Journal of Applied Economics and Business Research
JAEBR, 13(2):57-66(2023)

A disruptive industrial environment – Aspects to reflect on as a manufacturing SME

Kerstin Johansen[1]
Jönköping University, Sweden

Abstract

Resource-efficient production including life-cycle approaches was stated as early as 2002 as the only way forward for the industry. Now, twenty years later, this is a reality in many ways. This represents a challenge to manufacturing small- and medium-sized enterprises (SMEs) due to a disruptive industrial environment as well as changing market needs that require more capability to manage predictable as well as unpredictable changes. This paper explores some aspects manufacturing SMEs must manage, such as developing new capabilities to stay competitive in a disruptive industrial environment with uncertainties in supply chains, technologies, energy costs, changes in customer demands, and circularity. This paper presents a conceptual guideline for assessing the capabilities to develop as a manufacturing SME in a circular industrial environment. One way to manage this transition towards circularity in an industrial environment can be to develop transdisciplinary collaborations between different stakeholders and competencies.

Keywords: Manufacturing, SMEs, Circular economy, Transdisciplinary engineering, Assessment tool

Jel Codes: L25, L60, O32

1. Introduction

Today's global society has experienced serious challenges, such as the Covid-19 pandemic, diverse conflicts (Karabag & Imre, 2022), a lack of materials in Europe for the electric transition (e.g., cobalt, natural graphite, and lithium) (Mayyas et al., 2019), no consensus on how to prioritize actions for developing satisfactory solutions for managing the climate change problems (Nordén, 2022), and natural catastrophes like earthquakes. In the Turkey-Syria earthquake, Turkey's second largest harbor was affected, and hundreds of shipping containers caught fire (British Broadcasting Corporation [BBC], 2023); the impact on logistics was comparable to the unplanned effects on the supply chain for manufacturers at the beginning of the Covid-19 pandemic (Johansen, 2020) or when a container ship got stuck in the Suez Canal for 106 days (Reuters, 2021). All this indicates a need for manufacturing small- and medium-sized enterprises (SMEs) to develop the resilience to manage unplanned and unpredictable societal disturbances and challenges to the manufacturing system.

The European Commission stated as early as in 2002 that sustainable development is the only way forward (European Commission [EC], 2002), with the goal of leading the development of resource-efficient production, including life-cycle approaches, eco-labelling, and environmental impact assessments. Furthermore, the need for managing the triple bottom-

[1] Correspondence to Kerstin Johansen, Email to: kerstin.johansen@ju.se

line of sustainability (Elkington, 1994) is important since focusing on people, planet, and profit must be possible in a disruptive industrial environment. Today's focus on a transition towards a circular economy with the aim of reducing environmental impact (EC, 2021) is a continuation of the triple bottom-line approach, but there are challenges in how to define circular economy (Kirchherr et al., 2017). One way to define circular economy is, according to Kirchherr et al. (2017) as "*an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes*". The ambition within Europe to move towards a circular economy indicates a need for manufacturing SMEs to acquire an understanding of how to act in a circular economy as well as develop the capabilities to manage predictable changes that stem from modifications to government directives in order to comply with EC strategies.

Based on the above, the paper will explore aspects that need to be managed as a manufacturing SME in a disruptive industrial environment that is evolving towards a more circular industry and sustainable society, where both unpredictable as well as predictable events demand internal capabilities to remain competitive. The paper first presents some trends (societal, technological, and regulation-based) that affect manufacturing SMEs (Ch.2) by presenting examples that contribute to a disruptive industrial environment. In Chapter 3, observations based on interactions and interviews with manufacturing SMEs are presented that illustrate the challenges these companies face in relation to trends and changes in the industrial environment. To support the manufacturing SMEs in managing these challenges, a conceptual guideline is presented (Ch.4) that is inspired by the "Read a Plant" assessment tool (Goodson, 2002) combined with triple-bottom line aspects (inspired by Elkington, 1994). Finally, some concluding remarks summarize the need for more transdisciplinary collaborations that aim to strengthen the manufacturing SMEs' capabilities in the disruptive industrial environment, facilitating the management of both predictable as well as unpredictable changes in a competitive market.

2. Some trends affecting manufacturing SMEs

The triple-bottom line of sustainability (Elkington, 1994) can be connected to different areas that needs to be managed, such as societal changes, technological possibilities, as well as new regulations that are implemented. One example is climate action focusing on reducing $CO2$ emissions by facilitating the implementation of renewable energy solutions (United Nations [UN], 2023). However, energy prices have been greatly affected by the war in Ukraine (Ari et al., 2022) since the beginning of 2022, and the European manufacturing industry faces increased and fluctuating prices that challenge their businesses. Ari et al. (2022) argue for developing support initiatives for companies, preferably from a long-term perspective, that makes it easier for them to reduce their energy use. In parallel, a huge ongoing transition towards an all-electric society, which is in line with renewable energy solutions (UN, 2023), aims to reach Net Zero Emissions by 2050, and the electrification of light-duty vehicles corresponds to most of the reduction between 2020 and 2030 (International Energy Agency [IEA], 2022). To summarize, the fluctuation in energy prices is an example of an unpredictable trend that affects the manufacturing SMEs, while the transition towards electrification in society is a long-term transition that is predictable. However, the transition towards electric engines in vehicles is changing the type of components and the products that need to be manufactured compared to combustion engines, both in volume and characteristics, which challenges the manufacturing SMEs and changes the market requirements.

Sustainability, the key in a triple-bottom line, is strategically important to manage as a manufacturing SME, but it is difficult to be competitive while managing sustainability requirements in a profitable way at the same time (Machado et al., 2017). Reflecting the need for profitability, it is also important to identify the role of a manufacturing SME in the overall

 ISSN 1927-033X

industrial transition towards a circular economy. Here, a triple-level analysis could be used as a guide. This refers to three levels—micro (within a company), meso (between companies, i.e., industrial eco-systems), and macro (on a societal scale, with legislation and standards)—within the fields of engineering and management (Kirshherr et al., 2017; Nikolaou et al., 2021). Nikolaou et al. (2021). Although, it is important to develop knowledge and skills on how to achieve a relationship between these three levels—micro, meso and macro—to develop efficient tools that support collaboration between companies and their suppliers in a circular economy. The transition from a linear to a circular economy challenges the industry overall, and Ghisellini et al. (2016) promote collaboration between different actors as a key factor for success, which indicates the need for a transdisciplinary engineering approach.

In a high-cost environment such as Europe, manufacturing SMEs can be competitive if they develop and maintain capabilities such as innovation, flexibility, and sustainability (Sansone et al., 2021), which can be key capabilities in a disruptive industrial environment. Here, several technological solutions can be the key for managing the ongoing transition towards a circular economy. Flexibility might be achieved through production innovations related to either human-robot collaborative applications (Koren et al., 2018; Malik & Bilberg, 2019) or reconfigurable manufacturing systems (Koren et al., 2018). However, implementing innovative production solutions for achieving changeable and automated-assisted manufacturing challenges the operators in their role (Johansen et al., 2021, Sigurjónsson et al., 2022). This indicates a need for life-long learning activities related to new technological solutions in manufacturing SMEs in order to remain competitive in a business environment that changes over time.

Furthermore, the transition towards a circular economy also increases the need for traceability in the product life cycle, which can be supported by implementing Industry 4.0 with emerging technologies and digitalization (Jamwal et al., 2021), in which digitalization can be a crucial enabler to reach circularity (Antikainen et al., 2018). The upcoming demands for digital product passports are closely related to several different concepts regarding traceability needs, such as Bills of Materials, Product Lifecycle Management, Digital Twins, Ecocertificates and ecolabels (van Capelleveen et al., 2023). Based on a literature review, van Capelleveen et al. (2023) presents an overview of passport stakeholders during a product life cycle, and it can be summarized with five interacting layers: the physical system (i.e., the product), the owner chain (i.e., the user/consumer), the governance chain (i.e., legislation and standards), the financial chain (i.e., the leasing company or banking), and finally, the production chain (i.e., typically a manufacturing SME or material supplier). On the research front today, van Capelleveen et al. (2023) summarizes that product passports have some common links since they are digital, act as an interface, create a certified identity, address a single product individually, and are based on the components registered in the product life cycle in order to gain insight into sustainability and circularity characteristics. Here, the technology can support the triple-bottom line for sustainability for people, planet, and profit as mentioned by Elkington (1994), with these insights on how product passports contribute to performing value estimations and identifying opportunities. However, van Capelleveen et al. (2023) raise one important issue for future product passports, and that is how to negotiate agreements within the supply chain in the future. And here, the manufacturing SMEs will be challenged by the demands of digitalization, transparency in information, as well as how to estimate the value of knowledge and information from the manufacturing process.

3. Challenges as a manufacturing SME

During 2021 and 2022, representatives of manufacturing SMEs in the foundry and mechanical industry in Sweden were interviewed. The interviews were semi-structured and performed remotely due to remaining pandemic restrictions and geographical distance. The

 ISSN 1927-033X

open questions were related to sustainability and a circular economy when it comes to material choice, product design, the supply chain, standards, and energy considerations. This was complemented by a virtual benchmarking relative to the ongoing electrification of the transportation system as combustion engines are replaced by electric engines in vehicles.

The foundry SMEs were highly affected by the disruptive energy prices in Sweden that existed in 2022, some due to the fluctuating price of electricity and some due to the gas prices. In parallel, the increased number of electric vehicles stressed the electrical infrastructure as well, thus contributing to a higher demand for energy. Here, the company representatives expressed that they experienced a stressful situation from an economical perspective and desired a stable financial system and directives with a long-term view supporting strategic business decisions for companies. These observations corresponded with what Ari et al. (2022) argues for with regard to the long-term view, which supports the transition towards reducing energy needs. From a product passport perspective (van Capelleveen et al., 2023), the foundry SMEs had excellent control over which materials were used in the alloys, the energy used for the process, and the internal recycling loop for waste material, which corresponds to the micro-perspective described by Nikolaou et al. (2021). At the meso-level (Nikolaou et al., 2021), however, some challenges were appearing, such as those related to the fact that customers' production systems are usually organized with lean production and Just-In-Time delivery of components to the assembly line in order to reduce work-in-process inventory (McLachlin, 1997). The foundry SMEs have a process that starts with a mixture of metals and results in alloys which are cast into single components. The process can be described as a transition from a continuous flow to a single cast component that should usually be delivered to a lean production line. For an SME, the assessment to be lean according to Goodson (2002) might be challenging in this situation due to the fact that customers for these cast components want to buy customized batches at smaller quantities, which affects planning of the batches in the continuous flow as well as the logistics regarding the transport of smaller batches. Furthermore, cast components are easy to melt anywhere globally at the end-of-life phase of a product, which affects the ability to achieve circularity based on known alloys from their own manufacturing process.

Both the foundry SMEs and machining manufacturing SMEs are affected by the transition towards the electrification of vehicles since combustion engines are being phased out in favor of electric engines. This means that future demands for components are going to change dramatically. A traditional combustion engine consists of approximately 30,000 mechanical components (machined as well as cast) and weighs about 220 to 880 lbs., including many injection-molded polymer components for purposes such as cooling. An electric engine, in comparison, weighs about 55 to 110 lbs. and consists of about 15,000 components, both mechanical and electrical. This indicates that the manufacturing SMEs are facing new requirements for components as well as changing demands for technologies and materials. The foundries are also challenged by the trend towards megacasting, which means that the body in white for a vehicle is pressed in one piece (Schuh et al., 2022). The consequences are a reduced number of components to manufacture at manufacturing SMEs, and a need for a more in-depth analysis concerning the impact that this new casting technology will have on manufacturing SMEs as suppliers, as pointed out by Schuh et al. (2022).

The increased demand for circularity also affects the material supply chain as well as the operators in a production system that must manage the potential differences in material quality. The recycled material can affect the process window in the start-up phase of a batch, which indicates that greater skill is required to control the process as well as more specific instructions for how to manage tolerances of incoming materials, which corresponds to the identified need for life-long learning activities (Johansen et al., 2021; Sigurjónsson et al., 2022). In a machining line, the operators also need to sort the different cutting tools and manage waste material from

 ISSN 1927-033X

the process in order to increase quality when recycling materials. Since manufacturing SMEs can sell waste material such as worn-out cutting tools or cutting chips, the price is dependent on the quality of the sorting of the material. The future layout planning for a manufacturing SME must incorporate internal loops for managing circularity with traceability; at the same time, it must be able to log relevant information on the future product passport and share that information with the product-owning customers.

The example presented above has been observed in all industrial contexts and illustrates the consequences faced by manufacturing SMEs, which will require a variety of tools for managing the ongoing transition towards a more electrified and circular industry. Along with new production methods and techniques that are implemented in the industry, these observations reveal several challenges that manufacturing SMEs must face in the future. Several of these changes disruptively challenge many manufacturing SMEs, which need to be able to transform their own business in order to adopt to the disruptive volume changes that can be predicted due to technology shifts in the market towards new product power sources, such as batteries, that utilize renewable energy sources. This also shows that there is a need for solutions and methods that combine several engineering aspects to manage the transition towards a circular industry. This industrial need is being addressed in ongoing work within ISO aimed at creating the ISO/TC 323 – Circular economy standard (www.iso.org/committee/7203984.html).

4. Discussion

Manufacturing SMEs need to develop capabilities for managing the requirements related to a circular industrial environment. Table 1 presents a conceptual assessment guideline.

A conceptual guideline inspired by Goodson (2002) for assessing the capabilities to develop as a manufacturing SME in a circular industrial environment has been suggested (see Table 1) that can support the manufacturing SMEs in managing the ongoing changes disrupting the industrial environment. The 11 categories in the assessment based on Goodson (2002) could be used by manufacturing SMEs to help identify the activities needed during the ongoing transition towards a circular economy inspired by Elkington's (1994) triple-bottom line for sustainability. In Table 1, the disruptive changes to society, technologies, and regulations are organized into three different columns (B-D) summarizing aspects from the trends (Ch.2) and the challenges (Ch.3), and relating them to Goodson's (2002) 11 categories (Column A). The manufacturing SMEs' capabilities shown in Table 1/Column E are an interpretation derived from Columns A-D and the challenges observed in combination with the trends in society affecting the industrial environment. The shift towards more digitalization and information-sharing between different stakeholders illustrates the complexity of the knowledge and skills required to manage this transition (see Column C in Table 1). Here, the manufacturing SMEs can benefit from implementing a more transdisciplinary approach (Gooding et al., 2022) in their business development.

New production technologies, such as megacasting and Industry 4.0 technologies, are all emerging in the industry to help manage the increased demands of circularity. However, these new technologies and regulations will affect the manufacturing SMEs' businesses and roles in society as a whole (See Column E in Table 1). Today, many manufacturing SMEs are in smaller cities contributing to the local economies, at least in the studied geographical area in Sweden. Due to megacasting, which is dependent on large investments in new infrastructure and preferably utilized on the product-owning company's vehicle assembly line (Schuh et at., 2022), the production volumes at foundry SMEs are predicted to decrease along with the need for manufactured components from manufacturing SMEs..

 ISSN 1927-033X

Table 1: A conceptual guideline for assessing the capabilities to develop as a manufacturing SME in a circular industrial environment (Inspired by Goodson, 2002 and Elkington, 1994)

	A	B	C	D	E
No	**Categories (Goodson, 2002)**	**Societal changes**	**Technological possibilities**	**Regulation demands**	**Manufacturing SME capabilities to develop**
1	Customer satisfaction	Customers demand environmental information related to the products	Integration of Industry 4.0 technologies to provide traceability during several life-cycles	Trade flows will change due to changes in the source of materials	Managing new customer demands related to environmental requirements as well as developing the ability to reach out to new customers
2	Safety, environment, cleanliness, & order	Interact with stakeholders in the value chain	Automated solutions—both robots as well as digitization	Governmental regulations for waste management	Managing internal waste loops and material handling in a safe way
3	Visual management system	Life-long learning activities	Develop and implement digitalized support	Traceability in product information	Implement virtual decision support for circularity
4	Scheduling system	Adjust production volume and material usage	Continuous tracking of manufacturing process data	Traceability in product information	Manage energy, tools, information, and materials in a planning system
5	Use of space, movement of materials, and product line flow	High accuracy in sorting waste material integrated in the regular production line	Integrate infra-structural aspects in layouts, such as energy needs, material flows and digitalization	Working environment regulations	Layout planning adjusted for waste and material, including energy to and from the system
6	Level of inventory and work in the process	Promote greater use of recycled or reused materials	Utilizing digitalization as an enabler for traceability	Reduce the need and use of virgin material	Traceability of recycled/reused materials in combination with ordinary materials and components in the process
7	Teamwork and motivation	Interact with stakeholders, incl. end-users to develop and reach an understanding	Transdisciplinary engineering approach to develop solutions	Standards related to circularity to contribute to sustainable development	Life-long learning related to the circular economy and emerging technologies such as digitalization and automation
8	Condition and maintenance of equipment and tools	Stakeholders see value in reused and maintained products	Ensure quality through engineering solutions	Standards facilitating circular solutions	Maintenance, upgrading, and reuse of equipment and tools
9	Management of complexity and variability	Increased number of circular requirements from different stakeholders	Solutions that manage information security protecting the SMEs' business	Product life-cycle information for circularity transparent	Ability to manage circular requirements as well as changes in technology that affect business opportunities
10	Supply Chain Integration	Interact and share requirements with stakeholders to reach fair agreements in the value chain	Digital support for managing lean and green requirements efficiently	Change in trade flows due to change in material sources	As a manufacturing SME, manage integration in the supply chain related to lean and green requirements
11	Commitment to quality	Reduce the environmental impacts from products, i.e., CO_2 emissions	Collect data from the manufacturing system in a traceable way	Digital product passports	Effectively manage information about the manufacturing process relevant to customer needs for a digital product passport

This technology change is expected to contribute to a disruptive change for the manufacturing SMEs that supply the European automotive industry. Here, the need for a consequence analysis for local communities that have many manufacturing SMEs in its region has been identified, which is in line with the conclusions drawn by Schuh et al. (2022), who indicate a need for more in-depth consequence analysis. Another reflection made regarding this change towards megacasting is that traditional robotized body-in-white-welding in the automotive industry will be dramatically reduced, which will negatively impact the robot suppliers as well as decrease the market needs in this industrial segment. However, all these robots might have a high reusability value and can therefore contribute to circularity, but this might lead to a new type of business related to old automation infrastructures corresponding to Category 8 in Table 1.

As Agrawala and Yamaguchi (2018) indicate, there will most likely be a change in the trade flows of materials due to demands to reuse and recycle material as well as reduce the need for virgin material in industrial applications. In relation to this change, the digital passports that are to be implemented due to laws and regulations for trace materials and sustainability indicators challenge the manufacturing SMEs as well (See Column D in Table 1). One example is the digital interfaces the product-owning companies use to collect information from their suppliers. Here, manufacturing SMEs must log a wide range of information just to qualify for a position as a supplier before getting the opportunity to be selected as one. These interfaces are internationally designed, which means that the information needs to be in English due to global supply chains. One example of a cost-driver for manufacturing SMEs in the transition towards digitalization supporting circularity is the translation into English of the authorities' assessments and information, which can be in the local language. This is time-consuming and does not guarantee a quality translation. Here, transdisciplinary collaboration might support engineering development (Gooding et al., 2022) by combining several knowledge fields that can support the manufacturing SMEs in developing solutions that contribute to efficient and reliable information management.

Furthermore, the traceability of materials and processes also needs to be assured, and here Industry 4.0 technologies and digitalization can support greater capabilities (Antikainen et al., 2018; Jamwal et al., 2021). However, it is important for the industry to understand and evaluate all new emerging technologies, such as sensors and interactive databases, to be able to invest and decide upon investments that are resilient and do not harm future businesses. Here, there is a need for new skills and life-long learning approaches in the overall industry since the transition towards a circular economy is moving fast. In a future circular economy, the traditional way of doing business is challenged, so it is important to reflect upon what is contributing to the profit indicated in a company's future annual reports. Sharma et al. (2020) indicate that manufacturing SMEs must have a strong commitment to management in order to shift from a linear to circular industry. Furthermore, they conclude that there is a need for capabilities relative to managing innovation, upgrading technology, life-long learning, motivation, and developing appropriate guidelines (Sharma et al., 2020). However, to be competitive, a manufacturing SMEs must also be profitable, so there is a need to identify what is contributing to value in a future revenue equation as well as what expenses are related to new regulations driving the transition towards a circular economy within a supply chain.

5. Concluding remarks

The various aspects that a manufacturing SME needs to manage in a disruptive industrial environment can be both unpredictable and predicable and challenge the industry in several ways. The manufacturing SMEs must manage a disruptive industrial environment with fluctuations in energy costs and drastic technology changeover both in production technologies (i.e., megacasting and human-robot collaboration) and product system configurations (i.e., electrification and the shift towards renewable energy use and products). This also includes new regulations and legislation relative to the demands of circularity, including new standards. Since these different changes are occurring simultaneously, the situation for a manufacturing SME is challenging and necessitates support for a start, in order to evaluate how to navigate its business so it is sustainable in the future, which is confirmed by Sharma et al. (2020). Sharma et al. (2020 argue for a need for commitment and understanding in management. Manufacturing SMEs need to develop the capability to identify new customer segments that might arise in this transition towards a circular economy due to disruptive technology changes. The transition towards renewable energy solutions contributes to the shift from combustion engines to electric engines, which affects the production volumes as well as the requirements for manufacturing capabilities. Here, the conceptual assessment tool presented in Table 1, which corresponds to the needs for guidelines suggested by Sharma et al. (2020), can be a guide for the manufacturing SMEs.

To conclude, some of the trends identified in the literature challenge the manufacturing SMEs, and there is a need to manage these successfully in order to be competitive in a future circular economy. As a manufacturing SME, it is important to reflect upon these trends and how they might affect the business strategically in 5 to 10 years even though for many of the manufacturing SMEs, business will continue as usual—until their product-owning customers make the switch to new technologies. One way to manage the fast transition can be to implement a more transdisciplinary engineering approach when collaborating with different suppliers and customers (Gooding et al., 2022). This will improve their problem-solving capability as well as integrate the solutions into the manufacturing SMEs' businesses by involving the relevant stakeholders. In this way, the manufacturing SMEs can interact with the product-owning companies between the three levels—micro, meso, and macro (Nikolaou et al., 2021)—and prepare the transition step-by-step together to reach an integrated solution with corresponding interfaces and a common understanding of the requirements to manage a circular economy.

Funding

This work was supported by the Swedish Government Innovation Agency (Vinnova) through the research project GRETA (grant number: 2021-01313) and the research project ToolTrace (grant number: 2022-01285).

Acknowledgements

The author would like to acknowledge and thank the SPARK research environment at Jönköping university funded by the KK-foundation, and the regional manufacturing SMEs in the southern part of Sweden for all the fruitful discussions.

References

Agrawala, S., Yamaguchi, S. (2018). International Trade and the Transition to a Circular Economy. *OECD*. Available at: https://www.oecd.org/environment/waste/policy-highlights-international-trade-and-the-transition-to-a-circular-economy.pdf

Antikainen, M., Uusitalo, T., Kivikytö-Reponen, P. (2018). Digitalisation as an Enabler of Circular Economy. *Procedia CIRP 73*, 45-49. https://doi.org/10.1016/j.procir.2018.04.027

Ari, A., Arregui, N., Black, S., Celasun, O., Iakova, D., Mineshima, A., Mylonas, V., Parry, I., Teodoru, I., Zhunussova, K. (2022). Surging Energy Prices in Europe in the Aftermath of the War: How to Support the Vunerable and Speed up the Transition Away from Fossil Fuels. *IMF Working Papers, 2022/152*

BBC. (2023). Turkey-Syria earthquake: Fire at Iskenderun port extinguished, Available at: www.bbc.com/news/world-europe-64570458. Accessed on February 12 2023.

 ISSN 1927-033X

van Capelleveen, G., Vegter, D., Olthaar, M., van Hillegersberg, J. (2023). The anatomy of a passport for the circular economy: a conceptual definition, vision and structured literature review, *Resources, Conservation & Recycling Advances 17.* 200131. https://doi.org/10.1016/j.rcradv.2023.200131.

EC. (2002). *People, planet, prosperity*. The World Summit on Sustainable Development. ISBN 92-894-3885-1. Available at https://ec.europa.eu/environment/archives/wssd/documents/wssd_brochure.pdf

EC. (2021) Horizon Europe – Investing to shape our future. Available at https://research-and-innovation.ec.europa.eu/system/files/2022-06/ec_rtd_he-investing-to-shape-our-future_0.pdf

Elkington, J. (1994) Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development. *California management review 36(2).* 90-100. http://doi.org/10.2307/41165746

Ghisellini, P. Cialani, C., Ulgiati, S. (2016) A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Prodroduction 114*. 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Goodson, R.E. (2002) Read a Plant – Fast. *Harvard business review 80(5).* 105-113.

Gooding, H., Lattanzio, S., Parry, G., Newnes, L., Alpay, E. (2022). Characterising the transdisciplinary research approach. *Product, Management & Development 20(2),* e20220012. https://doi.org/10.4322/pmd.2022.02

IEA. (2022). *Electrification*, IEA, Paris. Available at https://www.iea.org/reports/electrification

Jamwal, A., Agrawal, R., Sharma, M., Giallanza, A. (2021) Industry 4.0 Technologies for Manufacturing Sustainability: A Systematic Review and Future Research Directions. *Applied Sciences 11*. 5725. https://doi.org/10.3390/app11125725.

Johansen K. (2020). Challenges for Manufacturers when Customers are Locked Down: Is it Possible to be Prepared? *The Journal of Applied Economics and Business Research* 10:2, 54-58. Available at http://www.aebrjournal.org/uploads/6/6/2/2/6622240/joaebrjune2020_54_58.pdf

Johansen, K., Rao, S., Ashourpour, M. (2021) The Role of Automation in Complexities of High-Mix in Low-Volume Production – A Literature Review. *Procedia CIRP 104(8).*1452-1457. https://doi.org/10.1016/j.procir.2021.11.245.

Karabag SF, Imre Ö. (2022) The Global, Regional, National, Sectoral, Economic, and Commercial Impact of the Russo-Ukrainian War and the Emerging Second Cold War. *Journal of Applied Economics and Business Research* 12:1. 58-70. Available at http://www.aebrjournal.org/uploads/6/6/2/2/6622240/joaebrdecember2022_58_70.pdf

Kirchherr, J., Reike, D., Hekkert, M (2017). Conceptualizing the circular economy: An analysis of 144 definitions. *Resources, Conservation & Recycling 127.* 221-232. http://dx.doi.org/10.1016/j.resconrec.2017.09.005

Koren, Y., Gu, X., Guo, W. (2018) Reconfigurable manufacturing systems: Principles, design, and future trends. *Frontiers of Mechanical Engineering 13*. 121–136. https://doi.org/10.1007/s11465-018-0483-0

Machado, C.G., Pinheiro de Lima, E., Gouvea da Costa, S.E., Angelis, J.J., Mattioda, R.A. (2017) Framing maturity based on sustainable operations management principles. *International Journal of Production Economics 190*, 3-21. https://doi.org/10.1016/j.ijpe.2017.01.020.

Malik, A.A., Bilberg, A. (2019) Human centered lean automation in assembly. *Procedia CIRP 81*, 659–664. https://doi.org/10.1016/j.procir.2019.03.172.

Mayyas A., Steward D., Mann M. (2019) The Case for Recycling: Overview and Challenges in the Material Supply Chain for Automotive LI-ion Batteries. *Sustainable Materials and Technologies 19.* https://doi.org/10.1016/j.susmat.2018.e00087

McLachlin, R. (1997) Management initiatives and just-in-time manufacturing. *Journal of Operations Management 15(4).* 271-292. https://doi.org/10.1016/S0272-6963(97)00010-7.

Nikolaou, I.E., Jones, N., Stefanakis, A. (2021) Circular Economy and Sustainability: the Past, the Present and the Directions. *Circular Economy and Sustainability 1.* 1-20. https://doi.org/10.1007/s43615-021-00030-3.

Nordén B. (2022) Mitigating Climate Change Effects: A Global Approach. *Molecular Frontiers Journal* 06:01n02, 7-23. https://doi.org/10.1142/S2529732522400028

Reuters. (2021). Ever Given container ship leaves Suez Canal 106 days after getting stuck, Available at: https://www.reuters.com/world/ever-given-container-ship-set-leave-suez-canal-2021-07-07/, Accessed on February 12 2023.

Sansone, C., Johansen, K., Rösiö, C. (2021). Competitive manufacturing in a high-cost environment: a SME's perspective, Proceedings for the 28th EurOMA Conference, 4th – 7th of July.

Schuh, G., Bergweiler, G., Dworog, L., Fiedler, F. (2022) Die Karosserie aus dem Aluminium-Druckguss/Opportunities and Risks of Mega-Casting in Automotive Production – The Aluminium Die-Cast Body in White, In: *Werkstattstechnik 112(9)*. 580-586. In German. https://doi.org/10.37544/1436-4980-2022-09-52.

Sharma, N.K., Govindan, K., Lai, K.K., Chen, W.K., Kumar, V. (2020) The transition from linear economy to circular economy for sustainability among SMEs: A study on prospects, impediments, and prerequisites. *Business Strategy and the Environment 30*. 1803-1822. https://doi.org/10.1002/bse.2717

Sigurjónsson, V., Johansen, K., Rösiö, C. (2022) Exploring the operator's role within changeable and automated manufacturing – A literature review. *Procedia CIRP 107*. 369-374. https://doi.org/10.1016/j.procir.2022.04.060.

UN. (2023) Renewable energy – powering a safer future. Accessed: 2023-07-03. Available at: https://www.un.org/en/climatechange/raising-ambition/renewable-energy

 ISSN 1927-033X