it
[b] CNR-STIIMA, Via Corti, 12, 20133 Milano, Italy
andrea.zangiacomi@stiima.cnr.it

Abstract. This work aims to study the evolution of Supply Chain (SC) towards Society 5.0 paradigm proposing a set of SCs to enhance the active role of involved stakeholders leveraging on digital technologies. Social macro-trends indeed strongly impact on companies' business creating the urgent need to significantly adapt the way their SCs are organized and interlinked. The work is based on a consultation with experts representing different kind of companies, industrial sectors, function, role in the SC and research fields. Results lead to the identification of possible SCs for the future, and among them, three solutions seems to particularly fit current challenges related to the evolution of society: Human-centric SC, SC for active citizens and SC in urban context. According to the identified SCs, specific issues are presented and possible solutions basing on new technologies have been mapped with the support of experts. The need to integrate strategies at industrial and societal level urge thus for a new holistic way where business eco-system capabilities merge with civil society needs for have people wellbeing as a major priority.

Keywords: Supply Chain, Digital Technologies, Social Trends, Industry5.0, human centric approach.

1 Introduction and background

Nowadays, Supply Chains (SC) work in a global and complex environment, and in the future they will have to be more and more able to adapt and identify possible future evolutions to preserve their competitiveness and meet the challenges of this scenario. [7, 8].

According to this view, digitalization and the adoption of Industry 4.0 (I4.0) paradigm represented an opportunity to be leveraged by the whole SC. SC processes are thus increasingly managed with a wide variety of innovative technologies and analytical methods to generate new forms of revenue and business value for all the involved actors, moving towards a "digital SC" [6].

[1] https://orcid.org/0000-0002-7198-2254
[2] Corresponding author
[3] https://orcid.org/0000-0002-2298-8481

However, despite I4.0 revolution is associated with various enabling technologies, such as artificial intelligence, Internet of Things, additive manufacturing, cyber-physical systems, cloud computing, automation and robotics in the manufacturing processes, until now, it has primarily focused on digitalisation for increasing production efficiency and flexibility of companies and SCs and less on the original principles of social fairness and sustainability [14]. While the main concern in Industry 4.0 is about automation, the evolution towards Industry 5.0 will embrace a synergy between humans and autonomous machines, and the autonomous workforce will be perceptive and informed about human intention and desire [25, 26]. In the industrial context, indeed advances have still to be done for what concerns the human-centric approach. In order to ensure that both companies and workers benefit from the digital transition, rethinking and redesigning SC is necessary and workers should be involved in all step of the transition. The concept of Industry 5.0 provides thus a different focus, highlighting the importance of supporting industry in its long-term service to humanity and society. Most of contributions on Industry 5.0 address increased collaboration between humans and smart systems allowing to merge the high-speed accuracy of industrial automation with the cognitive, critical thinking skills of humans [1, 14]. The concept of Society 5.0 - or "super-smart society", presented and promoted by the Japanese government [9], is linked to Industry 5.0. It represents indeed the vision of a new human-centered society, where advanced technologies are applied in everyday life, and in different spheres of activity, to provide products and services satisfying various potential needs as well as reducing economic and social gaps, for the benefit and convenience of all citizens [14, 16].

Despite the advanced pace of technology adoption, humans will continue to play active roles even if these roles may change over time [28]. Human factors and ergonomics, knowledge, skills, and competencies will therefore be essential in guaranteeing and optimizing effortless and safe work processes [28, 29]. Moreover, social media and digitalization in manufacturing are creating a paradigm shift whereby end users are engaging in industrial processes. The main agents of the new society are indeed citizens that will play a leading role, for what concerns the transformation of cities, as innovators creating the desired urban environments. [10].

In light of the envisaged scenario, the aim of this work is to reflect on the evolution of SC towards Society 5.0 paradigm proposing a set of SCs to enhance the active role of stakeholders such as workers, consumers, citizens and leveraging on digital technologies to enable manufacturing industry contribution to this essential change of pace. This concept till now has been partly applied in the factory context [11, 19] but a similar approach specifically addressing SC and its peculiar needs and potentials is still in its infancy and current research gaps call for novel contributions.

1.1 Societal Trends

Some important trends affecting the global scenario are related to the social dimension, in particular, changes in demographic, urban environment and customer habits. For what concerns demographic changes, the aging population has a prominent role: on one side by 2050 1 in 6 people in the world is expected to be over the age of 65, nearly

doubling the quote of 2019 [30], on the other side a lack of awareness of new I4.0 technologies and related skilled workers is urging new actions [12, 22].

The growth of urban population and consequent emergence of megacities [30] will congest the urban environment due to larger transfer of people and goods and raise the need for the development of smart cities provided with sentient and intelligent infrastructure in order to improve people's quality of living, and sustainability levels [18]. Moreover, trends, such as the middle-class explosion and the rise of individualism and personalisation have increasingly orientated consumers towards extreme personalization requirements to satisfy their own personal needs [15] and will force companies to enrich customer relationship and ensure more flexibility in their SC [5]. Finally, rise of the "do it yourself" (DIY) paradigm in society, enabling customers to realize by themselves in small factories within the urban context, or directly at home, their preferred products [2, 24] also press companies to redefine their SC configuration to provide citizens with the accessibility to reliable means of production [2].

2 Methodology

In this paper, we report part of a study related to the definition of a set of SCs and research and innovation topics for digitalisation. More details on the results can be found in [1]. The work is based on a consultation with experts representing: companies (large, SMEs, start-ups), industrial sectors (i.e. automotive, steel, consumer goods, IT, fashion, transportation), function (CEO, Operation Mangers, SC manager, industrial and academic researcher), role in the SC (i.e. managers from focal company, suppliers, vendors, outsourcers) and academia (SC management and configuration, manufacturing, logistics, engineering, risk management, etc.). In particular, we report the results of two workshops organised in 2019 as face-to-face brainstorming sessions, each of them focusing on a particular topic, under the guidance of a moderator [17]: the first was dedicated to the validation of research and innovation in digital technologies, the second to the identification of possible SCs for the future. The interaction among participants was organized to be open-minded, with informal atmosphere to facilitate the generation of fast-result insights. Each workshop involved a sub-set of the whole group of experts according to the specific topics and aim of analysis to assure plurality of point of view and to cross-cut the results with double check. All in all, 40 experts were involved in the 2 rounds. The work has been conducted according to the following phases:

1. **Collection of Research and Innovation needs**: experts both from academia and from industry were directly involved through a workshop in order to collect ideas, opinions and proposals for the definition of the Research and Innovation needs to be addressed to face challenges impacting on SCs. Starting from a set of trends and related scenarios, experts discussed in small groups using brainstorming tools like posters, mind-maps, post-its.
2. **Clusterisation of ideas**: This phase supported the analysis of opinions collected during the workshops applying thematic analysis. This technique is a qualitative research method for identifying, analyzing, organizing, describing, and reporting themes found within the collected data [3]. This technique was used by the research

team to summarize key features and produce a clear and organised output, to discover correspondences between the data collected and homogenously frame the results of the consultation [4, 27].

3. **Proposition of a set of SC strategies for the future**: in this stage, a dedicated workshop was held with a restricted number of experts in order to discuss how companies should adapt their networks to face evolutions identified according to the different trends impacting SCs and stay competitive. The research and innovation needs have been grouped and a set of strategies as the most promising to overcome SC challenges of the next decade were identified. In this insight, three of them are considered in relation to the specific societal trends.

3 Results

In the following the set of SC identified as prominent to face the societal challenges previously highlighted and to support the transition towards the Society 5.0 paradigm are presented.

3.1 Human centric Supply Chain

The aim of the Human Centric supply chain (HSC) is enabling the valorisation of humans contributing to increase satisfaction and well-being of workers, consumers and citizens. SCs are expected to become increasingly inclusive, focusing on the involvement of all types of stakeholders, enabling the different actors to perform complex activities in an easy, safe and more secure way, supported by innovative digital technologies [31]. Therefore, the human centric technological change in the SC processes is aimed, not only at efficiency and flexibility but also in extended corporate responsibility by fostering socially and inclusive responsible practices [13]. Some issues emerging from the workshops with the experts regard:

- *Training programs for new SC skills*: given the gaps in specialised talent in SC workforce caused by digitalization, it is essential the context-aware identification of both hard and soft SC skills to manage networks in a sustainable way. Specialised skill programmes need to be designed according to human-centred organizational design principles basing on technologies such VR/AR. Also AI can be used to manage the skill gaps and propose appropriate training programmes to the workers.
- *Acceptance and awareness of new technologies*: when designing the future of work in SCs, it has to be taken into consideration the employee point of view to optimize technology-equipment user experience. In particular, cross-cultural acceptance of technological solutions needs to be successfully managed. When designing global SC processes, it is necessary to take into account the socio-cultural differences in the workforce spread in different premises around the world, as they affect the technology's perceived usefulness, user attitude and behaviour.
- *Safety and ergonomics in the work environment*: the potential of autonomous systems and collaborative robots is based on sharing work environment with humans,

relieving them from risky and heavy tasks in SC operations. Advanced human-machine interfaces will facilitate the interaction and support ergonomic and safety. The use of exoskeletons will help workers (especially aged ones) in their activities, enhancing safety and productivity both in production and logistics.

- *Social Sustainability and ethical issues*: Health and Safety protocols and Corporate Social Responsibility protocols can be automatized and easily controlled sharing practices and real-time data in cloud based platforms accessible by all stakeholders. When developing decision systems based for example on machine and deep learning, natural language processing, ethical challenges have to be considered, to reduce the risk of unfair decisions and undesirable behaviours.

3.2 Supply chain for empowered citizens

In recent years, citizens have been undergoing rapid changes in behaviour with an increasingly informed role, in a market with a choice of products wider than ever. Moreover, social media and enterprise mobility together enable new consumption patterns. Decisions along the SC thus need to be driven by customer's needs, expressing their own singularity in terms of products and services. The customer should also hold an active role in the SC as a co-creator [21] of her/his own product/service. Customer driven SC mainly rely on the agility concept, which aims for demand and production alignment, fast production and delivery of products in response to change in customer demand [23]. The following issues arise in this case:

- *Customer specificity*: each customer is different, and understanding customer demand is essential to assure inclusivity and that specificity of each societal groups are catched in SC value proposition thanks to technologies as Big Data and Analytics, social platforms and sensors. In this sense, the development of new models and tools for gathering and handling huge volumes of data from customers is needed. Moreover, also customer experience has to be enriched, for example with VR/AR technologies in the purchasing phase and sensors and AI to provide support in the post-sale.
- *SC Collaboration & Orchestration*: the development of new mechanisms based on digital platform and CPS to increase coordination and synchronization among all the actors of the chain is required to create agile/responsive SCs
- *Personalized shipping*: smart management of personalized goods grows the complexity shipping due to a set of factors (e.g. size, package, confidential information, lack of bundling opportunities). Localization and communication technologies are needed to properly handle multiple flows related also to the use of autonomous vehicles (e.g. drones)
- *SC traceability for customer trust:* in order to guarantee the quality, sustainability and originality of materials and processes for consumer trust it is necessary to implement technologies such as and track and trace systems, blockchain, sensor based real time monitoring (e.g. IoT).

- *IPR and privacy*: the increased involvement of customer and supplier concerned with the development of customization and personalization practices and the consequent data exchange requires properly handling IRP related issues. Data privacy should be taken into consideration too, especially when several actors are involved.

3.3 Supply Chain in urban context

The spread of new production technologies, such as additive and hybrid manufacturing, the increase in ecommerce and the rise of smart cities, characterised by high connectivity and new sustainable urban mobility [20] are changing the role of SC in relation to the urban context. The proximity of the end users largely influences the design of new processes for the SC. The focus will be on small scale manufacturing systems in urban areas, with the growing importance of fab-labs and local producers. The expansion of the urban environment involves a more complex development of the city logistics, impacting on the different flows (assets, people, vehicles etc). The location of facilities in the city will also force companies and their logistics to be more environmental friendly and more resource efficient too. The following issues arise from the experts:

- *Coping with urban context*: it is essential to integrate manufacturing and distribution into the urban context and with smart cities infrastructures thanks to appropriate localization and communication technologies. SC should also optimize city logistics to efficiently implement last mile transportation and delivery thanks to Digital platforms.
- *Information and goods flows in urban areas:* issues such as traffic jam, overcapacity of some axis of circulation, local pollution etc., have to be overcome with advanced decision support systems based on AI (such as machine and deep learning) to optimize the flows of citizens and goods in a sustainable manner. At an even more radical level, automated driving will be ready for practical application.
- *Urban manufacturing*: due to automation and advancements in additive and hybrid manufacturing technologies, the development and implementation of modular facilities represent an enabler for the relocation of small manufacturing sites within urban areas and to exploit the DYI paradigm. Online platforms can support the shared management of both facilities and integrated purchasing of materials, enabling individual citizens to realize their own products.
- *New entrepreneurial generation:* the rise of DYI and personalization paradigm will impact the ambition of the new generation, which will exploit potential of digital technologies and social media to provide a service or a product to the society. This can be supported, for example, facilitating the creation of start-ups and fab-labs.

4 Conclusions

Global macro-trends such as the acceleration of technological developments, the demanding consumer needs and behaviors, the rise of aging population strongly impact on companies' business. This creates the urgent need to significantly adapt the way

their SC are organized and interlinked. Companies are indeed forced, not only to identify new business model, but also to focus their strategy on redefining their value creation with upstream and downstream partners of their SCs.

This paper represents a first attempt to understand how SC can contribute to the rise of Society 5.0 accomplishing societal trends thanks to implementation of digital technologies. The work defines three possible type of SCs and define possible ways to answer in a proactive or reactive way to the societal changes. The need to integrate more than ever strategies at industrial and societal level urge for a new holistic way where business eco-systems merge with civil society

Further research will be focused on deepening how the different enabling technologies can support the issues addressed in each of the three SC typology considered, with the aim to provide insights to the discussion on SC contribution to the development of a smarter and human centric society. Each SC typology need to be further designed along the most important dimensions like sourcing, purchasing, manufacturing and distribution to reshape the role of technologies and provide the opportunity for exploring new social paths.

Acknowledgment

This work has been partly conducted in the Next-Net project (n° 768884) (Next generation technologies for networked Europe), co-funded by the European Union under the Horizon 2020 programme. The authors wish to acknowledge the European Commission for their support. They also wish to acknowledge their gratitude and appreciation to all the project team for their contribution during the development of this research.

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