How could a SME supplier's value chain be evaluated by circular production principles?

Citation for the original published paper (version of record):
Lindahl, E., Kurdve, M., Bellgran, M. (2022). How could a SME supplier's value chain be evaluated by circular production principles?. Procedia CIRP, 105: 648-653.
http://dx.doi.org/10.1016/j.procir.2022.02.108

Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 105 (2022) 648–653

www.elsevier.com/locate/procedia

29th CIRP Life Cycle Engineering Conference

How could a SME supplier's value chain be evaluated by circular production principles?

Emma Lindahl[a]*, Martin Kurdve[b,c], Monica Bellgran[a]

[a]KTH, Royal Institute of Technology, Department of Sustainable Production Development
[b]RISE, Research Institutes of Sweden
[c]Chalmers University of Technology, Department of Technology Management and Economics

* Corresponding author. Tel.: +46 70 233 08 71. *E-mail address:* emlindah@kth.se

Abstract

Increased demands for circularity in manufacturing industry put pressure on transformation in order to meet the Sustainable Development Goals. Small-and-medium-sized-enterprises (SME)'s have an important role, supplying value chains with material and components for larger companies and original-equipment-manufacturers (OEMs). SME suppliers' net environmental footprint contributes to the OEM's overall footprint, however, SME suppliers are characterized by limited resources and competence to perform circularity activities. SME net environmental footprint consists of both production related targets combined with product related targets. Circular product performance evaluation have raised a demand for easy-to-use, self-assisting tools as a complement or substitute for standardised life-cycle-assessment (LCA) methods, often considered as costly with advanced calculations, and highlights the need for the development of accessible tools and guides that support the SMEs' circularity work. An established industrial tool based on previous research called the Green Performance Map (GPM), has successfully been used to assist circularity performance in production operations. This paper sets out to test the GPM tool in a new setting, addressing circularity in an extended value chain context, including three main areas; production and sourcing, product use and product end-of-life. The research presented is based on an in-depth case study with an interactive research approach and aims to explore how to reach a full value chain perspective on circularity in production. The result indicates that a joint and inclusive collaboration centred on the adapted GPM-tool, identifies and structures circular production principles as well as product use and end-of-life performance as a basis for evaluation. Findings from research study show that a comprehensive input-output tool could be used with limited competence and time, achieve increased employee awareness of circularity in the product value chain. This single case study brings a small empirical contribution to existing literature on SME circular production transformation, however it clearly shows on the urgency to evaluate circularity along the value chain in order to support a full industrial circular production transformation.

Keywords: Circular Economy; Production Operations; Production Management; GPM tool; Green Kaizen

1. Introduction

The concept of circular economy (CE) originates from industry driven ideas on how corporations could achieve sustainability [1], by adopting a systems approach, involving relevant stakeholders [2]. On policy level, the concept is frequently used in business discussions since it appears in e.g. product and environmental legislations. In literature, CE is often described by a set of principles, originating from established theories on eco-efficiency, resource circulation and business competitiveness. Hence, the concept of CE seeks conformity for comparison and measurement reasons by standardization [3]. Until now, guidelines on CE for organizations mainly emphasize the formulation of principles and business management steering towards a high ambitioned CE approach in dialogue with stakeholders, although it lacks relevant experience from the CE reality [4].

In the field of production operations and production

10.1016/j.procir.2022.02.108

logistics, circular economy has not yet been established as a well-known paradigm partly because implementation of the concept encounter barriers [5]. Parts of the production and logistics systems use built-in circularity in terms of remanufacturing and reverse logistics to illustrate take-back systems for resell of products [6]. From a product manufacturing context, design and calculation of products' environmental performance, often through Life Cycle Engineering (LCE)-related systems, is common and sometimes linked to the circular economy concept. Taxonomy and state-of-the-art has been framed by for example Pecas et al., [7], and among others, have Lindahl et al., [8], introduced an integrated product and service offering that satisfied an identified customer need by incorporating production, use and the end-of-life treatment phases of a product. In line with the principles of CE concepts, Product-Service Systems or servitization of manufacturing, transforms production-centric manufactures into manufacturing solution providers, a concept highlighting co-creation processes and shared resources along the value chain in order to contribute to a circular economy [9].

To the authors' knowledge, little attention has been shed towards SME suppliers, especially in the electronic- and manufacturing industry where SMEs are often part of large value chain networks, i.e. in the supply of vital electronic components within the manufacturing industry. Electronic components manufacturing industry's environmental and carbon footprint needs to be improved, and as procurement processes gradually increase focus on sustainability and circularity performance, suppliers must also oblige to meet new demands, both internal and external. SME suppliers act as intermediates in product value chain, attached to component and raw material suppliers as well as downstream, e.g. sales towards OEMs. It also arranges for its own production. The SME value chain, include production, product use, product end-of-life and disposal and involves multiple actors and stakeholders which respond for production-related environmental footprint. Therefore, industry related research needs to further investigate how SME-suppliers can improve their overall sustainability and circularity performance, considering the special characteristics of these firms.

The objective with this research is twofold; first to adapt and try out a modified environmental production tool, Green Performance Map tool (GPM) [10], for circular production, and secondly, to gain empirical knowledge through a collaborative workshop series in order to complement existing literature on application of circular principles in production operations, which today consist of a smaller selection of research cases. Objectives are fulfilled by answering the following research questions; RQ1: What are the main circular manufacturing issues that could be solved by CE principles? RQ2: How can SME-suppliers show on circularity in main areas of the value chain? The paper is structured as the following: part 1; introduction, part 2; literature framework, part 3 research methodology, part 4; results, part 5; analysis and discussion and part 6; conclusions.

2. Literature overview

2.1. Production and product measures forming circularity performance

SME operations as a group are heterogeneous but they are in general challenged by less structure and are more dependent on management network and interest [11],[12]. A standardized work regarding environmental performance may not be in place. Most of the larger manufactures work with standardized environmental improvements in production today, inspired by Lean management practices translated into environmental purposes, where Green-Lean is a dominating concept. The Green-Lean integration in production operation practices has for example been elaborated on by e.g. Siegler et al., [11], and in the study carried out by Cherrafi et al., [13], 15 barriers to a successful implementation of Green-Lean in organizations were found. Among the barriers, no coherent circular performance indicators have been presented [14], [15]. More specifically within the Green-Lean concept, selected tools investigate environmental aspects and circularity performance mainly by resource efficiency and waste management in production, such as the 'Environmental Value Stream Mapping', the 'Eco Design Wheel' and the 'Green Performance Map' etc. [10]. Common for these research studies is the circularity performance measurement, presented from a rather narrow perspective, only focusing on the production, isolated from the full value chain.

Regarding the product assessment, Life Cycle Assessment (LCA) tools are often used to calculate the overall environmental product footprint. Product LCA calculations in general, tend to require a vast numbers of measure points which requires large company resources [16]. For SME-suppliers in manufacturing, LCA might require expertise and more resources compared to what is offered. Lack of specialized competence, supportive methods and concrete measurement tools, can be reasons why the LCA work is sometimes costly and not always prioritized. Product LCA is not necessarily connected to production performance measurement but is still essential for a better understanding of the total environmental performance, where both the production phase and the product use phase, founds the ground for a total performance and have a possibility to form indicators for a circular transformation.

With limited resources in time, money and competence, SMEs need easy-to-use, multi-functional Green-Lean tools with the ability to support, not only one area of the value stream i.e. the production area or the product assessment, but the overall value chain performance. A successful implementation and development could assist SME to gradually transform and comply towards a circular production.

2.2. Circular economy principles in production operations

Based on a literature search, a literature framework including literature reviews was constructed to support the research study. The circular economy concept has a systems approach which connects societal layers, an important dimension of the concept being maintaining the holistic approach and contributing to a sustainable development [4].

However, limitations in concept boundaries are inevitable when translating a theoretical concept into practice. In the literature search, the Scopus database was used; TITLE-ABS-KEY(review AND (production OR manufacturing OR operational) AND principles AND ("Circular Economy" OR "Circular Economics" OR "Industrial Symbiosis")). From 136 hits, a sorting of titles and abstracts were made. Choosing production-relevant articles, only four literature reviews were left illustrating circular economy indicators or principles applicable for operations. In short, articles considered operational principles for circular economy, Suárez-Eiroa et al., 2019 [17]. Kristensen et al., 2020 [18], show on indicators for CE, mainly micro level, and Acerbi et al, 2020 [19], describes an analysis of circular manufacturing principles combined with the scale of adoption (macro, meso and micro). Diaz et al., 2021 show on relevant research visualizing the most common strategies on micro level, comprising R-strategies for circular economy, e.g. value-retention activities such as Refuse, Reduce, Reuse, Recycle etc. were also found [20]. All together, these publications form a theoretical basis for the design of a framework that gives coherence on circular economy principles in operations, visualized in table 1.

2.3. *Construction of references*

Table 1 provides a comprehensive literature framework for main principles of circular economy in operations found in respective publication. Aspects on circularity are mixed from several parts of the value chain and does not give any guidance on what principle to be acknowledge where in the production system. From the framework, main areas are found, describing the different *modes* in the production system. Three modes were identified and categorize and prioritize on respective focus area in the value chain and are explained in figure 1.

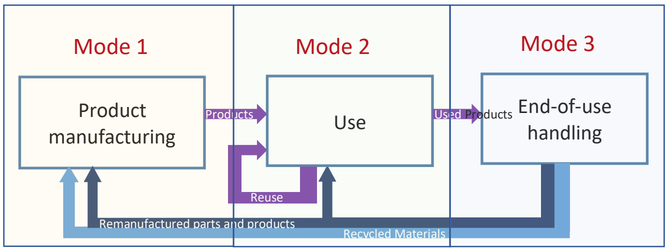

Fig. 1. Own model of the value chain translated into modes. Extractions and production (mode 1), Use phase (mode 2), End of life and recovery, (mode 3).

Table 1. Circular economy operational principles framework

Research publications	Circular Economy principles							
Operational principles for CE [17]	Adjusting inputs to the systems to regeneration rates	Adjusting outputs from the system to absorption rates	Closing the system	Maintaining resources value within the system	Reducing the system's size	Designing for circular economy	Education for circular economy	
Main micro levels for CE [18]	Recycling	Remanufacturing	Reuse	Resource efficiency	Disassembly	Life-time extension	Waste, E-o-L management	Multi-dimensional indicators
Most common CE-strategies on micro level [19]	Cleaner Production	Circular business model	Waste management	Remanufacturing	Recycling	Reuse	Material and energy efficiency	Circular design practices
R-strategies for CE at micro level [20]	Product material	Product architecture	Product service	Product business model	Product ecosystem			

To the authors knowledge there are only a few tools qualified for the evaluation for all three modes. One tool that have been successfully implemented and used in manufacturing companies, is the Green Performance Map (GPM), also known as Green Kaizen [10, 21]. The tool has been applied in several Swedish manufacturing companies, identifying Green-Lean wastes and environmental losses in the production phase, also presented as mode 1 according to the figure 1. The GPM-method is a hands-on operational method for a team to identify and visualize circular and environmental aspects and to prioritize and improve these by making continuous improvements. The circularity evaluation of residual and process material is assisted by the waste hierarchy, as depicted in Figure 2, see [21].

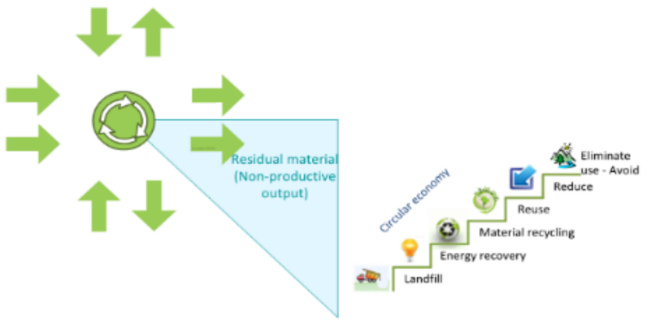

Fig. 2. Using the waste hierarchy model as part of the GPM tool for CE-evaluation of the production output [21].

To fully cover the circularity evaluation in the complete value chain, authors claim that the GPM production map is not enough. There is a need for a tool also covering the product use phase as well as end-of-life and recovery. This study has therefore focused on the GPM tool but adopted it to be able to assist the product use phase and the after usage-phase, mode 2 and 3 according to figure 1.

3. Research methodology

This qualitative research approaches the action research field, considering the research team planned and designed the study in advance, hence the workshop format opened up for unexpected changes and possible new directions. The final scope and delimitations of the study were determined collectively, involving both the researchers and practitioners as long as workshops took place. However, the extended value chain approach for this study was predetermined; the production phase, the usage phase and the end-of-life phase, see figure 3, 4 and 5.

With support from the literature search, only four articles were considered relevant, gives perspective on the lack of research on circular production operation transformation, and even more for a SME. This situation fits the selection of an in-depth single case study with the purpose of performing an intimate analysis of complexities. Such engaged scholarship motivates the explorative research questions and permissive research design, in order to add more empirical findings [22]. In this setup, a collaboration between the researchers and the case company took place to scrutinize circular principles and further develop the GPM tool to fulfill this broader need. The joint conceptualization and interpretation of the research objective was formed as explorative research, in line with Berglund et al., [23]. For the data collection, a series of workshops was performed, based on the following three principles, in line with Coughlan et al., [24]: A pre-stage to create understanding of context and purpose; a meso-step to collect, and analyze data and plan, implement, and evaluate actions; a meta-step for monitoring with focus on collecting data for academic research. The case company is a SME electronic component manufacturer supplying parts to larger OEMs. It is committed to contribute to a sustainable community, and works systematically with environmental improvements. The case company was selected based on the special characteristics of the company size, manufacturing procedure and sustainability interest from the management level. The workshop series was conducted over a 6-month period. The first workshop with operators took place on-site, while workshop 2 and 3 were executed in a digital format due to Covid restrictions and, using interactive web-platform based tools (www.mural.com), one example is shown in figure 4. The data collection used mixed sources, also including interviews and secondary company data. Main data was collected during workshops, where notes from the discussions formed the basis of analysis. The long-term and sequenced data collection made it possible to get acquainted with the case company and created an understanding of the overall challenges for circular production transformation. The interactive research setup, the workshops, were occupied by the sustainability manager, production leader and particular technical experts, from the company's side. From researcher's side, a production coach and circular production researcher took part. In the following chapter, the arrangement and consequent outcome and result of the workshops are described.

4. Results

In the first workshop, the GPM-tool was implemented in a regular manner, for environmental production performance as described in e.g. Romvall et al., [20] to engage operational personnel in environmental improvements. Two process leaders were trained in a two-day course by Green-Lean coaches before using the tool. For the first pilot team, researchers participated for training, support, and observation purposes. Environmental aspects were identified and visualized in the GPM (the map as illustrated in figure 3). Examples of found aspects identified for improvements were excess packaging materials, electrical energy and ventilation losses. Both opportunities to avoid material losses and to recirculate materials were identified. The first workshop corresponds to capture mode 1 in the value chain system, (figure 1).

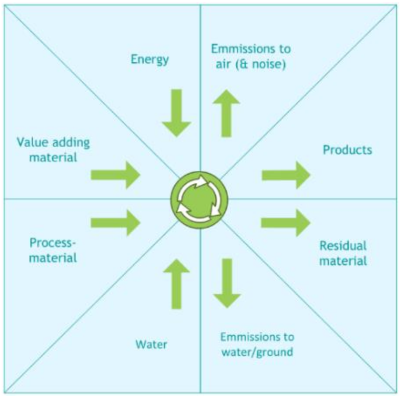

Fig. 3. First extraction and production phase was evaluated using GPM.

In the second workshop of the case study, the objective was to practice circular performance evaluation of a product. For this occasion, the GPM-tool was adapted to evaluate the product use phase, exchanging the output labels to function and residual & unnecessary material. The specimen product had a recent update towards higher performance criteria. Three mapped operations, inbound goods receiving, one assembly cell, and out-bound transportation were found relevant for the exercise. Environmental aspects of high importance were quantified, such as supplied component like parts microchips, power components, regulators and circuits. Circularity aspects for example of reuse of component materials, metals, and substitution of materials, were identified and prioritized. The main improvement potentials were to decrease energy losses in the product and to increase circularity by using recycled raw material sources and by reusing or recycling associated packaging. Other significant aspects were related to design and sourcing of incoming materials and components. Characteristic for the use phase was the output category which was formulated as a product function together with residuals and unnecessary materials from production. The product evaluation was captured as mode 2 in the value chain system.

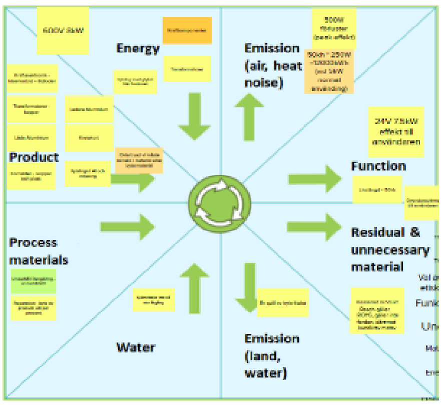

Fig. 4. Second - product use phase was evaluated using GPM.

The third workshop (figure 5) had the objective to identify the end-of-life and recovery of the product. In this workshop, the GPM tool was viewed from the product's perspective, input was named product and output was named new raw materials and reused components. In the evaluation, environmental and circular potentials were identified, where the goal was to prolong life and close loops as long as possible for the product. The importance of using recycled source for the (Aluminum) frame was highlighted. Most hindrance aspects were found for material composition in the product as well as customer user information of the product and business model of the OEM.

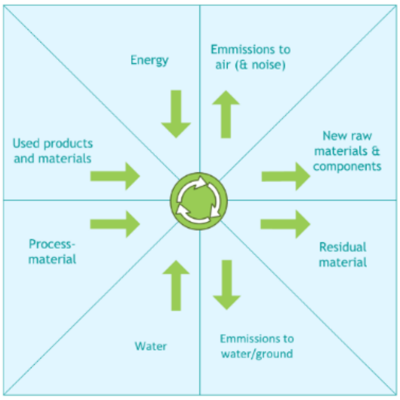

Fig. 5. Third - the product end-of-life phase evaluated by using the GPM.

The third workshop covered the mode 3 in the value chain systems model (figure 1). The three workshops using the case-specific GPM tool, constituted the main data collection with a gradual understanding of the company's reality and situation in the value chain. Complementary interviews gave a deeper reflection from the company manager's perspective and added company information on the environmental strategy. Results from the case show that circular aspects throughout the value chain, could be identified, prioritized and actionable with help from the GPM tool adjusted to the three areas.

5. Analysis and discussion

The workshop series covered the case company's extended value chain, from production, product evaluation and end-of-life handling in order to assess the overall circular performance. The GPM-tool, adapted to fit the cross-value chain purpose, proved to be effective, as it is easy-to-use and worked out as a forum, gathering key competences from the own organization to come up with solutions. It was noted that additional data from suppliers related to critical materials was needed for some components. Increased LCA application e.g. using IDEMAT apps [25] for materials environmental impacts was further identified useful for a detailed material assessments.

Table 2. Result of found circularity in value chain within the circular principles framework

Found CE principles	Production phase, mode 1	Use phase, mode 2	End-of-life and recovery phase, mode 3
Designing systems or products for CE	Identification of environmental aspects and set up local routines. Train the trainers for effective design and production.	Identification of environmental aspects for design feedback. Substitution of critical materials.	Better communication with OEM, instructions for remanufacturing.
Maintenance, prolonging loop	Expand product life expectancy by design. Reuse suppliers packaging and process materials. Decrease energy losses.	Education of product characteristics and reparability. Part replacement.	Need of data collection from usage phase and material identification data.
Systems dimension and stakeholder engagement	Integration of user feedback and environmental assessment incl. circular design phase aspects.	Product development in line with constituents for a composite product cycle.	Improved communication of materials & components recyclability with suppliers and of repair/take-back systems with OEMs.

A main hindrance for taking full stewardship of a CE path for the product was the OEMs control of product usage. However, it was anticipated that OEMs in the future might demand take-back, repairs or other CE-strategies, and preparing for such a scenario by e.g. initiating discussions with the OEM customers was considered a business opportunity for the SME case company.

In the regular extraction and production phase (mode 1), the GPM showed on expected results in line with previous research [10, 21]. In the production facility, excessive packaging material, energy usage were identified. By enforcing circular principles regarding minimization of wastes, overall improvement could be seen. In the use phase (mode 2), material and parts composition of the product were regarded. Some materials were easier to environmentally declare/track and substitute, whilst some data was connected to a less detectable SME supplier. Here, circularity principles were found close to design and composition of the product/material. Guided by the material data, referred in [25], suggestions on less harmful substitutes were suggested. In the end-of-life and recovery phase, mode 3, CE-principles were identified but affirmed unavailable in current business model. The case company's dependency on OEMs, made a stewardship for circular transformation inaccessible. Increased industrial collaboration and material data, formed opportunities.

Through the three workshops, CE principles according to table 2, were found and identified throughout the extended value chain. It was shown that the dependency and close link between supplier, OEM and user has an impact on the overall industry circular transformation, however system delimitations, three modes, gave certain priority and focus on certain circular aspects in respective systems, which gives answers to RQ1. Workshop series and implementation support were executed via an online web-based platform, which is a cost-efficient enabler for SMEs. Self-guiding and easy handling tools derives the answers to RQ2. The outcome of the study was found satisfactory to the manufacturing company as outcome was adapted and incorporated into its own production system. Outcome from this research also adds perspective to existing literature framework of circular production principles. Circularity is found to be systems specific enhancing certain characteristics depending on physical system. By emphasizing on the three *modes* of the product value chain, a notion is pointed out to future research to carefully define physical position and identification of system limits. Regarding the delimitations of time and competences, the project output was found satisfactory for both case company/practitioner and researchers. High utilization and case application form the quality criteria for this research, whilst external transferability direct to other cases might be difficult [26].

6. Conclusion

The concept of circular economy has reached the production industry as an instrument to transform the production industry towards sustainability. To this date, research studies have identified circular operation principles [17, 18, 19, 20]. So far, no explicit tool or principle embraces the full value chain of one manufacturing company. This single case study showed on a comprehensive framework on evaluating circularity within the full product value chain. Based on previous successful usage of the GPM-tool in a production setting [21], the GPM tool was used for an expanded purpose, to include the full value chain derived into 3 *modes*; production, product use and the end-of-life and recovery. Guided by previous research of circular economy principles and with support from different value chain systems, a new use of GPM-tool was developed in order to fill a gap of a self-serving managerial support tool for CE performance evaluation. The research study was carried out in a collaborative approach, emphasizing the close dialogue in case set-up and execution by researchers and practitioners. Results from workshops formulate the gain of engaging people with a variance of competences from stakeholders to collectively come up with the research problem and insightful advances to science and practice [22]. Answers were given to research questions by taking on a holistic approach towards the full product value chain, which gives a better understanding of circular performance for the production company. It also showed that a tool designed for environmental production evaluation, can be expanded in the life cycle stages to encompass product circularity in general for a SME supplier. For the research community, contributions are seen in the practical use of circular production principles and the dependability of actors along the value chain, upstream as well as downstream. Further studies are recommended to repeat the workshop series in order to examine outcome in other cases. Researchers foresee that such practical tools, guiding for circularity in the value chain, are desired for the environmentally challenging sectors, e.g. electronics manufacturing, which are obliged to minimize environmental impact in a near future.

Acknowledgements

This research, connected to sustainable production research in XPRES and to Chalmers university area of advance Production, was made possible by the funding from Sweden’s Innovation Agency, VINNOVA, in the research project Lead Green (“Leda Grönt” in Swedish) and is based on previous research projects on the GPM tool and green kaizen.

References

[1] Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. The Circular Economy – A new sustainability paradigm? JCLP 2017.

[2] Murray, A., Skene, K., & Haynes, K. The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. Journal of Business Ethics 2017 140:3, 369–380.

[3] Lieder, M., & Rashid, A. Towards circular economy implementation: A comprehensive review in context of manufacturing industry. In Journal of Cleaner Production 2016;115, pp. 36–51).

[4] Pauliuk, S. Critical appraisal of the circular economy standard BS 8001:2017 and a dashboard of quantitative system indicators for its implementation in organizations. Resources, Conservation and Recycling, 2018. 129;81–92.

[5] Ritzén, S., Sandström, G. Ö. Barriers to the Circular Economy - Integration of Perspectives and Domains, 2017. Procedia CIRP, 64;7–12.

[6] Kurilova-Palisaitiene, J., Sundin, E., Poksinska, B. Remanufacturing challenges and possible lean improvements. JCLP, 2018.

[7] Peças, P., Götze, U., Henriques, E., Ribeiro, I., Schmidt, A. and Symmank, C. Life Cycle Engineering–Taxonomy and State-of-the-art. Procedia CIRP, 2016, 48, pp.73-78.

[8] Lindahl, M., Sundin, E., Sakao, T., and Shimomura, Y., Integrated Product and Service Engineering versus Design for Environment A Comparison and Evaluation of Advantages and Disadvantages. Advances in Life Cycle Engineering for Sustainable Manufacturing Businesses, 2007 pp. 137 – 142 - Springer London

[9] Baines, T., Ziaee Bigdeli, A., Bustinza, O.F., Shi, V.G., Baldwin, J., Ridgway, K. Servitization: revisiting the state-of-the-art and research priorities. International Journal of Operations and Production Management, 2017, 37;2, pp. 256-278

[10] Romvall, K., Kurdve, M., Bellgran, M., & Wiktorsson, J. Green Performance Map – An Industrial Tool for Enhancing Environmental Improvements within a Production System. Glocalized Solutions for Sustainability. Manufacturing, 2011. Springer Berlin, pp. 353–358).

[11] Siegel, R., Antony, J., Garza-Reyes, J. A., Cherrafi, A., & Lameijer, B.. Integrated green lean approach and sustainability for SMEs: From literature review to a conceptual framework. Journal of Cleaner Production, 2019.

[12] Kaufmann, A., Tödtling, F., How effective is innovation support for SMEs? An analysis of the region of Upper Austria-Technovation, Volume 22, Issue 3, 2002, pp.147-159.

[13] Cherrafi, A., Elfezazi, S., Garza-Reyes, J. A., Benhida, K., & Mokhlis, A. Barriers in green lean implementation: A combined systematic literature review and interpretive structural modelling approach. Production Planning and Control, 2017. 28; 10, pp. 829–842

[14] Dagiliene, L., Frendzel, M., Sutiene, K., & Wnukpel, T. Wise managers think about circular economy, wiser report and analyze it. Research of environmental reporting practices in EU manufacturing companies. Journal of Cleaner Production, 2020, 274, 121968.

[15] Corona, B., Shen, L., Reike, D., Carreón, J. R., & Worrell, E. Towards sustainable development through the circular economy — A review and critical assessment on current circularity metrics. Resources, Conservation & Recycling, 2020. 151, 104498.

[16] Shahbazi, S., Jönsson, C., Wiktorsson, M., Kurdve, M., & Bjelkemyr, M. Material efficiency measurements in manufacturing: Swedish case studies. Journal of Cleaner Production, 2018, 181, pp.17–32

[17] Suárez-Eiroa, B., Fernández, E., Méndez-Martínez, G., & Soto-Oñate, D. Operational principles of circular economy for sustainable development: Linking theory and practice. JCLP, 2019, 214, 952–961.

[18] Kristensen, H. S., & Mosgaard, M. A. A review of micro level indicators for a circular economy – moving away from the three dimensions of sustainability? Journal of Cleaner Production, 2020 243, 118531.

[19] Acerbi, F., & Taisch, M. A literature review on circular economy adoption in the manufacturing sector. JCLP, 2020 273, 123086.

[20] Diaz, A., Schöggl, J. P., Reyes, T., & Baumgartner, R. J. Sustainable product development in a circular economy: Implications for products, actors, decision-making support and lifecycle information management. Sustainable Prod. and Consump., 2021, 26, 1031–1045.

[21] Kurdve, M., & Bellgran, M. Green lean operationalisation of the circular economy concept on production shop floor level. Journal of Cleaner Production, 2021, 278, 123223.

[22] Van de Ven, A. H. Engaged Scholarship. Oxford University Press, 2006, Oxford, United Kingdom,

[23] Berglund, M., Harlin, U., & Säfsten, K. Interactive research in production start-up application and outcomes. Journal of Manufacturing Technology Management, 2020, 31;8, 1561–1581.

[24] Coughlan, P., & Coghlan, D. Action research for operations management. International Journal of Operations and Production Management, 2002, 22;2, pp. 220–240.

[25] IDEMAT Homepage, http://idematapp.com, last accessed 2021/03/19.

[26] Miles, M. B., Huberman, A. M., & Saldaña, J.: Qualitative data analysis: A methods sourcebook. 2018, Sage publications.