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Research article

Process Performance measurement framework for circular supply chains: An updated SCOR perspective

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Abstract

This paper presents a theoretical and conceptual approach for measuring the supply chain's performance in the circular economy era. Since not only economic but also environmental, social, and especially circularity performance must be measured within circular supply chains, adapted performance measurement systems are required. The proposed performance measurement system is based on a SCOR model adapted for circular supply chains (including the processes use and recover) and provides a comprehensive composition of indicators to holistically measure the supply chain's performance from an economic, environmental, social, and circular perspective.

Keywords: Circular supply chain, performance measurement system, SCOR model

INTRODUCTION

Circular supply chains (CSCs) systematically incorporate circular strategies into the management of the supply chain (SC) and are often perceived as new path toward sustainable supply chain management (SCM) and sustainable development (Farooque et al., 2019). However, CSCs are not necessarily more sustainable than other SC concepts in the sustainability discourse (Sehnem et al., 2019). Too often, circular economy (CE) is equated with sustainability and the specific impacts of circular strategies on the three dimensions of sustainability, especially the environmental perspective, are not considered.

Managing a SC generally requires detailed information about its performance, especially in terms of its processes and relationships. Performance measurement systems (PMSs) help decision-makers quantify the SC's efficiency and effectiveness and enable successful management (Maestrini et al., 2017). To comprehensively and holistically measure SC performance in the CE era, it is necessary – and in current literature uncommon – to assess its performance in the three sustainability dimensions as well as in the circularity dimension (Vegter et al., 2021). Therefore, new and adapted PMSs are needed that can meet the higher requirements of CSC management (Blum et al., 2020; Vegter et al., 2021).

Since literature on PMSs for CSCs is scarce and too often neglects key aspects of the CE, this research paper follows the call of Vegter et al. (2021) and develops a theoretical and conceptual framework for measuring the performance of CSC in a holistic manner. As the SC's transition from linearity to circularity plays a decisive role in achieving a more sustainable production and consumption, its performance – particularly with respect to circular performance – must be measured accordingly to support a successful transition. Therefore, the research question is formulated as follows: *Which are the key performance measures that adequately and holistically depict the circular supply chain?*

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The main contribution of this study is the proposal of a conceptual framework that provides a basis for the comprehensive and holistic measurement of CSCs' performance. The novelty of this framework is that it incorporates the three traditional dimensions of sustainability – economic, environmental and social – as well as the new circular perspective of performance, thus reconciling the goals of sustainability and circularity.

Since the literature on PMS for CSCs is still in its infancy, the study can be classified as a state-of-the-art review that aims to address a current topic in a qualitative and narrative form (Grant and Booth, 2009). By synthesizing the existing literature within this framework, future research opportunities in the field of CSC are illuminated.

This paper first presents the theoretical background on CSCs, PMSs and the SCOR model. Following this, the four performance perspectives of the developed PMS are shortly described and a clear distinction between circular performance and environmental performance is provided. The last section presents the conceptual framework with its four dimensions and possible performance measures. Lastly, the findings and contribution of this study are summarized and possible future research opportunities for PMSs are briefly discussed.

THEORETICAL BACKGROUND

Circular Economy and Supply Chains

The integration of circular thinking into the management of SCs is one of the emerging research streams of the sustainability discourse in SCM (Farooque et al., 2019; Farooque et al., 2022). In the last five to ten years, the number of published scientific papers focusing on the CSC and its management has increased significantly (Lengyel et al., 2021; Montag, 2022). Although the link between CE and SCM was mentioned as early as 2006 (Farooque et al., 2019), publication data show that a differentiated field of research has only recently been established (Montag, 2022).

Given the lack of conceptual consensus on the underlying parent concept of the CSC and the resulting inconsistencies and divergence in the understanding as well as application of the CE concept (Kirchherr et al., 2017), it is of great importance for the CSC to have its concept more clearly framed and differentiated from other related sustainable SC concepts. Farooque et al. (2019) proposed an early formal definition that focuses on the restoration of technical materials and regeneration of biological materials, aiming toward a zero-waste ideal by a system-wide inclusion of all stakeholders, including the end-user. Vegter et al. (2020) define the CSC as one that “strives for economic, environmental and social benefits by reducing, maintaining, and recovering resources” (p. 12), thus clearly addressing the three dimensions of sustainability. However, to differentiate the CSC concept and fully capture the unique characteristics that set it apart from previous concepts by going beyond green, closed loop, or sustainable SCs, a more holistic definition is needed. To counter this criticism, Vegter et al. (2021) very recently extended their previous definition and added the key characteristic of restorative and regenerative cycles.

To fill this gap in the conceptualization of the CSC, Montag (2022) synthesized in a previous work six archetypal characteristics that aim to provide transparency for the CSC concept:

- **R-Imperatives**: implementation of a waste hierarchy and value retention strategies
- **Restorative and Regenerative Cycles**: differentiation between restoration of technical materials and regeneration of biological materials
- **Sustainability Framework**: aims to contribute to all three dimensions of sustainability (economic, environmental, and social wins)
- **Value Focus**: implementation of a value logic framework to propose, create, deliver and capture value in the SC
- **Holistic System-Thinking**: transition toward circularity requires thinking in systems and the integration of all actors along the SC
- **Paradigm Shift**: holistic transformation of the linear SC to fully adopt circular principles

This understanding follows the one from e.g., Batista et al. (2018), Farooque et al. (2019), Hussain and Malik (2020), Vegter et al. (2020), Vegter et al. (2021) and Farooque et al. (2022) that CSCs should be recognized as major advancements in the sustainable SCM research field. However, the relationship between CSC and their sustainability potential is complex, and thus adequate measurement systems are required, assessing not only the circular, but also the economic, environmental, and social performance of the CSC (Vegter et al., 2021; Blum et al. 2020).

Supply Chain Performance Measurement

In a globalized world that is characterized by increased performance-based competition, systemic and strategic management of the SC and all its business functions and processes is required so that the long-term performance of both the individual company and the SC is improved (Mentzer et al., 2001). To evaluate how well a SC is managed, PMS play a vital role by quantifying the efficiency and effectiveness of the SC's processes and relationships (Maestrini et al., 2017). A PMS can further be characterized as a set of measures that provides information on the multiple organizational functions and firms, enabling decision making and deployment of the SC strategy (Maestrini et al., 2017).

While the initial focus of performance measurement (PM) was on measuring the economic performance and therefore, the development of economic measures (Eccles, 1991), the field has increasingly expanded to include environmental and social measures (Vegter et al., 2020). These measures provide important information on current performance levels and ensure comparability between this current and the desired future performance level of a SC. The latter, in particular, is the key to initiating actions for a transition toward an improved state of performance (Elgazzar et al., 2019; Vegter et al., 2021). This transformative nature of PMS has implications for decision-makers and their managerial mindsets: new strategic priorities and consequently different ways to measure performance will be the result (Eccles, 1991).

As the CE is currently the most considered concept in sustainability and SCM research, PMSs no longer need to measure only the economic, environmental, and social performance of SC, but also need to integrate the circular performance perspective and thus measure, evaluate, and control more measures. These higher requirements represent a current challenge in the field of PMS research, especially with regard to the selection, number, and the specific formulation of circularity and sustainability measures for CSCs (Vegter et al., 2021).

SCOR Model in the Circular Economy

When measuring the performance of a SC, the horizontal integration - namely the alignment of measures along all SC processes – is a key requirement to identify, evaluate and link the measures, aiming to identify the processes that need improvement (Elgazzar et al., 2019; Vegter et al., 2021). Besides the Balanced Scorecard, the renowned SCOR model – as a framework for SC processes and performance objectives – is one of the most frequently used tool for developing performance measures in the SC context (Elgazzar et al., 2019), being considered as a useful framework both in academic and business communities (McCormack et al., 2008).

SCOR recognizes six major processes that are executed to meet the goal of fulfilling the customer's need (APICS, 2022): plan, source, make, deliver, return and enable. While these may be sufficient to describe the mostly linear activities in traditional SCs, they do not adequately express the activities, and thus processes, in a CSC. Vegter et al. (2020) recently updated the SCOR framework for SCs in circular business models by adding two processes: use (by the customer) and recover (e.g., reuse, remanufacture, refurbish, recycle). Table 1 presents a characterization of this circular SCOR framework. Figure 1 depicts the CSC, including the circular SCOR processes.

Table 1 – Circular SCOR Processes (APICS, 2022; Vegter et al., 2020)

SCOR Process	Main Objective	Characterization
Plan	Development of plans to operate the SC	All activities associated with determining requirements, collecting information on resources, balancing of requirements and resources, determining capabilities and gaps, and identifying counteractions.
Source	Acquisition of goods and services	All activities associated with procurement, e.g., ordering, deliveries, receipt and transfer of raw materials, products, or services.
Make	Transformation of products and services	All activities associated with production and manufacturing, e.g., assembly, processing, manufacturing, and other material conversions to create content for orders.
Deliver	Fulfilment of customers' demand	All activities associated with order and distribution management, e.g., scheduling order deliveries, picking, packing, and shipping.
Use	Use/consumption of products	All activities associated with the use phase of the product, e.g., controlling the quantity, quality, and location of the product as well as prolonging lifetime through maintenance and repair.
Return	Management of reverse flows	All activities associated with reverse movements of goods, services, and information, e.g., take-back of used or defective products as well as collection for maintenance, repair, and overhaul.
Recover	Value retention within and across the SC	All activities associated with preserving content and value within and across the SC, e.g., reuse, remanufacturing, refurbishing, upcycling, recycling, downcycling.
Enable	SC management	All activities associated with business management, e.g., performance, data, resources, facilities, contracts, compliance, and risk as well as customer management.

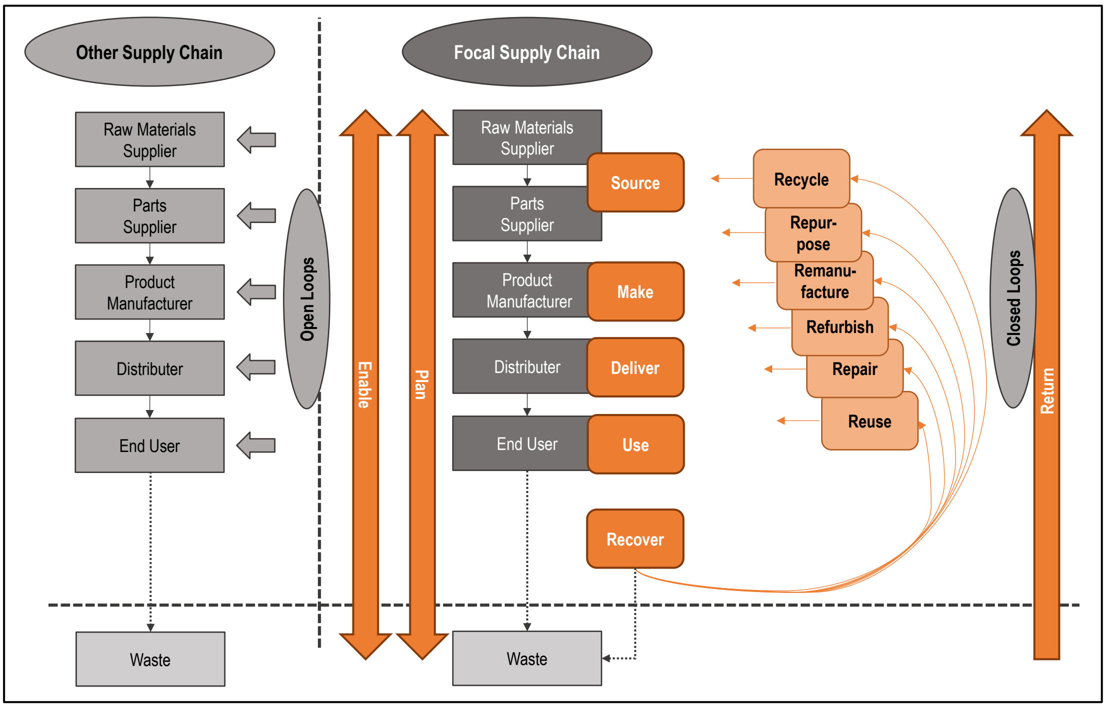

Figure 1 – Circular Supply Chain (Source: Authors)

Performance Perspectives for Circular Supply Chains

As Vegter et al. (2021) have stated in their literature review, PMS for CSCs are faced with higher requirements due to the complex relationship between circularity and sustainability. According to them, two key requirements that a PMS should meet are the inclusion of multiple dimensions of performance and a horizontal integration. In the context of CSCs, the former refers primarily to the distinction between the three dimensions of sustainability and the circularity dimension. The latter refers to the PMS containing measures for all processes along the CSC.

The conceptual PM framework that will be presented in the next section thus consists of four performance perspectives that cover the circular as well as the sustainable dimension of the CSC. They can be briefly characterized as follows (Blum et al., 2020):

- **Circular performance**: aims for more material circulation (at highest possible quality level) by applying circular strategies such as reuse, repair, refurbish, remanufacture, recycle.
- **Economic performance**: aims for positive economic value generation and economic sustainability of the CSC (e.g., costs, profits).
- **Environmental performance**: aims for a positive environmental development through less harm to the environmental ecosystem (e.g., reduction of climate change).
- **Social performance**: aims for positive social conditions for humans (e.g., better and safer working conditions, employee benefits, no child labour).

Within their discussion, Vegter et al. (2021) mention that current PMSs for CSCs do not yet provide a clear distinction between circularity performance and sustainability performance. Too often, these two perspectives overlap and create confusion, hindering the further development and implementation of effective PMSs. To propose a theoretical framework to measure the performance of a CSC, this section makes the attempt to provide a clear and intuitive distinction between circularity and environmental performance.

The assumption that circular products or circular production are also sustainable in terms of economic, environmental, and social impacts is not per se correct (Braun et al., 2021; Kravchenko et al., 2019). Although many conceptualizations understand CE and the application of circularity as a step toward sustainability, CE does not necessarily lead to more (environmental) sustainability, either way (Blum et al., 2020; Braun et al., 2021; Vegter et al., 2021). In particular, the distinction between the environmental and circular perspective is critical to the goal of a sustainable CE, as they share common goals but use different methods, leading to conflicting goals. While the CE aims for keeping products, components and materials in circulation for as long as possible and with highest value as possible through strategies such as reuse and recycling, environmental sustainability's goal is to reduce the harm on the earth's ecosystem by reducing waste and other negative outputs, such as CO_2 emissions (Blum et al., 2020; Lieder and Rashid, 2016).

This conceptual difference could lead to undesired outcomes when applying circular strategies. For example, the processing of an end-of-life product must be considered from both perspectives: From a circular one, it is desirable to maximize the circulation of this product, e.g., through closed-loop reverse flows (e.g., repair, recycling) or open-loop forward-cascaded flows into other SCs (Batista et al., 2018), aiming for a reduction in virgin material use. Indeed, even longer-existing waste that cannot yet be recycled could later become a new resource source as new technologies are developed and adopted in the CSC (Burlakovs et al., 2018). These processes may require additional transportation, have higher energy consumption, use new materials, apply toxins or produce waste that should be minimized from the environmental perspective (Braun et al., 2021). While the circular performance perspective strives to maximize the circulation (for the most part regardless of the environmental outcomes), the environmental performance perspective aims to minimize the damage on the earth's ecosystem. Only when both perspectives and their goals and methods are considered simultaneously (in addition to the economic and social perspective) can circular actions be truly sustainable (Blum et al., 2020).

Figure 2 shows a graphical illustration of this alignment between these two different goals and provides a reference for harmonizing the two perspectives of circular and environmental performance.

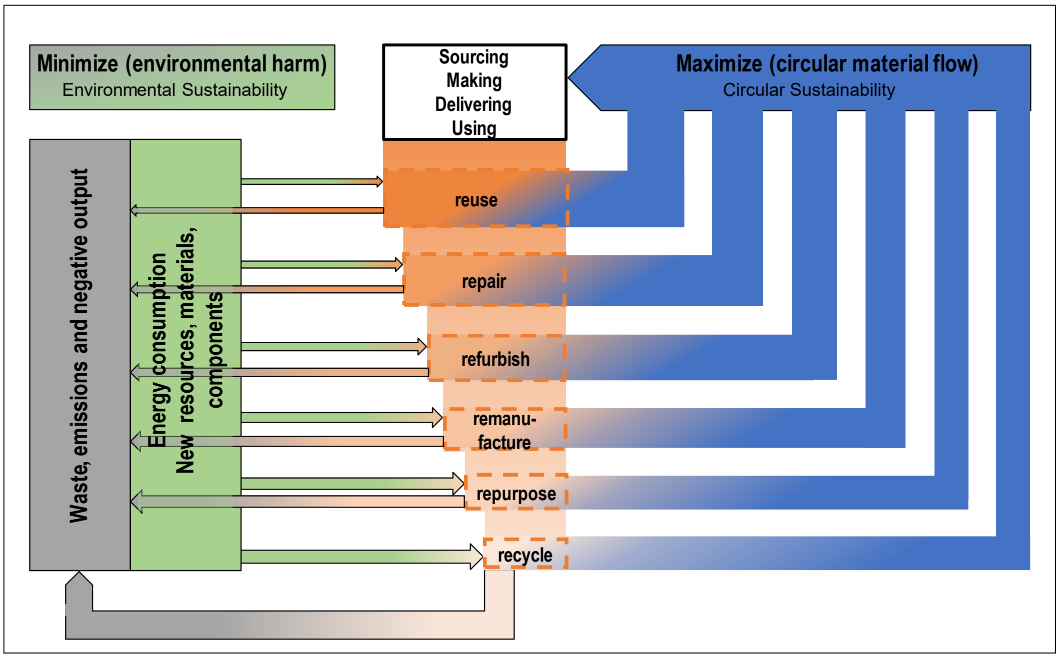

Figure 2 – Alignment of Circular and Environmental Sustainability (Source: Authors)

Conceptual Framework for Performance Measurement for Circular Supply

Based on the circular SCOR processes and the differentiation between circular and environmental sustainability, Table 2 presents the proposed framework for measuring the performance of CSCs. This table illustrates the measurement approaches for each circular process in each performance perspective. It follows the same rationale as the initially developed SCOR processes, providing a process attribute or objective and possible measures to assess the performance of the respective perspective.

It is important to emphasize that the developed framework is of conceptual nature and therefore should be understood as generic framework that can be used as guidance for measuring the performance of CSCs. It is the first step toward developing a necessary PMS that takes all four dimensions into account and forms a basis for further development (Blum et al., 2020). The measures developed represent approaches to performance evaluation and need to be adapted to the CSC by decision-makers in specific use cases. Some of the measures will be more applicable than other, more specific measures.

Considering the requirements for PMSs for CSCs (Vegter et al., 2021), the framework proposed here has strengths and weaknesses. By including a perspective for CE and a perspective for each sustainability dimension, the PMS holistically captures the specific characteristics of the CSC. Especially the clear differentiation between circular (maximizing material circulation) and environmental (minimizing harm on the earth's ecosystem) performance represents a step beyond other PMSs. Furthermore, the framework also includes a set of social measures that are so far under-represented and thus fills a critical gap in PMS research.

In addition to that, the PMS aims for a systematic horizontal integration that aligns measures along all processes of the CSC. As Vegter et al. (2021) criticize, so far, no PMS for CSCs includes the processes *plan* and *enable* into its PM. Since the proposed framework is based on the adapted SCOR processes for CSCs, various measures per process are developed, covering the entire SC in its circular characteristics.

Nevertheless, not all requirements developed by Vegter et al. (2021) were met. For once, the range of measures is not limited, nor is it very balanced. Yet, the PMS proposed here is to be understood as a generic framework that is still in the development phase, intended to build the basis for further research. Same applies for the – at least not clearly explicitly mentioned – vertical integration.

Table 2 – Conceptual Performance Measurement Framework (Source: Authors)

	Process	Attribute / Objective	Measures	Sources
Circular Performance	Plan	Plan for circularity implementation along the supply chain	No. of circular processes / circularity gaps Acquisition of second-hand equipment Recovery capacity	Chaouni et al. (2021); Lanaras-Mamounis et al. (2022)
	Source	Sourcing of compatible inputs for circularity with minimized resource extraction	Fraction of secondary/primary inputs; Amount of renewable/bio-based inputs Amount recyclable inputs; Amount secondary inputs Quality of secondary inputs	Nattassha et al. (2020); Lanaras-Mamounis et al. (2022)
	Make	Manufacturing of products capable being circulated	Fraction of renewable energy used Recovery and use of waste and by-products Fraction of recycled waste	EMA Foundation (2015); Calzolari et al. (2022); Farooque et al. (2022)
	Deliver	Efficient combination of delivery and take-backs	Amount of deliver-take-backs-combinations Reusable packaging take-backs Use of reusable packaging	Kalmykova et al. (2018); Vegter et al. (2020); Farooque et al. (2022)
	Use	Prolonging product life and use	Time of product use; Durability/reliability of product; No. of customer per product; Provision of product warranty + technical support; Accessibility of repairs/upgrading; Incentives for customers to repair/maintain Upgradability / repairability of products; Usage data collection	EMA Foundation (2015); Kalmykova et al. (2018); Lanaras-Mamounis et al. (2022)
	Return	Reclaiming of end-of-life/obsolete products	Fraction of returns from customers; Fraction of returns from distributor No. of collection centers/ease of returns Reusable packaging returns/returnability Incentives for customers to return products	EMA Foundation (2015); Kalmykova et al. (2018); Ansari et al. (2020); Farooque et al. (2022); Lanaras-Mamounis et al. (2022)
	Recover	Restoration and regeneration of end-of-life products and materials at the highest level	Efficiency of recovery processes; Ease of separation/disassembly/recycling Amount of recovered energy from waste; Amount of secondary inputs from recycling; Amount of refurbished products; Amount of reusable products; Amount of regenerated waste; State-of-the-art recover technologies	EMA Foundation (2015); Kalmykova et al. (2018); Farooque et al. (2022); Lanaras-Mamounis et al. (2022)
	Enable	Enabling circular management of the supply chain	Corporate Circular Reporting (Y/N); Identification of explicit circular performance goals; Identification of circular performance barriers; Circular product design; R&D for further regeneration/restoration; Fraction of shared SC assets; Technology application / IoT implementation readiness; Increase of usability of waste and by-products; Implementation of deposit /take-back systems	EMA Foundation (2015); Farooque et al. (2022);
Economic Performance	Plan	Plan for economic sustainability along the circular supply chain	Process Reliability Availability of assets/equipment Possibility of ad-hoc decision/changes Capacity utilization rate	Chaouni et al. (2021)
	Source	Sourcing of cost-efficient and reliable inputs for circular production	Sourcing costs; Sourcing costs secondary inputs + products Fraction secondary sourcing/primary sourcing costs; Input availability Reliability and quality of supply (primary + secondary)	Calzolari et al. (2022); Farooque et al. (2022)
	Make	Cost-efficient manufacturing of high qualitative, circular products	Production costs; Production time Standardized production (process + product); Flexibility of material input Substitution ability of inputs; Dependency on products/inputs Product quality level; Profits (net present value)	Kalmykova et al. (2018); Calzolari et al. (2022); Farooque et al. (2022)
	Deliver	Time-, cost-efficient and flexible delivery of circular products	Routing costs Packaging costs Delivery time / delay Flexibility of order scheduling	Kravchenko et al. (2019); Ansari et al. (2020); Calzolari et al. (2022)
	Use	Cost-efficient after-sales - service	Amount of needed repairs Warranty replacement costs Repair, upgrade and maintenance revenues After-sales-service costs	Kravchenko et al. (2019); Ansari et al. (2020); Blum et al. (2020)
	Return	Cost-minimizing return of end-of-life products	Costs for return flows Cost for extra take backs Costs for extra routing Costs for extra packaging	Kravchenko et al. (2019)
	Recover	Cost-efficient recovery processes	Recovery costs; Energy costs Generated profits/revenues; Quality of returned products Waste and by-product treatment costs + profits Waste discharge/disposal fees	Kravchenko et al. (2019); Calzolari et al. (2022); Farooque et al. (2022)
	Enable	Enabling economically sustainable management of the circular supply chain	Circular business model implementation Identification of explicit economic performance goals; Identification of economic performance barriers; Risk management (economic + political); Prospective analysis of future trends; Investment risks; No. of long-term supplier contracts; Cost reduction through cooperation	Chaouni et al. (2021)

	Process	Attribute / Objective	Measures	Sources
Environmental Performance	Plan	Plan for environmental sustainability along the circular supply chain	Energy self-sufficiency Acquisition of clean technologies/clean equipment Acquisition of long-lasting and durable equipment	Kalmykova et al. (2018); Farooque et al. (2022); Lanaras-Mamounis et al. (2022)
	Source	Sourcing of environmentally friendly inputs	CO2e emissions of sourcing CO2e emissions of transportation Fraction of toxic/non-biodegradable raw materials Amount of received packaging materials; Amount of byproducts	Kalmykova et al. (2018); Kravchenko et al. (2019); Saroha et al. (2021); Lanaras-Mamounis et al. (2022); Farooque et al. (2022)
	Make	Environmentally friendly production of circular products	Amount of (hazardous) waste + byproducts CO2e emissions; Other emissions Energy use; Production efficiency Water use / water depletion Soil use / soil depletion;Land use	Saroha et al. (2021); Calzolari et al. (2022); Farooque et al. (2022)
	Deliver	Environmentally friendly delivery	CO2e emission Environmentally friendly packaging Shared use of infrastructure Amount of of empty trips	Chaouni et al. (2021); Calzolari et al. (2022)
	Use	Enhancement of environmentally friendly use	CO2e emissions Product wear + tear Environmental restrictions Availability of environmental instructions Possibility of environmentally friendly use	Kravchenko et al. (2019); Chaouni et al. (2021)
	Return	Environmentally friendly return	CO2e emissions Other emissions Land use Support for correct disposal	Chaouni et al. (2021)
	Recover	Environmentally friendly recovery processes of circular products	Amount of (hazardous) waste + byproducts CO2e emissions; Other emissions Energy use; Recovery process efficiency Water use / water depletion; Soil use / soil depletion Land use; Use of toxic/corrosive chemicals	Kravchenko et al. (2019); Chaouni et al. (2021)
	Enable	Enabling environmentally sustainable management of the circular supply chain	Identification of explicit environmental performance goals Identification of environmental performance barriers Environmentally friendly product design R&D for new, environmentally compatible inputs Fraction of compensated emissions	Farooque et al. (2022)

	Process	Attribute / Objective	Measures	Sources
Social Performance	Plan	Plan for social sustainability along the circular supply chain	No. of socially engaged processes Amount of social gaps Work quality and safety Work-life-balanced schedule	Vegter et al. (2020); Calzolari et al. (2022)
	Source	Sourcing of ethical and local inputs	Fraction of ethical suppliers (e.g., labels) Fraction of local suppliers Fraction of integrative suppliers Transparent suppliers	Kravchenko et al. (2019); Azevedo et al. (2021); Walker et al. (2021)
	Make	Safe and healthy manufacturing processes	Unhealthy working conditions No. of accidents/incidents Implementation of health and safety standards Transparency of production site	Kravchenko et al. (2019)
	Deliver	Safe and healthy deliveries	Unhealthy working conditions No. of accidents in deliveries Implementation of health and safety standards Job creation	Chaouni et al. (2021)
	Use	Safe and reliable product use	No. of usage accidents No. of incidents of consumer complaints Customer loyalty No. of participative workshops	Kalmykova et al. (2022); Azevedo et al. (2021); Walker et al. (2021)
	Return	Socially compatible returns	Unhealthy working conditions No. of accidents in returns Job creation (fixed + variable) Customer incentives for recovery Firm incentives for recovery	Kravchenko et al. (2019); Chaouni et al. (2021); Calzolari et al. (2022); Lanaras-Mamounis et al. (2022)
	Recover	Socially compatible recovery processes	Unhealthy working conditions Job creation (fixed + variable) No. of accidents/incidents in recoveries Fraction of domestic value recovery	Kravchenko et al. (2019); Calzolari et al. (2022)
	Enable	Enabling socially sustainable management of the circular supply chain	Identification of explicit social performance goals; Identification of social performance barriers; CSC transparency and communication; Credible labels and certifications; R&D for social innovations; Job creation in local communities; Fair living wages; Additional employee benefits; Employee turnover; Employee satisfaction and participation; Amount of safety-related training; Amount of training provided on CE; Integrative employment policies; Gender ratio in board positions; Donations to local communities	Kalmykova et al. (2018); Azevedo et al. (2021); Saroha et al. (2021); Calzolari et al. (2022); Walker et al. (2021)

Although a certain hierarchical structure has already been created through the SCOR processes (e.g., the process *plan* was interpreted more operational than strategic, especially compared to the process *enable*), it was not yet possible to assign the measures to the different hierarchical levels. This will also be a future research opportunity. Lastly, apart from the distinction between circularity and (environmental) sustainability, possible interdependencies among measures and perspectives were not yet critically investigated. In the context of process *recover*, for example, the measures from the four perspectives may have conflicting goals. From a circular perspective, one goal is to maximize the reprocessing of waste generated in previous processes. From an economic perspective, one goal is to minimize the costs incurred by these reprocessing activities. Both the environmental and social perspectives aim to minimize the harmful consequences of this regeneration. To reconcile these conflicting goals, interdependencies or perhaps even complementarities must be explored to holistically improve CSC performance.

Conclusion and Future Research Opportunities

PM for SCs in the CE era is – despite its relevance for the transition from linearity to circularity – an underexplored research field and literature on explicit PMSs for CSCs is scarce (Vegter et al., 2021). This paper is an attempt to fill this gap by conceptualizing a PMS that holistically depicts the CSC. Based on adapted SCOR processes for circularity, it provides a horizontally integrated composition of performance measures to comprehensively assess the CSC's performance from an economic, environmental, social and circular perspective. Additionally, an attempt was made to clearly differentiate circular and environmental performance perspectives, enabling a clarification for the complex relationship between circularity and sustainability.

The conceptualized framework can serve as guidance and help practitioners to rigorously evaluate the performance of a CSC. By doing so, it supports the further transition from linearity to circularity. The framework can also support other researchers by supplying a theoretical concept for conducting empirical research on this matter, further driving the theoretical knowledge base of the CSC.

Future research opportunities lie in the adoption of a digital performance perspective, depicting the impact of digital technology on the CSC performance. In particular, the blockchain technology, which enhances the SC transparency and traceability to support the performance monitoring and reporting (Esmaeilian et al., 2020) and thus provides better assurance of fair labor and human rights practices (social perspective) (Saberi et al., 2018) is a promising digital technology within the CSC context. Nevertheless, digital technologies also have drawbacks like the huge energy consumption (Esmaeilian et al., 2020) and consequently high CO_2 emission (environmental perspective). Another interesting aspect is the role of digital platforms for business collaboration, where the holistic perspective of sustainable performance could be integrated as a sustainability guide for decision makers.

DECLARATIONS

Competing interests The author declares no competing interests.

REFERENCES

Ansari, Z. N., Kant, R. and Shankar, R. (2020), "Remanufacturing supply chain: an analysis of performance indicator areas", International Journal of Productivity and Performance Management, Vol. 71, No. 1, pp. 25–57.

APICS (2022), Introduction to Processes [Online]. Available at https://scor.ascm.org/processes/introduction (Accessed 21 April 2022).

Azevedo, S. G., Pimentel, C. M. O., Alves, A. C. and Matias, J. C. O. (2021), "Support of Advanced Technologies in Supply Chain Processes and Sustainability Impact", Applied Sciences, Vol. 11, No. 7, p. 3026.

Batista, L., Bourlakis, M., Smart, P. and Maull, R. (2018), "In search of a circular supply chain archetype – a content-analysis-based literature review", Production Planning & Control, Vol. 29, No. 6, pp. 438–451.

Blum, N. U., Haupt, M. and Bening, C. R. (2020), "Why “Circular” doesn't always mean “Sustainable”", Resources, Conservation and Recycling, Vol. 162, p. 105042.

Braun, G., Som, C., Schmutz, M. and Hischier, R. (2021), "Environmental Consequences of Closing the Textile Loop—Life Cycle Assessment of a Circular Polyester Jacket", Applied Sciences, Vol. 11, No. 7, p. 2964.

Burlakovs, J., Jani, Y., Kriipsalu, M., Vincevica-Gaile, Z., Kaczala, F., Celma, G., Ozola, R., Rozina, L., Rudovica, V., Hogland, M., Viksna, A., Pehme, K.-M., Hogland, W. and Klavins, M. (2018), "On the way to ‘zero waste’ management: Recovery potential of elements, including rare earth elements, from fine fraction of waste", Journal of Cleaner Production, Vol. 186, pp. 81–90.

Calzolari, T., Genovese, A. and Brint, A. (2022), "Circular Economy indicators for supply chains: A systematic literature review", Environmental and Sustainability Indicators, Vol. 13, p. 100160.

Chaouni Benabdellah, A., Zekhnini, K. and Cherrafi, A. (2021), "Sustainable and Resilience Improvement Through the Design for Circular Digital Supply Chain", in Dolgui, A., Bernard, A., Lemoine, D., Cieminski, G. von and Romero, D. (Eds), Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems, Springer International Publishing, Cham, pp. 550–559.

Eccles, R. G. (1991), "The performance measurement manifesto", Harvard Business Review, Vol. 69, No. 1, pp. 131–137.

Elgazzar, S., Tipi, N. and Jones, G. (2019), "Key characteristics for designing a supply chain performance measurement system", International Journal of Productivity and Performance Management, Vol. 68, No. 2, pp. 296–318.

EMA Foundation (2015), Towards a circular economy: business rationale for an accelerated transition [Online]. Available at https://www.ellenmacarthurfoundation.org/publications/ towards-a-circular-economy-business-rationale-for-an-accelerated-transition (Accessed 06.07.20).

Esmaeilian, B., Sarkis, J., Lewis, K. and Behdad, S. (2020), "Blockchain for the future of sustainable supply chain management in Industry 4.0", Resources, Conservation and Recycling, Vol. 163, p. 105064.

Farooque, M., Zhang, A., Liu, Y. and Hartley, J. L. (2022), "Circular supply chain management: Performance outcomes and the role of eco-industrial parks in China", Transportation Research Part E: Logistics and Transportation Review, Vol. 157, p. 102596.

Farooque, M., Zhang, A., Thürer, M., Qu, T. and Huisingh, D. (2019), "Circular supply chain management: A definition and structured literature review", Journal of Cleaner Production, Vol. 228, pp. 882–900.

Grant, M. J. and Booth, A. (2009), "A typology of reviews: an analysis of 14 review types and associated methodologies", Health information and libraries journal, Vol. 26, No. 2, pp. 91–108.

Hussain, M. and Malik, M. (2020), "Organizational enablers for circular economy in the context of sustainable supply chain management", Journal of Cleaner Production, Vol. 256, p. 120375.

Kalmykova, Y., Sadagopan, M. and Rosado, L. (2018), "Circular economy – From review of theories and practices to development of implementation tools", Resources, Conservation and Recycling, Vol. 135, pp. 190–201.

Kirchherr, J., Reike, D. and Hekkert, M. (2017), "Conceptualizing the circular economy: An analysis of 114 definitions", Resources, Conservation and Recycling, Vol. 127, pp. 221–232.

Kravchenko, M., Pigosso, D. C. and McAloone, T. C. (2019), "Towards the ex-ante sustainability screening of circular economy initiatives in manufacturing companies: Consolidation of leading sustainability-related performance indicators", Journal of Cleaner Production, Vol. 241, p. 118318.

Lanaras-Mamounis, G., Kipritsis, A., Tsalis, T. A., Vatalis, K. I. and Nikolaou, I. E. (2022), "A Framework for Assessing the Contribution of Firms to Circular Economy: a Triple-Level Approach", Circular Economy and Sustainability.

Lengyel, P., Bai, A., Gabnai, Z., Mustafa, O. M. A., Balogh, P., Péter, E., Tóth-Kaszás, N. and Németh, K. (2021), "Development of the Concept of Circular Supply Chain Management—A Systematic Review", Processes, Vol. 9, No. 10, p. 1740.

Lieder, M. and Rashid, A. (2016), "Towards circular economy implementation: a comprehensive review in context of manufacturing industry", Journal of Cleaner Production, Vol. 115, pp. 36–51.

Maestrini, V., Luzzini, D., Maccarrone, P. and Caniato, F. (2017), "Supply chain performance measurement systems: A systematic review and research agenda", International Journal of Production Economics, Vol. 183, pp. 299–315.

McCormack, K., Bronzo Ladeira, M. and Paulo Valadares de Oliveira, M. (2008), "Supply chain maturity and performance in Brazil", Supply Chain Management: An International Journal, Vol. 13, No. 4, pp. 272–282.

Mentzer, J. T., Witt, W. de, Keebler, J. S., Min, S., Nix, N. W., Smith, C. D. and Zacharia, Z. G. (2001), "DEFINING SUPPLY CHAIN MANAGEMENT", Journal of Business Logistics, Vol. 22, No. 2, pp. 1–25.

Montag, L. (2022), "Circular Economy and Supply Chains: Definitions, Conceptualizations, and Research Agenda of the Circular Supply Chain Framework", Circular Economy and Sustainability, https://doi.org/10.1007/s43615-022-00172-y.

Nattassha, R., Handayati, Y. and Simatupang, T. M. (2020), "Linear and circular supply chain: SCOR framework stages, actor analysis and the illustrative case of cassava farming", International Journal of Business and Globalisation, Vol. 26, 1/2, pp. 3–23.

Saberi, S., Kouhizadeh, M., Sarkis, J. and Shen, L. (2018), "Blockchain technology and its relationships to sustainable supply chain management", International Journal of Production Research, Vol. 57, No. 7, pp. 2117–2135.

Saroha, M., Garg, D. and Luthra, S. (2021), "Analyzing the circular supply chain management performance measurement framework: the modified balanced scorecard technique", International Journal of System Assurance Engineering and Management.

Sehnem, S., Vazquez-Brust, D., Pereira, S. C. F. and Campos, L. M. (2019), "Circular economy: benefits, impacts and overlapping", Supply Chain Management: An International Journal, Vol. 24, No. 6, pp. 784–804.

Vegter, D., van Hillegersberg, J. and Olthaar, M. (2020), "Supply chains in circular business models: processes and performance objectives", Resources, Conservation and Recycling, Vol. 162, p. 105046.

Vegter, D., van Hillegersberg, J. and Olthaar, M. (2021), "Performance Measurement Systems for Circular Supply Chain Management: Current State of Development", Sustainability, Vol. 13, No. 21, p. 12082.

Walker, A. M., Opferkuch, K., Roos Lindgreen, E., Simboli, A., Vermeulen, W. J. and Raggi, A. (2021), "Assessing the social sustainability of circular economy practices: Industry perspectives from Italy and the Netherlands", Sustainable Production and Consumption, Vol. 27, pp. 831–844.