

Towards Context-Oriented Process Modelling in the Circular Economy

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Abstract. In the linear economy model, Lean Management and Process Excellence were initially developed in the automotive industry but they were slowly adapted by service industries, such as banks or insurance companies to optimize their own Business Processes (BP). When optimizing BP, models are created and BPMN (Business Process Modelling Notation) serves as a standard notation to design and optimize BP with the help of well-known KPIs (Key Performance Indicators). However, the recent trend of considering the circular economy in an organization's optimization initiatives has resulted in increasing pressure to put additional focus on environmental-friendly production processes.

Consequently, business process models today should not only be optimized according to the principles of process excellence but also put more emphasis on design as a part of circular economy (CE) to gain environmental excellence. Thus, BPMN models need to become more context aware. The objective of this exploratory paper proposes varying ways to incorporate well-known aspects of CE into the methods, models and tools of Business Process Management in order to move towards a Context-Oriented Process Modelling in the Circular Economy. The aim is to contribute to the discussion on how additional measures from environmental, economic and financial incentives could generate an impact on how products and services should be designed in a human-centered and environmentally friendly Society 5.0.

Keywords: Circular Economy, Business Processes, BPMN, Recycling, Refurbishing, Sustainability, Financial Incentives, Key Drivers

1 Introduction

During the Third Industrial Revolution, the automation of processes in the manufacturing industries was heavily influenced by the Japanese car manufacturers. Additionally, the breakthrough of Business Process Management (BPM) was initiated by Ford Motor Company's observations that Mazda's purchasing process was about three times more efficient than its own process. In the Fourth Industrial Revolution, the

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focus is on further process improvements with the help of Internet of Things (IoT), and the idea to generate more insights for improvement by creating a Data-Information-Knowledge cycle. In contrast to Industry 4.0, Society 5.0 shifts its focus on the impact of technology on the public and the aim and need to create a better society (Society, 2020).

However, a human-centered society will not happen without taking Sustainable Development Goals (SDG) into account, which the U.N. agreed to in 2015. In the United Nations Environment Programme 2019.3 (UNEP, 2019), sustainable consumption, production and resource efficiency are mentioned as key elements for achieving the 2030 Agenda. Besides enabling policies on the environment and a sustainable lifestyle, sustainability in businesses is one of the key focus areas of the Resource Efficiency sub-programme, which is divided in five different indicators. Amongst these, “increasing the number of public and private finance stakeholders that adopt sustainable finance principles, processes and frameworks” and “increase in the number of companies that report sustainable management practices they have adopted” are mentioned. But can we actually measure the facts and figures in order to show progress?

Given the fact that the Fourth Industrial Revolution preserves the basic principles and best practices of the Third Revolution in terms of BPM, and also adds the insights from IoT to build an additional context of data and knowledge to the production process, SDG could serve as additional context for Society 5.0 by adding aspects of the circular economy to BPM. The importance of context-orientation of BPM is well recognized and numerous methods to incorporate the different process dimensions (e.g. value contribution, knowledge intensity, creativity etc.), organization dimensions (e.g. industry, size, culture, resources etc.) as well as environmental dimensions (e.g. competitiveness, uncertainty) into account (vom Brocke et al., 2021). However, the processes management of the linear economy models should be turned into circular process thinking and the ideas of lean management of processes should be enriched with clean management objectives including, once again, a move towards a Context-Oriented Process Modelling in the Circular Economy.

2 What is the Circular Economy?

2.1 Background

The current linear economy where resources are extracted, shaped into products, sold to consumers, and then simply wasted at the end of their life cycle is undisputedly behind the record levels of pollution such as discarded plastics, microplastics, e-waste, apparel, etc. in the environment. This same linear economy is also responsible for the pressure on renewable energy flows that are reaching the breaking point. Additionally, the linear economy model has caused a tripling of the global extraction of materials between 1970 to 2017 (Oberle et al., 2019).

Consequently, this is undeniably posing a major global risk, not only because of ever increasing resource scarcity, but also because 90% of our biodiversity loss and water

stress has been directly linked to material extraction. Hence, a new model of production is clearly required to help halt environmental degradation and excessive material loss caused by the linear economy's "take-make-consume-waste" processes. The goal of circular economy principles of production is to mimic nature where everything is available in abundance and nothing is wasted. In the future, there will be two material streams: metals that are kept in circulation as long as possible; and biomaterials that can biodegrade and become a resource for new products. The circular economy will also rely on renewable energy and additionally be free of toxins (Ellen MacArthur Foundation, 2013).

The outline below, designed by the Ellen MacArthur Foundation, illustrates this flow of two different materials, namely Renewables and Finite materials:

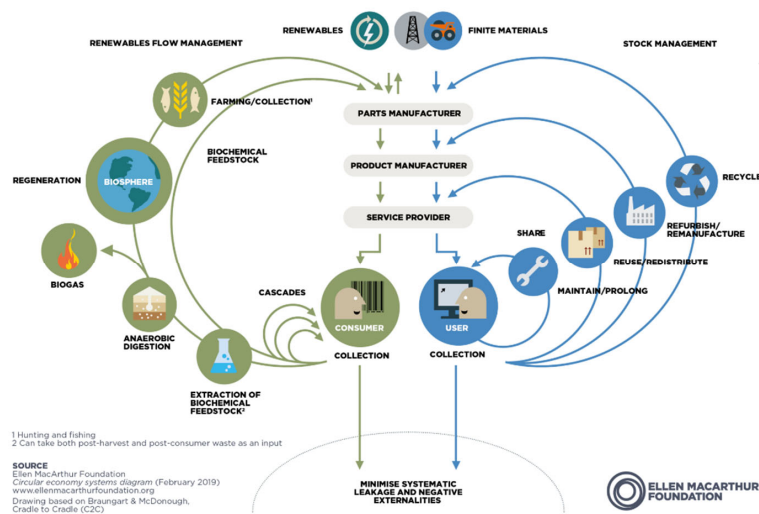


Fig. 1. Outline of the Circular Economy

Source: Ellen MacArthur Foundation

Aligned with this Outline of the Circular Economy are three principles:

- Principle 1: Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows.
- Principle 2: Optimize resource yields by circulating products, components, and materials, at the highest utility at all times, in both technical and biological cycles.
- Principle 3: Foster system effectiveness by revealing and designing out negative externalities.

At the core of Principle 2, is the design for remanufacturing, refurbishing, and recycling in order to keep materials in circulation. What is meant by "to design for

remanufacturing, refurbishing and recycling” for companies? Simply put, a new modelling is required to design out waste. And waste analysis needs to be incorporated into our current business models, as well as, our current business process models for organizations.

2.2 Design Out Waste

The first person to introduce the Cradle-to-Cradle concept was Walter Stahel, who is considered by many as the “father” of the circular economy (Stahel, 2010). This term gained worldwide traction when William McDonough and Michael Braungart published a book with the same title, *Cradle to Cradle: Remaking the Way We Make Things*. Their fundamental premise is that – like in nature – waste is reused and in effect ultimately becomes nutrients for subsequent growth (Baumgart & McDonough, 2009).

As the world is increasingly still being covered in waste, to reach this level of alignment with nature, a totally different approach to products and services is clearly required. The primary responsibility lies in the design phase because once a product specification is decided, it enters the production phase and then afterwards only minor changes become possible (Nasr, 2016). Decisions made at the design phase influences 75% of the products economic cost and 75% of its social and environmental impacts.

Not surprisingly then, design has gained an important role in rethinking the production process, but this new requirement must consider not only designing products that are going to have another life cycle but to also design out waste completely. This requires a momentous shift in thinking about immediate product form and functionality to the product’s ultimate long-term value to the customer. In the circular economy, the “why” behind purchasing a product will have to play a key role in design. In a human-centered society, this will mean that products ought to be designed for consumer attachment and trust or emotional durability.

In the following chapter, we will elaborate about how this new development influences the production process and more specifically why a move towards a Context-Oriented Process Modelling that considers the CE will become increasingly essential.

3 Business Models and Business Process Modelling for Circular Economies

Reshaping industry and revamping existing organizations will also necessarily result in the need to adjust the models that we use to describe them. The purpose of models can either be descriptive or prescriptive. Descriptive models can be used to visualize an existing artefact and prescriptive models can be used as design blueprints to describe this object to be built. Models can also be used at different abstraction levels. Current models of the circular economy, such as those from the EMF (Ellen MacArthur Foundation, 2013), are mostly of a prescriptive character and are described from a very high abstraction level. In effect, they are graphical semantic representations rather than models with a defined syntax of different drawing elements. Yet, some models do describe the CE from the system dynamics approach, which can prescribe the effects

of remanufacturing, analyze sensitivities of the different input parameters or plot essential system parameters such as transportation cost, energy consumption, or any other KPI of interest over time, such as the model of a Reverse Supply Chain by A. Brissaud (Alamerew & Brissaud, 2020).

Nevertheless, standardized business process models or business process landscapes, which are often used to describe the process architectures of circular economies are rarely be found in the BPM literature. Process redesigns and process improvements related to aspects of lean thinking during the Third Industrial Revolution are mainly focused on the qualitative and quantitative analysis of value adding, business value adding and non-value adding activities (VA, BVA, NVA) within the business processes and targeted towards the elimination of waste, such as the well-known seven Mudras (transportation, inventory, motion, waiting, over processing, overproduction, and defects).

With respect to a data-driven and event-based approach of Industry 4.0, event-driven information system architectures such as the Line Information Systems Architecture (LISA) have been proposed (Theorin et al., 2017) and describe the processes from a perspective of functional hierarchies of processes from a Level 5 (company management) down to Level 0 (the actual production process). However, as yet, no comparative approaches exist which incorporate aspects of CE to the BP modelling.

3.1 Current Business Models and Process Landscapes

When addressing business process management within organizations, process landscapes serve as the first entry to grasp the Level 5 or Level 4 process architecture. Most BPM tools support to draw abstract models with these typical process shapes, while some of the tools even provide the possibility to draw organizational charts and link them with control objectives or performance indicators.

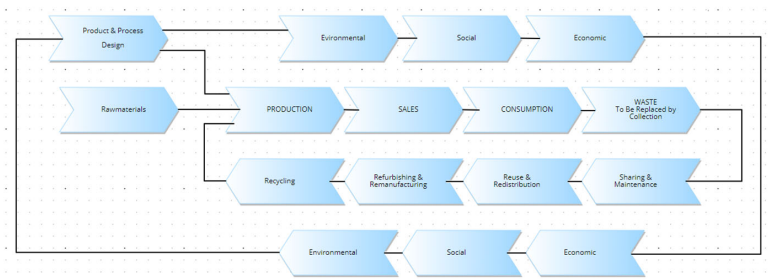


Fig. 2. Process Landscape for Circular Economies

Most products today are still designed for a single use purpose and become, at the end of their life cycle, a waste product where the process landscape only contains the process chains of raw materials – PRODUCTION – SALES – CONSUMPTION - WASTE, as depicted in the second row of the process landscape in Figure 2. While the product and process elements of the production have been improved and optimized, the

goal has been on resource efficiency as raw resources are a major cost factor in the production. And the process of Collection, which is the entry point of the CE, is not taken into account.

After a company has produced a product, the Sales Department's primary effort is to convince customers to purchase as many as possible of these goods. The next goal related to the products' consumption – from the producer's standpoint – is to ensure that the products last a very limited period of time in order to bring the consumer back to the Sales Department. The role of the optimization has been to create a perfect process for a product but, in practice, this process should not be too perfect! If too perfect, the product will not be wasted and would not open the door to a new purchases as increased sales remains a key element of the old, linear process model. This approach led to planned obsolescence. *“Most products are designed for a single life cycle and then discarded.”* (Nasr, 2016). In the new circular economy model, design carries with it far more responsibility. Indeed, it is at the very center of decision making because design will determine the length of the lifecycle and the path of the product at the end of its life. In the linear model, in effect, waste was never even considered.

The circular economy is also shifting the focus from the quantity of products sold to the core value of the product itself. For example, the rise of the sharing economy where a product is fundamentally a service that offers customers the functionality and value of the product, but these considerations need not be aligned with the actual ownership of the product. A new generation of the consumers is primarily interested in the benefit of the product but without ownership. At the same time, this development is creating an additional incentive for producers to manufacture durable products because companies can also be paid for the service and usage of the product and, consequently, are no longer under urgent pressure to replace it with a new product. This same premise obviously is valid for the Three Rs (Reuse, Repair and Recycle).

As the following graphs illustrate, when design is at the center of the production process, the former equilibrium of the linear economy shifts.

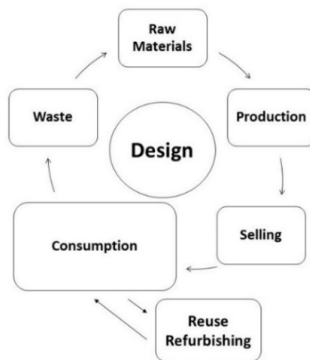


Fig. 3. The Circular Flow for Reuse and Repair with the Design at its Core

In the Reuse element above, the increased lifecycle of the product requires higher quality criteria and standards as products are resold and enter their second (or even third) lifecycle. Due to reusing products, there is significant less need for new raw materials which – in the end – leads obviously to less waste.

The same Refurbishing element, “Right to Repair” is one of the corner pieces of the new European Green Deal (European Commission, 2019). The Repair concept adds similar challenges to the production and the quality expectations as with the Reuse model. The core difference is that the product remains with the same ownership, but the lifecycle of the product gets extended. The third option is the Recycling solution. Again, when design is at the center of the production process, the decision as to what happens with the product at the end of the lifecycle is actually decided during the design phase. This process will ultimately eliminate landfills, incinerators, and the illegal trade of waste.

However, this model requires a few additional steps before the products can be returned fully to be used as raw materials once again. These include the separation process conducted by consumers, professional collection options and waste separation that is then prepared for recycling.

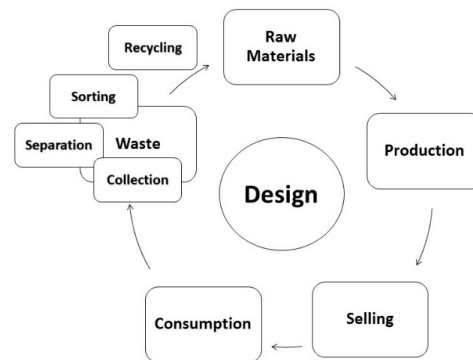


Fig. 4. The Circular Flow for Recycling

Considering all of the required changes to the production process, how can a company adjust its processes to meet these emerging market demands?

3.2 Improving Existing Process Models

The International Organization for Standards provides and develops standardized frameworks and principles which help to implement SDGs, where the ISO 14000 family is dedicated to support organizations to minimize the negative effects of their

operational processes on the environment. The well-known Plan-Do-Check-Act (PDCA) cycle, mentioned in ISO14001, points out the important aspects of a continuous process improvement. However, not all of the processes that are implemented in organizations will have an impact on the global SDGs and also on the traditional assessments of the process portfolio where the processes can be listed on a two-dimensional pick-chart in order to determine, which of the processes should be focused on first to generate the highest possible return on investment.

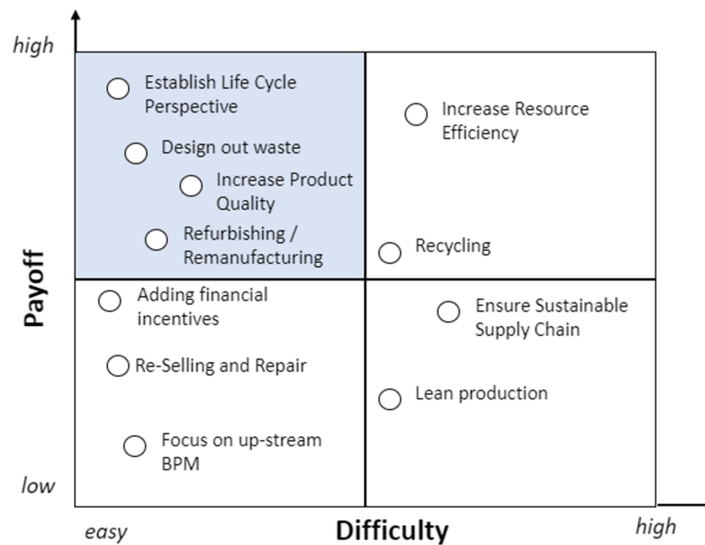


Fig. 5. Pick-charts to Prioritize the Processes Candidates for CE Improvements

Figure 5 shows some examples of process candidates. The processes on the upper left corner should be picked first, since they are easier to implement and the impact, which could be generated in terms improving the KPIs of CE, is at the highest. The processes could be taken from the different abstraction levels. The lower the level, the more detailed the process needs to be described.

Once the candidates for improvements are identified, the processes are analyzed and modelled at the appropriate level of detail with the help of the standardized Business Process Modelling Notation (BPMN 2.0). In many cases, they might still be on a high abstraction level such as those from the process landscape in Figure 2. However, when talking about manufacturing processes in a circular economy, circular visualizations such as those in Figure 3 and Figure 4 should be taken into account. With current tools, traditional linear landscapes can easily be modelled in the typical traditional up-stream and down-stream thinking models. Workarounds to build circular models such as illustrated in Figure 2 are possible, but not as yet satisfactory.

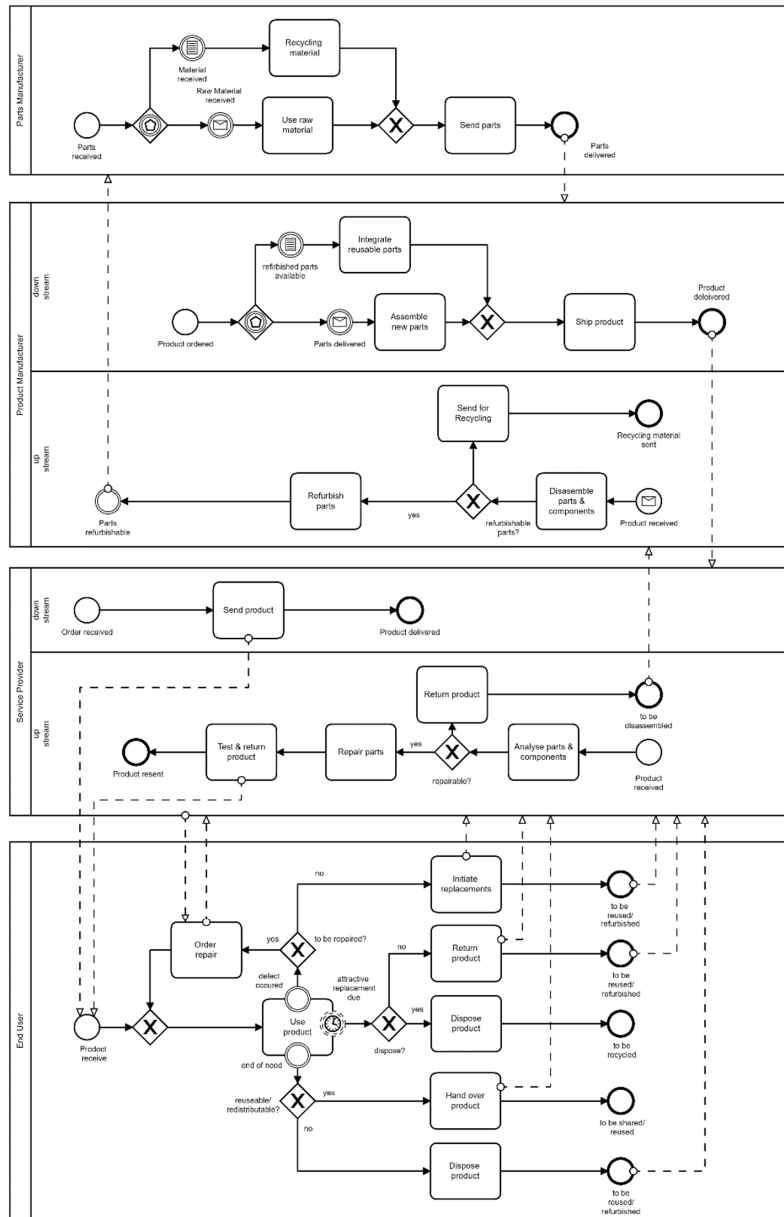


Fig. 6. Detailed BPMN models including up-stream processes from CE

Also, when diving deeper on the BPMN level to describe operational processes, there are certain difficulties to mimic circular processes. Given the scenario of any typical production process, which should be redesigned according to the principles of collecting, reusing and refurbishing or recycled raw materials, the material flow cannot be well be expressed with the current layout possibilities, as seen in Figure 6.

Such process models could be used to analyze the activities in place and are capable to point out some aspects for re-design. However, the possibilities of this low-level process modelling currently also has some shortcomings with respect to the expressiveness of the model, as previously noted in terms of a circular layout of high-level process landscapes. At lower levels, BPMN 2.0 currently only provides two types of flow: the dashed arrow represents information flow; and the arrow with the solid line represents sequence flows. Yet, there is the possibility to add information objects as input or output of activities, as there is currently no syntax for the representation of material flow!

Nonetheless, new process models should incorporate the idea from turning the “take-make-consume-waste” pattern of many of our current goods into a service-based scenario. In the linear economy era, the end-users must decide whether a broken product should be repaired or thrown away. Due to high service costs, they will likely throw the product away or perhaps return it to the store they bought it. In the circular model, this decision should be assigned to the service provider, who in turn can further delegate decisions to the product manufacturer. So, ultimately, the likelihood of refurbishing parts will be more likely increased. Unfortunately, this development is often associated with increased initial costs for the manufacturer. So, why would a company change? Which incentives could motivate the manufacturer to incorporate this new circular model?

4 Driving Forces and Factors

A main driving force for any change within the company is considering consumer preferences, and clearly these days there is evidence that indicates consumers are ready and willing to contribute to a more sustainable world. Additionally, governments are adjusting their rules and regulations to meet these sustainability demands. It is also increasingly beneficial for companies to go green as it has been shown that enterprises that comply with environmental standards have higher profits (Yao & Yang, 2012). Yet, despite this evidence and the enforcing framework, how can companies finance their transition?

The major factor behind all business development is, without any doubt, the access to capital. However, the recent transition to the circular economy has caught financial institutions flatfooted and unprepared. One of the reasons for this is that financial institutions are under pressure to comply with the ESG criteria which have an environmental aspect within but do not as yet require a transition to the circular economy. Hence, the circular economy is still largely underrepresented within the financial industry.

As Yunyan & Biao (2014) rightfully argue, to accomplish resource reduction, companies must depend on large-scale production to reach economies of scale. Committing to only a small circular change does not help the company, nor the environment, and a complete transition is associated with high investments. When recycled parts are added to the original raw materials, this changes the requirements for the entire production process, starting with the machines. Cost reduction of the original input prices can thus create a compelling incentive for change.

The authors have highlighted several ways, financial institutions can support this transition “...*declining interest rate, extending the credit period, increasing the loan amount and relaxing repayment condition...*”(Yunyan & Biao, 2014) as incentives for companies to manage the transition to the circular economy. When these conditions apply for a whole industry, healthy competition can support a drive towards the circular economy. Plus, it would naturally also include enterprises along the whole value chain, causing positive cascading effects.

Stahel proposed over twenty years ago that governments need to create a legal framework for change to take root, like the taxing of non-renewable resources. He admits that he “...*underestimated the inertia of public policy making...*” (Stahel, 2013). Nonetheless, increased raw material prices ought to force companies to look for alternatives.

Considering that the market offers a variety of other positive effects for companies that are producing circular products such as enhanced brand strength and attracting new customers, an adjustment to BPMN that enables Context-Oriented Process Modelling in the CE becomes increasingly essential.

5 Conclusion

In order to reach the SDGs on a global scale, the pressure to transform the linear economy into a circular one is very both critical and increasingly more urgent. Incorporating the possibility to enable the modelling community to share their thoughts about optimal process architectures on Level 5 or Level 4, as well as, creating best practice process models which are easily shareable through standardized BPMN models at the lower levels could be essential in sharing best practices and reaching the SDGs as fast as possible. From an historical perspective, the idea of lean manufacturing had a strong influence on how business processes were analyzed.

Today, as mentioned at the outset, principles which were originally conceived on the production lines of the automobile industry are now as commonly used in financial and service industries, where Business Process Management has been implemented and processes can now be modelled with the help of many varying tools. High level models such as process landscapes, but also low-level models, could be modelled with BPMN or even automated with the help of workflow engines to orchestrate processes across service providers, product, or part manufacturers.

However, when moving to such scenarios, the implementation suggestions of the circular economy which are currently envisioned and described with the help of non-

standardized graphical pictures such as those in Figure 1, are neither reusable models nor yet supported by the BPM tool providers.

Firstly, the circular layout of processes is not an option, and secondly and even more challenging, is the representation of material flows. BPMN currently supports message and sequence flows, but no material flows, which are intrinsically important in circular processes. Current investigations in CE are on the agenda of many manufacturing companies and accompanying financial incentives will add additional pressure to optimize processes in the manufacturing industries and, in the long run, ultimately design out waste. Given the need of SDGs and the financial incentives for enterprises to implement not only lean, but also clean thinking, the time has come where these very same manufacturing industries could profit from all the tools and methods of BPM which the service industry developed by incorporating lean thinking.

We have, and share, the hope, that a model-driven process adopted by the finance and service industry and transition to a comparable, context-oriented process modelling that incorporates CE objectives and thus circulate back enabling manufacturing industries to finally implement urgently needed lean and clean circular processes.

6 Limitations

This paper has several limitations and partially raises question without providing specific solutions. This paper is an invitation to evaluate BPMN in the context of circular economy principles. It is pointing out the need of additional views and shapes in modeling tools to improve the ability to model circular economies, circularity in process landscapes, circular processes and material flows. Future conversations with companies will deliver additional insights and help the authors better understand challenges of such a transformative transition. Additional publications will be necessary to shed more light into specific suggestions or potential enhancements of BPMN to support the transition to the circular economy.

7 References

- Alamerew, Y. A., & Brissaud, D. (2020). Modelling reverse supply chain through system dynamics for realizing the transition towards the circular economy: A case study on electric vehicle batteries. *Journal of Cleaner Production*, 254. <https://doi.org/10.1016/j.jclepro.2020.120025>
- Baumgart, M., & McDonough, W. (2009). *Cradle to Cradle (Patterns of the Planet)* (Kindle Edi). Retrieved from <https://www.amazon.com/Cradle-Patterns-Planet-Life-ebook/dp/B0031RDV9G>
- Ellen MacArthur Foundation. (2013). *Towards the circular economy* (Vol. 40).
- European Commission. (2019). The European Green Deal. *European Commission*, 53(9), 24. <https://doi.org/10.1017/CBO9781107415324.004>
- Nasr, N. (2016). A New Dynamic 2: Effective Systems in a Circular Economy. In *Remanufacturing and the circular economy* (pp. 107–128). Retrieved from <https://www.ellenmacarthurfoundation.org/publications/a-new-dynamic-2>

- Oberle, B., Bringezu, S., Hatfield-Dodds, S., Hellweg, S., Schandl, H., Clement, J., ... Zhu, B. (2019). *Global Resources Outlook*.
- Society, A. P. S. (2020). Society 5.0: A people-centric super-smart society. In Hitachi-UTokyo Laboratory (Ed.), *Society 5.0: A People-centric Super-smart Society*. <https://doi.org/10.1007/978-981-15-2989-4>
- Stahel, W. R. (2010). *The Performance Economy*.
- Stahel, W. R. (2013). Policy for material efficiency - Sustainable taxation as a departure from the throwaway society. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 371(1986). <https://doi.org/10.1098/rsta.2011.0567>
- Theorin, A., Bengtsson, K., Provost, J., Lieder, M., Johnsson, C., Lundholm, T., & Lennartson, B. (2017). An event-driven manufacturing information system architecture for Industry 4.0. *International Journal of Production Research*, 55(5), 1297–1311. <https://doi.org/10.1080/00207543.2016.1201604>
- UNEP. (2019). Resolution 3/4 - United Nations Environment Assembly of the United Nations Environment Programme. *United Nations Environment Programme*, (September). Retrieved from [http://wedocs.unep.org/bitstream/handle/20.500.11822/29932/UNEP.CPR.SC2019.3 Programme Performance review .pdf](http://wedocs.unep.org/bitstream/handle/20.500.11822/29932/UNEP.CPR.SC2019.3%20Programme%20Performance%20review.pdf)
- vom Brocke, J., Baier, M. S., Schmiedel, T., Stelzl, K., Röglinger, M., & Wehking, C. (2021). Context-Aware Business Process Management: Method Assessment and Selection. *Business and Information Systems Engineering*. <https://doi.org/10.1007/s12599-021-00685-0>
- Yunyan, L., & Biao, Z. (2014). *Innovation and Development Strategies of Investment and Financing Modes for Circular Economy*. 5(6), 50–53.